GREEN SUPPLY CHAIN INTEGRATION AND SUSTAINABLE PERFORMANCE IN CHINA'S PHARMACEUTICAL INDUSTRY: THE MEDIATING EFFECT OF SUPPLY CHAIN AGILITY AND THE MODERATING ROLE OF DIGITAL ORIENTATION

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by

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LIST OF ABBREVIATIONS

AVE	Average Variance Extracted
CAGR	Compound Annual Growth Rate
COVID-19	Corona Virus Disease 2019
CMV	Common Method Variance
CNY	Chinese Yuan
CSR	Corporate Social Responsibility
CT	Contingency Theory
DC	Dynamic Capabilities
DCT	Dynamic Capabilities Theory
DO	Digital Orientation
D-Tec	Digital Technology
DT	Digital Transformation
EP	Environmental Performance
ESG	Environmental, Social and Governance
FP	Economic Performance
GCI	Green Customer Integration
GEI	Green External Integration
GHRM	Green Human Resource Management
GI	Green Innovation
GII	Green Internal Integration
GKM	Green Knowledge Management
GP	Green Performance
GSCI	Green Supply Chain Integration
GSCM	Green Supply Chain Management
GSI	Green Supplier Integration
NBS	National Bureau of Statistics
NRBV	Natural Resource-based View
PM-Industry	Pharmaceutical Manufacturing Industry
PI	Pharmaceutical Industry
PLS	Partial Least Square

RBV	Resource-based View
R&D	Research and Development
RO	Research Objectives
RQ	Research Questions
SC	Supply Chain
SCA	Supply Chain Agility
SCI	Supply Chain Integration
SCM	Supply Chain Management
SCP	Supply Chain Performance
SCT	Social Contagion Theory
SDGs	Sustainable Development Goals
SEM	Structural Equation Modeling
SET	Social Exchange Theory
SMEs	Small and Medium-Sized Enterprises
SP	Social Performance
TBL	Triple Bottom Line
USD	U.S. Dollars

LIST OF APPENDICES

INTEGRASI RANTAIAN BEKALAN HIJAU DAN PRESTASI LESTARI DALAM INDUSTRI FARMASEUTIKAL DI CHINA: KESAN PERANTARAAN KELINCAHAN RANTAIAN BEKALAN DAN PERANAN PEMODERATAN ORIENTASI DIGITAL

ABSTRAK

Industri farmaseutikal memikul tanggungjawab alam sekitar dan sosial yang semakin meningkat tetapi masih ketinggalan dalam pembangunan lestari akibat sifatnya yang konservatif. Memandangkan integrasi rantaian bekalan hijau menjadi kunci kepada kelestarian, tesis ini mengkaji bagaimana dan bila integrasi dalaman hijau, integrasi pembekal hijau dan integrasi pelanggan hijau mempengaruhi prestasi ekonomi, sosial dan alam sekitar. Berdasarkan Natural Resource-Based View (NRBV), Dynamic Capabilities Theory (DCT) dan Contingency Theory (CT), data diperoleh daripada 289 firma farmaseutikal di China. Menggunakan SEM dan PROCESS, 32 hipotesis diuji, dengan 21 disokong dan 11 tidak. Hasil menunjukkan integrasi dalaman hijau meningkatkan integrasi pembekal dan pelanggan hijau. Ketiga-tiga dimensi memberi kesan positif kepada kecekapan rantaian bekalan yang seterusnya meningkatkan semua aspek prestasi lestari. Kecekapan ini turut memainkan peranan sebagai perantara. Orientasi digital menunjukkan kesan pemoderasi yang terhad tetapi menguatkan pengaruh tidak langsung integrasi pembekal hijau terhadap hasil alam sekitar dan sosial. Penemuan ini menjelaskan mekanisme hubungan antara integrasi hijau dan kelestarian serta peranan bersyarat orientasi digital.

GREEN SUPPLY CHAIN INTEGRATION AND SUSTAINABLE PERFORMANCE IN CHINA'S PHARMACEUTICAL INDUSTRY: THE MEDIATING EFFECT OF SUPPLY CHAIN AGILITY AND THE MODERATING ROLE OF DIGITAL ORIENTATION

ABSTRACT

The pharmaceutical industry bears increasing environmental and social responsibilities but lags in sustainable development due to its conservative nature. As green supply chain integration becomes key to sustainability, this thesis examines how and when green internal integration, green supplier integration, and green customer integration influence economic, social, and environmental performance. Drawing on the natural resource-based view (NRBV), dynamic capabilities theory (DCT), and contingency theory (CT), data were collected from 289 Chinese pharmaceutical firms. Using SEM and PROCESS, 32 hypotheses were tested, with 21 supported and 11 not supported. Results show that green internal integration promotes both green supplier and customer integration. All three integration dimensions positively affect supply chain agility, which in turn improves all aspects of sustainable performance. Supply chain agility also mediates these relationships. Digital orientation shows limited moderating effects, but it strengthens the indirect influence of green supplier integration on environmental and social outcomes. These findings clarify the mechanisms linking green integration and sustainability, and highlight the conditional role of digital orientation.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter focuses on the current state of Chinese pharmaceutical industry (PI). It also introduces the prominent role of PI sustainability in the global economy, environment, and society, and emphasizes the necessity of green supply chain integration (GSCI) in achieving sustainability within the PI. The following section highlights the key problems addressed in this thesis. Next, the research objectives and significance are presented. Then, the operational definitions of the research constructs are provided. Finally, the chapter concludes with a summary of the subsequent sections in this thesis.

1.2 Background of the Study

1.2.1 Pharmaceutical Industry Status in China

The PI is often regarded as a 'never-recession' sunrise industry with a clear trajectory for future development. Factors such as an aging population, rapid urbanization, rising health awareness, and a broadening disease spectrum have collectively driven sustained growth in pharmaceutical demand (Guo, 2024). The global pharmaceutical market is projected to grow at a compound annual growth rate (CAGR) of 4.8%, surpassing 2 trillion USD by 2028 (Figure 1.1) (SWS Research, 2024). According to the Global Drug Market Research forecast, global pharmaceutical

expenditures are expected to reach 2.2 trillion USD by 2028, with a CAGR of 6.6% from 2024 to 2028.

