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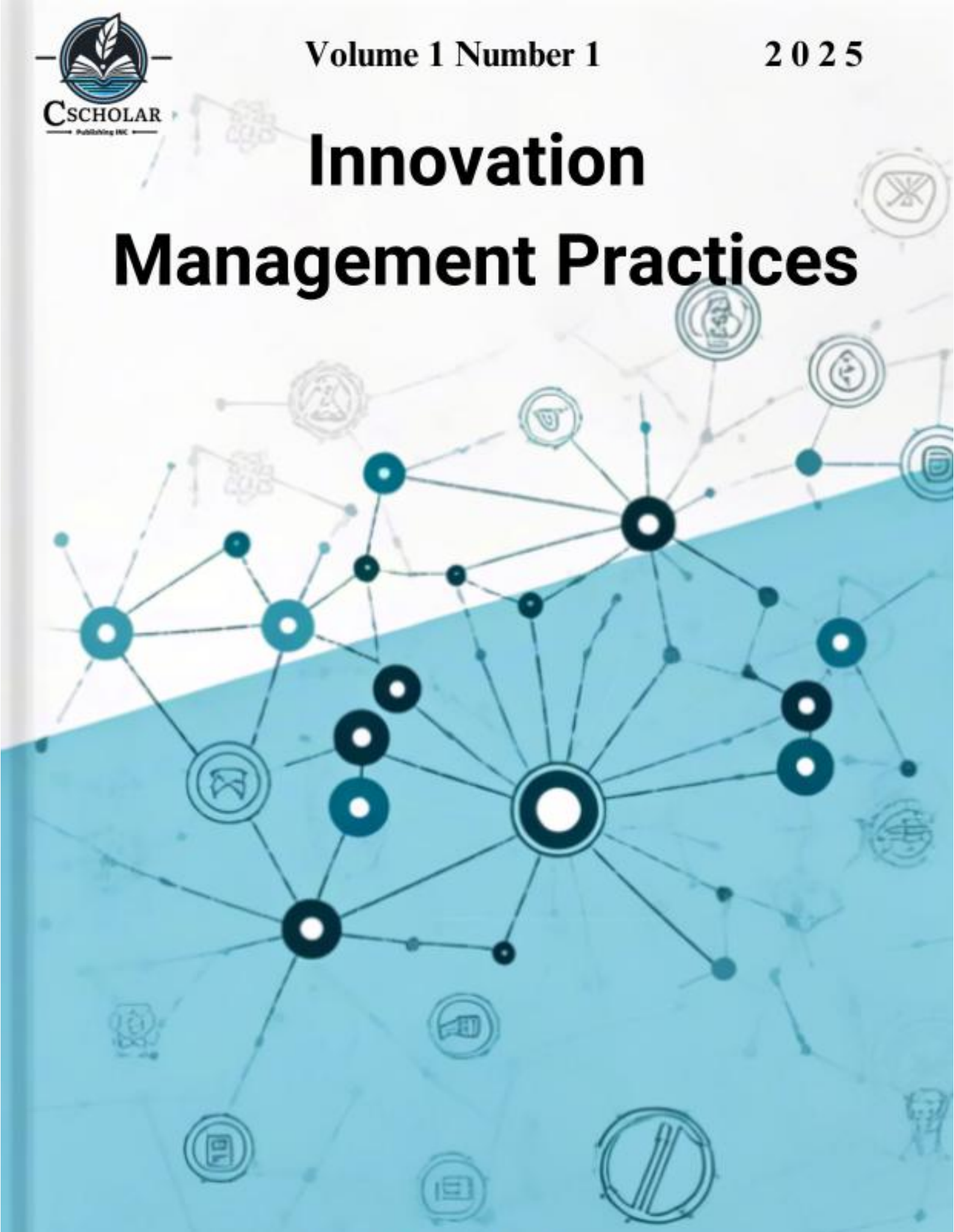

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Editorial

Everything in Innovation Management：Welcome to Innovation Management Practices

Peng Wang[1]

[1]College of Politics and Public Administration, Shandong Youth University of Political Science, Jinan 250103, China; wpyouth@126.com

Innovation stands as the central engine driving the establishment and growth of organizations and industries, while also serving as a crucial determinant of competitive advantage and sustainability. In an era marked by the rapid proliferation of groundbreaking scientific and technological achievements, innovation has captured global concern and also affects everyone. Scholars and managers worldwide have dedicated extensive efforts to advancing innovation research and practice, accelerating technological progress, economic growth, and societal transformation through their contributions.

In recent years, the surge of global scientific and technological advancements has imposed new demands on innovation. High-speedy, complexity, uncertainty, volatility, and even unconventional failures have emerged as defining characteristics of today's innovation landscape. These challenges necessitate fresh perspectives in innovation management theory and practice, inviting novel research agendas to address this evolving paradigm.

Innovation Management Practices (IMP) is founded to address these global imperatives and multidisciplinary innovation management needs. The journal aspires to serve as a dynamic platform for dialogue among researchers, practitioners, and stakeholders invested in innovation. We invite submissions spanning all disciplines, industries, and domains that explore innovation management themes. We actively solicit:

- Empirical investigations employing quantitative, qualitative, or mixed-method approaches;
- Critical analyses of novel management paradigms and frameworks;
- Evidence-based practice reports documenting organizational innovation implementation;
- Case studies addressing sector-specific innovation challenges;
- Interdisciplinary research.

In alignment with IMP's mission, we have meticulously assembled an editorial team committed to excellence, integrity, and timeliness. Every submission will undergo a fair, rigorous, and efficient review process, with editors serving as highly responsible liaisons between authors and reviewers. Leveraging our collective expertise, we pledge to support authors in refining their work while maintaining the highest academic standards. We recognize the formidable challenges of establishing a new journal but remain steadfast in our resolve to cultivate IMP into a leading forum for innovation discourse. We humbly request the patience and trust of our readers as we

embark on this journey.Here, we would also like to thank each of our reviewers and readers.Your intellectual generosity and engagement are the bedrock of this endeavor. We extend our profound gratitude for your partnership in advancing IMP.

This inaugural issue presents a curated selection of pioneering studies spanning diverse facets of innovation management. We trust these contributions will inspire researchers, inform practitioners, and facilitate impactful practices. In closing, we acknowledge the global community of innovation scholars and leaders whose work sustains this field. Together, let us continue to promote the progress of innovation management research.

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The Role and Responsibility of Artificial Intelligence in Society

Xinyi Zhou[1], Yue Liu[2*]

[1]School of Economics and Management, Beijing City University, Beijing 100000, China; mosheng81111@qq.com

[2]School of Economics and Management, Beijing City University, Beijing 100000, China; 1078243475@qq.com

*** Correspondence:**
Yue Liu
1078243475@qq.com

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Abstract

Artificial Intelligence (AI) has undergone multiple developmental stages since its inception in 1956 and has emerged as a significant force driving economic and social progress. This paper provides an overview of AI's role and responsibility in society, deeply analyzing current research statuses, hot topics, controversies, and future directions. Through literature review and case analysis, the paper explores how AI promotes social advancement and improves quality of life, while also posing ethical, legal, and social issues. Correspondingly, solutions and recommendations are proposed.

Keywords: Artificial Intelligence; ESG; ChatGPT

1. Introduction

Originating in 1956, AI was proposed by a group of scientists led by McCarthy, Minsky, Rochester, and Shannon, aiming to simulate human intelligence through machines, enhance human capabilities, improve quality of life, and drive green economy and sustainable development(Du, 2024; Feng, 2024). With the rapid advancement of technologies such as big data, cloud computing, and the Internet of Things, AI has been extensively applied in various fields including healthcare, education, finance, transportation, and more, serving as a crucial support for new-quality productivity(Han, 2024). However, the rapid development of AI has also brought numerous challenges, such as privacy protection, data security, algorithmic bias, and changes in employment structure, sparking widespread concern and debate.

2. Current Research Status

2.1. Developmental Stages of AI

The developmental history of AI can be clearly divided into six stages:

Initial Development Period (1956-early 1960s): After the concept of AI was first proposed, a series of remarkable research achievements were made, such as machine theorem proving, checkers programs, and the LISP list processing language, marking the first climax in AI development.

Reflective Development Period (1960s-early 1970s): Due to overly high expectations and unrealistic research goals, a series of failures and unmet objectives led to a lull in AI development.

Applied Development Period (early 1970s-mid-1980s): The emergence of expert systems marked a significant breakthrough from theoretical research to practical application and from general reasoning strategies to the application of specialized knowledge, propelling AI into a new high of applied development.

Low Development Period (mid-1980s-mid-1990s): With the expansion of AI applications, issues in expert systems gradually surfaced, such as narrow application fields and lack of common-sense knowledge, plunging AI development into a downturn.

Steady Development Period (mid-1990s-2010): Driven by the development of network technologies, particularly the popularize of internet technology, the aggregation of information and data continuously accelerated, promoting the further practicalization of AI technologies.

Vigorous Development Period (2011-present): With the development of technologies such as big data, cloud computing, and the Internet of Things, AI technologies have flourished, with breakthroughs in image classification, speech recognition, knowledge question answering, human-computer chess, autonomous driving, and other fields, entering a new climax of explosive growth.

2.2. The Role of AI in Society

AI plays multiple roles in society, which can be classified into capability attributes, utility attributes, and tool attributes based on their properties(Doe, 2023).

Capability Attributes: Emphasize that AI should not possess independent will but should obey human will. This primarily fulfills basic human needs, such as voice navigation and smart translation.

Utility Attributes: Refer to AI's ability to solve practical problems for humans. This is closer to human intelligence but does not possess thinking and cognitive systems compared to tool attributes.

Tool Attributes: Indicate that AI can significantly enhance human work efficiency. This fulfills advanced human needs, such as rational thinking, scientific innovation, and social skills.

2.3. Responsibilities and Challenges of AI

With the widespread application of AI, its responsibilities and challenges have also become increasingly prominent. Microsoft's concept of "Responsible AI" encompasses privacy protection, security, fairness, explainability, and other aspects. Meanwhile, issues such as algorithmic bias in decision-making, asynchrony between technological development and governance, ethical issues, and impacts on employment structures have become the focus of social attention.

3. Research Hotspots and Controversies

3.1. The Importance of Small Data and High-quality Data

In recent years, small data and high-quality data have gradually gained attention as keys to precision-driven applications. Compared with big data, small data focuses more on data accuracy and relevance, reducing AI algorithms' reliance on data and uncertainty. This trend has driven AI applications in specific fields such as healthcare and financial risk control. In healthcare, the application of small data facilitates personalized medicine, improving diagnostic accuracy and treatment outcomes; in financial risk control, it aids in identifying potential risks and enhancing risk control efficiency.

3.2. Ethical and Moral Issues in Human-AI Alignment

Human-AI alignment has become an important direction in AI technology development, where AI's output must align with human values. This is not only a manifestation of technological progress but also a requirement of ethical and moral constraints. Achieving consistency between AI and human values, avoiding algorithmic bias and discrimination, is currently a research hotspot. To address this, researchers have proposed various methods such as reinforcement learning from human feedback (RLHF) and value compasses. These methods aim to enable AI models to follow mainstream human values in decision-making, achieving goals consistent with human expectations.

3.3. AI Usage Boundaries and Ethical Oversight Models

With the continuous development of AI technology, establishing usage boundaries and ethical oversight has become an urgent issue. Ensuring the reasonable application of AI technology and avoiding abuse and misuse has become the focus of attention from all sectors of society. To address this, effective ethical oversight models need to be established to regulate and guide the use of AI technology. This includes formulating clear ethical guidelines, establishing ethical review mechanisms, and strengthening ethical education. At the same time, interdisciplinary cooperation should be strengthened, combining AI technology with disciplines such as ethics and law to jointly promote the healthy development of AI technology.

3.4. Explainable Models

Enhancing the explainability of AI systems helps gain users' trust and promote the widespread application of AI technology. Current research is devoted to developing more explainable AI models, through transparent decision-making processes and reasonable explanation mechanisms,

to enhance the credibility and acceptability of AI systems. To achieve this, researchers have proposed various methods such as rule-based models and knowledge-based models. These methods aim to provide clear explanations and bases for AI models' decision-making processes, enabling users to understand and accept AI decision outcomes.

4. Future Development Directions

4.1. Artificial General Intelligence (AGI)

AGI refers to intelligent systems possessing human-like comprehensive abilities, capable of adaptively solving diverse problems. Future AI development will gradually break through the limitations of dedicated tasks, progressing towards general intelligence. This will provide possibilities for AI technology applications in more fields, driving further enhancements in social productivity. To achieve AGI, multiple key technical issues need to be resolved, such as knowledge representation, reasoning mechanisms, and learning algorithms. At the same time, interdisciplinary cooperation should be strengthened, combining AI technology with disciplines such as cognitive science and neuroscience to jointly promote the development of AGI.

Technological Leadership: Grasp global AI development trends, emphasize the forward-looking nature of R&D deployment, explore and deploy in key frontier areas, provide long-term support, strive for transformative and disruptive breakthroughs in theory, methods, tools, and systems, comprehensively enhance original AI innovation capabilities, accelerate the construction of first-mover advantages, and achieve high-end-led development.

Systematic Layout: According to the different characteristics of basic research, technological development, industrial development, and industry applications, formulate targeted system development strategies. Fully leverage the advantage of the socialist system's ability to concentrate efforts on major tasks, promote the coordinated layout of projects, bases, and talents, organically connect deployed major projects with new tasks, link up immediate needs with long-term development in a tiered manner, and jointly promote innovation capability construction, institutional mechanism reform, and policy environment creation.

Market Dominance: Follow market laws, adhere to application orientation, highlight enterprises' leading role in selecting technological routes and formulating industry product standards, accelerate the commercial application of AI technological achievements, and form competitive advantages. Balance the division of government and market roles, and better leverage the government's role in planning guidance, policy support, security precautions, market supervision, environment creation, and the formulation of ethical and legal regulations.

Open Source and Openness: Advocate the concept of open source sharing and promote co-creation and sharing among various innovation entities in industry, academia, research, and application. Follow the law of coordinated development between economic construction and national defense construction, promote the two-way transformation and application of military and civilian scientific and technological achievements, and the joint construction and sharing of military and civilian innovation resources, forming an all-element, multi-field, and highly

efficient new development pattern of deep military-civilian integration. Actively participate in global AI R&D and governance, and optimize the allocation of innovation resources worldwide. (State Council, 2017). Notice of The State Council on the Issuance of the Development Plan for the New Generation of Artificial Intelligence. China Legal System Publishing House)

4.2. Edge Computing and Smart Devices

With the explosive growth in the number of IoT devices, deploying AI models on edge devices will become a trend. This can reduce latency and dependence on cloud resources, enabling more devices to possess intelligent functions. The combination of edge computing and smart devices will drive the application of AI technology in fields such as intelligent manufacturing and smart cities. To achieve this, multiple technical challenges need to be addressed, such as model compression and optimization algorithms. At the same time, standardization work should be strengthened, with unified edge computing standards and protocols formulated to promote interconnectivity between different devices.

4.3. Human-AI Fusion

Future AI development is not merely about replacing human work but about forming collaboration with humans. AI will become an important tool to enhance human capabilities, achieving deeper human-AI fusion through technologies such as brain-computer interfaces and smart devices. This will bring revolutionary changes to fields such as healthcare, education, and entertainment. To achieve the goal of human-AI fusion, multiple key technical issues need to be resolved, such as brain-computer interface technology and human-computer interaction technology. At the same time, research on ethical, moral, and social issues should be strengthened to ensure the rationality and sustainability of human-AI fusion technology.

4.4. Improvement of AI Ethics and Regulations

With the widespread application of AI technology, related ethical and regulatory issues have become increasingly prominent. Future AI development needs to strengthen regulation and guidance in ensuring data security, privacy protection, and algorithmic fairness(Li, 2024). Meanwhile, international cooperation should be strengthened to jointly promote the healthy development of AI technology. To achieve this, a comprehensive legal and regulatory system needs to be formulated, clarifying the scope and limitations of AI technology usage. At the same time, regulatory enforcement should be strengthened to supervise and evaluate the use of AI technology. In addition, international cooperation and exchanges should be enhanced to jointly promote the healthy development of AI technology.

5. Case Analysis

5.1. Microsoft's Role in the Field of AI

(1) Technological Innovation Leader

Since the 1990s, Microsoft has been involved in the field of AI and has recently increased its R&D investment, dedicated to driving innovation and development in AI technology. Its

developed intelligent assistants such as Xiaoice and Cortana, as well as platforms such as Azure Machine Learning and Azure Cognitive Services, have not only enhanced user experience but also provided powerful tool support for developers. Microsoft has also promoted the popularization and application of AI technology by open-sourcing the deep learning framework ONNX and launching tools such as Bot Framework(Johnson, 2025).

(2) Industry Application Driver

Microsoft has applied AI technology extensively in fields such as healthcare, education, manufacturing, and retail, using intelligent solutions to help enterprises improve production efficiency, optimize decision-making processes, and enhance user experience. For instance, in healthcare, Microsoft leverages AI technology to assist doctors in disease diagnosis and drug development; in education, it uses intelligent recommendation systems to provide students with personalized learning resources; in manufacturing, AI technology is used to predict equipment failures and optimize production processes(Smith, 2024). With advancements in algorithms, computing power, computer hardware, and the advent of the big data era, AI technology has flourished and infiltrated the medical field, transforming traditional medical practices. It has played a significant role in clinical work such as emergency pre-screening, disease assessment, medical diagnosis, treatment plan decision-making, surgery, anesthesia, nursing, rehabilitation therapy, pharmacological research, and pharmaceutical development, bringing tremendous convenience to clinical work. (Liu et al., 2021)

(3) Social Responsibility Bearer

Microsoft is deeply aware of the double-edged nature of AI technology. Therefore, while driving technological progress, it also actively bears social responsibilities, focusing on AI ethics and privacy protection(Qian & Chu, 2023). Microsoft has published the "Six AI Principles," emphasizing fairness, transparency, and accountability in AI technology, and established an AI Ethics Committee to review the potential risks of AI projects and ensure the moral legitimacy of technological applications(Wei, 2024).

5.2. Case Analysis of Microsoft's AI Applications

(1) Healthcare: AI-assisted Diagnosis and Treatment

Microsoft has collaborated with multiple medical institutions to utilize AI technology to enhance the efficiency and quality of medical services. For example, Microsoft and the Mayo Clinic have jointly developed an AI system capable of analyzing patients' medical records and imaging data to assist doctors in early diagnosis of tumors, cardiovascular diseases, and other conditions. Additionally, Microsoft leverages AI technology to accelerate new drug development by analyzing vast amounts of compound data to predict drug efficacy and side effects, shortening the drug development cycle.

(2) Education: Personalized Learning Experience

Microsoft's AI solutions for education aim to provide students with personalized learning paths and resources. By analyzing students' learning behaviors, grades, and other data, AI systems can identify students' learning needs and interests, recommending suitable learning materials and

activities(Yang, 2017). Furthermore, Microsoft collaborates with educational institutions to improve teaching quality using AI technology, such as through intelligent classroom management systems that monitor students' learning progress and provide feedback and suggestions for teachers.

(3) Manufacturing: Intelligent Operations and Predictive Maintenance

Microsoft applies AI technology in manufacturing to help enterprises achieve intelligent and automated production processes. By collecting and analyzing equipment operation data, AI systems can predict equipment failures, arrange maintenance in advance, and reduce downtime. Additionally, AI technology is used to optimize production processes and improve production efficiency(Xue & Wang, 2024). For instance, Microsoft has collaborated with an automobile manufacturer to utilize AI technology to optimize production line layouts, reducing production costs and enhancing product quality.

(4) Retail: Intelligent Recommendation and Inventory Management

In the retail sector, Microsoft leverages AI technology to enhance customer experience and operational efficiency. By analyzing consumers' shopping histories, browsing behaviors, and other data, AI systems can recommend personalized products to users, improving conversion rates(Yuan, 2024). Simultaneously, AI technology is used for inventory management, predicting future demand through sales data analysis, optimizing inventory levels, and reducing inventory backlog and stockouts.

