THE IMPACT OF GREEN TECHNOLOGY INNOVATION AND ESG PERFORMANCE ON THE FINANCIAL PERFORMANCE OF A-LISTED COMPANIES IN CHINA: THE INTERACTION EFFECT OF DIGITAL LEVEL

TENG SHUNPING

UNIVERSITI SAINS MALAYSIA

2025

THE IMPACT OF GREEN TECHNOLOGY INNOVATION AND ESG PERFORMANCE ON THE FINANCIAL PERFORMANCE OF A-LISTED COMPANIES IN CHINA: THE INTERACTION EFFECT OF DIGITAL LEVEL

by

TENG SHUNPING

Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

August 2025

ACKNOWLEDGEMENT

Looking back on several years of my PhD life, many emotions welled up in my mind. I would like to express my sincere gratitude to the teachers who taught me and made me progress academically. I would also like to thank the beautiful Universiti Sains Malaysia (USM). Every plant and tree here have witnessed my study progress over the years and is the most valuable asset in my life. Firstly, I am especially grateful to my supervisor, Associate Professor Dr. Haslindar Ibrahim. My thesis is about to be completed, which is inseparable from the hard guidance of my supervisor. My supervisor has been giving me very professional and patient guidance throughout the writing process of my thesis. She is rigorous in her academic research and sincere in her treatment of others. It has set an example for me in both work and study as well as in my daily dealings with people, which will benefit me in the future. Secondly, I am very thankful to examiners, Dr. Aslam Mia and Dr. Nik Hadiyan Nik Azman for providing a lot of constructive comments on my thesis. These valuable comments have given me new insights and knowledge about my thesis. Thirdly, I would like to express my special thanks to the School of Management (SOM) for organizing various rich scientific research activities, which provide a good environment for my research and study. Here, special thanks to Ms Robitah and Ms Rosnah for their diligence and responsibility in handling various school affairs. These increase my knowledge and sense of belonging to the school. Fourthly, I would like to thank my family, colleagues, classmates and friends for their help during my PhD studies.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

2SLS	Two-Stage Least Squares
AI	Artificial Intelligence
BSE	Beijing Stock Exchange
CAPCO	China Association for Public Companies
CASVI	China Alliance of Social Value Investment
CCMRI	China Capital Market Research Institute
CNRDS	Chinese Research Data Services
CPC	Communist Party of China
CSMAR	China Stock Market & Accounting Research
CSRC	China Securities Regulatory Commission
E	Environmental
EBIT	Earnings before Interest and Taxes
EPS	Earnings Per Share
ESG	Environmental, Social and Governance
FEM	Fixed Effects Model
G	Governance
GEM	The Growth Enterprise Markets
GHG	Greenhouse Gas
HKSE	Hong Kong Stock Exchange
MEE	Ministry of Ecology and Environment
MOST	Ministry of Science and Technology
NDRC	National Development and Reform Commission
OLS	Ordinary Least Squares
POLS	Pooled Ordinary Least Squares
PRC	The People's Republic of China
PSX	Pakistan Stock Exchange
R&D	Research and Development
REM	Random Effects Model
ROA	Return on Total Assets
ROE	Return on Equity
S	Social

SASAC	State-Owned Assets Supervision and Administration Commission
SCSRC	State Council Securities Regulatory Commission
SDG	Sustainable Development Goal
SME	Small and Medium Enterprise
SOEs	State-Owned Enterprises
SSE	Shanghai Stock Exchange
ST	Special Treatment
SZSE	Shenzhen Stock Exchange
TWSE	Taiwan Stock Exchange
VIF	Variance Inflation Factor
WIPO	The World Intellectual Property Organization

LIST OF APPENDICES

KESAN INOVASI TEKNOLOGI HIJAU DAN PRESTASI ESG TERHADAP PRESTASI KEWANGAN SYARIKAT TERSENARAI A DI CHINA: KESAN INTERAKSI TAHAP DIGITAL