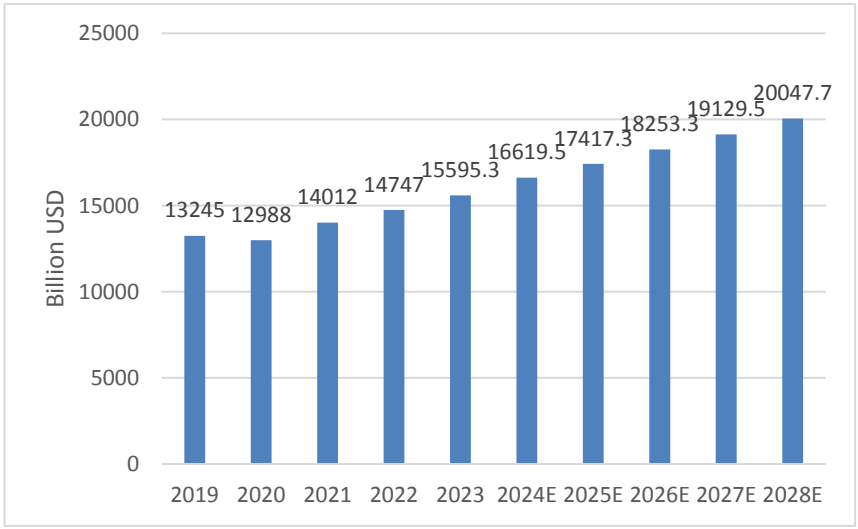

Figure 1.1 Global Pharmaceutical Scale and Forecast for 2019-2028E
Data source: IQVIA. (2023). IQVIA quarterly pharmaceutical market outlook*;* SWS Research. (2024). Pharmaceutical industry internationalisation report: Innovation upgrade, set sail for internationalisation.

The IQVIA report indicates that global drug spending in 2023 reached approximately 1.6 trillion USD, with a CAGR of 6.0% from 2019 to 2023. Key drivers of this growth include increased drug utilization, the introduction of new pharmaceuticals, patent expirations, and the rising adoption of biosimilars (Jiemian, 2024). As a developing country, China's per capita GDP ranks in the middle globally. However, its aging population and declining birth rate resemble trends observed in developed countries. There remains substantial unmet demand for medication on the medical reimbursement side. Currently, the accessibility of new drugs in China stands at only 24%, which is significantly lower than the 85% in the United States, indicating considerable room for future growth (Sina, 2024a).

The global pharmaceutical market is projected to reach an estimated 2,225–2,255 billion USD by 2028 (Figure 1.2). North America is expected to achieve a CAGR of 6–9%, with its market size reaching 1,050–1,080 billion USD. Latin America is forecast to grow at a slightly higher rate of 7–10%, reaching 115–135 billion USD. Western Europe is projected to experience a 4–7% CAGR, with a market size of 390–410 billion USD. China's pharmaceutical market is anticipated to grow more moderately at a CAGR of 2–5%, with a projected market size of 185–215 billion USD. The Asia-Pacific region (excluding China, Japan, and India) is forecast to grow at 5–8%, reaching 120–140 billion USD (SWS Research, 2024). Although growth in the Chinese pharmaceutical market may be relatively modest between 2024 and 2028, its overall market share remains significant.

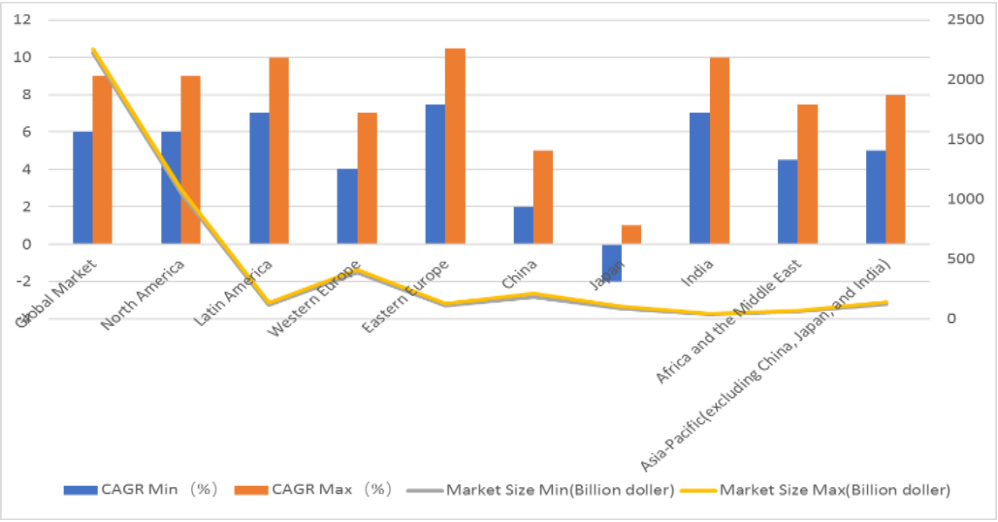

Figure 1.2　Global Pharmaceutical Scales（2024-2028E）

Data source: IQVIA. (2023). IQVIA quarterly pharmaceutical market outlook*; SWS Research. (2024).* Pharmaceutical industry internationalisation report: Innovation upgrade, set sail for internationalisation.

The stacked bar chart on the left side of Figure 1.3 shows the changes in the contribution of various countries to global pharmaceutical market growth during 2017–2022 and 2022–2027. From 2017 to 2022, the United States contributed the most, accounting for 46%, followed by Europe (EU+UK) and other regions (RoW), at 14% and 15% respectively. China contributed 8%, Pharmerging Tier 2+3 (emerging pharmaceutical markets Tier 2 and Tier 3) contributed 15%, and Japan only 1%. During the forecast period 2022–2027, the US contribution is expected to rise to 52%, while Europe and RoW will maintain their shares at 13% and 14%, respectively. China's contribution is projected to decline to 6%, Pharmerging Tier 2+3 to 16%, and Japan's share will remain low. Overall, the US will continue to lead the global pharmaceutical market in the coming years, while the contributions from China and Europe may decline.