5.3. Microsoft's Practices in AI Ethics and Responsibility

(1) Strengthening AI Ethics Review

Microsoft has established an AI Ethics Committee responsible for reviewing the potential risks of all AI projects and ensuring the moral legitimacy of technological applications. This committee consists of interdisciplinary experts, including ethicists, sociologists, legal experts, etc., who evaluate AI projects from multiple perspectives to ensure that technology does not negatively impact individuals or society.

(2) Promoting AI Fairness

Microsoft is committed to eliminating bias and discrimination in AI technology. Its AI Ethics Principles emphasize algorithmic fairness, requiring that the needs and interests of different groups be fully considered during the design, development, and deployment of AI systems to avoid algorithmic discrimination. To achieve this goal, Microsoft has adopted a series of measures during data collection, model training, and other stages, such as increasing data diversity and using unbiased algorithms.

(3) Enhancing Privacy Protection

Microsoft is deeply aware of the importance of privacy protection in AI technology. Therefore, it always prioritizes user privacy in product design and service provision. Its Azure Machine Learning Service, Cortana, and other intelligent assistants adopt strict privacy protection measures to ensure the security and confidentiality of user data. Simultaneously, Microsoft actively

participates in the formulation of international privacy protection standards to promote the compliant application of AI technology.

(4) Conducting AI Education and Training

To enhance public understanding and awareness of AI technology, Microsoft actively conducts AI education and training activities. Its "AI for Earth" project aims to support environmental protection and social development by providing AI technology and resources. Additionally, Microsoft collaborates with universities and educational institutions to offer AI courses and workshops, fostering AI talent and promoting the popularization and application of AI technology.

(5) Launching New Search Features

At an AI-themed event in San Francisco, Microsoft announced a series of "Bing" updates, aiming to make Bing smarter by incorporating the company's AI research results and establishing a new partnership with Reddit. The company demonstrated specific methods for infusing AI intelligence into the Bing search engine. One-third of desktop search results in the United States are completed on Bing. These updates focus on providing users with more conversational and nuanced answers.

5.4. Challenges and Coping Strategies Faced by Microsoft in AI

(1) Technological Challenges

Despite significant progress in AI technology, Microsoft still faces numerous technological challenges(Zhang, 2024). For example, how to further improve the accuracy and reliability of AI systems, reduce the cost and threshold of AI technology, and achieve cross-domain integration of AI technology. To address these challenges, Microsoft will continue to increase R&D investment, strengthen cooperation and exchanges with international peers, and promote continuous innovation and development in AI technology.

(2) Ethical Challenges

The rapid development of AI technology has also brought ethical challenges. How to ensure the fairness and transparency of AI technology, avoid algorithmic discrimination and abuse, and balance technological progress and social stability are issues that Microsoft needs to address. To this end, Microsoft will continue to strengthen its AI ethics review mechanism, clarify the humanistic stance in generative AI applications, construct ethical rules for generative AI governance, enhance communication and collaboration with various sectors of society, and jointly promote the healthy development of AI technology.

(3) Regulatory challenges

With the widespread application of AI technology, regulatory issues have become increasingly prominent. How to formulate reasonable regulatory policies that can ensure the compliance application of AI technology while avoiding excessive regulation that hinders technological innovation is a concern for technology companies such as Microsoft. To this end, Microsoft will actively participate in the formulation and discussion of international regulatory policies, and promote the establishment of a fair, transparent and predictable regulatory environment.

(4) Asynchronous Challenge

Under the leading trend of accelerating basic research and development and accelerating the implementation of industrial applications, the externalities of artificial intelligence, both positive and negative, are constantly being released. While generating huge economic and social development benefits, it also faces the challenge of technological development and governance not being synchronized. To this end, we should constantly improve bilateral mechanisms, strengthen communication, and enhance global governance.

6. Conclusion

Strengthen basic research: increase investment in AI basic research, and promote algorithm innovation and technological breakthroughs. This will help enhance the core competitiveness of AI technology and provide strong support for future industrial development.

(1) Build a dual circulation system: relying on the market, domestic circulation, and strengthening participation in the international circulation. The dual circulation of international and domestic development and construction.
(2) At the same time, it is also necessary to promote the deep integration of new generation AI technology with industry, economy and society, and to build a dual circulation system of "education-technology-talent" and "finance-technology-industry".
(3) Improve the legal system: Establish and improve the AI-related legal and regulatory system to ensure data security, privacy protection, and algorithm fairness. This will help regulate the use of AI technology and protect the legitimate rights and interests of users.
(4) Promote international cooperation: Strengthen international cooperation and exchanges, and jointly promote the healthy development of AI technology. This helps to share experience and resources and jointly address global challenges and problems.

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Conceptualization, X.Z and Y.L.; methodology, X.Z and Y.L.; software, X.Z and Y.L.; validation, X.Z and Y.L.; formal analysis, X.Z and Y.L.; investigation, X.Z and Y.L.; resources, X.Z and Y.L.; data curation, X.Z and Y.L.; writing—original draft preparation, X.Z and Y.L.; writing—review and editing, X.Z and Y.L.; visualization, X.Z and Y.L.; supervision, X.Z and Y.L.; project administration, X.Z and Y.L.; funding acquisition, X.Z and Y.L. All authors have read and agreed to the published version of the manuscript.

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Profit Quality Analysis on the Listed Company

— A Case Study from CATL

Yicong Zhang[1], Yufei Wang [2*]

[1]School of Management, Hebei University, Baoding 071000, China; zhangyicong@hbu.edu.cn

[2] School of Management, Hebei University, Baoding 071000, China; lluvia1031@163.com

*** Correspondence:**
Yufei Wang
lluvia1031@163.com

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Abstract

Contemporary Amperex Technology Co.Limited (CATL) has emerged as a standout player in the fierce global and domestic competition and has gradually developed into the largest domestic battery power battery vehicle, becoming a benchmark company in China's new energy industry. In the stock market, investors pay attention to profit indicators to judge the operating development of a company, but there are also listed companies that adjust their profit totals to whitewashing their financial data. Profit quality, as a true reflection of a company's profitability, has gradually become an important indicator for investors to judge the authenticity of a company's financial statements. This paper conducts a case study on CATL, introduces the development of CATL and its industry, and selects the financial data of CATL from 2018 to 2023 to conduct a comprehensive analysis of its profit quality. The current study provides decision-making references for the company's shareholders, managers, and other relevant parties. In addition, the findings of this paper serve as an inspiration and reference for other companies in the same industry.

Keywords: Profit Quality; Core Profit; Profitability; Growth; Cash Receipts; Stability

1. Introduction

The development of listed companies plays a crucial role in China's national economy. Analyzing the profit quality of listed companies can reveal the advantages and disadvantages of their operations, thereby providing reliable financial information for improving profit quality, optimizing economic decisions, and promoting the high-quality development of listed companies. Companies are economic organizations born to make profits, and profitability is the fundamental ability that determines their survival and development. Investors usually evaluate the profitability of companies based on their profits, but the reported numbers may not necessarily match the

company's actual profitability. Only the profits that can be converted into cash flow are the company's real earnings. Profit quality refers to the reliability of the information expressed by accounting earnings about the economic value created by the company, and it is the embodiment of the intrinsic value of profits (Bai, 2021). To judge the profit quality of a company, it is not enough to rely solely on profit levels. Investors should also pay attention to the sources of profits, the structure of profits, and the relevance of profits to the company's business activities. By analyzing the profit composition angle, investors can determine the matching degree between accounting profits and real profits, the availability of cash, and the company's financial condition. In real business operations, there are cases in which companies have high profits but weak profitability, mainly due to the high manipulability of company profits, with some companies trying to create the illusion of high profits by adjusting their financial data. Therefore, studying the profit quality of companies is beneficial for investors to focus on the profit quality dimension when making investment decisions.

Contemporary Amperex Technology Co.Limited (CATL) has sprung up in the fierce international and domestic competition, and has gradually developed into the largest domestic power battery enterprise, becoming a benchmark company in China's new energy industry. Therefore, this paper selects CATL as a case enterprise, uses the method of factor analysis to calculate financial indicators such as core profit margin from the perspectives of profitability, cash flow, stability and growth, analyzes the profit quality, and objectively and comprehensively evaluates the profit quality of CATL. Then, the paper investigates the key points to improve the profit quality for CATL and puts forward measures to effectively promote the profit quality so as to provide support for improving the profit quality of enterprises in the same industry and realizing sustainable development.

2. Overview of CATL Enterprises

2.1. Industry Background

To meet the challenge of global climate change, green, low-carbon and sustainable development have become a global consensus. Global carbon emissions are mainly from the fields of power and transportation. The effective way to reduce carbon emissions in the power industry is to increase the proportion of green and clean energy power generation, such as wind power and photovoltaic power. The main way to reduce carbon emissions in the transportation industry is to improve the electrification rate of travel tools and use green energy. Electrochemical energy storage devices are one of the essential carriers of green and clean energy. It is widely used in the storage, conversion, and use of green and clean energy in the context of carbon emission reduction, and this measure has become an important strategy.

(1) Power Battery Industry

Benefiting from factors such as the improvement of comprehensive advantages of new energy vehicles in terms of mileage and convenient energy replenishment, as well as the expansion of terminal channels and the improvement of infrastructure facilities, the global market demand for new energy vehicles continues to grow rapidly, driving the rapid increase in the scale of the

power battery industry. In the domestic market, the popularity of new energy vehicles has gradually expanded from the first and second-tier cities with high acceptance to the third and fourth-tier cities, and the recognition of new energy vehicles has generally increased, driving the continuous and rapid growth of the demand for new energy vehicles. In the global market, the subsidy policies for new energy vehicles in most European countries have been continuously implemented, and the time target for the prohibition of fuel vehicles has been further clarified. The United States has also issued several policies to support the development of the new energy industry, and the penetration rate of new energy vehicles in Europe and the United States has also continued to increase rapidly.

(2) Energy Storage Industry

In recent years, under the guidance of national carbon emission reduction targets, the installed capacity of green energy power generation represented by photovoltaic and wind power has been growing rapidly. As a necessary means to solve the intermittency and volatility of wind and solar power generation and enhance the security and flexibility of power systems, the energy storage system has great potential for market development, with its security and economy continuously improving. In the domestic market, various provinces continue to implement the wind and solar energy distribution and storage policy and gradually clarify the compensation mechanism for energy storage costs to improve the income of energy storage power stations through sharing leasing, capacity compensation, and participating in power market transactions; In Europe, based on the positive carbon neutral goal, the proportion of photovoltaic and wind power generation continues to increase, and the demand for pre balance sheet energy storage market is skyrocketing. Affected by the sharp rise in electricity prices since last year, the economy of household photovoltaic energy distribution and storage is highlighted, which promotes the rapid growth of household energy storage market demand. Many states in the United States have set energy storage installation targets, increased the intensity of photovoltaic investment and storage tax credit (ITC), extended the policy period by 10 years to 2032, and included independent energy storage in the scope of ITC subsidies for the first time, promoting the rapid increase of pre balance sheet energy storage installation.

(3) Battery Materials and Recycling

With the rapid growth of the demand for power and energy storage batteries, the scale of battery material industries such as positive pole, negative pole and electrolyte has expanded rapidly. Battery recycling is one of the sources of battery materials. With the continuous growth of new energy vehicles, the continuous progress of battery disassembly and recycling technology, and the gradual expansion of channels, the decommissioning and recycling of power batteries will become an important source of battery materials. The "14th five-year plan" for the development of the circular economy clearly stipulates that China will vigorously develop the circular economy.

2.2. Overview of CATL Enterprises

CATL's full name is Contemporary Amperex Technology Co.Limited, which was founded in 2011. In 2018, it was successfully listed on the Shenzhen Stock Exchange. In 2020, it established a joint venture with the State Grid integrated power supply company and set up the 21C

Technology Research Institute. The company's power battery devices have been the lead in the country for six consecutive years, and the national share of the total amount of energy storage power batteries has also remained the first.

The main business of CATL New Energy Technology Co., Ltd. is the R&D, production, sales and after-sales service of power batteries, energy storage batteries and battery recycling products. Its main products include power battery system, energy storage system and lithium battery materials. Besides, the company attaches great importance to the research and development of products and technologies, and has established a perfect research and development system covering product research and development, engineering design, test and verification, process manufacturing and other fields. The company has established the National Engineering Research Center for electrochemical energy storage technology, the Key Laboratory for lithium-ion battery enterprises in Fujian Province, the test and Verification Center certified by the China National Accreditation Service for conformity assessment (CNAs), and has set up "Fujian academician expert workstation" and "post-doctoral research workstation", with outstanding advantages in research and development and technology. CATL is the world's leading supplier of power battery systems, focusing on the R&D, production, and sales of power battery systems and energy storage systems for new energy vehicles. CATL is committed to providing first-class solutions for new energy applications globally. The company has core technology advantages and sustainable R&D capabilities in key areas of the industrial chain, such as battery materials, battery systems, and battery recycling. It has formed a comprehensive and perfect production service system.

3. Profit Quality Analysis

3.1. Profitability Index Analysis

Profitability refers to the ability of enterprises to obtain profits. Profitability index evaluation can reflect the use of enterprise resources well. If resources are fully utilized, it shows that the profitability of enterprises is high and the profit quality of enterprises is good. On the contrary, when resource utilization is low, the profitability is weak, and the quality of profits is poor, indicating that the competitiveness of enterprises is not strong.

(1) Return on Total Assets

Considering the large scale of enterprise assets in CATL, this paper uses the method of most studies for reference. It selects the Return on Total Assets (ROTA) as an indicator to measure the utilization efficiency of enterprise assets. The Return on Total Assets is closely related to the company's competitive strength and development ability. The larger the index, the higher the utilization efficiency of assets, the stronger the competitiveness and development ability of enterprises, and the better the profit quality of enterprises (Fan, 2024).

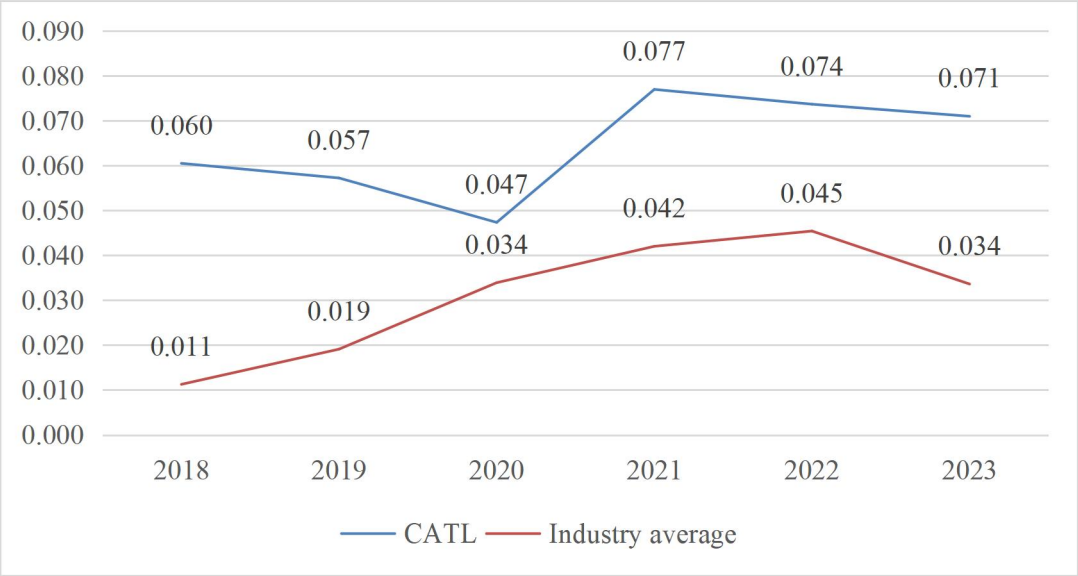

Figure 1. Changes in Return on Total Assets

The figure shows that CATL's Return on Total Assets in the past six years was higher than the industry average. Except for the impact of the epidemic in 2020, the Return on Total Assets of CATL fell to 4.73%, and the overall situation remained rising at other times. From 2021 to 2023, the changing trend of Return on Total Assets of CATL was consistent with that of the industry, showing a trend of first rising and then falling, reaching a maximum of 7.69% in 2021.

(2) Cost-Volume-Profit Ratio

One of the common indicators of enterprise profitability is the Cost-Volume-Profit Ratio (CVP), which indicates the revenue an enterprise can get for every dollar of cost and expense invested. This indicator reflects the revenue results achieved by the enterprise because of operational consumption. A larger value of this indicator indicates that a business is compensated by a more significant inflow of revenue for each unit of costs and expenses it spends. Therefore, the higher the Cost-Volume-Profit Ratio, the greater the enterprise's profitability and the higher the quality of profits (Luo, 2022).

According to the chart, CATL's Cost-Volume-Profit Ratio is gradually increasing in 2019–2021, and the indicator value is consistently below 20%. In 2018-2021, the company's Cost-Volume-Profit Ratio compared favorably with the industry average and was close to the industry average in 2022. In recent years, CATL's selling and administrative expenses have increased by almost ten times annually as the company's scale grows. However, selling and administrative expenses account for a small proportion of operating income, indicating that the business can control costs and expenses. CATL has also established a steady supply-and-demand connection with downstream automakers like Tesla. Therefore, by increasing the efficiency of its sales and management expenses, CATL can continue to strengthen its capacity to control costs and expenses, boost profitability, raise profitability levels, and eventually improve the quality of its earnings.

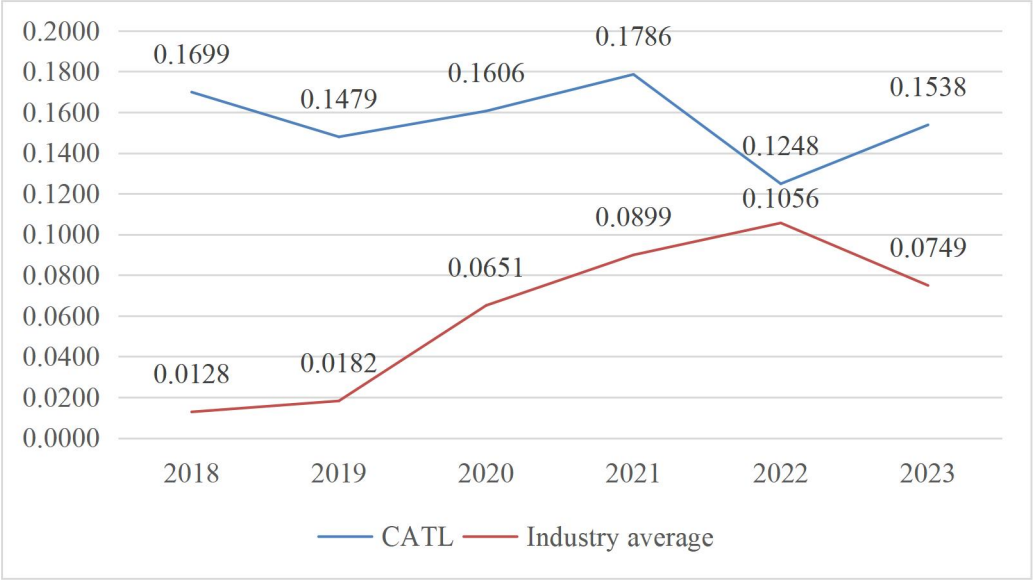

Figure 2. Changes in Cost-Volume-Profit Ratio

(3) Return on Equity (ROE)

Return on Equity, also known as Return on Shareholders' Equity, is the core of the DuPont Analysis. It is a comprehensive financial indicator that measures the profitability of a company's equity. The higher the ROE, the higher the utilization efficiency of the company's equity, and the better the return level for shareholders. Therefore, the guarantee of profit quality will also be higher. From 2018 to 2019, after-tax profits decreased due to the continuous rise in raw material prices and the decline in policy subsidies. Meanwhile, the increase in net assets was more significant than the increase in after-tax profits, causing CATL's ROE to decline but remain above the industry average. In 2020, the ROE began to rise. During that time, CATL's sales grew significantly, and net profits increased substantially, indicating that the utilization efficiency of CATL's equity reached its peak in 2020.