ABSTRAK

Inovasi teknologi hijau, alam sekitar, masyarakat dan tadbir urus (ESG) dan pendigitalan adalah langkah penting yang perlu diambil oleh syarikat dalam proses pembangunan, penekanan yang sama kepada faedah ekonomi, sosial dan ekologi. Oleh itu, kajian ini mengkaji kesan inovasi teknologi hijau dan prestasi ESG terhadap prestasi kewangan syarikat tersenarai A di China. Selain itu, ia meneroka kesan interaksi tahap digital. Kajian ini menggunakan syarikat tersenarai A di Shanghai dan Shenzhen sebagai sampel penyelidikan dari 2015 hingga 2022. Ia menggunakan model kesan tetap (*FEM*) untuk analisis regresi. Didapati bahawa dua dimensi dan inovasi teknologi hijau secara keseluruhan mempunyai korelasi negatif yang signifikan dengan prestasi kewangan syarikat. Namun, keseluruhan dan tiga dimensi prestasi ESG mempunyai hubungan positif yang signifikan dengan prestasi kewangan syarikat. Bagi kesan interaksi tiga dimensi tahap digital, ia melemahkan kesan inovasi teknologi hijau terhadap prestasi kewangan syarikat tetapi menguatkan kesan prestasi ESG terhadap prestasi kewangan syarikat. Selepas itu, dalam ujian kekukuhan, kajian ini menggunakan kaedah *two-stage least squares*, kaedah pembolehubah pengganti dan segmentasi masa untuk mengesahkan penemuan regresi. Kesimpulannya menunjukkan bahawa inovasi teknologi hijau menghalang prestasi kewangan syarikat, di mana inovasi teknologi hijau yang substantif mempunyai kesan penghalang yang lebih kuat; prestasi ESG meningkatkan prestasi kewangan syarikat, di mana prestasi *S* mempunyai kesan pendorong yang terkuat.

Selain itu, tiga dimensi tahap digital mempunyai interaksi negatif terhadap hubungan antara inovasi teknologi hijau dan prestasi kewangan syarikat, tetapi mempunyai interaksi positif terhadap hubungan antara prestasi ESG dan prestasi kewangan syarikat. Keputusan penyelidikan memberikan bukti empirikal yang relevan tentang bagaimana syarikat tersenarai A dapat menggunakan inovasi teknologi hijau, prestasi ESG dan digitalisasi untuk mempromosikan prestasi kewangan syarikat.

THE IMPACT OF GREEN TECHNOLOGY INNOVATION AND ESG PERFORMANCE ON THE FINANCIAL PERFORMANCE OF A-LISTED COMPANIES IN CHINA: THE INTERACTION EFFECT OF DIGITAL LEVEL

ABSTRACT

Green technology innovation, environmental, social, and governance (ESG), and digitalization are essential initiatives that enterprises should undertake in the course of development, emphasizing a balanced pursuit of economic, social, and ecological benefits. Consequently, this study examines the effect of green technology innovation and ESG performance on the financial performance of A-listed companies in China. Moreover, it explores the interaction effect of digital level. This study uses A-listed companies in Shanghai and Shenzhen as the sample from 2015 to 2022. It employs a fixed effects model (FEM) for the regression analysis. It is found that the two dimensions and overall green technology innovation are significantly negatively correlated with financial performance. However, the overall and three dimensions of ESG performance are significantly positively related to financial performance. For the interaction effects of the three dimensions of digital level, they weaken the effect of green technology innovation on financial performance, but strengthen the effect of ESG performance on financial performance. Furthermore, in the robustness tests, this study applies the two-stage least squares method, the substitution variable method and time segmentation to verify the findings of the regression. The conclusion shows that green technology innovation inhibits financial

performance, among which substantive green technology innovation has a stronger inhibitory effect; ESG performance promotes financial performance, among which social (S) performance has the strongest promoting effect. In addition, the three dimensions of digital level have a negative interaction effect on the relationship between green technology innovation and financial performance, but have a positive interaction effect on the relationship between ESG performance and financial performance. The research results provide relevant empirical evidence on how A-listed companies can use green technology innovation, ESG performance and digitalization to affect financial performance.