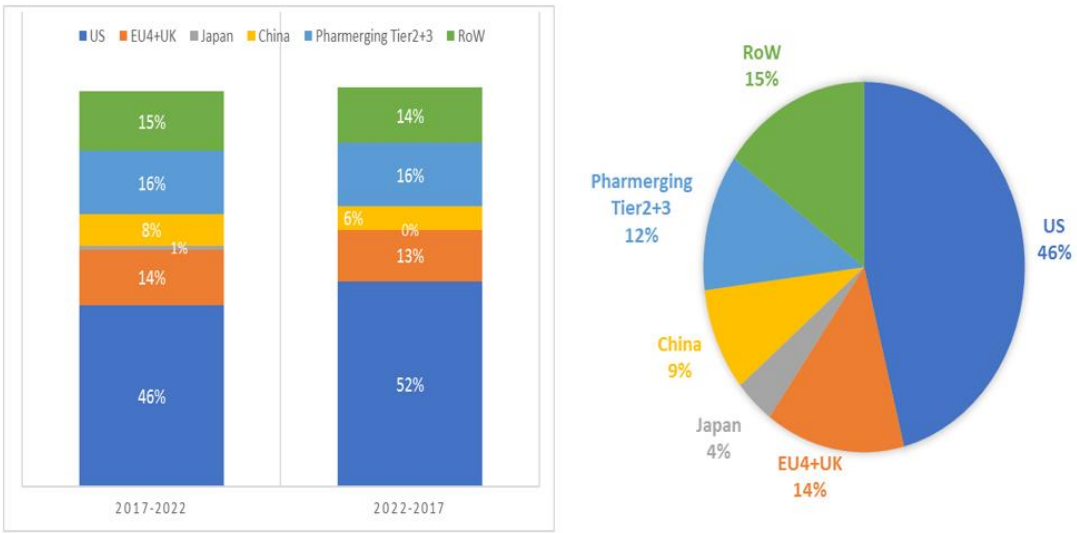

Figure 1.3 Regional Contribution to Growth (USD)

Data source: IQVIA. (2023). IQVIA quarterly pharmaceutical market outlook.

The pie chart on the right side of Figure 1.3 shows the expected regional market share of the worldwide pharmaceutical market in 2027. The US will remain the largest market, accounting for 46% of the total, far ahead of other regions (IQVIA, 2023). This indicates that although the growth contributions of emerging markets such as China and Europe are expected to decline, they will still hold a notable share, while the United States continues to maintain a dominant position.

The list of the 'Top 50 Global Pharmaceutical Enterprises in 2024' (ranked by global sales revenue of prescription drug business in 2023) released by the magazine Pharmaceutical Executive shows that four Chinese pharmaceutical enterprises were included: Yunnan Baiyao, Sino Biopharm, Shanghai Pharmaceuticals, and Hengrui Medicine, with revenues of 5.52 billion, 4.43 billion, 4.23 billion, and 3.23 billion US dollars respectively, ranking 33rd, 38th, 42nd, and 48th (Christel, 2024). As of January 2024, new drug R&D enterprises in China accounted for 16% of the global total, ranking second worldwide. This proportion is three times that of the UK, five times that of Japan and France, and eight times that of Germany. In terms of the number of drugs under development, China (excluding Taiwan) has 6,098 active drugs in the pipeline, second only to the United States with 11,200. This is nearly twice the number in South Korea (3,233) and the UK (3,156) and about 2.5 times the number in Germany, Canada, Australia, and France. Four Chinese enterprises are currently among the top 25 globally regarding the number of medications under development (Christel, 2024).

The United States has always been a major driving force in global drug R&D, but its expansion rate has slowed in recent years. Meanwhile, China's R&D has grown rapidly, and the gap between the two countries has narrowed significantly. For example, in 2016, the pharmaceutical R&D scale in the US was about 7 times that of China; by 2024, this ratio had narrowed to 1.8 times (Sina, 2024b). The proportion of pharmaceutical R&D enterprises headquartered in the US is expected to decrease from 43% in 2023 to 39% in 2024, while the proportion of Chinese pharmaceutical R&D enterprises is expected to increase from 13% in 2023 to 16% in 2024 (Figure 1.4) (Citeline, 2024). This growth reflects China's continued rise in the global pharmaceutical sector and demonstrates its growing drug R&D capabilities.

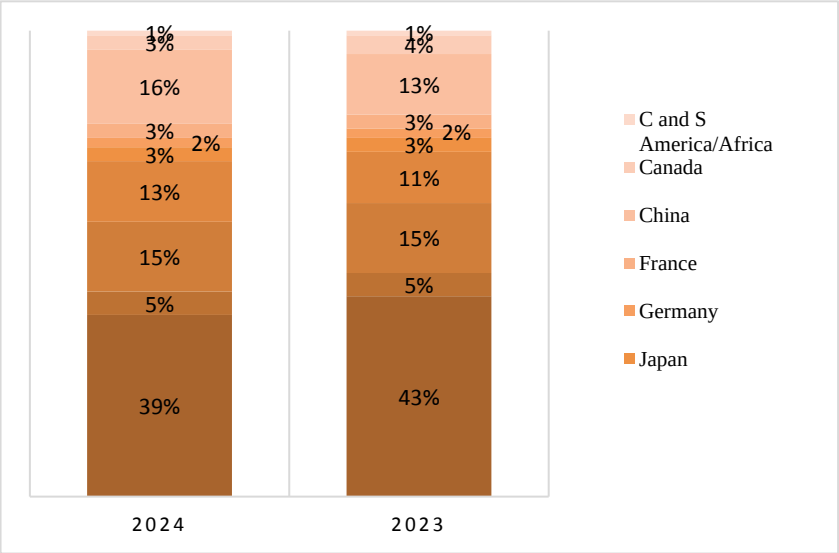

Figure 1.4 Distribution of Pharma R&D Enterprises by HQ Country/Region
Data source: Citeline. (2024). Pharma R&D annual review 2024 infographic. https://www.citeline.com/-/media/citeline/resources/pdf/infographic_pharma-rd-2024.pdf