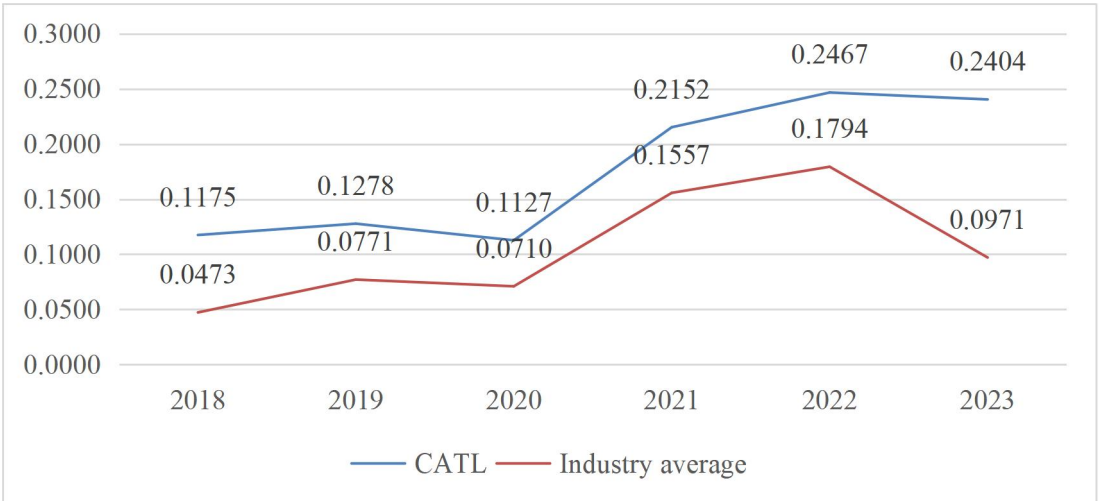

Figure 3. Changes in Return on Equity

(4) Core Profit Margin

According to the new accounting standards, profits and losses that are similar to asset disposal gains, other gains, and those that are not closely related to the company's core business are also included in operating profit, so they cannot reliably reflect the company's contribution to its core business. Therefore, this paper uses the core profit margin indicator to replace the operating profit contribution rate indicator. Core profit is the amount generated by deducting operating costs, selling expenses, management expenses, financial expenses, R&D expenses, taxes, and additional charges from revenue. It can better measure the stability of the company's profit structure (Wang & Qu, 2022). The core profit margin indicator can reflect the company's ability to generate revenue through its operating activities. It is one of the key indicators for evaluating the company's business results. The larger the indicator, the better the profit quality. The core profit margin is calculated by dividing core profit by revenue. Among them, core profit reflects the revenue generated by the company's sales activities and the financial, sales, management, and product-related costs generated by the sales activities. It excludes income that is not generated from operating production activities. The company generates profits from its core business, so the core profit margin can better reflect the stability of the company's profits. This indicator is a positive indicator.

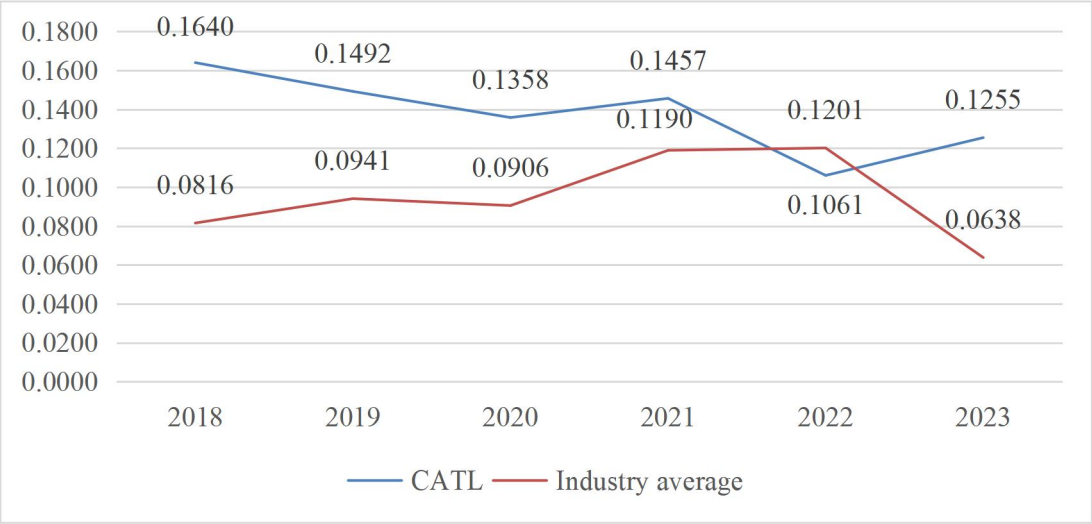

Figure 4. Changes in Core Profit Margin

As shown in the figure, the core profit margin of CATL in the past five years has been higher than the industry average, with an increase in 2021 and 2023, and the core profit margin has remained above 10% for the past six years, consistently above the industry average. Although the industry average has been below 10% in the past six years, there is still a particular gap compared with the industry average. After analysis, it can be seen that CATL's ability to generate profits through its operating activities is gradually increasing, but there is still room for further development.

3.2. Stability index analysis

When an enterprise faces risks from changes in the internal and external environment, its profit quality level may be adversely affected. However, for those enterprises in a low competitive environment or high market concentration, the profit quality can be effectively guaranteed because they have a more stable consumer base and profit source (Sulistiawan & Rudiawarni, 2019).

(1) Proportion of Accounts Receivable

To a certain extent, the proportion of accounts receivable can reflect an enterprise's turn over rate and cash flow risk level (Perotti & Wagenhofer, 2014). It shows that CATL co nstantly optimizes the asset structure, allocates assets reasonably, and reduces the depende nce on accounts receivable.

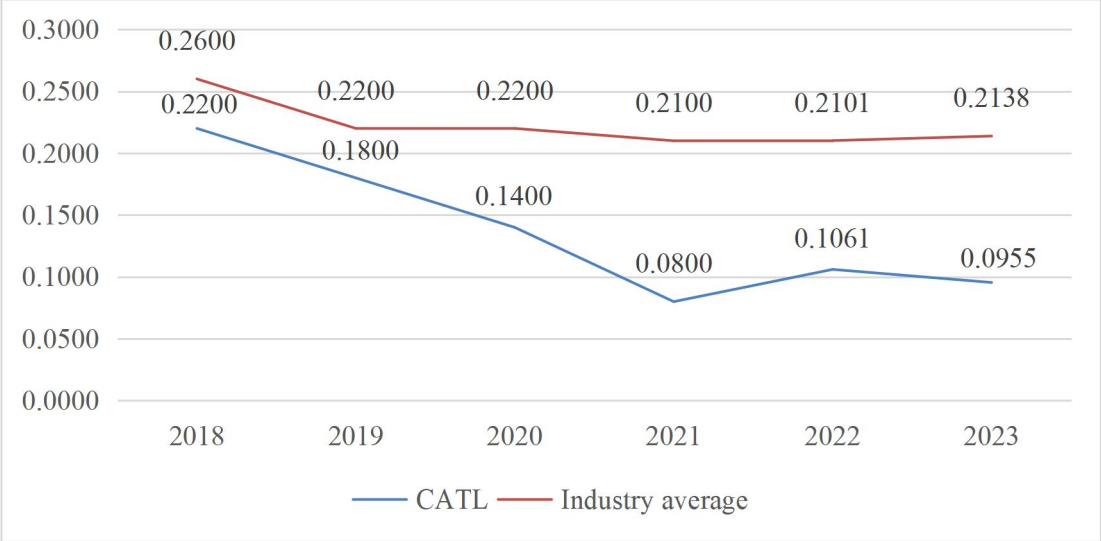

Figure 5. Changes in Proportion of Accounts Receivable

(2) Proportion of Operating Profit

The proportion of operating profit refers to the proportion of the enterprise's operating profit in the total profit, which is one of the critical indicators of the enterprise's operating ability. The proportion of operating profit is a positive indicator. When the proportion of operating profit is relatively high, it indicates that the profit of the enterprise has better stability and higher income quality. Therefore, enterprises should enhance the profitability of the main business to improve the profit quality (Shin et al., 2018).

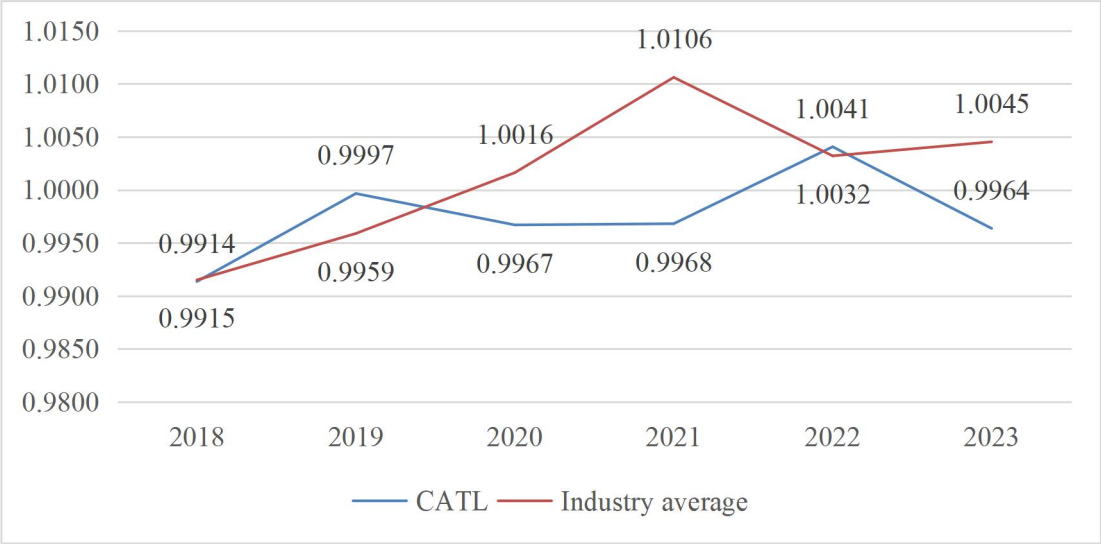

Figure 6. Changes in Proportion of Operating Profit

As shown in the figure, from 2022 to 2023, the proportion of operating profit in the CATL is lower than the industry average. Although the proportion of operating profit in CATL began to increase after the impact of the epidemic in 2020, there was still a certain distance from the industry average, and the proportion of operating profit in the CATL showed a downward trend in 2023. Therefore, CATL needs to strengthen cost management and sales management to improve the stability of profits.

3.3. Analysis of cash index

The proportion of operating profit refers to the proportion of the enterprise's operating profit in the total profit, which is one of the essential indicators of the enterprise's operating ability. The proportion of operating profit is a positive indicator. That is, when the proportion of operating profit is relatively high, it indicates that the profit of the profitability refers to the ability to convert corporate profits into cash flow. The sales revenue ratio is a positive indicator. Through studying the cash flow statement, the information in the statement truly and reliably reflects the company's operating conditions, so it can help judge the company's earnings quality (Andekina & Rakhmetova, 2013). The cash flow of enterprises will promote the quality of their profits, and the level of profit quality of enterprises will increase with the increase in cash flow (Artikis & Papanastasopoulos, 2016). Therefore, accurate and adequate cash flow information can help investors and shareholders better understand the profit quality of enterprises (Dichev et al., 2013).

(1) Sales Revenue Rate

The rate of revenue from sales reflects the proportion of income generated by the sale of goods and services that are recovered in cash. When the sales cash rate is closer to 1, it indicates that the cash flow received from operating activities maintains a reasonable and proportional relationship with the scale of operating income, and it also suggests that the company's profit has a higher cash availability.

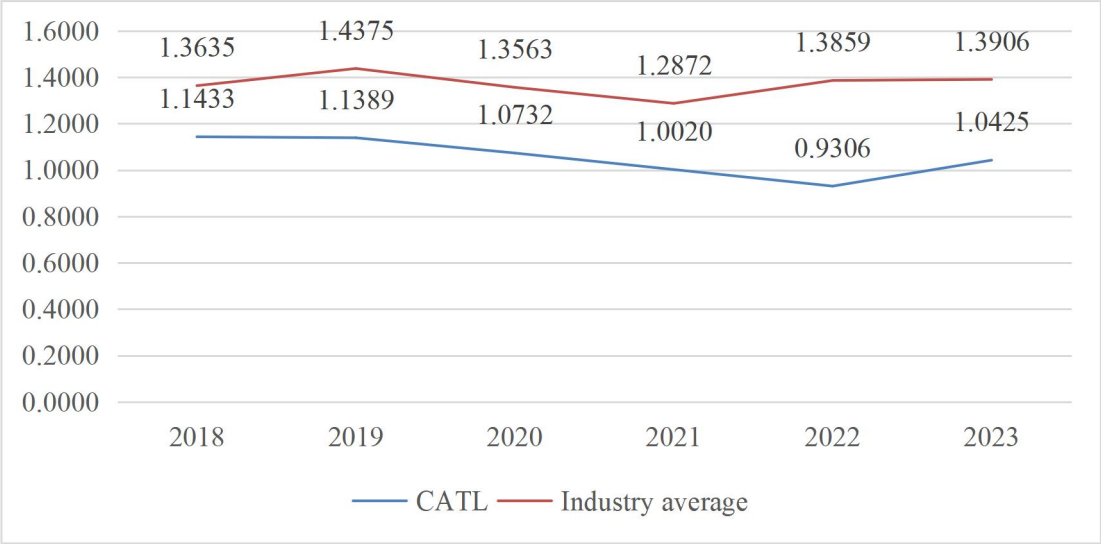

Figure 7. Changes in Sales Revenue Rate

As depicted in the figure, the sales cash collection rate of CATL from 2018 to 2023 maintained a roughly similar trend to the industry average. It increased after consecutive years of decline and fluctuated around 1, suggesting that the cash flow received from CATL's operating activities maintained a reasonable, proportional relationship with the scale of its operating income. The firm had a relatively strong cash realization ability, and its profits had a relatively high profitability.

(2) Total Asset Cash Collection Rate

The total asset cash collection rate reflects an ability to generate cash from all a company's assets. Specifically, it is the operating cash net flow ratio to total assets. This indicator will evaluate a company's ability to generate cash from all its assets. The larger the indicator value, the better the company can generate cash flow from its assets. By calculating the reciprocal of the indicator, we can analyze the period required for the total assets to be recovered through operating activities. The shorter the period, the stronger the asset's ability to generate cash. The larger the ratio, the better the asset utilization effect, the more cash inflows generated by the asset, and the stronger the company's ability to generate cash. Conversely, the company needs to improve its management level and economic efficiency.

The chart shows that CATL's total cash collection rate has fluctuated since 2018. It increased between 2020 and 2021 and 2022 afterward, all higher than the industry average, indicating that CATL's profits have strong liquidity.

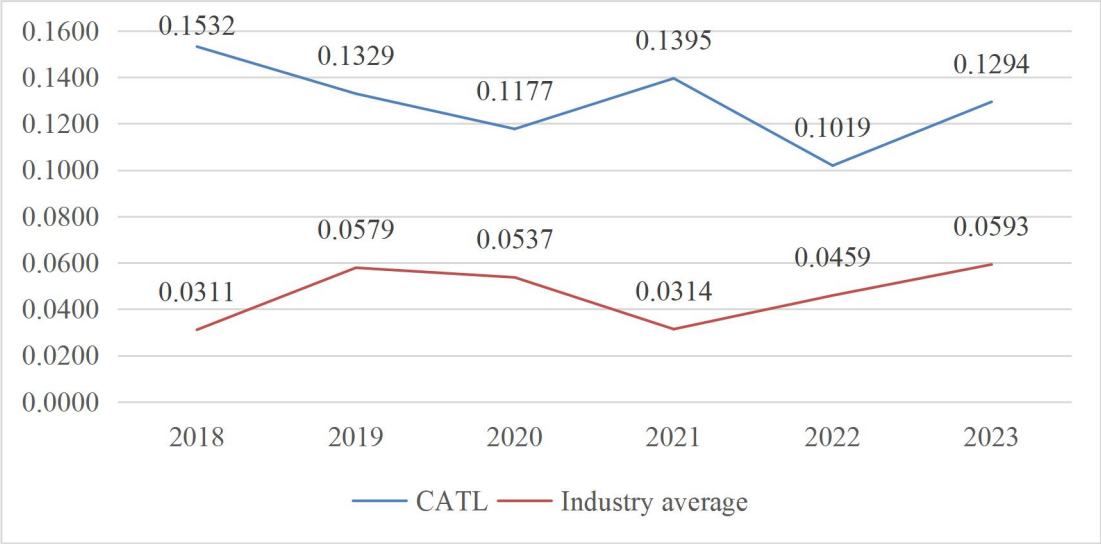

Figure 8. Changes in Total Asset Cash Collection Rate

3.4. Growth Indicators

Profitability's growth ability and profit quality level are closely interrelated and mutually influencing. Together, they provide practical information for enterprise investors (Aboody et al., 2005).

(1) The Growth Rate of Gross Profit Margin

The growth rate of gross profit margin refers to the increase in the gross profit margin of an enterprise in the current period compared to that in the previous period. By identifying the superior or inferior business segments based on the magnitude of this value, the implementation of strategies can be effectively analyzed. Therefore, when analyzing the profitability of an enterprise, the gross profit margin indicator should be utilized, which can effectively evaluate the future development potential of the enterprise (Zhang, 2023). If the growth rate of the gross profit margin is positive, it indicates an improvement in the enterprise's profitability.

The figure shows that the growth rate of NATL's gross profit margin was negative before 2023. It was lower than the industry average in 2018, 2019, and 2022, mainly because the new energy market was booming in 2022, and lithium was in short supply, with a significant price increase, causing the cost of the company's products to rise. At the same time, the price of power batteries decreased, and the company gradually invested in upstream lithium battery enterprises through strategic cooperation and self-production to ensure the supply of upstream materials. Managers need to formulate more reasonable business strategies to improve the company's profitability. With the expansion of upstream capacity, NATL's gross profit margin began to grow significantly in 2023.

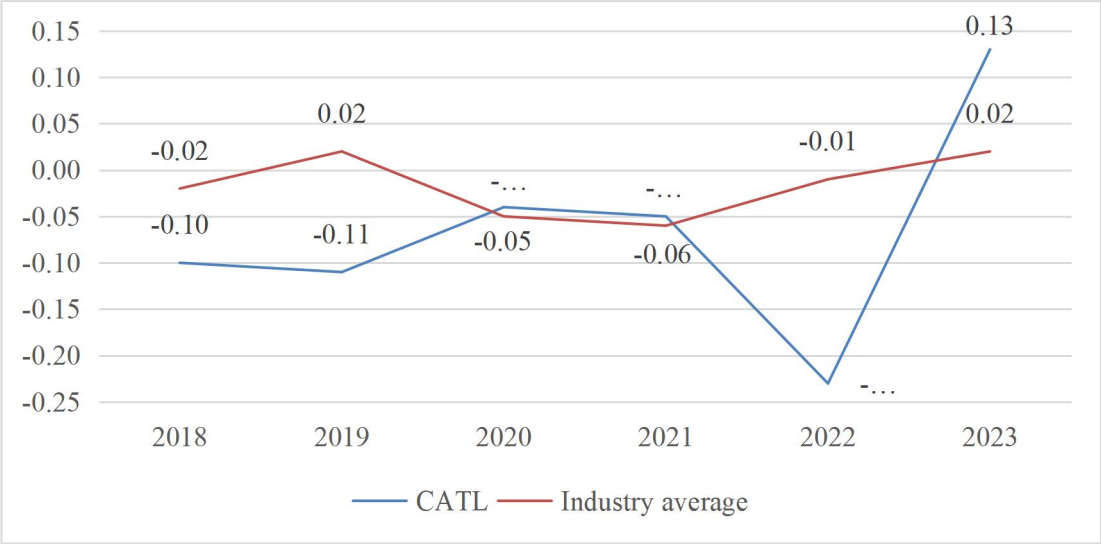

Figure 9. Changes in the Growth Rate of Gross Profit Margin

(2) The Growth Rate of Operating Revenue

Revenue structure plays a significant role in an enterprise's profit quality. The enterprise's operating revenue fluctuations are manifested more directly in its profit quality level (Bonacchi et al., 2019). The growth rate of operating revenue is not only a crucial indicator for gauging an enterprise's growth status and development potential but also for assessing its market possession ability and product competitiveness. The larger this indicator is, the more consumers favor the enterprise's products and the better the enterprise's development prospects. Therefore, the greater the growth rate of operating revenue, the better the profit growth potential of the enterprise.