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the context of the digital economy, green technology innovation is the key to guaranteeing economic and social benefits (Li, 2022). The idea of green development was originally introduced in October 2015 at the Fifth Plenary Session of the 18th Central Committee of the Communist Party of China (CPC). Since then, the idea that "clear waters and green mountains are as good as mountains of gold and silver" (*Opinions on Accelerating the Construction of Ecological Civilization*, 2015) has grown more deeply ingrained in people's imaginations.

Then, in April 2019, China's National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST) pointed out that the government needs to intervene in the market to help establish a green technology innovation system (*Guidance on Building Market-Oriented Green Technology Innovation*, 2019). This was the first time that China had provided a unified definition of green technology. In May 2020, the 14th Five-Year Plan further specified the construction of a market-oriented green technology innovation system. Green technology innovation has increasingly become an inevitable requirement for achieving sustainable development (Zheng & Zhang, 2023).

Moreover, the concept of a "low-carbon economy" (Samargandi & Sohag, 2022), which emphasizes environmental protection and economic growth, has

gradually emerged and received widespread attention (Li, Ji, Zhang & Zhu, 2024). In December 2022, China's National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST) proposed to fully leverage the key supporting role of green technology in green and low-carbon development, and to strengthen key green technology research and development (R&D) (*Implementation Program on Further Improving the Market-Oriented Green Technology Innovation System (2023-2025)*, 2022).

Meanwhile, countries around the world are paying increasing attention to corporate performance in environmental, social, and governance aspects, that is, corporate ESG performance (Chen, Zhu, Zhong, Liu, Wu & Zeng, 2019). ESG conveys the concept of sustainable development, in which companies pursue the integration of economic interests and social values, and offers a theoretical framework for companies to achieve sustainable development (Li, Yang, Chen & Cui, 2021).

In July 2018, for the first time, China introduced legal requirements for ESG disclosure. Starting in 2020, the Chinese government has continued to publish the *China ESG Development White Paper*. It fosters the advancement of ESG practices. On this basis, the disclosure of ESG information has also attracted great attention from the academic community (Srouji, Hamdallah, Al-Hamadeen, Al-Okaily & Elamer, 2023).

In July 2015, the implementation of the State Council's *Guiding Opinions on Actively Promoting the "Internet Plus" Initiative* officially marked China's entry into a new era of digital development. The report of the 20th National Congress of the Communist Party of China (CPC) clearly stated that it is necessary to accelerate the development of the digital economy and promote the deep integration of the digital economy and the real economy (*Report of the 20th National Congress of the CPC*, 2022).