PI is an important pillar for building a medical and healthcare system and a comprehensive industry integrating traditional and modern industries and secondary

and tertiary industries. It is vital in safeguarding people's livelihood and social stability (Chyxx, 2024). PI not only has the function of safeguarding people's livelihoods but also has a competitive advantage due to high technical barriers. Focusing on the entire life process, PI is irreplaceable in maintaining people's health through the support of drugs, medical devices, etc (Insight and Info, 2022).

The ‘Healthy China 2030 Outline’ proposes that by 2030, the potential of PI size is expected to reach 8 trillion CNY, making it one of the most dynamic and promising industries in China. As the cornerstone of health protection, PI is benefiting from the accelerating aging of the population, the increasing demand for medical treatment, and the progress in medical technology and the development of biomedicine, which are bringing new growth points. China's pharmaceutical market will exceed 3 trillion CNY by 2025 (Landray Research Insitute, 2024). China's PI is growing with an average annual growth rate exceeding 20% (Griffin et al., 2021). Overall, the development potential of the Chinese pharmaceutical market is huge.

The profound impact of PI on human life makes it particularly notable for its high growth and high profitability. The Chinese PI has experienced rapid development from scratch, from traditional craftsmanship to large-scale modern technology. The PI's annual production growth rate has reached 17.7%. With a growth rate significantly higher than the national average and higher than the average growth rate of major pharmaceutical countries worldwide, China has emerged as one of the world's fastest-

growing pharmaceutical powers, particularly since the reform and opening up (Insight and Info, 2022).

The primary business revenue of China's PI has increased at an average yearly rate of 9.3% since the 14th Five-Year Plan was implemented. The total profit has increased at an average annual rate of 11.3%, laying a strong basis for development, further optimizing the industrial system, and attaining consistent development with improved quality and efficiency. During the same period, the industry-wide R&D investment increased at an average yearly pace of over 20%, with original breakthroughs in basic research and innovative achievements in innovative drugs and high-end medical devices emerging endlessly. The pharmaceutical stockpile system is becoming increasingly complete (Jingjiribao, 2023).

China's pharmaceutical market continues to expand rapidly driven by economic growth and healthcare system reform. It is now the biggest developing pharmaceutical market in the world. As people's quality of life has increased, the promotion of urbanization, and the aggravation of aging, the demand for healthcare is steadily rising, and PI is becoming increasingly important in the national economy. Figure 1.5 shows that China's pharmaceutical market reached 1,797.7 billion CNY in 2023 and will expand to 2,064.5 billion CNY in 2025. The CAGR between 2021 and 2025 is 6.74%, showing a stable growth trend (Beijing SHKB Pharmaceutical CO.LTD, 2023). At the same time, with people's rising health awareness, there is a growing demand for preventive healthcare and health management. This change in

demand has promoted the R&D and manufacturing of pharmaceutical items and prompted PI to adjust its marketing strategies.

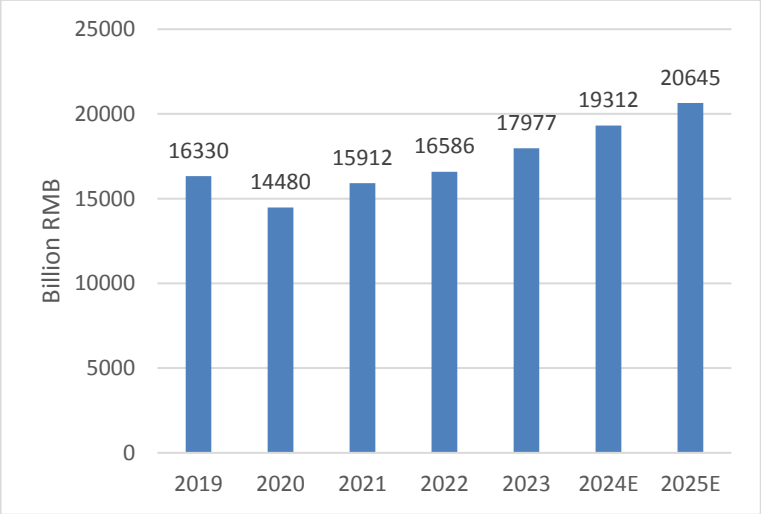

Figure 1.5 2019-2025E China Pharmaceutical Market Size Trend
Data source: Beijing SHKB Pharmaceutical Co., Ltd. (2023). Beijing Sihuan Kebo Pharmaceutical Co., Ltd. stock prospectus (Draft for filing).

From January to August 2024, China's PI achieved operating revenue of 1,603.72 billion CNY, a 0.5% year over year decline, and an overall profit was 202.4 billion CNY, down 0.3% year over year (Figure 1.6). According to the 'Economic Operation of PI in the First Half of 2024' released by the China Pharmaceutical Enterprise Management Association, the added value of China's above-scale PI increased by 1.2% annually in the first half of 2024; above-scale PI achieved operating income of 1,446.55 billion CNY and profits of 211.12 billion CNY. Compared to the national industry's overall growth rate, the growth rates of the three indicators mentioned above were 4.8, 4.3, and 4.7 percentage points lower. This means that the performance of PI has changed from the previous situation of leading the industrial

sector for many years, reflecting the challenges and pressures facing the development of PI.