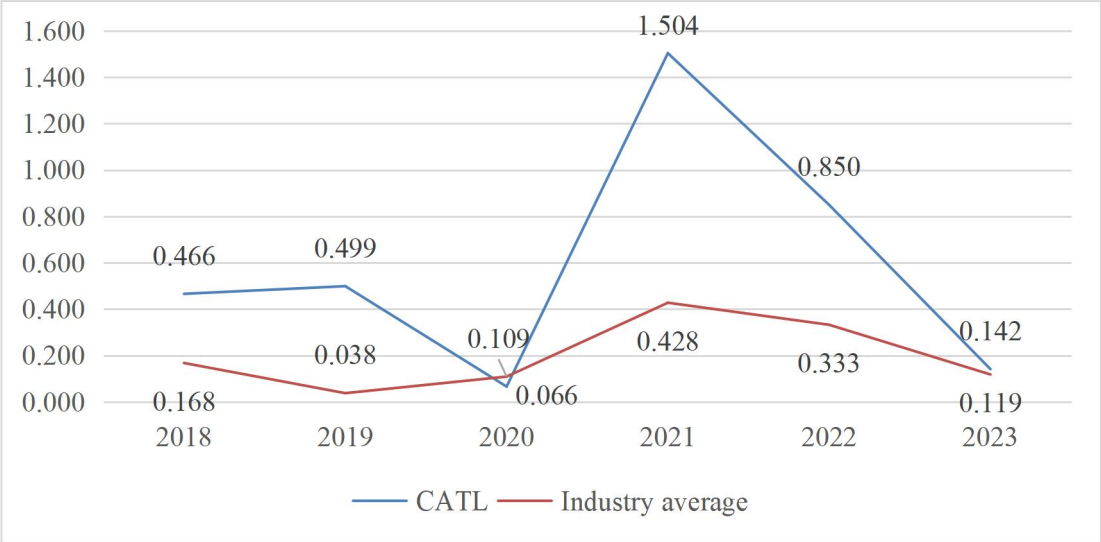

Figure 10. Changes in the Growth Rate of Operating Revenue

It can be observed from the graph that the revenue growth rate of CATL has fluctuated significantly in recent years, maintaining a trend of initially decreasing, then increasing, and subsequently decreasing. Specifically, it reached a maximum of 150.35% in 2021. In 2020, CATL

was adversely affected by the epidemic and exhibited a negative growth trend. Nevertheless, compared with the revenue growth rates of enterprises in the same industry, CATL benefits from its scale effect and relatively high profitability. Although CATL's revenue growth rate is not satisfactory and the growth rate is unstable, it can sustain positive growth. With the continuous increase of electric vehicles in the future, CATL enjoys a favorable market prospect.

4. Factor Analysis

4.1. Sample Selection

The samples in this analysis are selected from 45 companies in the power equipment industry listed on the Shanghai and Shenzhen stock markets. The information disclosure of these listed companies is standardized, and their financial information is complete, which is of reference significance for the current situation of the power equipment industry.

4.2. Construction of Profit Quality Evaluation System

The profit quality of a company is a comprehensive manifestation of its financial operation quality. Studies on corporate finance have found that financial indicators are relatively objective indicators for evaluating a company's financial status and business performance and can reflect the company's operation from different aspects. Therefore, economic data and indicators are selected to analyze the profit quality of listed companies in the power equipment industry. This paper selects ten representative secondary indicators from four aspects: profitability, stability, cash collection, and growth, namely gross profit growth rate X1, accounts receivable proportion X2, core profit margin X3, return on total assets X4, return on net assets X5, cost and expense profit margin X6, proportion of operating profit X7, revenue growth rate X8, sales cash collection rate X9, and total cash recovery rate X10, to construct a profit quality evaluation system.

4.3. Factor Analysis

Factor analysis is adopted to analyze the profit quality of companies in the power equipment industry listed on the A-share market. The principle is to group the original variables based on their correlations, obtaining a few factors that integrate the majority of the original variables and reducing the dimensions to decrease the number of original variables.

4.3.1. Data Verification

The data was imported into SPSS 23.0 for the KMO-Bartlett's sphericity test. The KMO statistic was 0.682, greater than 0.5; Bartlett's sphericity test statistic was 368.676, and the P-value was close to 0. This passed the significance test, indicating a strong correlation among the 10 variables, and it is suitable for factor analysis.

4.3.2. Determination of Common Factors

The extracted common factors follow the principle that the cumulative contribution rate exceeds 80%. The cumulative variance contribution was 84.257%, greater than 80%, indicating that the four extracted principal factors can represent the original variables.

4.3.3. Factor Loading Matrix

Factor rotation is conducted to name and explain the factors. The larger the absolute value of the factor loading in the rotation matrix, the closer the relationship between this common factor and a particular variable and the more potent its ability to explain the information contained in the variable.

Table 1. Rotated component matrix

	Component			
	1	2	3	4
Zscore (The Growth Rate of Gross Profit Margin)	0.297	0.209	0.790	-0.056
Zscore (Proportion of Accounts Receivable)	-0.038	-0.237	-0.003	0.828
Zscore (Core Profit Margin)	0.806	0.424	0.149	0.005
Zscore (Return on total assets)	0.899	0.289	0.161	-0.098
Zscore (Return on equity (ROE))	0.886	0.093	0.193	-0.011
Zscore (Cost-Volume-Profit Ratio)	0.865	0.376	0.054	-0.071
Zscore (Proportion of Operating Profit)	-.0048	.0157	-0.076	0.855
Zscore (The Growth Rate of Operating Revenue)	0.062	-0.123	0.903	-0.034
Zscore (Sales Revenue Rate)	0.385	0.890	0.025	-0.014
Zscore (Total Asset Cash Collection Rate)	0.350	0.867	0.014	-0.063

4.3.4. Factor Naming

From Table 2, the loadings of each variable on the relevant factors are obtained, and they are named based on the comprehensive data characteristics. The common factor F1 has relatively large loading coefficients on the core profit rate, return on total assets, return on net assets, profit rate of cost, and expense. This factor reflects the enterprise's profit-generating ability and is thus named the Profit Quality Factor. The common factor F2 has relatively large loading coefficients on the sales cash collection rate and the total cash recovery rate. This factor reflects the cash collection situation of the company and is therefore named the Profit Cash Collection Factor. The common factor F3 has relatively large loading coefficients on the growth rate of gross profit and operating income growth rate. This factor reflects the growth potential of the company's profits and is accordingly named the Growth Factor. The common factor F4 has relatively large loading coefficients on the accounts receivable and operating profit proportion. This factor reflects the company's stability and is named the Stability Factor.

Table 2. Top 20 in comprehensive ranking and factor ranking

Stock abbreviation	Comprehensive Score	Fac_1	Fac_2	Fac_3	Fac_4
Dexin Technology	1	13	1	29	6
Anfu Technology	2	2	22	9	21
Derui lithium Battery	3	17	4	8	16
GP Energy	4	37	10	26	1
Hangke Technology	5	1	38	12	14
CATL	6	12	13	7	17
Zhejiang HENGWEI	7	8	12	21	23
Starsource Material	8	15	8	22	7
Yinghe Technology	9	16	16	1	10
Tianhua Xinneng	10	3	3	45	33
NeoState	11	22	2	32	13
Tiannai Technology	12	6	21	35	27
Kodali	13	9	36	10	22
Yiwei lithium Energy	14	25	15	3	18
Xiangtan Electrochemical	15	10	20	25	31
Dangsheng Technology	16	4	31	33	35
Mustang Battery	17	18	23	16	29
Lijia Technology	18	20	17	19	25
Godsend Material	19	5	26	40	32

4.3.5. Factor Scores and Rankings

The factors are expressed as linear combinations of variables based on the factor score coefficient matrix, and the score functions of each factor are obtained. The variance contribution rate of each common factor is used as the weight to weigh each common factor and construct the comprehensive score evaluation model of profit quality: Comprehensive score = (FAC_1 * 33.559 + FAC_2 * 20.966 + FAC_3*15.330 + FAC_4 * 14.402 +) / 84.257. It can represent the

comprehensive score of the financial indicators reflecting the profit quality of each company, and the ranking is carried out to reflect the differences in the profit quality of each enterprise.

5. Suggestions for Improving Profit Quality

5.1. Financial Advice

Rapidly growing revenue may not lead to the synchronous growth of profitability, so companies are suggested to conduct the following strategies: strengthen the management system of enterprise supply, production, and marketing, and monitor costs; strictly control the cost management system, a bottom-up and top-down return system, strictly follow the implementation of the planned project, reduce the expenses during the period, and improve the income efficiency(Zhang, 2023).

Another practical suggestion is to actively adjust the production and operation mode, reduce inventory and total inventory, and enhance the liquidity of assets. CATL's annual decline in gross profit margin and other indicators is related to expanding capacity and inventory backlog. Managers are advised to strengthen inventory control, reasonably optimize inventory composition, and improve supply chain control processes and mechanisms.

To strengthen the development of the central business of listed companies, first of all, the company should carefully determine its strategic positioning. When the company grasps the market from the height of strategy, its market field is broadened to clarify the company's main business better, avoid outdated business, and develop its innovation research at the same time. Second, the company should avoid blindly implementing diversification. Diversification may easily lead to the dispersion of company resources, which makes the company unable to concentrate its advantages to carry out its main business and even hinders the development of its primary business. Finally, the company should track and investigate the implementation process of its primary business, find and solve problems anytime and anywhere, nip these problems in the cradle, and end all matters that hinder its main business so that its main business can be carried out smoothly.

5.2. Strategic Recommendations

Firstly, expand follow-up service areas. Due to the unbalanced development of the five major fields, the proportion of investment in the power battery field is increasing, and it is easy to face the huge impact of industrial development fluctuations. The downstream users are relatively concentrated. CATL can expand the follow-up service areas with good performance and good market prospects in accordance with the business growth goals and market support so as to prevent business difficulties.

Secondly, expand overseas business. At present, CATL is limited to domestic industries. Although foreign projects have developed, they are small in scale. Therefore, CATL can take advantage of the development advantages of domestic industries, actively expand cooperation with foreign excellent new energy enterprises, realize the expansion of foreign projects, and expand overseas business.

By improving the internal governance level of enterprises, the ability of enterprises to cope with external risks can be improved, which is conducive to the stability of profit quality (Melgarejo, 2019). Establish a scientific organizational structure, improve management efficiency, improve the internal organizational system, and carry out a scientific and efficient management system. Establish an employee incentive system, improve the enthusiasm of employees, regularly organize learning, and improve the knowledge level of employees. The reform of the upper-level system of enterprises will also impact the composition of enterprise profits (Purwaningsih et al., 2020). Enhance the strategic vision of the management and carry out scientific management. At the same time, the managers can shape the corporate culture and improve the cohesion of employees. In addition, the development strategy that aligns with the enterprise's nature shall be formulated according to the business scale.

Author Contributions:

Conceptualization, Y.Z. and Y.W.; methodology, Y.Z. and Y.W.; software, Y.Z. and Y.W.; validation, Y.Z. and Y.W.; formal analysis, Y.Z. and Y.W.; investigation, Y.Z. and Y.W.; resources, Y.Z. and Y.W.; data curation, Y.Z. and Y.W.; writing—original draft preparation, Y.Z. and Y.W.; writing—review and editing, Y.Z. and Y.W.; visualization, Y.Z. and Y.W.; supervision, Y.Z. and Y.W.; project administration, Y.Z. and Y.W.; funding acquisition, Y.Z. and Y.W. All authors have read and agreed to the published version of the manuscript.

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Literature Review on the Impact of Risk Management Committees on the Effectiveness of Enterprise Risk Management

Na Xu[1], Jincheng Guo[2*]

[1]Business School, University of International and Economics, Beijing 100000, China; 202100320084@uibe.edu.com

[2]China CITIC Bank, Beijing 100000, China; 396327430@qq.com

*** Correspondence:**
Jincheng Guo
396327430@qq.com

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Abstract

The establishment of the Risk Management Committee aims to enhance the board's ability to monitor risks, but there is no consensus on its impact on the effectiveness of enterprise risk management. This article provides a literature review from two aspects: whether the risk management committee will improve the effectiveness of enterprise risk management, and which features will affect the effectiveness of enterprise risk management. Research has found that the structural characteristics of risk management committees, including size, independence, professional knowledge and skills, meeting frequency, and proportion of female members, have a significant impact on the effectiveness of enterprise risk management. However, the relationship between these characteristics and corporate performance is not consistent and may be influenced by moderating variables such as external environmental uncertainty, industry competition intensity, and corporate complexity. This article suggests that companies should establish a reasonable risk management committee based on their own characteristics and consider incorporating digital skills into the professional knowledge of committee members. Future research should consider the impact of specific situational factors on the relationship between risk management committees and the effectiveness of enterprise risk management.

Keywords: Risk Management Committee; Enterprise Risk Management; Structure

1. Introduction

For enterprises, risk is a double-edged sword. High performance often comes with high risk, and conversely, reducing risk may also inhibit the performance of the enterprise. Therefore, effective risk management is crucial for enterprises. Effective risk management can significantly improve a company's performance. Studies have shown that effective enterprise risk management can significantly improve a company's Tobin Q (Hoyt et al., 2011). Gordon et al.(2009)

developed a comprehensive index of enterprise risk management to study the relationship between enterprise risk management and enterprise performance. The research results showed that there is a significant positive correlation between enterprise risk management and enterprise performance, and the strength of this relationship depends on the matching of enterprise risk management processes with the operating environment of the enterprise.

The board of directors, as an effective control mechanism for corporate governance, is responsible to shareholders for the effectiveness of comprehensive risk management work. Therefore, the board of directors plays a crucial role in the implementation of enterprise risk management. According to agency theory, the board of directors should establish a risk management committee to assist in fulfilling its risk management responsibilities and enhance its ability to monitor risks. At the same time, the bankruptcy of enterprises in the early 21st century and the global financial crisis in 2008 have promoted efforts to improve international regulation, with clear requirements for the composition structure of the board of directors. For example, the Sarbanes Oxley Act in the United States requires that the board of directors of listed companies must have no less than 50% independent directors, and the audit committee must be composed entirely of independent directors. The Corporate Governance Committee of the Australian Securities Exchange requires listed companies to establish an independent risk management committee to enhance the regulatory function of the board of directors. Therefore, these regulatory requirements provide a certain foundation for relevant academic research.

At present, there are many studies on the relationship between risk management committees and enterprise risk management, but no consensus has been reached on the results. This article will conduct a literature review from two aspects: first, whether the risk management committee will improve the effectiveness of enterprise risk management, and second, which characteristics of the risk management committee will affect the effectiveness of enterprise risk management. The research aims to explore how the structural characteristics of risk management committees affect the effectiveness of enterprise risk management, and analyze the potential impact of these characteristics on enterprise performance. The goal is to provide theoretical and empirical support for optimizing risk management practices, improving governance structures, and enhancing performance for enterprises, while responding to international regulatory requirements and providing guidance for future research directions.

2. Risk Management Committee and Effectiveness of Enterprise Risk Management

Compared with traditional risk management methods, enterprise risk management adopts a holistic approach of assessing and managing risks and capturing opportunities in an interdependent environment (Farrell et al., 2015). Enterprise risk management requires the integration of risk management into a company's strategic plan. COSO (2004) defines enterprise risk management as a process jointly implemented by the company's board of directors, management, and other personnel, applied to the strategic framework of the entire enterprise, aimed at identifying potential risk events that may affect the enterprise and managing them within risk appetite, thereby providing reasonable assurance for achieving the company's goals (Zhao et

al., 2014). Therefore, enterprise risk management requires the board of directors to enhance its ability to supervise enterprise risks.

In fact, many companies have also applied the "Integrated Framework for Enterprise Risk Management" proposed by COSO to their actual risk management activities, especially since the board of directors has established an independent audit committee to assist them in fulfilling their risk monitoring responsibilities. However, the audit committee bears significant responsibilities for both internal control and financial reporting, and therefore cannot effectively handle risk management related matters (Elamer, 2018). Furthermore, the professional knowledge possessed by the audit committee does not fully match the skills required to manage complex risks. More researchers have shown that due to a lack of professional knowledge and additional responsibilities, audit committees do not have enough time to provide optimal risk management solutions to the board of directors. Based on this, some countries in developed economic market regions have further requirements for the structure and composition of the board of directors. In particular, the 2009 UK Walker Report proposed that the board of directors of listed companies should establish an independent risk management committee to monitor current and future risks.

At present, there are many literature studies on risk management committees, but the results have not tended towards consistency. Among them, Yatim (2010) pointed out that an independent risk management committee has a positive impact on the performance of a company. In addition, Minton et al. (2011) conducted a study using data from 235 banks in the United States, and the results showed a positive impact between risk committees and corporate financial performance. Meanwhile, Jia et al. (2020) conducted an empirical study on the relationship between risk management committees and corporate performance using data from non-financial listed companies in Australia. The study found that companies with independent risk management committees performed better than other companies. From this, it can be seen that the risk management committee can increase corporate performance by strengthening the effectiveness of enterprise risk management. Malik et al.(2020) precisely validated this pathway. In addition, risk management committees can prevent companies from falling into financial difficulties by reducing the likelihood of tail end risks (Beasley et al., 2008). Zhou et al.(2020) pointed out that risk management committees can reduce information asymmetry by strengthening supervision of managers, which can help companies reduce a certain degree of risk.

However, Aebi et al.(2012) suggest that a risk management committee may not necessarily be a feasible solution to improve the effectiveness of risk management, as establishing a risk committee would increase the corresponding costs but would not eliminate all risks. An empirical study using data from listed companies of Malaysian investment banks showed that companies with risk management committees exhibited poorer performance. Meanwhile, Zemzem and Kacem (2014) studied the relationship between risk committees and corporate financial performance using data from 2002 to 2011, and the results showed a negative correlation between risk management committees and corporate financial performance. Further research has shown that there is no significant relationship between risk management committees and corporate performance.

The reason may be that different enterprises have different structural characteristics when establishing risk management committees, and risk management committees with different structural characteristics play different roles in fulfilling risk regulatory responsibilities, resulting in inconsistent research results. As Kallamu (2015) pointed out, if the risk management committee cannot operate effectively, its establishment cannot increase any revenue for the enterprise. Therefore, having a strong risk management committee is necessary for enterprises.

3. Structural Characteristics of Risk Management Committee and Effectiveness of Enterprise Risk Management

At present, most of the literature on the structural characteristics of risk management committees focuses on the committee's size, independence, professional knowledge and skills, number of committee meetings, and whether the committee has female members. This section will also conduct a literature review from these five aspects.

3.1. Scale of Risk Management Committee

The composition of the committee has a significant impact on its efficiency in performing its duties. Although regulations in various countries do not specify the number of committee members, it is usually emphasized that the number of members should be reasonable. Smith (2003) pointed out that the risk management committee should have at least three members, while Vafeas (2005) believes that having too many members may lead to free riding problems.