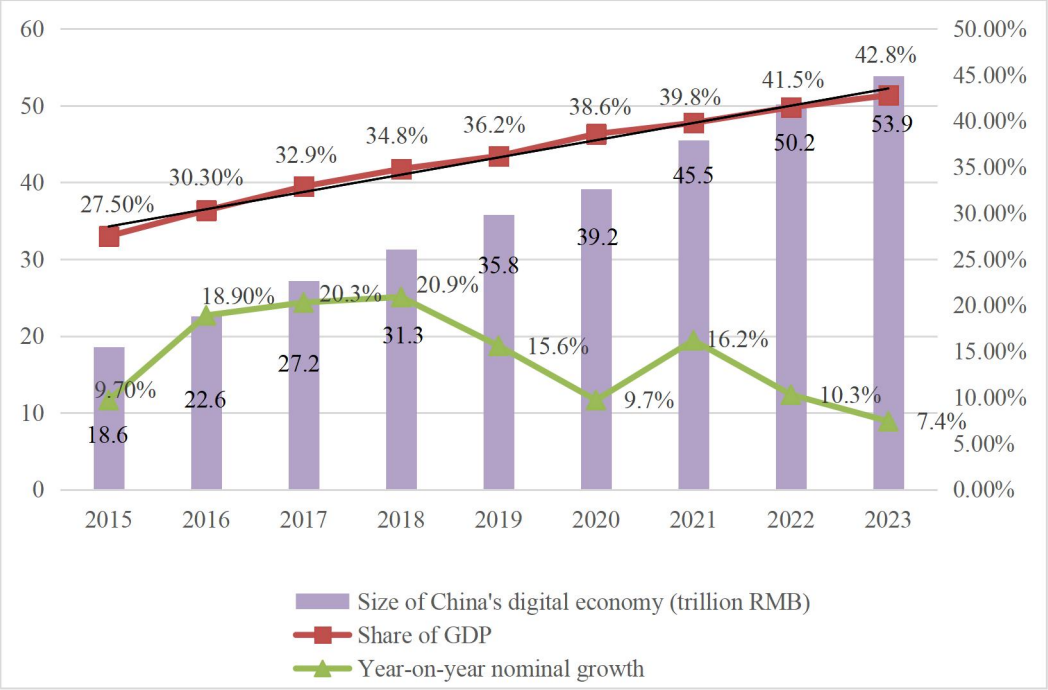

Figure 1.1 Indicators Related to China's Digital Economy from 2015 to 2023
Source: China Academy of Information and Communications Technology (CAICT) (2024)

As shown in Figure 1.1, China's digital economy reached 53.9 trillion yuan in 2023, further strengthening its role in the national economy (*Research Report on China's Digital Economy Development (2024)*, 2024). However, the year-on-year

nominal growth rate of the digital economy was volatile from 2020 to 2023 due to the impact of the Covid-19 epidemic.

In the context of the rapid development of the digital economy, companies should accelerate the in-depth integration of digital technology with the production, research and development (R&D), management, sales, and service functions of companies. With the continuous emergence of new technologies, new models, and new business forms, digitalization has increasingly emerged as a significant factor in promoting corporate green technology innovation (Gao, Li, Meng, Shi, & Zhu). Meanwhile, corporate digital transformation can effectively improve its ESG performance. However, enterprises must allocate considerable human, material, and financial resources to engage in green technology innovation, ESG practices, and digital transformation — particularly for green technology innovation, which often demands even greater input. Whether these efforts can contribute to corporate financial performance is a question worth pondering.

Listed companies are the main force of the national economy, and they are the "power source" that drives China's economic growth (*White Papers on Digital Economy of China's Listed Companies*, 2022). Considering the availability of research data, this study uses the data of A-listed companies in Shanghai and Shenzhen from 2015 to 2022 as the sample. It incorporates green technology innovation, ESG performance, and digital level into the research framework in relation to financial performance. This is of great significance to the construction of a

new development pattern of the "double-cycle" economy, and the strategy of realizing the goal of "dual carbon".

1.2 Background of the Study

1.2.1 Chinese A-Listed Company

A listed company refers to a company limited by shares whose shares are listed and traded on a stock exchange (*Company Law of the People's Republic of China (PRC)*, 2018). It is a form of a company limited by shares. According to *the Company Law* of the PRC, the listing of shares must be in accordance with the relevant laws, administrative regulations, and the trading rules of the stock exchange. At present, there are five stock exchanges in China, namely, the Shanghai Stock Exchange (SSE), the Shenzhen Stock Exchange (SZSE), the Hong Kong Stock Exchange (HKEX), the Beijing Stock Exchange (BSE), and the Taiwan Stock Exchange (TWSE).