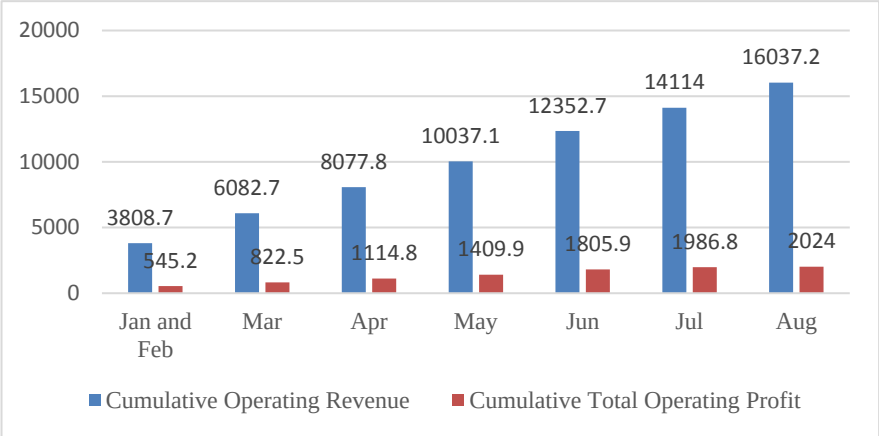

Figure 1.6 Cumulative Operating Revenue and Total Operating Profit of China's PI from January to August 2024

Data source: AskCI. (2024). January–August 2024 monthly report on the economic operation of China's pharmaceutical industry.

Although PI faces certain contraction risks, pharmaceutical exports have performed well, with export delivery value increasing by 5.1% annually, indicating a rebound in international market demand. Innovative products have also achieved a relatively high growth rate, and the effect of innovation-driven transformation is beginning to emerge. However, domestic pharmaceutical sales experienced negative growth, and drug prices fell significantly. The overall profit margin of PI has been squeezed (AskCI, 2024). Faced with challenges, PI needs to reduce costs and increase efficiency to cope with the pressure of industry contraction.

PI strongly correlates with people's healthy living and has strong momentum for long-term development. During 2024's first three quarters, China's per capita healthcare spending increased by 3.5%, accounting for 9.2% of per capita consumption

expenditure (Figure 1.7). Meanwhile, the 2023 National Ageing Development Annual Report shows that China will have 297 million people aged 60 and over by the end of 2023, making up 21.1% of the total population, indicating that China is entering a moderately aging society. The demand for examinations and treatments is expected to continue to increase.

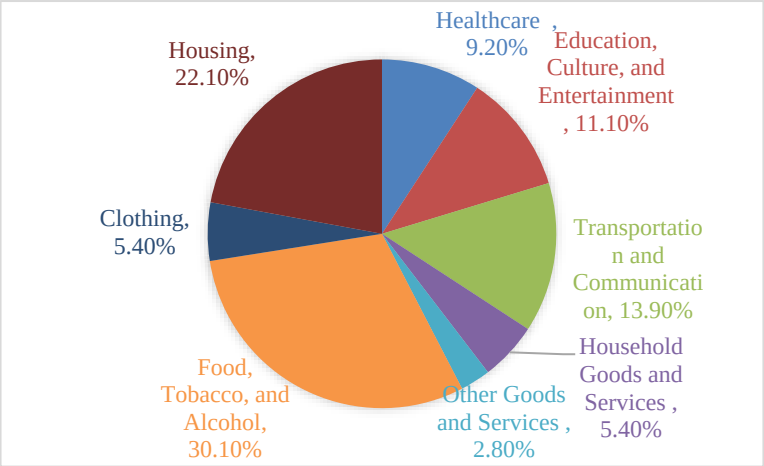

Figure 1.7 The Composition of Per Capita Consumer Expenditure of Residents in The First Three Quarters Of 2024

Data source: The State Council of the People's Republic of China. (2024, October 10). Income and consumption expenditure of residents in the first three quarters of 2024.

The government has also increased investment to promote the growth of PI. According to the 2023 Statistical Bulletin on the Development of China's Health Industry, total health expenditure has exceeded 9 trillion CNY, and the proportion of GDP has reached a new high of 7.2%, after two years of stagnation. The government's capital investment has effectively driven the expansion of the pharmaceutical market. The government has also issued several favourable policies to build a demand-oriented, more concentrated, benignly competitive, and sustainable pharmaceutical market.

Promoting policies will provide a more favourable environment and sustained support for PI (Szirn, 2024).

Digital Economy Development Research Report (2023)" indicates that China's digital economy is poised for substantial growth. In 2022, the digital economy's scale increased nominally by 10.3% yearly to 50.2 trillion CNY, and its contribution to GDP rose to 41.5%. With the rise of digitalization, PI is entering a critical period of transformation and upgrading. DT of PI refers to optimizing enterprise management, resource allocation, product production, and services through D-Tec, accelerating R&D, reducing costs, improving efficiency, and achieving sustainable growth.

As an important means, digitalization can run through the enterprise's top-level design and various operational links, promote PI's high-quality development, and help them achieve value recycling, optimization, and upgrading (Iyiou, 2023). Currently, PI is entering a new stage of development that is integrated, intelligent, and unified. Intelligent supply chains, global collaborative R&D, pharmaceutical e-commerce, and digital factories have become industry hotspots. These innovative applications have accelerated PI's transformation from a traditional model to one that is efficient and intelligent, providing strong support for the high-quality development of PI.

Digitalization is crucial to the development of PI, not only improving production efficiency and optimizing resource allocation but also driving PI innovation and enhancing competitiveness (Landray Research Insitute, 2024). The

application of internet collaboration is gradually deepening in PI. With the help of internet platforms, PI can achieve real-time communication and information sharing between suppliers, customers, partners and other parties, thereby building an efficient collaborative mechanism. This collaboration improves the enterprise's operational efficiency, reduces operating expenses, enhances the SC stability, and improves product quality and safety (Table 1.1). With the continuous advancement of technology and the expansion of application scenarios, digitalization is expected to play an increasingly important role in PI, further driving innovation and development across PI. This trend will enable PI to maintain an advantage in fierce market competition and meet ever-changing market demands.