Empirical research shows that there is a certain positive relationship between committee size and corporate performance. For example, increasing the size of the risk management committee can enhance supervision of managers' risk management behavior, ensure that investments align with strategic goals, and thereby avoid financial crises by reducing adverse choices and moral hazard (Aebi et al, 2012; Yatim, 2010. This viewpoint is consistent with agency theory. In addition, according to the resource dependence theory, larger committee sizes can gather more professional knowledge, thereby providing more constructive recommendations to the board of directors (Bédard et al., 2004).

However, other studies suggest the opposite view. The empirical research by Kakanda (2018) and Malik (2021) suggests that committee size may have a negative impact on firm performance. Similarly, Elamer's(2018) study on UK financial institutions found a negative correlation between the size of risk management committees and financial performance. This negative impact may stem from communication barriers caused by an excessive number of members, which can exacerbate conflicts between shareholders and management and ultimately damage corporate performance. The study by Wu et al. (2009) on board size further supports this conclusion. In addition, the expansion of the committee size may also lead to an increase in agency costs, which may have a negative impact on corporate performance. Therefore, the board of directors of a company should establish a reasonable number of risk management committees based on its own development characteristics.

3.2. Independence of the Risk Management Committee

The agency theory suggests that the board of directors should be equipped with an appropriate number of external directors to ensure their independence, thereby effectively supervising managers and providing objective recommendations to the board. This is because external directors are more concerned with their own "reputation" rather than focusing on economic interests. Therefore, they are able to better fulfill their regulatory responsibilities.

The US Sarbanes Oxley Act provides clear regulations on how many independent directors a board of directors should have, requiring that the board of directors of US listed companies must have no less than 50% independent directors. However, there is no clear regulation on the number of independent directors in the risk management committee.

Existing research indicates that there is no consensus on the relationship between the independence of risk committees and corporate performance. A study conducted by Zemzem and Kacem (2014) on Tunisian loan companies showed that the percentage of independent members in the risk management committee is positively correlated with corporate performance. Kallamu et al.(2013) also found a positive correlation between the percentage of independent directors in the risk management committee and a company's financial performance, and found a positive correlation between the percentage of independent directors in the risk management committee and the company's market valuation. These results are supported by agency theory, which suggests that the more independent members a board of directors has, the higher the degree of control and objectivity in decision-making.

However, an empirical study conducted by Yeh et al.(2011) showed a negative correlation between the independence of risk management committees and a company's financial performance. Meanwhile, an empirical study conducted by Elamer (2018) on the impact of risk committees on the financial performance of UK financial institutions confirmed a negative correlation between the independence of risk management committees and financial performance. These results are supported by the stewardship theory, which suggests that due to the lack of relevant operational information of the enterprise by external directors, even if they can excessively supervise the enterprise, it will lead to a decrease in the value of the enterprise. In addition, unnecessary regulation can hinder management from making decisions in accordance with the company's goals. In addition, research on the impact of independent directors on corporate risk management has shown that a large number of independent directors can lead to excessive use of interest rate derivatives, resulting in high risks for the company and a decrease in its valuation.

Therefore, when setting up a risk management committee, the board of directors of a company should not only consider the number of independent boards, but also the degree to which the committee has access to company information, in order to establish a strong risk management committee.

3.3. Professional Knowledge and Skills of the Risk Management Committee

As the main responsibility of the Risk Management Committee is to manage risks on behalf of the Board of Directors and monitor the behavior of managers. Therefore, it must possess some risk management knowledge that the current board of directors does not possess.

Kallamu(2015) pointed out that directors with financial knowledge can better understand the complexity and risks of the committee. Xie et al. (2001) argue that directors with only financial knowledge may make more unfavorable decisions, leading to higher costs. Studies have shown that during financial crises, committee members with financial knowledge did not avoid losses. Therefore, financial knowledge is not sufficient to become a necessary skill for managing risks. When establishing a risk management committee, the board of directors of a company should consider whether the members have experience in risk management, such as whether they have served as the chief risk officer or have experience in risk management.

3.4. Frequency of Risk Management Committee Meetings

Smith (2003) pointed out that the risk management committee should hold at least three meetings a year. The main purpose of establishing a risk management committee by the board of directors is to ensure that risks can be regularly evaluated and managed. The committee members communicate effectively through regular meetings to avoid delays in risk management actions. In addition, the number of meetings of the Risk Management Committee can also reflect the level of effort it has put in to complete its tasks.

An empirical study by Aebi et al.(2012) showed that the frequency of risk management committee meetings has a significant positive impact on the performance of Bank of America. Meanwhile, the research conducted by Kakanda(2018) using data from listed financial services companies in Nigeria showed that the frequency of risk management committee meetings has a significant positive impact on a company's book to book ratio (MTB). Hoque et al.(2013) found no significant relationship between the number of risk management committee meetings and corporate financial performance.

However, studies have shown that high-frequency committee meetings are only effective during times of crisis, and an increase in the number of meetings during normal times can lead to increased costs, thereby having a negative impact on business performance. Ng et al. (2012) found that the number of risk management committee meetings is negatively correlated with corporate financial performance. Meanwhile, a study conducted by Elamer(2018) using data from UK financial institutions also confirmed a negative correlation between the number of risk management committee meetings and corporate financial performance. Therefore, the frequency of committee meetings should be determined based on the performance of the committee itself and the characteristics it aims to accomplish its tasks.

3.5. Female Members of the Risk Management Committee

Behavioral theory suggests that the behavior of a committee is related to its gender composition. Loukil and Yousf (2016) pointed out that female directors tend to be more averse to risk than male directors in risk related decision-making. Meanwhile, Campbell and Minguez Vera (2008)

pointed out that female directors are more likely to improve a company's performance by enhancing its innovation capabilities. Malik et al. (2020) conducted an empirical study that precisely demonstrated a significant positive relationship between female members of risk management committees and company performance.

However, the study by Adams and Ferreira (2009) suggests that female boards excessively regulate risky decisions, to the extent that it harms the interests of shareholders. In addition, their research also found that arranging female directors in committees is just a symbol for companies. The empirical research results of Kakanda (2018) precisely confirm this point. There is a significant negative relationship between female directors of the risk management committee and the market value of the enterprise. Therefore, when considering the gender of members of the risk management committee, the board of directors of a company should determine it based on the actual situation of the company. Female directors should not be seen as a symbol, nor should high-yield venture capital be abandoned due to the supervision of female directors.

4. Conclusion

In summary, the risk management committee can improve the effectiveness of enterprise risk management under certain conditions, thereby increasing the performance of the enterprise. The certain conditions are reflected in the fact that the risk management committee must have the advantage of risk control in its structural composition, including having a reasonable scale, a reasonable number of independent directors, corresponding knowledge of risk management, and holding a reasonable number of meetings based on the operation of the enterprise, and considering whether to include female directors based on the characteristics of enterprise risks. In short, a strong structured risk management committee can help the board better fulfill its responsibilities in risk control. Jia et al. (2020) constructed a comprehensive index of the structural characteristics of risk management committees to examine the impact of best practices in risk management on corporate performance. The results further confirmed that companies with strong risk committee structures have better corporate performance.

However, the relationship between the Enterprise Risk Management Committee and the effectiveness of enterprise risk management may be influenced by some moderating variables, such as the uncertainty of the external environment of the enterprise, the intensity of competition in the industry in which the enterprise operates, and the complexity of the enterprise. Existing research has not considered the impact of these special factors on the relationship between the two. Therefore, when studying the impact of risk management committees on the effectiveness of enterprise risk management, certain specific contextual factors should be considered.

Furthermore, as mentioned earlier, the audit committee, as a committee under the board of directors, bears significant responsibilities for internal control and financial reporting. The structural characteristics of the audit committee are related to the quality of the company's financial statements and information disclosure. According to COSO (2004), enterprise risks are divided into strategic risk, operational risk, compliance risk, and reporting risk. Therefore, audit committees also have a certain impact on the effectiveness of enterprise risk management.

Therefore, it is necessary to simultaneously consider the impact of the characteristics of the risk management committee and the audit committee on the effectiveness of enterprise risk management, as existing literature studies these two separately.

Finally, in the era of enterprise digital transformation, digitization can be seen as an environmental factor that can influence the structure and functionality of a company, and this factor further affects the implementation of enterprise risk management. Therefore, committee members should possess corresponding digital skills. However, existing literature only considers knowledge related to accounting and risk management when studying the impact of committee expertise on the effectiveness of enterprise risk management, without taking into account corresponding digital skills. Therefore, future research can consider using digital skills as a factor that affects the effectiveness of enterprise risk management.

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Conceptualization, N.X and J.G.; methodology, N.X and J.G.; software, N.X and J.G.; validation, N.X and J.G.; formal analysis, N.X and J.G.; investigation, N.X and J.G.; resources, N.X and J.G.; data curation, N.X and J.G.; writing—original draft preparation, N.X and J.G.; writing—review and editing, N.X and J.G.; visualization, N.X and J.G.; supervision, N.X and J.G.; project administration, N.X and J.G.; funding acquisition, N.X and J.G. All authors have read and agreed to the published version of the manuscript.

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The Impact of Board Structure Characteristics on Corporate Risk

Jincheng Guo[1], Wenting Hou[2*]

[1]China CITIC Bank, Beijing 100000, China; 396327430@qq.com

[2]School of Construction Engineering Management, Inner Mongolia Technical College of Construction, Hohhot 010000, China; 27411909@qq.com

*** Correspondence:**
Wenting Hou
27411909@qq.com

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Abstract

Risk runs through all aspects of enterprise operation, therefore, risk management is particularly important for enterprises. As the core control mechanism of corporate governance, the structural characteristics of the board of directors directly affect its ability to supervise and manage enterprise risks, and different structural characteristics may have differentiated effects on risk management. This article takes non-financial listed companies on the A-share market in China from 2009 to 2017 as samples, uses monthly return volatility as a proxy variable for corporate risk, selects board size and board independence as two characteristics, constructs a multiple linear regression model, and empirically analyzes the impact of board structure characteristics on corporate risk. The research results show that board size has a certain positive impact on corporate risk, while board independence has no significant effect on corporate risk.

Keywords: Board Structure; Corporate Risk; Risk Management; Board Independence

1. Introduction

Risk is ubiquitous and runs through all aspects of business operations, therefore, risk management is particularly important for enterprises. Risk management was initially defined as a series of methods and strategies that help businesses achieve their primary goals by controlling and monitoring risks. Effective risk management is closely related and interdependent with corporate governance (Sobel and Reding, 2004), and can significantly enhance enterprise value. Research has shown that the integration of risk management and corporate governance is crucial for businesses to respond to crises. Aebi et al. (2012) found that during the global financial crisis, banks with a Chief Risk Officer who reports directly to the board of directors rather than the CEO performed better. This mechanism strengthened the synergy between risk management and corporate governance, thereby improving the risk environment for businesses. However, Elamer's (2018) study points out that many financial institutions have failed to fully integrate risk

management practices into corporate governance, leading to large-scale economic crises worldwide. Gupta et al. (2013) further pointed out that poor governance systems, such as inadequate board oversight of management and inefficient risk management practices, are key reasons why companies face significant risks. Therefore, the board of directors plays a crucial role in corporate governance and risk management.

As the core control mechanism of corporate governance, the board of directors is responsible to shareholders for the effectiveness of comprehensive risk management. Amran et al. (2010) pointed out that the responsibilities of the board of directors include carrying out supervisory tasks, eliminating agency costs, coordinating the interests of shareholders and management, appointing and dismissing management personnel, and supervising the behavior of the CEO. According to COSO (2004), the responsibilities of the board of directors in risk management include: clarifying the overall objectives, risk preferences, and risk tolerance of enterprise risk management, approving risk management strategies and major risk response plans. At the same time, the board of directors needs to have a comprehensive understanding of the major risks faced by the enterprise and their management status, and make effective risk control decisions. However, the structural characteristics of the board of directors directly affect its supervision and management capabilities, and different board structural characteristics may have different effects on risk management.

The corporate bankruptcies at the beginning of the 21st century and the global financial crisis in 2008 have driven improvements in international regulation and put forward clear requirements for board structure. For example, the Sarbanes Oxley Act in the United States stipulates that at least 50% of the board of directors of listed companies must be independent directors, and all members of the audit committee must be independent directors. The guidelines of the UK Financial Reporting Council require listed companies to establish comprehensive risk management frameworks and emphasize the active participation of the board of directors in risk management. The new rules established by the New York Stock Exchange in 2004 further strengthened the requirement for board independence. However, in China, there is still a lack of specialized normative documents for enterprise risk management (Dong, 2021). Therefore, it is necessary to test whether the governance practices of developed countries can also play a certain role in emerging countries. Based on this, this article uses panel data from Chinese A-share listed companies in Shanghai and Shenzhen from 2009 to 2017 to empirically analyze the impact of board structure characteristics on corporate risk.

2. Literature Review

At present, a large amount of literature has studied the characteristics of the board of directors, but most of them focus on their impact on corporate performance. For example, An (2021) empirically analyzed the relationship between board characteristics, heterogeneity, and corporate performance based on cross-sectional data of A-share listed companies. The results showed that the positive effect of board characteristics on corporate performance has not been fully utilized. Bansal et al. (2016) found that board size has a significant positive impact on firm performance.

However, Adams (2010) found that board size has a negative impact on organizational performance. The inconsistency of these research conclusions may be related to sample differences.

The academic consensus on the impact of board independence on corporate performance is inconsistent. Abidin et al. (2009) found a positive correlation between board independence and corporate financial performance, while Wu et al. (2009) pointed out a negative correlation between the two. To explain this inconsistency, Li and Yang (2020) combined board capital to examine the interaction effect between board independence and board capital. The research results showed that board independence indirectly improves business efficiency through the synergistic effect with board capital. This indicates that the independence of the board of directors can only effectively play a role under specific conditions.

The board of directors, as the core control mechanism of corporate governance, is responsible to shareholders for the effectiveness of comprehensive risk management. Therefore, studying the impact of the structural characteristics of the board of directors on its supervisory ability and risk management is of great significance. However, there is limited research on the relationship between board structure characteristics and corporate risk in existing domestic literature, and accounting indicators are often used as proxy variables for corporate risk. For example, Zheng (2015) used profit volatility as a proxy variable for corporate risk-taking and analyzed the impact of board characteristics of non-financial listed companies on risk-taking decisions; Lv and Yin (2017) used the Z-Score index as a proxy variable for bank risk-taking and studied the impact of board characteristics on risk-taking ability in 17 Chinese commercial banks.

However, accounting indicators are difficult to fully reflect market volatility. Based on this, this article uses the monthly return volatility of individual stocks as a proxy variable for corporate risk, selects two structural characteristics of board size and board independence, and empirically analyzes the relationship between board characteristics and corporate risk based on panel data of Chinese A-share listed companies in Shanghai and Shenzhen from 2009 to 2017.

3. Theoretical Background and Assumptions

According to agency theory, agents cannot always prioritize the best interests of the principal and may harm the interests of shareholders for their own benefit, resulting in conflicts of interest between shareholders and managers. Corporate governance, as a control mechanism for enterprises, has the core goal of reducing agency costs. In corporate governance, the board of directors plays a crucial role (Kose and Senbet, 1998). As the core control mechanism of governance, the board of directors is accountable to shareholders for the effectiveness of comprehensive risk management. Therefore, a good board structure can significantly enhance its risk management capabilities. Previous studies have shown that different elements of board structure play important roles in risk management, including board size and board independence.

3.1. Board Size

From a theoretical perspective, according to the resource-based theory, the board of directors should be composed of a wide and diverse range of members to enhance its unique abilities and effectively fulfill its supervisory responsibilities, thereby improving organizational performance. Kutum (2015) conducted an empirical study based on data from Palestinian listed companies, which showed a positive correlation between board size and company performance. Similarly, Bansal et al. (2016) and Liu et al. (2019) validated the positive relationship between board size and corporate performance through studies with different samples. However, according to agency theory, small-scale boards of directors are more efficient in executive supervision because of smooth communication among their members, higher coordination of activities, and less free riding. Larger boards of directors may have a negative impact on organizational performance due to increased complexity (Adams, 2010). The study by Wu et al. (2009) suggests that a large board size may lead to communication barriers and interaction issues, thereby reducing corporate performance. In addition, larger boards of directors have slower decision-making speeds and are more easily controlled by the CEO.

From the perspective of risk management, there is controversy over the effectiveness of risk management among boards of directors of different sizes. Some studies have shown that small-scale boards of directors are more effective in risk management, while others have found that small-scale boards are more likely to face greater risks. Aebi et al. (2012) argue that as the size of the board of directors increases, diversified knowledge helps ensure that corporate investments align with strategic goals and avoid financial crises by reducing adverse selection and moral hazard. Cheng's (2008) empirical study found that companies with larger board sizes have significantly lower volatility in accounting and market performance compared to companies with smaller board sizes. Pathan (2009) pointed out that an increase in board size is significantly correlated with a decrease in the volatility of financial institution returns. In contrast, Wang and Wang (2021) found a significant positive correlation between board size and corporate financial risk based on data from Chinese A-share listed companies from 2017 to 2019. Based on the above discussion, this article proposes the first competitive hypothesis.

Hypothesis 1a: The increase in board size has a positive impact on corporate risk.

Hypothesis 1b: The increase in board size has a negative impact on corporate risk.

3.2. Independence of the Board of Directors

From a theoretical perspective, agency theory advocates strengthening corporate governance mechanisms by appointing independent directors (i.e. external directors). External directors usually have the motivation to maintain the reputation of "expert supervisors" and are therefore more inclined to take effective regulatory measures to reduce agency costs between managers and shareholders. Dionne and Triki (2005) pointed out that the higher the proportion of independent directors, the better the board can maintain a high level of control and objectivity in decision-making. Abidin et al. (2009) further pointed out that the diversity of backgrounds, characteristics, experiences, and professional knowledge brought about by a high proportion of independent

directors can help optimize the supervisory process and decision-making efficiency of the board of directors, thereby improving company performance.

However, the stewardship theory suggests that due to the lack of in-depth understanding of internal information by independent directors, their excessive supervision may lead to unnecessary monitoring, thereby hindering management from making decisions based on corporate goals and ultimately reducing the value of the enterprise. Wu et al. (2009) found that independent directors have a lower ability to control organizational governance mechanisms compared to internal directors. Bhagat and Black (1999) further pointed out that too many independent directors may weaken the regulatory function of the board of directors, and suggested that an ideal board of directors should consist of independent directors, internal directors, and affiliated directors to ensure that the board has diverse skills and knowledge.

From the perspective of risk management, independent directors tend to objectively evaluate management activities and effectively mitigate unnecessary risks. However, Borokhovich et al. (2004) found that with the addition of external directors, firms' tendency to use interest rate derivatives increases, which in turn increases firm risk. Pathan's (2009) study also suggests that companies with more independent directors are more inclined to engage in high-risk activities and are therefore more likely to face credit risk or bankruptcy threats. In addition, Ng et al. (2012) studied the relationship between board characteristics and corporate risk-taking based on data from insurance institutions listed on the Malaysian Stock Exchange. The results showed a significant negative correlation between board independence and corporate performance. These research findings suggest that independent directors may not effectively enhance a company's risk management and monitoring capabilities. Based on the above discussion, this article proposes the second competitive hypothesis.

Hypothesis 2a: Board independence has a positive impact on corporate risk.

Hypothesis 2b: The independence of the board of directors has a negative impact on corporate risk.

4. Research Design

4.1. Sample Selection and Data Sources

This article takes non-financial enterprises listed on the Shanghai and Shenzhen A-shares as the research sample, and the research period is from 2009 to 2017. Choosing 2009 as the starting point is mainly based on the following two considerations: firstly, after the global economic crisis in 2008, enterprises in various countries have significantly increased their attention to risk regulation; The second is that the "Basic Norms for Enterprise Internal Control" (2008), as a guiding document, for the first time clarified the concept of risk oriented internal control, which can reflect its implementation effect since 2009. Due to the particularity of the financial industry, this study excluded samples from the financial industry. Meanwhile, due to the close connection between the real estate industry and the financial industry, it is also excluded. In addition, samples

with missing values in the data are also excluded. After screening, 5488 sample observations were ultimately retained, all data from the RESSET database.