As of December 31, 2023, there were 5346 listed companies in China, including 2263 on the Shanghai Stock Exchange (SSE), 2844 on the Shenzhen Stock Exchange (SZSE), and 239 on the Beijing Stock Exchange (BSE). In terms of industry distribution, the majority are in manufacturing, information transmission, and software and information technology services (China Association for Public Companies, 2024). The number of listed companies in China has grown significantly, and the quality has continued to improve. Therefore, their role in promoting the development of the national economy has become increasingly prominent. The SSE

and the SZSE are the largest and second-largest stock exchanges in China, respectively. The two occupy the majority of the A-share market and together constitute the core of the Chinese stock market. Consequently, this study uses Shanghai and Shenzhen A-listed companies as the sample for research.

Listed companies are a group of Chinese companies with strong comprehensive strength. They have a certain asset size and have the ability and demand for green technology innovation (Yang, 2020). In May 2022, the State-Owned Assets Supervision and Administration Commission (SASAC) required listed companies owned by central enterprises to implement the new development concept and explore the establishment of a sound ESG system (*Morketing 2022 ESG Case Book*, 2022). This has set higher requirements for the green technology innovation and ESG performance of listed companies. It helps to stimulate them to proactively implement these initiatives in order to realize the task of building a beautiful China and achieving the "dual carbon" goal as soon as possible.

1.2.2 Financial Performance

Gaining insight into corporate performance has been critical for both practitioners and scholars, especially in the management domain (Stainer & Stainer, 1998; Shashi, Cerchione, & Singh, 2019). Financial performance is an important component in enhancing economic returns in a company's daily operations. It is the operating results that a company can achieve over a certain period of time (Chen & Cheng, 2023). Financial performance is the most basic goal of a company and the fundamental reason for its emergence, existence, and development (Gong & Dou,

2007). It is an important measure of a company's financial health and performance and is crucial for achieving long-term success and sustainability (Setiani, 2023).

At the Boao Forum for Asia 2023, Wu, president of the China Capital Market Research Institute (CCMRI), pointed out that companies need to do a good job in their main business first, which is the cornerstone of good ESG performance (Chai, 2023). The "main business" refers to the financial performance of the company. It is an intuitive and comprehensive reflection of the company's operating results and is a matter of concern to various stakeholders inside and outside the company (Ding, 2022). The level of financial performance has a direct or indirect impact on investor investment, bank lending, supplier and customer commercial credit, and even the company's market share (Ding, 2022).

In general, financial performance is divided into two types: accounting-based financial performance and market-based financial performance. In conducting academic research, previous scholars generally used return on total assets (ROA), return on equity (ROE), earnings per share (EPS), Tobin's Q, and stock price for measurement. Among them, ROA, ROE, and EPS are accounting indicators based on financial statements. They measure the accounting-based financial performance that is more closely related to the operation of the company. Tobin's Q and stock price are market indicators based on the capital market. They measure the market-based financial performance that focuses on shareholder wealth and corporate market value (Alajlani, 2019).

Overall, accounting-based financial performance indicators reflect a company's operating capabilities more directly. When companies gradually diversify their operations, market-based financial performance indicators may increase, while accounting-based financial performance indicators may decrease. This study argues that the prerequisite for Tobin's Q and stock price to measure the operational capability of companies is the availability of a developed financial market and rational investors. However, this prerequisite is not fully valid in China (Teimet, 2021). Consequently, this study adopts accounting-based financial performance indicators to measure the financial performance of companies. It measures the financial performance of a company over a period of time using return on total assets (ROA).

1.2.3 Green Technology Innovation

1.2.3(a) Emergence of Green Technology Innovation

Reducing carbon emissions and promoting sustainable development have become a prominent topic of global discussion (Dogan, Chishti, Alavijeh & Tzeremes, 2022). The Chinese government actively responds to environmental protection strategies. In September 2020, China officially put forward the vision of realizing the goals of carbon peaking and carbon neutrality (The 75th Session of the United Nations General Assembly, 2020). Since then, the report of the 20th National Congress of the Communist Party of China (CPC) has emphasized the importance of planning development from the perspective of the harmonious coexistence of human beings and nature, and actively and steadily advancing carbon peaking and carbon

neutrality (*Report of the 20th National Congress of the CPC*, 2022). In this context, green technology innovation has emerged.