Table 1.1 Digital Advantages of the Pharmaceutical Industry

Process	Function
Raw Material Procurement	Through internet platforms, PI can achieve real-time connectivity and information sharing with suppliers. This lowers procurement costs and increases procurement efficiency while guaranteeing a stable supply of raw materials.
Production Stage	By introducing D-Tec, PI can monitor the operating status of production equipment, production progress, and quality in real time, allowing them to detect and fix problems.
Sales Stage	PI can expand its sales channels and increase market coverage through online sales platforms. Additionally, PI can better understand market demand and consumer preferences by collecting and analysing user data, providing strong support for product development and marketing.

Data source: Landray Research Institute. (2024). 2024 pharmaceutical manufacturing digitalization white paper.

PI has always been a strategic emerging industry that China has focused on cultivating. ‘Made in China 2025’ lists the development of PI as one of the ten key areas for building a strong manufacturing country, while the ‘14th Five-Year Plan for the Development of PI’ points out that the livelihood of the populace, economic growth, and national security are all impacted by PI, which is also a key pillar in the construction of a robust China. Therefore, PI is significant in protecting and improving people's well-being and quality of life. The steady growth of the Chinese economy and the medical system's deepening reform have created favourable conditions for PI, which has not only maintained rapid growth in total industrial output value but has also further consolidated China's standing as the biggest emerging pharmaceutical market in the world.

The Ministry of Industry and Information Technology plans to promote PI from four aspects: innovation drive, strengthening and supplementing the chain, transformation and upgrading, and industrial collaboration to create a collaborative innovation and manufacturing platform for the PI chain that is cross-disciplinary, highly collaborative, and rapidly iterative. In addition, the government will support industry associations, leading enterprises, and scientific research institutions to jointly establish a PI chain research institute, promote collaborative research in SC, and accelerate the construction of a traceability system for the entire traditional Chinese medicine industry. It will also promote the integrated development of medical

equipment and technologies, such as 5G and artificial intelligence, and cultivate new models and business formats (He, 2023).

1.2.2 Sustainable Performance of Pharmaceutical Industry

Sustainability in manufacturing has gained widespread recognition in recent years, with increasing calls for manufacturers to go beyond economic growth to ensure the protection of the environment and reduce social burdens. Sustainability is key to addressing environmental issues associated with rapid economic growth (Hashmi & Alam, 2019). Sustainability emphasizes enterprise contribution to society and the environment while maintaining financial profitability (Gupta & Kumar, 2013). Sustainable development integrating environmental and social issues with economic issues is now more crucial than ever for academic scholars and enterprise professionals (Gil-Doménech et al., 2021). Industries committed to sustainable development are likelier to perform well in the long term and increase market confidence.

Sustainable development is not simply the same as environmental protection. Academics often see it as a combination of economic progress, social fairness, and environmental stewardship (Lourenço et al., 2012). When sustainability was integrated into enterprise development, the concept of sustainability was born and later redefined by scholars as “business and investment strategies designed to apply optimal practices for addressing and balancing the needs of both current and future stakeholders” (Artiach et al., 2010).

PI is an important foundation that supports medical and health undertakings and the health service industry. It has strong growth potential, is highly relevant, and plays a driving role. It is a sunrise industry that has positively improved people's lives and stabilized growth (GO-PHDP, 2016).PI has greater economic, social, and environmental responsibilities. The daily needs of pharmaceuticals must be met, while the application of economic resources, customer satisfaction, and the environmental impact of pharmaceutical waste need to be considered. PI still requires attention to sustainable development (Sun et al., 2022).

In terms of the economy, according to the ‘Economic Operation of PI in the First Half of 2024’, due to the influence of various factors, the main economic indicators have experienced negative growth. PI is entering a period of adjustment, and PI is generally facing operational pressures. The development of the industry is relatively severe. Factors such as medical insurance cost control, institutionalization, and the normalization of volume-based procurement have caused PI's revenue and profits to fluctuate slightly in recent years. Specifically, in 2022, the operating income of above-scale PI fell by 1.60% annually, while the total profit fell by 31.80% year-on-year (Lianhe Credit, 2023).

Data from the China PI Information Center show that in 2023, the primary business income of the top 100 enterprises decreased by 0.29% compared to the previous year, and the export delivery value fell by 21.4% year-on-year. The threshold for the top 100 enterprises dropped from 3.39 billion CNY in 2022 to 3.09 billion CNY,

and the threshold for the top ten enterprises was also lowered from 26.46 billion CNY to 25.33 billion CNY. Nearly half of the enterprises saw varying degrees of decline in the number of employees and total wages payable. According to the "Economic Operation of PI in the First Half of 2024", the national PI's revenue and profits fell. In the pharmaceutical among PI sub-industries, revenue and profit increased by 1/3 and decreased by 2/3.

In the first half of 2024, the overall sales of marketing terminals nationwide decreased by 1.9%, which is rare in years other than 2020. In October 2024, NBS announced that the growth of PI in the first three quarters was only 3.1%, which was below to the overall industrial standard and below that of many industries, such as food manufacturing and metal products. The growth rate of the hospital drug market in the first and second quarters of 2024 will decrease by 1.4% and 0.2%, respectively, and the profitability of nearly half of the pharmaceutical and health enterprises was lower than that of the same period last year (Shao, 2024). It is still difficult for PI to achieve positive growth in annual operating income.

Regarding the environment, the Chinese government has announced the "dual carbon" goal of achieving a carbon emissions peak by 2030 and carbon neutrality by 2060, and this policy has been implemented for more than two years. Under this framework, the country continues to improve the "1+N" policy system to promote the implementation of carbon reduction measures in PI. Specific policy measures include but are not limited to the "Guiding Opinions on Promoting the Green Development of

the API Industry" and "The 14th Five-Year Plan for the Development of PI". Implementing these policies has brought new challenges to Chinese PI, making them face more stringent emission reduction requirements.