4.2. Main Variables and Models

The dependent variable of this article is enterprise risk (Frisk), measured through market-based risk assessment. Market based risk measurement is calculated using the standard deviation of monthly stock returns. When calculating the standard deviation of monthly stock returns, it is required to have at least 6 months of data per year, and samples lacking data will be excluded. The main independent variables of this article are board size (Bsize) and board independence (Bind). The size of the board of directors is measured by the number of board members, while the independence of the board is measured by the proportion of independent directors.

Following the approach of Naz (2017), this article selects company size (Fsize), company leverage, and company return on investment (ROA) as control variables, and controls for annual fixed effects and individual fixed effects. Choosing to control company size is because market returns and stock price fluctuations are highly sensitive to changes in company size. At the same time, large companies face more risks and have more resources to support risk management. The size of a company is measured by the logarithm of its total assets. The leverage ratio of a company has a significant impact on the cost of capital and capital budget decisions, therefore the asset liability ratio is used as a measure of leverage ratio. The return on investment is used as a control variable to isolate the impact of governance factors on corporate risk-taking. The specific descriptions of each variable are shown in Table 1.

Table 1. Variable Description

Variable Name	Variable code	Variable definition
Enterprise risk	Frisk	Measure by market risk and calculate the monthly stock standard deviation
Board size	Bsize	Number of Board Members
Independence of the Board of Directors	Bind	Number of independent directors/number of board members
Enterprise scale	Fsize	Natural logarithm of total assets of the enterprise
Enterprise leverage ratio	Leverage	Total liabilities/total assets of the enterprise
Enterprise investment return rate	ROA	Net profit/total assets
particular year	YEAR	Year dummy variable

This article conducted four main analyses: descriptive statistics to present the nature and distribution of data, correlation analysis to present preliminary evidence of the relationship between variables, fixed effects ordinary least squares regression to show the impact of board size and board independence on corporate risk, and analysis of variance to further analyze the influence of independent variables on the dependent variable. The ordinary least squares regression model is as follows:

$$Friskit=\beta_0+\beta_1 Bsizeit+\beta_2 Bindit+\beta_3 Fsizeit+\beta_4 Leverageit+\beta_5 ROAit+\varepsilon it \quad (1)$$

5. Empirical Results Analysis

5.1. Descriptive Statistics

Table 2 presents the descriptive statistical analysis results of the samples. From the table, it can be seen that the average return on assets (ROA) is 68%, significantly higher than the 4.78% reported by Malik et al. (2018). This indicates that the sample companies had a relatively good overall profitability level after the financial crisis. However, judging from the maximum value (73.25%) and minimum value (-71.23%) of ROA, there is a significant difference in performance among the sample companies. From a risk perspective, the average individual stock return volatility (Frisk) is 0.123, which is close to the 0.133 reported by Sayari (2017), but the difference is not significant. The maximum value of individual stock return volatility is 0.21 and the minimum value is 0.09, indicating that the overall risk of the sample enterprises is low, and the impact of the 2008 financial crisis on non-financial institutions is relatively small.

Regarding the size of the board of directors, the average of the sample companies is 13.37, significantly higher than the 8.8 reported by Sayari (2017), indicating that despite the lack of regulatory documents in China, listed companies still attach great importance to corporate governance. However, the maximum (41) and minimum (3) values of board size indicate that there are still significant differences in corporate governance among the sample companies. The average independence of the board of directors (Bind) is 0.34, significantly lower than the 0.769 reported by Sayari (2017), reflecting that there is still a significant gap between China's corporate governance practices and those of developed countries. The average leverage ratio is 52.33%, with a maximum of 329% and a minimum of 16.96%, indicating significant differences in debt levels among the sample companies. The average company size (Fsize) is 22.07, with a maximum value of 27.31 and a minimum value of 9.33, indicating significant differences in size among the sample companies.

The Pearson correlation coefficients between variables are shown in Table 3. From the table, it can be seen that the size of the board of directors (Bsize) is positively correlated with the volatility of individual stock returns (Frisk) at a significance level of 1%, while the correlation coefficient between board independence (Bind) and the volatility of individual stock returns (Frisk) is -0.0067, but not significant, indicating that board size has a positive impact on company risk to some extent, while board independence has no significant impact on company risk. The size of the board of directors (Bsize) is negatively correlated with the independence of the board of directors (Bind) at a significance level of 1%, indicating that sample companies do not rely on

the size of the board of directors in appointing independent directors. There is a significant negative correlation between enterprise size (Fsize) and individual stock return volatility (Frisk) at the 1% level, indicating that compared to small enterprises, large enterprises face more complex operating environments and therefore bear greater risks.

In addition, the correlation coefficients between the variables are all less than 0.6, and the average variance inflation factor (VIF) is 1.25, which is lower than 3, indicating that there is no multicollinearity among the variables and multiple linear regression analysis can be performed.

Table 2. Descriptive Statistical Analysis

Variable	Sample Size	Mean Value	Standard Deviation	Minimum Value	Maximum Value
Bsize	5488	13.37	4.26	3	41
Bind	5488	0.34	0.096	0.06	0.8
ROA	5488	68	8.3	-71.23	73.25
Leverage	5488	52.33	25.60	16.96	329.00
Fsize	5488	22.07	1.52	9.33	27.31
Frisk	5488	0.123	0.037	0.09	0.21

Table 3. Correlation Coefficient Table

Variable Name	Bsize	Bind	ROA	Leverage	Fsize	Frisk
Bsize	1.0000					
Bind	-0.289***	1.0000				
ROA	-0.0167	0.0110	1.0000			
Leverage	0.0163	-0.0445**	-0.5730	1.0000		
Fsize	0.1122***	-0.0067	-0.1085***	-0.1165***	1.0000	
Frisk	0.0446***	-0.0032	-0.0072	0.0160	0.1620***	1.0000

Note: * * * indicates that the value is significant at the 5% level

5.2. Multiple Linear Regression Analysis

Table 4 shows the results of the least squares regression with individual time fixed effects. From the table, it can be seen that the estimated coefficient of board size (Bsize) is 0.075, which

is significant at the 1% significance level, indicating that an increase in board size will increase the risk of the enterprise. This result supports hypothesis 1a. However, this result is inconsistent with Cheng's (2008) conclusion that companies with larger board sizes are based on lower market volatility. An excessively large board size may lead to increased complexity, communication barriers, and free riding issues, thereby slowing down decision-making speed and increasing corporate risk.

Regarding the independence of the board of directors (Bind), the estimated coefficient is -0.002, indicating that independent directors help to mitigate unnecessary risks. However, this coefficient is not significant, indicating that hypothesis 2 is not supported. This result is inconsistent with Borokhovich's (2004) and Pathan's (2009) conclusion that independent directors are more inclined to drive higher risk activities, but consistent with Wang Jinrong and Wang Ning's (2021). This may indicate that the appointment of independent directors by sample companies is more formal, and independent directors have not played their due role in risk regulation, or their participation is insufficient. This reflects that there is still a certain gap in risk management and regulation in China compared to developed countries.

Regarding the control variable, the estimated coefficient of return on assets (ROA) is -0.011, which is significant at the 10% level, indicating that low-risk enterprises typically have higher profit returns, consistent with Sayari's(2017) research results. The estimated coefficient of leverage ratio is 0.015, which is significant at the 5% level, indicating that high leverage enterprises face greater risks, consistent with the research results of Malik et al.(2018). The estimated coefficient of company size (Fsize) is 0.021, significant at the 1% level, indicating that large enterprises face greater risks compared to small businesses, which is consistent with the research results of Elamer(2018). Large scale enterprises typically have larger business volumes and face more complex operational environments.

Table 4. Results of Multiple Regression Analysis

	Frisk			
	coefficient	Standard error	T-value	P-value
Bsize	0.075***	0.028	2.69	0.007
Bind	-0.002	0.0118	-0.16	0.873
ROA	-0.011*	0.0068	-1.85	0.064
Leverage	0.015**	0.008	1.98	0.048
Fsize	0.021***	0.001	15.72	0.000
_cons	-0.351***	0.029	-11.89	0.000
individual	YES			

Year	YES
Observation value	5488
WithinR^2	0.1206

Note: *, * *, * * * respectively indicate significant values at the 10%, 5%, and 1% levels.

5.3. Further Analysis

In order to further explore the impact of board size and board independence on company risk, this article conducted a variance analysis on these two independent variables. Firstly, based on the size of the board of directors, the sample companies were divided into two groups: the group with a board size greater than the average (Big) and the group with a board size smaller than the average (Small). The results are shown in Table 5. Secondly, based on the independence of the board of directors, the sample companies were divided into two groups: the group with board independence greater than the average (High) and the group with board independence less than the average (Low). The results are shown in Table 5.

From Table 5, it can be seen that the average risk level of companies with larger board sizes is 0.126, while the average risk level of companies with smaller board sizes is 0.122. There is a significant difference between the two at the 5% level, indicating that larger board sizes increase the risk of companies, which is consistent with the results of the multiple regression analysis mentioned earlier. On the other hand, the average risk level of companies with high board independence is 0.1234, while the average risk level of companies with low board independence is 0.1232. There is no significant difference between the two, indicating that board independence has no significant impact on corporate risk, which is consistent with the results of the aforementioned multiple regression analysis.

Table 5. Results of Analysis of Variance

Bsize				Bind			
average value		Mean difference	P-value	average value		Mean difference	P-value
Big	Small			High	Low		
0 .12585963	0.1221277	0 .002732*** （7.21）	0.0073	0.12338155	0.12317105	0.000211 （ 0.04 ）	0.8347

Note: The number in parentheses is the F-value, and * * * indicates that the value is significant at the 5% level.

6. Conclusion

This article uses the monthly return volatility of individual stocks as a proxy variable for corporate risk. Based on data from non-financial listed companies in China's A-share market from 2009 to 2017, board size and board independence are selected as two board characteristics. The impact of board structure characteristics on corporate risk is empirically tested through a multiple linear regression model. The results of univariate analysis showed that the average size of the board of directors of the sample companies was 13.37, significantly higher than the 8.8 reported by Sayari (2017), indicating that Chinese listed companies attach more importance to corporate governance, but there are still significant differences in governance structure among companies. The results of multiple regression analysis indicate that the size of the board of directors has a significant positive impact on corporate risk, suggesting that an excessively large board size may lead to increased complexity, communication barriers, and free riding issues, thereby reducing decision-making efficiency and increasing corporate risk.

Regarding the independence of the board of directors, univariate analysis shows that the mean independence of the board of directors in the sample companies is 0.34, significantly lower than the 0.769 reported by Sayari (2017), reflecting the gap between China's corporate governance practices and those of developed countries. The multiple regression results indicate that board independence has no significant impact on corporate risk, which is inconsistent with the conclusions of Borokhovich (2004) and Pathan (2009), but consistent with the research of Wang Jinrong and Wang Ning (2021). The possible reason is that the appointment of independent directors by sample companies is more of a formality, and independent directors have not effectively played their role in risk regulation or have not fully participated in the risk regulation process.

Further grouping tests showed that companies with larger board sizes had significantly higher risks than those with smaller board sizes, while the risk difference between companies with higher and lower board independence was not significant. This conclusion further supports the results of multiple regression analysis.

This article has the following limitations: firstly, it only selects board size and board independence as characteristics of board structure, without considering other board characteristics; Secondly, when using individual stock return volatility as a proxy variable for corporate risk, market system risk is overlooked; Finally, this article only considers market-based risks and does not address risks based on accounting indicators.

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Conceptualization, J.G and W.H.; methodology, J.G and W.H.; software, J.G and W.H.; validation, J.G and W.H.; formal analysis, J.G and W.H.; investigation, J.G and W.H.; resources, J.G and W.H.; data curation, J.G and W.H.; writing—original draft preparation, J.G and W.H.; writing—review and editing, J.G and W.H.; visualization, J.G and W.H.; supervision, J.G and W.H.; project administration, J.G and W.H.; funding acquisition, J.G and W.H. All authors have read and agreed to the published version of the manuscript.

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Research on the Development of a New Model of Community-Mediated Accompanied Medical Care for the Elderly

Meiwen Wang[1], Jing Shen[2*], Xiaoyu Zhang [3], Mengtong Yan[4]

[1] Beijing City University, Beijing 100000, China; 2263434542@qq.com
[2] Beijing City University, Beijing 100000, China; shenjing6688@163.com
[3] Beijing City University, Beijing 100000, China; 3663471768@qq.com
[4] Beijing City University, Beijing 100000, China; 2335578269@qq.com

*** Correspondence:**

Jing Shen

shenjing6688@163.com

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Abstract

This paper aims to explore a new model of community-mediated accompanied medical care services for the benefit of the elderly. Through an analysis of the background, including national policies, the current status of population aging, and the development of the accompanied medical care industry, the advantages of the project are expounded. The research process and results of the project, including the development status of community accompanied medical care services, the wishes of residents, and the situation of accompanied medical care institutions, are introduced in detail. A new model for the benefit of the elderly and its implementation path are proposed. The scientific nature, feasibility, and social value of the research results are discussed. The problems that need attention during the implementation of the project are analyzed, and the future development direction is prospected, providing a reference for solving the medical care problems of the elderly and promoting the development of the accompanied medical care industry.

Keywords: Accompanied Medical Care; Community Services; Medical Assistance

1. Introduction

In the current social development process, the problem of population aging is becoming increasingly severe and has become a global challenge. As one of the countries with a relatively high degree of population aging in the world, China is facing enormous pressure in providing for the elderly. In this context, elderly care services have become the focus of social attention, and the medical care problems of the elderly are particularly prominent. The accompanied medical care service has emerged as a new model to solve this problem.

Currently, national policies support the development of elderly care services. Against the backdrop of an aging population, the "Report of the State Council on Promoting the Construction of the Elderly Care Service System and Strengthening and Improving the Care Work for Disabled Elderly" emphasizes the importance of developing elderly care services. The Third Plenary Session of the 20th CPC Central Committee also clarifies relevant policy mechanisms (Lu, 2024). An article in People's Daily points out that efforts should be focused on the reform of grassroots governance, the construction of an elderly care service system should be promoted, the problem of medical assistance for the elderly should be solved, and the development of the silver-haired economy should be facilitated. The development of home-based care for the elderly has brought about difficulties in medical care. According to data from the National Bureau of Statistics, the proportions of the population aged 60 and above and 65 and above are increasing. At least in the next five years, this trend will continue and the growth rate will accelerate (Kuang & Wang, 2024). Home-based care for the elderly has become a new socialized elderly care service model to address population aging (Gong, 2019). However, the elderly face difficulties in seeking medical treatment when receiving home-based care. Although some communities in Beijing have piloted accompanied medical care services for the elderly thanks to government investment and hospital cooperation, generally speaking, the specialization and popularization of community accompanied medical care services are low. Most of the services are provided voluntarily by staff, and a complete service system has not yet been formed. With the improvement of medical technology and services, the accompanied medical care industry has emerged and has become a new force in the medical and health field, attracting widespread attention from society.

To address these problems, it is urgent to explore an innovative and sustainable model of accompanied medical care for the elderly. The new model of accompanied medical care for the elderly mediated by the community can give full play to the advantages of the community in being close to residents and understanding their needs, integrate community resources, and build a bridge between the elderly and accompanied medical care institutions. It is expected to provide new ideas and methods for solving the medical care problems of the elderly and promoting the development of elderly care services. This study will deeply explore the feasibility, implementation path, and potential impact of this model, contributing to the construction of a more complete elderly care service system.

2. Research on the Three Parties Involved in the New Model

2.1. Community Survey Results

We learned about the community accompanied medical care services by asking community workers. Some family members of the elderly in the community asked about accompanied medical care services. However, there is currently no systematic process. Community workers dare not accompany the elderly to seek medical treatment alone without proper authorization. Without formal contracts, they need to bear risks. Moreover, community workers have their own jobs and cannot leave their posts many times to accompany the elderly to go out for medical treatment. If there are formal and professional accompanied medical care institutions, the

community is willing to act as a bridge, which can not only solve the elderly's demand for accompanied medical care but also provide a stable customer source for accompanied medical care institutions.

2.2. Survey Results of Residents' Wishes

(1) Market Status and Demand Analysis

Through market research, 70% of the respondents are aware of accompanied medical care services, and 74% have had the experience of needing accompanied medical care services, indicating that most people have a relatively high demand for accompanied medical care services, reflecting the need for such help in medical care. The main reasons for this situation are the growth of demand in the context of aging, the contradiction between busy family members and tight medical resources, the increasing demand for service quality, and the wide range of demands across age groups and regions.

(2) Analysis of Residents' Demand for Accompanied Medical Care Services

The survey shows that residents' demand for accompanied medical care mainly lies in its convenience. Accompanied medical care services can assist patients in completing procedures such as registration, picking up medicine, and examinations, reducing the time patients spend running around in the hospital and making the medical treatment process smoother. Accompanied medical care providers have certain medical knowledge and can provide professional advice and help during the medical treatment process. For example, in terms of understanding diseases and choosing drugs, they can provide valuable opinions for patients.

(3) Analysis of the Promotion Methods of Community Accompanied Medical Care Services

The survey shows that most residents are willing to have accompanied medical care services in the community, and the preferred method is online reservation. This indicates that in the later stage, a QR code can be established, and a community official account can be opened to promote such services and conduct forwarding and publicity. Residents can directly scan the code to make an appointment for accompanied medical care providers of their choice and select a time period for their parents or family members.

2.3. Survey Results of Accompanied Medical Care Institutions

Through communication with accompanied medical care institution personnel, it is learned that their current publicity channels are mainly various platforms. Therefore, they are very eager to cooperate. This can not only promote common development but also promote the development of the industry. From the perspective of profitability, this project can bring a broader customer source for them. Since the customers are in the community, long-term cooperation is possible, which is conducive to establishing a trust relationship.

3. Proposal of a New Model of Community-Mediated Accompanied Medical Care for the Elderly

We propose a new model for the benefit of the elderly, which mainly uses the community as a medium to connect elderly residents and accompanied medical care institutions. First, the elderly can feedback their needs for accompanied medical care to the community through various channels. The community classifies and integrates the needs of the elderly, verifies them one by one, and clarifies the details. Then, the community sends out cooperation invitations to accompanied medical care institutions. The accompanied medical care institutions submit their cooperation intentions. The community conducts qualification audits and signs a liability statement and a guarantee letter with high-quality institutions to finally establish a cooperation relationship. Finally, the accompanied medical care institutions provide accompanied medical care services to community customers, and the community conducts supervision and evaluation.