Green technology innovation refers to new processes, products, technologies, and services developed for the purpose of environmental protection (Schiederig, Tietze & Herstatt, 2012). It is an effective path to foster the harmonious development of the economy and the ecological environment. Additionally, these innovations represent a crucial impetus for achieving the "dual carbon" goals (Ren, Xiao, Xiao, Jin & Taghizadeh-Hesary, 2024). Green technology innovation aligns with global sustainability goals (Gong, Ying & Dai, 2023). According to statistics, most of China's carbon dioxide emissions come from daily corporate production and operation activities (Meng, Liu, Andrew, Zhou, Hubacek, Xue, Peters & Gao, 2018). This means that companies are the key subjects for realizing the "dual carbon" goal. In China, key state-owned enterprises (SOEs) in high-pollution and high-energy-consuming industries, as well as certain manufacturing firms in economically developed coastal regions, were among the first to adopt or implement green technology innovation, such as the State Grid Corporation and Baosteel Group.

Green technology innovation can effectively reduce energy consumption and pollution emissions (Li, Zhang, Lee & Li, 2021) and then promote a company's green sustainable development. As a combination of the two development concepts of green and innovation, green technology innovation is a key initiative to mitigate the conflict between economic development and environmental pollution, and to realize the transformation of the mode of economic development and the protection

of environmental resources. However, green innovation activity is a capital-intensive activity with high resource requirements. It faces the problems of high risk and high capital investment (Yang & Jia, 2024).

Like technological innovation, green technology innovation is defined by a long cycle, high investment, and high risk. Green production may impose a financial burden on companies (Kim & Lee, 2012; Baah, Opoku-Agyeman, Acquah, Issau & Moro Abdoulaye, 2020). However, the essential characteristic of green technology innovation is that it contributes to the improvement of ecological benefits or reduction of environmental pollution (Huber, 2008). It has the following characteristics: double externalities; high entry barriers; information asymmetry; benefit uncertainty and spillovers; and multiplicity of objectives.

Drawing on the research of previous scholars, this study divides green technology innovation into substantive green technology innovation and strategic green technology innovation according to their technical content (Liu & Xiao, 2022; Zhang, Qian & Cao, 2023). This classification helps to more precisely identify the essential characteristics of companies' green innovation activities.

Substantive green technology innovation often involves fundamental changes in core processes, products, or technological systems. This type of innovation emphasizes the development of breakthrough technologies. It involves higher research and development investment, longer development cycles, and greater technological uncertainty. As it requires mobilizing more organizational resources and specialized knowledge, its technological risks and market uncertainties are also

relatively higher (Argyres, 1996). In contrast, strategic green technology innovation tends to involve incremental improvements based on existing technologies, such as minor green enhancements to existing products or symbolic green practices aimed at regulatory compliance and meeting public expectations.

From a strategic perspective, a company's choice between substantive and strategic green technology innovation typically depends on factors such as its technological capabilities, resource endowments, environmental regulatory pressure, and market orientation. This study categorizes green technology innovation into substantive and strategic types, which helps to uncover the underlying motivations and mechanisms of companies' green innovation behaviors, and provides a theoretical foundation for empirically assessing their impact on financial performance.

1.2.3(b) Policies Related to Green Technology Innovation in China

Green technology innovation focuses on improving environmental quality and ecological efficiency while pursuing economic growth. The most important subject of green technology innovation is the company, which is mainly influenced by economic growth, research and development (R&D) investment, and policy guidance (Wang & Zhao, 2019). To promote green innovation, many countries have implemented policies aimed at fostering green production and promoting innovative development (Ai, Luo & Bu, 2024). In China, the introduction of a series of policy documents reflects the government's strong emphasis on green technology

innovation. Therefore, green technology innovation shows a distinct government-led feature.