PI has always been an industry with frequent environmental problems. According to statistics from the China Pharmaceutical Risk Early Warning Platform, from 2011 to 2021, 31 provinces have issued environmental protection fines to local pharmaceutical enterprises, especially major pharmaceutical provinces facing more significant environmental pressure. The daily operation of PI will generate a large amount of "three wastes" (wastewater, waste gas, and waste solids), which are huge in quantity and complex in composition. The discharged wastes are usually toxic, flammable, corrosive, chemically reactive, and infectious, posing a tremendous potential threat to the ecological environment and human health (Alnahas et al., 2020). In China, PI is the largest source of carbon emissions in the healthcare sector, accounting for more than half (55%) (Zhao et al., 2023). Numerous studies have highlighted the widespread presence of pharmaceuticals in surface water, groundwater, and drinking water throughout China (Cao et al., 2020; Jiang et al., 2019). Therefore, PI's environmental awareness and measures are particularly important (Zhang & Ye, 2024).

At the same time, the ESG risks of listed enterprises in PI are relatively high, and the overall environmental score is low (Figure 1.8). Most enterprises lack specific quantitative data on waste emissions and energy consumption, and the construction of

environmental-related systems also needs further improvement (Lianhe Credit, 2023). PI will generate many pollutants and waste during production, including chemical substances and drug residues. If they are not strictly treated and discharged, they are likely to cause harm to environment and human body. Due to the special production methods and supply chain, the pressure PI puts on the environment is relatively large.

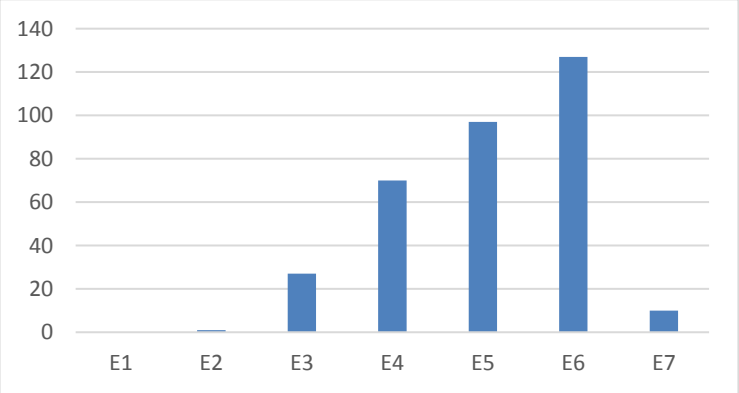

Figure 1.8 Distribution of Environmental Responsibility Scores for Listed Enterprises in PI

Note: ESG primary indicator environmental scores are divided into E1-E7, where E1 represents the best performance, and E7 represents the worst performance.

Data source: Adapted from 2023 ESG rating analysis report for the pharmaceutical industry, by Lianhe Credit, 2023, https://www.lhratings.com/file/f7e454f8773.pdf. Copyright 2023 by Lianhe Credit.

Social dimension: Product safety is an important indicator of PI in the social dimension. Unlike ordinary consumer goods, medicines and medical devices are intrinsically linked to individuals' bodily well-being and life security. Therefore, they are closely related to social harmony and stability. It is crucial to ensure product quality and safety. However, in recent years, deep-seated problems in drug quality and safety still exist, and instances of the production, sale, and utilization of counterfeit and substandard pharmaceuticals have arisen periodically (Lianhe Credit, 2023). In 2020,

there were 7,361 investigations and resolutions concerning the production, sale, and use of counterfeit and substandard medications nationally, resulting in the revocation of 38 licenses and the referral of 168 cases to legal authorities (National Medical Products Administration, 2021).

According to Figure 1.9, the overall performance of listed enterprises in PI in social responsibility is acceptable. From the perspective of level distribution, there are two enterprises with a score of S1, 24 enterprises with a score of S2, and 34 enterprises with a score of S3. Enterprises with higher scores have outstanding social contributions in product services, technological innovation, and supplier performance. The number of enterprises with a score of S4 is the largest, at 118, and there are 108 enterprises with a score of S5. There are 46 enterprises with a score of S6, and no enterprise has a score of S7 (Lianhe Credit, 2023). Overall, there is still room for improvement in the performance of PI in terms of social responsibility.

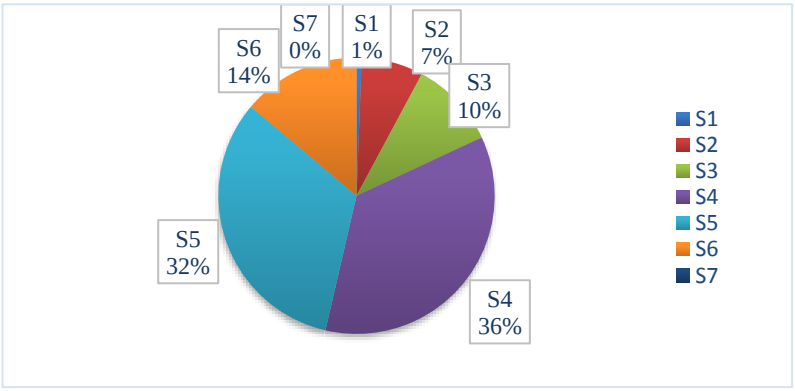

Figure 1.9 Social Responsibility Scores of Listed Enterprises in PI

Note: The social scores of the ESG primary indicators are divided into S1-S7, where S1 represents the best performance, and S7 represents the worst performance.

Data source: Adapted from 2023 ESG rating analysis report for the pharmaceutical industry, by Lianhe Credit, 2023, https://www.lhratings.com/file/f7e454f8773.pdf. Copyright 2023 by Lianhe Credit.

In general, China's PI's prospects for sustainable development are optimistic. However, as a risk-averse industry, the conservatism and caution of PI have led to a lag in its sustainability compared to other industries (Chen et al., 2023; Ma et al., 2023). China embraces the development philosophy that "green mountains are gold mountains," advocates harmonious coexistence between human beings and nature, and adheres to the path of green and sustainable development, indicating the trajectory for the synergistic advancement of China's economy, society, and environment.