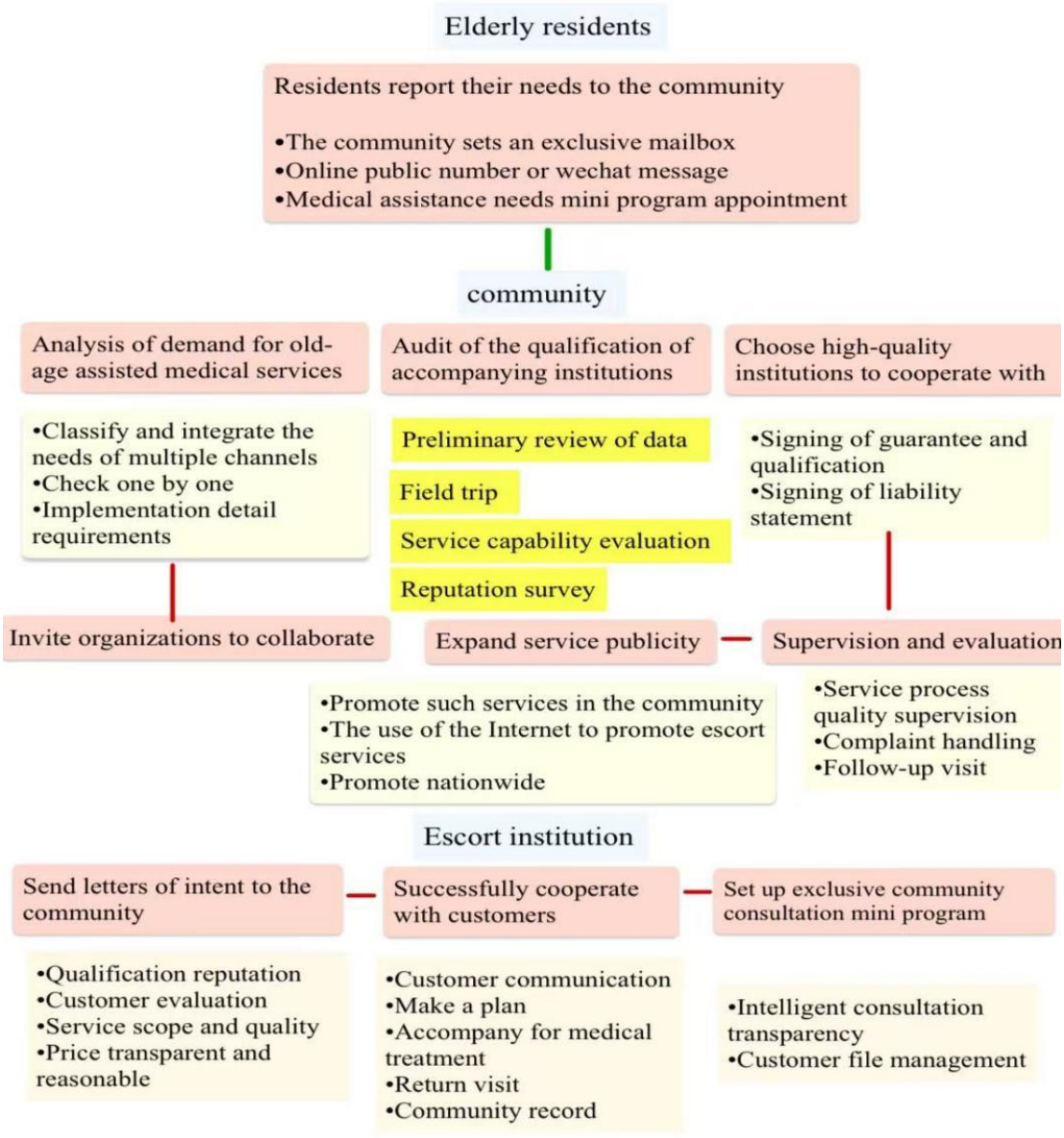

Figure 1. Diagram of the New Model of Community-Mediated Elderly Care and Benefit

3.1. Implementation Contents of the Three Parties in the New Model

3.1.1. Elderly Residents

The elderly can submit their needs and requirements for accompanied medical care to the community by putting them in the community's exclusive mailbox, leaving a message on the official account or WeChat of community workers, or making an appointment on the medical assistance applet (Peng, 2019).

3.1.2. Community

(1) Analyze the collected needs of residents for accompanied medical care. Classify, integrate, and verify the needs from multiple channels one by one, and clarify the details.
(2) Send out cooperation invitations to accompanied medical care institutions. Publish cooperation invitations to accompanied medical care institutions on various platforms and channels.
(3) Conduct qualification reviews of accompanied medical care institutions willing to cooperate. Conduct preliminary document review, on-site inspections, service ability assessments, and reputation investigations.
(4) Select high-quality institutions for cooperation. Sign guarantee letters and qualification certificates with the institutions, and sign liability statements with the accompanied medical care institutions and residents.
(5) Supervise and evaluate the accompanied medical care process. Continuously supervise accompanied medical care institutions to promptly identify various problems and better serve residents.
(6) Timely collect feedback on residents' satisfaction. Understand residents' satisfaction with accompanied medical care services and look for deficiencies.
(7) Expand service promotion. Promote such services within the community, use the Internet to publicize the situation of accompanied medical care services, and conduct national promotion.

3.1.3. Accompanied Medical Care Institutions

(1) Submit a cooperation intention letter to the community. Indicate their qualifications, reputation, customer evaluations, service scope, service quality, service price, institutional advantages, and professional information of accompanied medical care providers.
(2) Receive customers after successfully cooperating with the community. Communicate with customers, formulate targeted plans for different customers, do a good job in follow-up visits, and file in the community.
(3) Supervise the work of accompanied medical care providers. Prevent situations that are unfavorable to residents.
(4) Set up an exclusive community accompanied medical care applet. Make accompanied medical care services transparent.
(5) Ensure the security of residents' personal information. Prevent the leakage of residents' personal information to make residents and the community feel at ease.

3.2. Advantages of the New Model of Community-Mediated Accompanied Medical Care

The development of the accompanied medical care industry is an inevitable trend of new industries in the future. Better developing elderly support in grassroots communities is the development orientation of the country. This project benefits all three parties and truly reflects the needs of the elderly (Wang et al., 2024). At the same time, it also provides development prospects for the accompanied medical care industry. Different accompanied medical care services are provided according to different needs. Combining accompanied medical care with the community also has a different development idea from the past.

4. Implementation Path of the New Model of Accompanied Medical Care for the Elderly

4.1. Current Specific Implementation Path

4.1.1. Analysis of Elderly Care and Medical Assistance Service Needs

(1)Collect information through multiple channels

Use various methods such as questionnaires, interviews, and community meetings to comprehensively understand the health status, medical care needs, and difficulties of the elderly in the community. For example, community workers can regularly contact the elderly or their family members in the community by telephone. For the elderly with limited mobility or special needs, the community can arrange staff to visit them at home. Design a special questionnaire and distribute it to the elderly or their family members through community bulletin boards, WeChat groups, etc. Use community websites or mobile application platforms to set up an online registration function for accompanied medical care needs to facilitate the elderly or their family members to submit accompanied medical care needs at any time.

(2)Classify and integrate needs

Classify and sort the needs of the elderly, such as routine medical care needs, emergency rescue needs, rehabilitation care needs, and mental health support needs. Therefore, the needs can be evaluated and ranked according to their urgency and importance to determine the service items that need to be prioritized.

4.1.2. Qualification Audits of Accompanied Medical Care Institutions

(1) Preliminary document review

Formulate a detailed "List of Application Documents for Accompanied Medical Care Institutions", clearly requiring accompanied medical care institutions to submit copies of business licenses, organization code certificates, tax registration certificates, and other basic certificates to prove their legal business qualifications. Require accompanied medical care institutions to provide copies of the qualification certificates of all employees, such as certificates of medical-related professional backgrounds and accompanied medical care service training certificates, to evaluate the relevant professional qualities of their personnel. In addition, accompanied medical care institutions need to submit detailed records of past service cases, including the basic information of service objects, service contents, service effects, and customer satisfaction

feedback, to examine their actual service capabilities.

(2) Service ability assessment

Conduct in-depth assessments of the service capabilities of accompanied medical care institutions through methods such as listening to the plan reports of accompanied medical care institutions, asking questions and answering them, and simulated scenario tests. The focus of the assessment is on the medical knowledge level, communication and coordination abilities, and emergency handling abilities of accompanied medical care providers.

(3) Reputation investigation

Query the enterprise credit information publicity system to understand whether accompanied medical care institutions have illegal or disciplinary records, administrative penalties, and other bad credit information. Use Internet search engines to collect online evaluations of accompanied medical care institutions. Focus on the real evaluations and complaints from customers and analyze their service quality and customer satisfaction. Communicate with the customers previously served by accompanied medical care institutions by telephone or face-to-face to understand their real feelings and suggestions about the services of accompanied medical care institutions.

4.1.3. Selection and Cooperation of Accompanied Medical Care Institutions

According to the results of preliminary document review, on-site inspections, service ability assessments, and reputation investigations, the review team conducts a comprehensive assessment of accompanied medical care institutions. Set corresponding weights for each assessment dimension. For example, preliminary document review accounts for 20%, on-site inspections account for 30%, service ability assessments account for 30%, and reputation investigations account for 20%. Calculate the comprehensive score of accompanied medical care institutions based on their scores in each dimension. Rank accompanied medical care institutions according to their comprehensive scores. Select several accompanied medical care institutions with high rankings as cooperation candidates.

4.1.4. Optimization of the Process and Contents of Accompanied Medical Care Services

(1) Basic accompanied medical care services

According to the requirements of the accompanied person, the accompanied medical care institution selects a suitable accompanied medical care provider from the professional accompanied medical care personnel pool. The accompanied medical care provider contacts the elderly or their family members in advance to understand the detailed medical care needs and precautions. At the same time, the accompanied medical care provider also needs to familiarize themselves with the department distribution and medical treatment process of the hospital in advance and plan the best medical treatment route. Within a certain period of time (such as 24 hours) after the accompanied medical care is completed, make a telephone return visit to the elderly or their family members to understand their physical recovery status and satisfaction with the accompanied medical care service (Yang & Yu, 2022).

(2) Personalized services

Provide customized accompanied medical care services according to the special needs of the elderly, such as limited mobility, hearing or vision impairment. For example, assist in using a wheelchair and reading medical records aloud. For the elderly with chronic diseases, provide regular follow-up visit reminders and assistance services and help them establish health management files.

(3) Value-added services

Hold health knowledge lectures to popularize the prevention, treatment, and rehabilitation knowledge of common diseases for the elderly. Provide rehabilitation training guidance to help the elderly perform appropriate rehabilitation training during the postoperative or disease recovery period. Cooperate with community medical institutions to establish a green referral channel for the elderly to ensure that they can receive timely treatment in emergency situations.

4.1.5. Supervision and Evaluation

(1) Service quality supervision

Establish an evaluation mechanism for accompanied medical care services. After the accompanied medical care is completed, the elderly or their family members evaluate from aspects such as service attitude, professional level, and service effect. Evaluation methods can include questionnaires, telephone return visits, and online evaluations. At the same time, the community conducts irregular spot checks by following the on-site services, checking records, and communicating with service objects to check whether accompanied medical care providers serve according to the standardized process and can meet the needs of the elderly.

(2) Regular assessment and adjustment

Conduct a comprehensive assessment of accompanied medical care institutions every six months or one year. The assessment indicators cover service quality, customer satisfaction, complaint handling, and innovation ability. Based on the comprehensive evaluation of the assessment, excellent institutions are commended and rewarded, such as extending the cooperation period and increasing the number of orders. For institutions with poor performance, they are required to make rectifications within a time limit. If the rectification fails to meet the standards, the cooperation will be terminated. In addition, according to the changes in the needs of the elderly in the community and the development trend of services, adjust the requirements and cooperation strategies for accompanied medical care institutions in a timely manner to continuously optimize the service model and improve service quality and efficiency.

4.2. Long-Term Path Planning of the Model

(1) Technological innovation and intelligent upgrading

Research and develop an intelligent accompanied medical care system: Invest resources to build a system integrating patient information management, accompanied medical care scheduling, service monitoring, and feedback collection to achieve accurate matching, improve efficiency, and collect data to optimize services.

Integrate remote medical services: Cooperate with medical institutions to integrate remote consultation and diagnosis into accompanied medical care. With the help of 5G, AI and other technologies, realize high-definition video calls and remote medical monitoring to reduce the number of times the elderly need to go to the hospital.

Build a health data management platform: Collect and analyze the health data of the elderly, such as physical examination reports and medical histories, to provide personalized health management and early warning.

(2) Brand building and market promotion

Brand building: Establish a professional and reliable brand image with high-quality services and word-of-mouth. Strengthen publicity to enhance awareness and acceptance.

Market expansion: Consolidate the existing market and expand to surrounding areas and the whole country. Cooperate with medical institutions, communities, etc. to build an extensive service network.

Formulate marketing strategies: Launch preferential activities for the elderly and health-related public welfare activities to attract more elderly families to pay attention to and use accompanied medical care services.

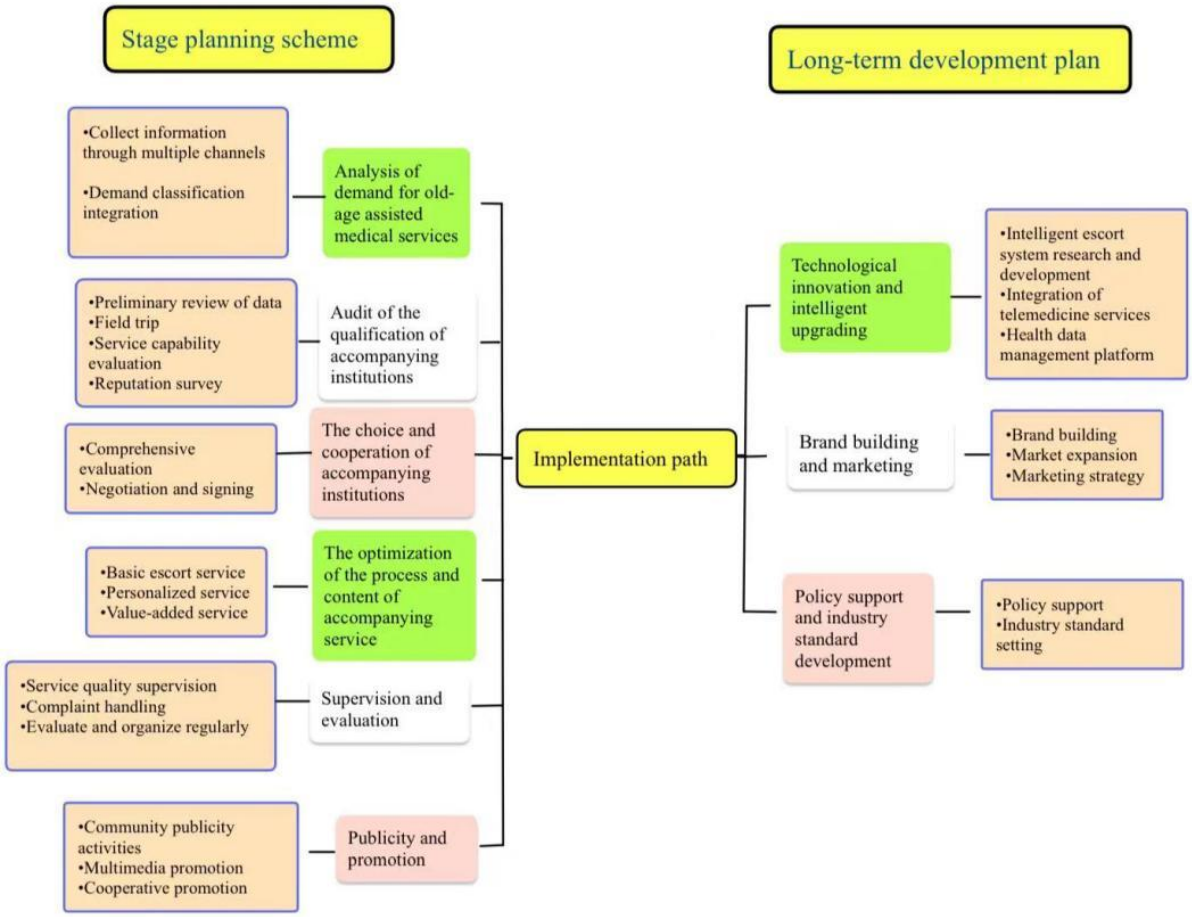

Figure 2. Implementation Path Diagram of the New Community-Mediated Elderly Assistance Model

5. Practical Concerns and Strategic Suggestions of the New Model of Community-Mediated Accompanied Medical Care for the Elderly

5.1. Practical Concerns

(1) The standardized management standard system of the accompanied medical care industry is imperfect.

There are no specific regulations for accompanied medical care providers in Chinese laws, and accompanied medical care providers are not included in the national vocational qualification catalog (Shi, 2022). In practice, mature industry practices have not yet been formed. Accompanied medical care services involve multiple fields such as medicine and services, and there is currently no clear and unified supervision. There are potential risks in protecting the privacy of patients during the accompanied medical care process. Accompanied medical care providers will have access to a large amount of personal privacy information of patients, such as medical conditions, medical records, and contact information. There is a lack of strict privacy protection measures and norms, and there is a risk of patient privacy leakage (Wang, 2024).

(2) It is difficult for the community to screen accompanied medical care institutions

In terms of liability assumption, accompanied medical care institutions and the community need to have good consultations and sign a disclaimer statement with family members. The community needs to screen for residents. Therefore, the assessment of cooperative accompanied medical care institutions is very important. The accompanied medical care institutions chosen by residents are strictly screened by the community. If an unexpected situation occurs, the credibility of the community will be greatly reduced in the eyes of residents.

(3) Residents' trust in the accompanied medical care industry

Currently, as a new industry, the accompanied medical care industry has a low level of consumer trust. Since accompanied medical care services are directly related to the physical health and life safety of patients, consumers are usually cautious when choosing accompanied medical care services. However, there are many problems in the current accompanied medical care industry, such as unstable service quality and uneven quality of employees, which have led to a low level of trust of consumers in accompanied medical care services and have restricted the development of the industry to a certain extent.

5.2. Strategic Suggestions

(1) Establish a standardized management standard system

Establishing a unified standard system for accompanied medical care services is the crucial first step in improving service efficiency and quality (Yang et al., 2024). The entry threshold for patient escorts is relatively low. Currently, the profession is mainly composed of part - time workers such as domestic helpers, nursing workers, and volunteers, who have limited professional skills. The service quality, quality, and ability of practitioners vary greatly, and there is also a lack of a unified training mechanism for the industry workforce. It is recommended to accelerate the formulation of industry standards for the patient escort profession (Wang, 2024). It is

recommended that the government improve laws and regulations and promulgate specific laws and regulations for accompanied medical care services as soon as possible to clarify the legal status of accompanied medical care services, the qualification requirements, rights and obligations of practitioners, etc., so as to provide a legal basis for the development of the industry.

(2) The community should establish an information database of accompanied medical care institutions

The community can actively collect information about regular accompanied medical care institutions in the surrounding area or after screening, including institutional qualifications, service contents, personnel allocation, charging standards, user evaluations, etc., establish a detailed information database, and publicize and promote it within the community to facilitate residents' query and selection. Through questionnaires, door-to-door visits and other methods, understand the demand situation of community residents for accompanied medical care services, including the characteristics of the population in need of accompanied medical care, service item requirements, expected prices, etc., and recommend appropriate accompanied medical care institutions based on the research results.

(3) Regulate market competition and enhance consumer trust

Regularly hold accompanied medical care service supply and demand matchmaking meetings or lectures, invite accompanied medical care institutions to the community for on-site introduction and promotion, allow residents to communicate with accompanied medical care institutions face to face, enhance mutual understanding, and also facilitate residents' comparison and selection.

6. Conclusion

This new model of accompanied medical care services for the elderly mediated by the community is scientific, feasible, and of high social value. It has a positive effect on meeting the needs of the elderly, improving community grassroots governance, and promoting the development of the accompanied medical care industry. Therefore, it may be promoted and implemented nationwide in the future.

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A Survey of Non-radial Directional Distance Function and Global Malmquist-Luenberger Index in Assessing Carbon Emission Performance of Urban Agglomerations

Ruotian Zhuang[1,*]

[1]School of Economics & Management, Tongji University, Shanghai 200092, China; 2230477@tongji.edu.cn

*** Correspondence:**
Ruotian Zhuang
2230477@tongji.edu.cn

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Abstract

This survey paper explores an advanced analytical framework that integrates non‐ radial directional distance functions (NDDF) and the Global Malmquist‐ Luenberger (GML) index to assess carbon emission performance and environmental efficiency in urban agglomerations. The study underscores the significance of evaluating carbon emissions, given the substantial contribution of urban centers to global greenhouse gas emissions. By accommodating undesirable outputs, NDDF offer a comprehensive assessment of environmental productivity ─ crucial for effective policy formulation in urban settings. Integration with the GML index enhances the evaluation of green total factor productivity, offering insights into the interplay between economic growth and environmental sustainability. The paper outlines the methodological framework and discusses case studies that illustrate the practical application of these tools in Chinese urban agglomerations. Challenges such as data availability, methodological limitations, and the integration of socioeconomic factors are addressed, highlighting the need for refined methodologies and policy innovations. The findings emphasize the importance of technological advancements and targeted policies in promoting sustainable urban development. By leveraging these methodologies, urban planners and policymakers can develop effective strategies to enhance environmental efficiency and support the transition towards sustainable urban futures.