The report of the 19th National Congress of the Communist Party of China (CPC) attaches great importance to green technology innovation and clearly puts forward the development direction of building a market-oriented green technology innovation system. Subsequently, the National Development and Reform Commission (NDRC) and other relevant departments jointly issued policy documents, further reflecting the importance of green technology innovation. Therefore, promoting green technology innovation has become a key task in China's ecological construction. On the one hand, the government formulates development plans at the macro level and provides policy guidance for green technology innovation. On the other hand, support for green technology innovation is provided through incentives such as special science and technology projects and national research and development (R&D) programs.

1.2.3(c) Development of Green Technology Innovation in China

Under the active promotion of the government, companies, investors, consumers, and other sectors, China's green technology innovation capacity has been continuously improved. Green patents are often associated with improvements in energy intensity (Wurwood & Noailly, 2018) and more broadly serve as indicators of progress in green innovation (Haščič & Migottoi, 2015).

Drawing on the practices of previous scholars and referring to the measurement method outlined in the *China Green Technology Innovation Index*

Report (2022) (Zero One Think Tank, 2023), this study uses the number of green patent applications to measure the level of corporate green technology innovation.

Green patents include green invention patents and green utility model patents. Among them, green invention patents emphasize high inventiveness and are usually entirely new methods or technologies, while green utility model patents emphasize practicality and novelty, and are usually improvements to existing technologies. In this study, green invention patents and green utility model patents are used to measure substantive and strategic green technology innovation, respectively. This helps to more thoroughly analyze the differentiated impacts of various types of green technology innovation on financial performance.

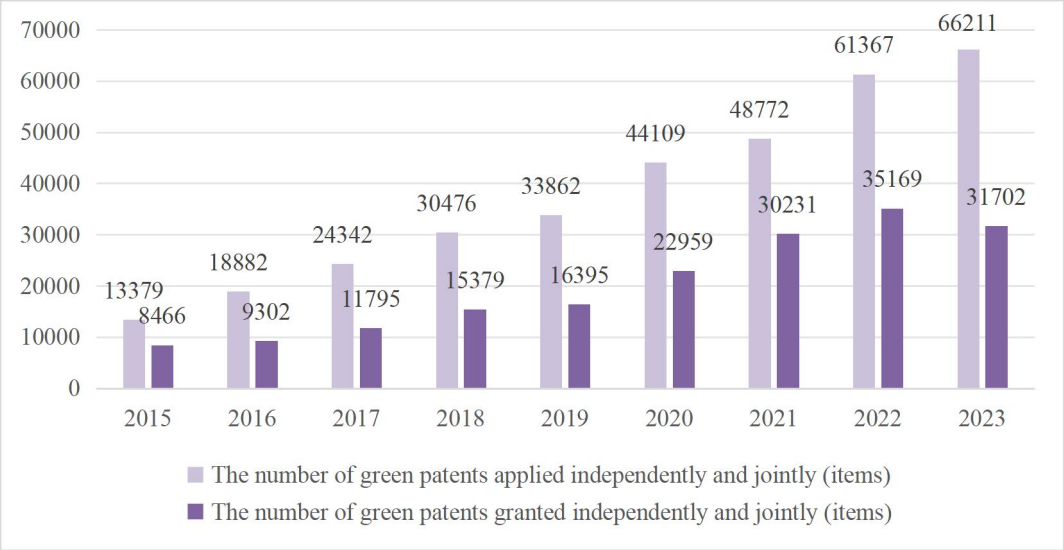

Figure1.2 Green Patent Applications and Grants by Listed Companies in China from 2015 to 2023
Source: Chinese Research Data Services (CNRDS)

As shown in Figure 1.2, the number of green patent applications by Chinese listed companies has shown a steady upward trend from 2015 to 2023. This indicates that corporate green innovation capacity has been increasing. Similarly, from 2015 to

2022, the number of green patents granted to listed companies increased year by year but experienced a slight decline in 2023. Corporate green technology innovation has become a guiding force for the construction of ecological civilization and an important way to achieve the objective of carbon neutrality strategy (Zheng et al., 2023).