1.2.3 Challenges Faced by Chinese Pharmaceutical Industry

PI's business activities have both economic and social attributes, which directly affect human life, health, and safety. The sustainable development of China's PI still faces huge challenges.

China's PI faces many problems in terms of enterprise structure. Government management departments and PI generally believe that there are too many PM-Industry with a small average scale and low production concentration. There are problems of overcapacity, low social resource utilization, and a lack of large enterprises with international competitiveness. As an important feature of PI, the enterprise structure reflects the development and evolution of China's PI to a certain extent. It is a crucial entry point for solving industry development problems and exploring new opportunities. Accelerating the adjustment of the structure of PI is not

only a pressing objective for China's PI to attain comprehensive and coordinated development and overall level improvement but also an urgent need to adapt to the populace's escalating health demands and achieve the goal of a healthy China (PwC, 2023). In addition, in China's PI, the supply chain is still in a decentralized state, and various decision-making entities have mechanism barriers in strategy formulation, planning, and demand response, which hinders the improvement of the overall efficiency of PI (Shushangyun, 2022).

In the past few years, all industries worldwide have faced severe supply chain challenges. For PI, if they cannot prevent possible delays, changes, and related obstacles in the supply chain in advance, they may eventually face billions of dollars in losses. The pandemic caused by COVID-19 has exposed the unstable nature of the global supply chain. Between 2019 and 2021, supply chain disruptions in PI increased by 350%, resulting in the delivery cycle of some raw materials and consumables being extended by about three times. In addition to the impact of COVID-19 itself, supply chain disruptions may also have serious consequences for PI and patients.

Production declines and drug shortages caused by supply chain problems cause enterprises to lose tens of billions of dollars yearly and may even have catastrophic consequences for PI (Bilodeau et al., 2023). In addition, insufficient product production or supply chain problems may also affect the ability of PI to obtain approval and market new drugs. In the future, integration and cooperation in PI will become an important development trend. Integrating resources and advantages to achieve

coordinated development and win-win results in the industrial chain will become a key direction for the development of PI (ChinaIRN, 2023).

The pain points of China's traditional PI are mainly concentrated in the following aspects (Figure 1.10): 1) The business model is too single; 2) Online supervision is lagging; 3) Insufficient management of SC. Therefore, the SC of PI urgently needs to be fully integrated to enhance the whole industry chain and fulfil PI's ongoing commitment to serve as a high-standard supply platform (iResearch, 2020).

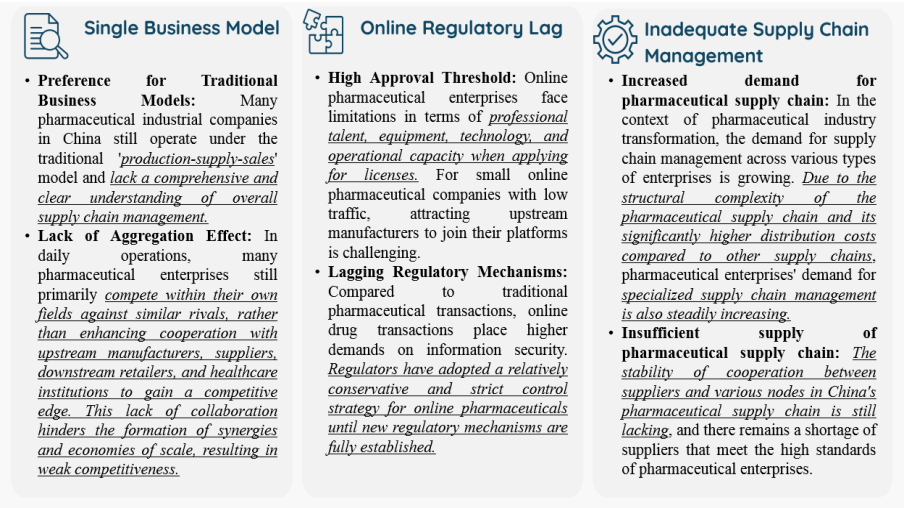

Figure 1.10 Analysis of Pain Points of China's PI in 2020
Data source: iResearch. (2020). Internet white paper on China’s pharmaceutical industry [in Chinese]. https://pdf.dfcfw.com/pdf/H3_AP202012161440695496_1.pdf

As China's total health expenditure increases yearly, the shortage of conventional and life-saving drugs has caused widespread reflection in the country and society. Mitigating the issue of "accessibility and expense of medical consultations" is intricately linked to the management of the pharmaceutical SC, and understanding the drug supply dilemma and the supply and demand contradictions in the upstream and downstream of SC has become an indispensable part of drug supply operation

management. In the current domestic medical environment, the traditional drug production model can no longer meet the existing drug supply needs. Therefore, it is imperative to optimize the current production management strategy, build a resilient and fast-responding supply chain, and adopt a new inventory management model (KPMGChina, 2022).

The Opinions on Further Reforming and Improving the Policies on Drug Production, Circulation, and Use clearly proposed that it is necessary to "integrate drug storage and transportation resources, realize multi-warehouse coordination, support cross-regional distribution of drug distribution enterprises, and expedite the establishment of a medication distribution network primarily composed of big backbone firms, supplemented by SMEs." At the same time, the General Office of the State Council issued the Guiding Opinions on Actively Promoting Supply Chain Innovation and Application, which pointed out that it is necessary to "encourage wholesale, retail and logistics enterprises to consolidate SC resources and establish a SC coordination platform for procurement, distribution, warehousing and delivery."

Supply chain reform and innovation is an important starting point for supply-side structural reform. Presently, the policies and pilot scopes introduced by various provinces are mainly limited to the province, and the progress of PI in realizing the integration of drug storage and transportation resources is still slow. The essence of the State Council document is to open up the veins of the national pharmaceutical supply chain, truly deepen the integration of SC resources, and enhance the synergy