Keywords: Carbon Emissions; National Urban Agglomerations; Non-Radial Directional Distance Function; Gml Index

1. Introduction

Urban agglomerations are major sources of greenhouse gas emissions, contributing roughly 70% of global emissions. Assessing carbon emission performance in these areas is important for sustainable development. The rapid growth of urban populations and infrastructures has increased

the need for improved methods to monitor productivity changes and evaluate the environmental impacts of urban growth (Wang et al., 2019; Olawumi and Chan, 2018; Liora et al., 2022). In response to these challenges, this study applies non-radial directional distance functions (NDDF) and the Global Malmquist-Luenberger (GML) index to provide a more detailed evaluation of carbon emissions and environmental efficiency in urban settings. Prior research has shown that traditional models do not fully capture the complexity of urban dynamics, particularly when both desirable outputs (such as economic growth) and undesirable outputs (such as carbon emissions) are considered.

This work makes a clear theoretical contribution by integrating NDDF with the GML index, thereby building on and refining existing productivity frameworks. The combined approach offers a fresh perspective on how economic activities and environmental factors interact in urban agglomerations, providing a more accurate analysis of performance than earlier methods. On the practical side, the findings of this study offer actionable insights for urban planners and policymakers. By identifying key drivers of carbon emissions and environmental inefficiencies, the research supports the design of strategies to reduce emissions, improve resource use, and guide sustainable urban development. These results are especially useful for cities facing rapid growth and environmental challenges, as they can inform policy measures aimed at achieving carbon neutrality and better managing urban expansion.

2. Background and Core Concepts

2.1. Global Malmquist-Luenberger Index

The Global Malmquist-Luenberger (GML) index uniquely incorporates both desirable and undesirable outputs (e.g., carbon emissions) into productivity analyses, offering a nuanced evaluation of efficiency and productivity changes over time (Li et al., 2020; Han et al., 2017). Originally defined by Oh (2010) and building on earlier Malmquist indices (Färe et al., 1994), the GML index provides a comprehensive understanding of environmental productivity and reflects the economic and environmental dynamics inherent in urban settings. By assessing green total factor productivity (GTFP), the GML index integrates energy inputs and environmental pollution, thereby establishing a robust framework for evaluating urban environmental efficiency.

2.2. Interrelationship and Significance in Urban Agglomerations

Urban agglomerations in China, characterized by dense populations and concentrated economic activities, present unique challenges and opportunities for sustainable development. By incorporating undesirable outputs such as carbon emissions, the GML index serves as a comprehensive tool for assessing environmental efficiency and identifying inefficiencies in total factor productivity growth (Li et al., 2020). Direct applications of NDDF in urban energy contexts have been demonstrated by Zhang et al. (2013) and Zhou et al. (2012). Modifications to the basic approach have been proposed by Meng (2019) and Wu et al. (2020), while theoretical advancements linking NDDF with slacks-based measures are provided by Färe and Grosskopf (2010), Färe et al. (2007), and Zhang et al. (2014).

3. Methodological Framework

The methodological framework is crucial to understanding the complexities of Chinese urban agglomerations. Table 1 outlines how NDDF and the GML index are integrated to assess environmental efficiency. Additionally, a comparative overview (as Table 2) highlights the systematic data utilization and holistic methods inherent in these approaches.

Table 1. A synergistic framework for evaluating carbon emission performance and environmental efficiency in urban agglomerations, integrating NDDF and the GML index

Category	Feature	Method
Synergistic Framework for Urban Agglomerations	Environmental Evaluation	NDDF, GML

Table 2. Key benchmarks used in evaluating environmental efficiency and productivity across Chinese urban agglomerations

Benchmark	Size	Domain	Task Format	Metric
GML	561	Environmental Economics	Productivity Measurement	Green Productivity Growth
NDDF	30	Power Generation	Efficiency Evaluation	CO_2 Emissions, Resource Use
MF-NDDF	17	Port Enterprises	Performance Assessment	Carbon Emission Performance

3.1. Integration of Non-Radial Directional Distance Functions

Integrating NDDF involves a systematic process that begins by identifying decision-making units (DMUs) such as cities or provinces and collecting relevant input–output data (Wang et al., 2019). NDDF effectively incorporate both desirable and undesirable outputs, offering a comprehensive assessment of environmental efficiency. They enable analysis of complex relationships between economic activities and environmental impacts by projecting DMUs onto an efficient frontier using exogenous and endogenous directional vectors. Foundational contributions by Chambers et al. (1996), Färe et al. (1989), and Färe et al. (1996), along with Chung et al. (1997), underpin the approach. Extensions linking NDDF with slacks-based measures are provided by Färe and Grosskopf (2010), while further modifications are proposed by Meng (2019), Wu et al. (2020), Färe et al. (2007), and Zhang et al. (2014). Lozano and Soltani (2018) further illustrate a lexicographic approach within the NDDF framework.

3.2. Synergistic Framework for Urban Agglomerations

Combining NDDF with the GML index offers a comprehensive method for evaluating carbon emission performance and environmental efficiency in Chinese urban agglomerations. By

integrating NDDF—which account for multiple outputs, including undesirable ones—with the GML index—which measures green productivity growth—the framework captures the complex interplay between economic activities and environmental impacts (Li et al., 2020; Han et al., 2017). This synergistic approach enables policymakers to identify inefficiencies and design targeted strategies to enhance urban sustainability.

4. Carbon Emission Performance in Urban Agglomerations

4.1. Current State of Carbon Emissions

Carbon emission profiles in urban agglomerations exhibit significant heterogeneity due to interactions among technological, economic, and infrastructural factors. Li et al. (2020) identified sectoral variations in productivity changes—especially in carbon-intensive industries—while Tao et al. (2017) demonstrated that technological innovation is a primary driver of performance. Green innovation efficiency further influences emission performance (Zhong et al., 2024).

4.2. Factors Influencing Carbon Emissions

Urban carbon emissions are influenced by economic, technological, and infrastructural factors. Urban sprawl increases emissions by promoting inefficient land use and higher energy demands (Zhou et al., 2012). In contrast, compact urban forms reduce emissions by lowering travel distances and enhancing public transit efficiency. Technological advancements, including cleaner production processes and renewable energy adoption, are crucial for reducing emissions (Shakhbulatov et al., 2019). Additionally, socioeconomic factors—such as higher income levels that lead to increased consumption—contribute to larger carbon footprints (Liora et al., 2022).

4.3. Role of Urban Agglomerations in National Carbon Footprint

Chinese urban agglomerations are central to the national carbon landscape due to their concentrated industrial production, transportation, and energy consumption (Li et al., 2020). Oliveira et al. (2014) identified a super linear scaling relationship between urban population size and carbon emissions. Advances in high-resolution mapping (Liu et al., 2024) and spatiotemporal analysis (Shi et al., 2024) provide further insights into emission patterns. Spatial pattern studies (Yu et al., 2024) and methodologies for inventorying emissions (Kennedy et al., 2010; Meng et al., 2014) enhance our understanding of urban contributions to national emissions.

4.4. Evaluating Carbon Emission Performance Using NDDF and GML

The integration of NDDF and the GML index offers a robust framework for evaluating carbon emission performance. NDDF capture both desirable economic outputs and undesirable environmental outputs, while the GML index (Oh, 2010) tracks dynamic changes in green productivity. Applications by Han et al. (2017) and Tao et al. (2017) have validated these methods. Moreover, decomposition analyses (Li et al., 2020; Qu et al., 2022) reveal key drivers of performance, supporting targeted policy interventions.

5. Environmental Efficiency and Sustainable Urban Development

5.1. Conceptualizing Environmental Efficiency

Environmental efficiency reflects an urban system's ability to optimize resource utilization while minimizing environmental impacts, particularly carbon emissions. It is closely linked to green total factor productivity (GTFP), which integrates static and dynamic performance while accounting for undesirable outputs (Chen et al., 2021). Accurate urban boundary definitions (Oliveira et al., 2014) and compact urban forms (Yao et al., 2022) are essential, as they help reduce biases in emissions data and promote lower energy consumption. The integration of NDDF with the GML index has advanced these assessments, providing insights into how economic activities and environmental sustainability interact (Han et al., 2017).

5.2. Factors Influencing Environmental Efficiency

Energy-efficient technologies in industries, buildings, and transportation systems significantly reduce urban carbon footprints (Wu et al., 2022). Regional differences in green innovation efficiency, as highlighted by Zhong et al. (2024), underscore the need for local innovation strategies. Digital technologies, such as blockchain, further enhance resource management and environmental data tracking (Shakhbulatov et al., 2019). Urban areas with service-oriented economies often demonstrate superior environmental efficiency compared to those reliant on heavy, resource-intensive industries (Li et al., 2020). While agglomeration economies can improve resource utilization, larger cities may also generate disproportionately higher emissions (Oliveira et al., 2014). Transitioning to less resource-intensive sectors is therefore key to improving overall efficiency (Tao et al., 2017). Compact urban forms reduce travel distances and support efficient public transit, leading to lower energy consumption and emissions (Yao et al., 2022). Well-developed transportation infrastructure further minimizes reliance on private vehicles, as shown by studies on urban logistics (Qu et al., 2022). Effective policies, including strict emission standards, energy regulations, and carbon pricing, drive improvements in urban environmental performance (Li et al., 2020). Financial incentives and integrated urban planning that coordinate land use, transportation, and economic strategies yield significant benefits (Tao et al., 2017; Yao et al., 2022).

5.3. Environmental Performance Measurement in Urban Agglomerations

Advanced methodologies that integrate NDDF with the GML index enable comprehensive evaluations of environmental efficiency in Chinese urban agglomerations. These methods reveal regional variations influenced by industrial structure, technological capacity, and policy frameworks. Studies have found that eastern coastal agglomerations tend to outperform central and western regions, with temporal trends showing steady improvements driven by innovation (Zhong et al., 2024; Tao et al., 2017; Oliveira et al., 2014).

5.4. Challenges and Opportunities in Environmental Efficiency Improvement

Despite significant methodological advances, challenges remain regarding data availability, inconsistent emissions inventories, and urban boundary definitions (Olawumi and Chan, 2018). Heterogeneity in economic structures and technological capacities requires tailored, region-

specific approaches (Elmqvist et al., 2019). Technological innovations and comprehensive policy frameworks, combined with climate resilience strategies, offer promising avenues for future improvement.

6. Case Studies and Applications

This section reviews empirical applications of NDDF and the GML index within Chinese urban agglomerations to assess environmental efficiency and carbon emission performance.

6.1. Case Studies and Benchmarking

NDDF and the GML index have been applied to evaluate environmental efficiency and productivity across Chinese urban agglomerations. For example, Wang et al. (2019) demonstrated dynamic efficiency analyses, while Tao et al. (2017) assessed green total factor productivity in rapidly industrializing regions. Benchmark studies by Yang et al. (2019) and Li et al. (2020) illustrate these approaches.

6.2. Logistics Performance and Carbon Emissions in Yunnan Province

Yang et al. (2019) documented rising logistics-related carbon emissions in Yunnan Province, highlighting the challenge of traditional transport modes that elevate emissions. NDDF and the GML index have been used to assess logistics eco-efficiency, incorporating carbon emissions into performance evaluations. Strategies focus on optimizing logistics networks, adopting cleaner transportation technologies, and promoting intermodal solutions to align with low-carbon development goals. Zhu et al. (2019) underscore that enhancing rail and waterway infrastructure, coupled with smart logistics systems, can significantly reduce emissions.

6.3. Urban Agglomerations in China: A Decadal Analysis

A decade-long analysis of Chinese urban agglomerations reveals that clusters with high industrial activity tend to exhibit higher emissions, whereas service-oriented economies perform better environmentally (Li et al., 2020). Tao et al. (2017) identify technological innovation as a key driver of efficiency improvements, with eastern coastal agglomerations generally outperforming central and western regions. Cleaner production technologies and energy-efficient practices have contributed to notable emission reductions, supporting national decarbonization goals (Zhong et al., 2024). Policy interventions promoting compact urban forms and smart city initiatives further enhance environmental efficiency.

6.4. Benchmarking Environmental Efficiency in the Beijing-Tianjin-Hebei Region

Zhong et al. (2024) applied NDDF and the GML index to assess environmental efficiency in the Beijing-Tianjin-Hebei (BTH) region. Findings reveal that Beijing's service-oriented economy yields superior efficiency compared to Tianjin and Hebei. Urban form and robust public transit are critical determinants; compact development and efficient transit systems in Beijing contribute significantly to its environmental performance. These insights support the design of targeted policies to mitigate industrial emissions and promote sustainable urban growth.

7. Challenges and Future Directions

Exploring the challenges and future directions in assessing environmental efficiency and carbon emission performance reveals a multifaceted landscape. As Chinese urban agglomerations expand, understanding these intricacies is vital for effective policy formulation and implementation. The following subsections address specific challenges and limitations in this field, emphasizing methodological hurdles and data-related issues for researchers and policymakers. Addressing these challenges is essential for establishing robust frameworks and innovative solutions to enhance urban sustainability.

7.1. Challenges and Limitations

Assessing environmental efficiency and carbon emission performance poses challenges due to the reliance on extensive data and significant computational resources required by methods like the GML index (Lozano and Soltani, 2018). Data availability and accuracy for undesirable outputs remain problematic (Han et al., 2017). Furthermore, disparities between core and peripheral cities and variations in regional infrastructure and economic conditions limit the generalizability of findings. Subjective semantic labels influenced by cultural variances also weaken reliability (Shakhbulatov et al., 2019). Moreover, focusing solely on CO_2 emissions, while neglecting other greenhouse gases, restricts the comprehensiveness of evaluations (Zhong et al., 2024).

7.2. Challenges in Measuring Carbon Emission Performance

Measuring carbon emission performance is complicated by the diversity of industrial processes and infrastructural differences across regions such as Yunnan Province (Liora et al., 2022; Oliveira et al., 2014; Qu et al., 2022). Limited and incomplete emissions data—especially in logistics sectors—further impede accurate assessments. Advanced spatial and remote sensing methodologies (Kennedy et al., 2010; Meng et al., 2014; Shan et al., 2022) and high-resolution emission databases (Cai et al., 2018; Chen et al., 2021) offer promising solutions for improving measurement precision.

7.3. Implications for Policy and Practice

Findings on carbon emission performance have significant policy implications. Integrating NDDF and the GML index provides a solid basis for evaluating environmental performance and informing targeted policies (Li et al., 2020; Han et al., 2017). These results underscore the need to promote technological innovation and cleaner production processes. Investments in renewable energy and energy-saving practices are crucial to reduce emissions and improve environmental efficiency. Urban planning that prioritizes compact development and efficient public transit can further reduce energy consumption. Additionally, addressing socioeconomic disparities through sustainable consumption policies is vital for equitable carbon reduction.

7.4. Future Directions and Policy Implications

Future research should focus on refining methodologies to overcome existing limitations and enhance sustainability outcomes. Leveraging cutting-edge technologies and expanding data collection are essential steps (Olawumi and Chan, 2018). Further improvements in the GML

index and the incorporation of additional environmental factors will enrich model comprehensiveness and inform policy decisions (Färe et al., 1994). The integration of ICT in urban planning and the development of AI frameworks for carbon monitoring represent promising avenues. Expanding studies to include other pollutants and human capital factors, and refining index systems for green growth in resource-dependent cities, are important future directions. A holistic approach is critical, given that Chinese cities contribute significantly to national emissions and face mounting climate challenges (Kii, 2021; Elmqvist et al., 2019).

7.5. Data Availability and Quality

Reliable data are critical for evaluating environmental efficiency and carbon emissions. Limited access to precise statistics and inconsistent regional classifications complicate analyses (Olawumi and Chan, 2018; Klopp and Petretta, 2017; Lozano and Soltani, 2018). Obtaining accurate data on undesirable outputs is particularly challenging in areas with underdeveloped monitoring systems, potentially skewing assessments (Elmqvist et al., 2019; Tao et al., 2017; Cai et al., 2018; Qu et al., 2022). Enhanced monitoring systems and standardized reporting protocols are essential to improve data quality and support reliable evaluations.

7.6. Methodological Limitations

Although the combined NDDF and GML approaches are robust, they require extensive datasets and significant computational resources (Lozano and Soltani, 2018). Infeasibility issues with cross-period directional distance functions and the exclusion of critical productivity variables reduce measurement completeness, particularly in regions with limited energy statistics (Liora et al., 2022). Additionally, cultural variations in semantic labels and limitations in data granularity hinder consistency. These drawbacks underscore the need for continuous refinement of sustainability methods to address the challenges posed by rapid urbanization, climate risks, and socioeconomic inequalities (Bibri and Krogstie, 2017; Klopp and Petretta, 2017; Kii, 2021; Elmqvist et al., 2019; Huang and Jiang, 2017).

7.7. Integration of Socioeconomic and Lifestyle Factors

Integrating socioeconomic and lifestyle factors is essential for a comprehensive understanding of urban sustainability. Variables such as income, education, and employment significantly influence energy consumption and carbon footprints (Li et al., 2020). Higher income levels are often associated with increased consumption of energy-intensive goods, leading to larger carbon footprints. Understanding these relationships is vital for designing targeted, equitable interventions that promote sustainable behaviors (Han et al., 2017).

7.8. Urban Agglomeration Dynamics

Urban agglomerations evolve through complex interactions among economic activities, population trends, infrastructure development, and environmental impacts (Li et al., 2020). While dense urban areas benefit from shared resources, they also face greater environmental pressures. Compact urban forms and efficient public transit can mitigate these impacts (Yao et al., 2022). Moreover, technological innovations and effective governance are critical for driving low-carbon development, and socioeconomic disparities influence overall resource utilization.

7.9. Technological and Policy Innovations

Technological and policy innovations are central to enhancing urban environmental efficiency. The adoption of smart city technologies—such as digital platforms, ICT-based tools, and blockchain systems—improves urban services and resource management (Shakhbulatov et al., 2019). Transitioning to renewable energy sources significantly reduces fossil fuel reliance and carbon emissions (Han et al., 2017). Policy innovations, including strict emission standards, financial incentives, and integrated urban planning, are essential for sustainable development (Li et al., 2020; Yao et al., 2022).

8. Conclusion

The exploration of non-radial directional distance functions together with the Global Malmquist-Luenberger index underscores their pivotal role in assessing carbon emission performance and environmental efficiency within Chinese urban agglomerations. These methodologies provide a robust framework by incorporating both desirable and undesirable outputs, thereby offering a comprehensive understanding of urban environmental dynamics and productivity evolution. The research emphasizes the critical need for improved production efficiency to enhance the impact of environmental policies and advance sustainable urban development.

The study highlights the importance of implementing targeted interventions and policy reforms to address high-carbon lifestyles, as many consumer groups already exceed carbon footprint benchmarks for 2030 and 2050. Recognizing the potential of alternative data sources is crucial for deepening our understanding of urban dynamics and supporting sustainable development. Moreover, the successful implementation of the Urban Sustainable Development Goal framework relies on local institutional involvement and the adaptation of indicators to meet specific urban needs.

Finally, integrating technological advancements with innovative policy measures is vital for enhancing urban environmental efficiency—especially given the increasing trend of urban concentration and its implications for infrastructure and sustainability strategies. The findings advocate for policies that support green agricultural practices and comprehensive strategies that harmonize economic growth with environmental sustainability.

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