However, the capability and motivation of corporate green technology innovation are still relatively weak (Guo, Wei & Li, 2019). Its dominant position in green technology innovation has not yet been fully established (Wang, Li & Wang, 2020). Due to the large gap between companies and traditional academic and research institutions in terms of talent reserves and scientific and technological resources, the research and development (R&D) system centered on scientific research institutions still cannot be changed in a short period of time (Wang et al., 2020). Therefore, green technology innovation has the potential to enhance economic competitiveness, and companies have become the key to realizing sustainable development.

1.2.3(d) Green Technology Innovation and Financial Performance

The concept of "green technology innovation" first appeared in 1994 (Brawn & Wield, 1994). It has dual positive externalities and is an effective means to realize green and sustainable development of companies. For example, through green technology innovation, companies can develop clean energy technologies, establish environmentally friendly production processes, and improve existing products with green modifications, thereby influencing their financial performance. Green

technology innovation can not only optimize a company's production process, increase product variety, play the role of energy conservation and emission reduction, but also optimize corporate structure and carry out organizational innovation, institutional innovation, and more.

However, there are also studies that suggest that the development of green innovation by companies will increase their innovation and operational costs, becoming an economic burden in the process of transformation and upgrading. It eventually crowds out other resources of the company and creates a negative effect on corporate financial performance (Ngniatedema, Li & Illia, 2014). Nevertheless, green innovation can reduce pollution and contribute to positive social value creation (Huang & Li, 2017). Compared with ordinary technology innovation, green technology innovation is more difficult and more risky, and uncertain, requiring stable and continuous research and development (R&D) investment for support (Qin, Sha, Di, Zhou & Wu, 2017).

Green technology innovation can continuously promote the transformation of companies' research and development (R&D) achievements into productivity, develop green products, explore new markets, and increase product sales (Amjad, Tabbasam & Ara, 2022; Chaithanapat, Punnakitikashem, Oo & Rakthin, 2022). This enables companies to reduce production costs while increasing sales revenue, thereby improving their financial performance (Montani, Staglianò, Sommovigo, Setti & Giorgi, 2023). A higher number of green technology innovation patent applications is

associated with higher sales levels and profitability, which is more conducive to improving a company's financial performance.

According to sustainable development theory, green technology innovation can enable companies to obtain patents, trademarks, and honors, which in turn improves their level of competition and lays the foundation for sustainable development. However, in the process of green process innovation, companies first have to pay additional costs for high-cost equipment, waste disposal, and employee training in environmental awareness. These factors may result in a decrease in current financial performance (Zotter, 2004; Lin, Zeng & Ma, 2015). Whether green technology innovation can contribute to corporate financial performance depends on the size of the "innovation compensation" effect. Therefore, exploring the impact of green technology innovation on corporate financial performance is of great significance in guiding corporate practice.

1.2.4 Environmental, Social and Governance (ESG) Performance

Environmental, social, and governance (ESG) is an investment philosophy and evaluation standard that focuses on corporate externalities and governance levels rather than financial performance (*2022 Sustainability (ESG) Investment White Paper*, 2022). For example, Alibaba Group reduces the energy consumption of its data centers through "green cloud computing", while the State Grid Corporation of China promotes the "electricity poverty alleviation" program to support poverty reduction in remote areas. ESG performance refers to the comprehensive performance of a company in terms of environment (E), social (S), and governance

(G). The study introduces the company's ESG performance from three aspects: ESG practice, ESG disclosure, and ESG rating. It then elaborates on ESG performance from three dimensions: E, S, and G, and finally examines the relationship between ESG performance and corporate financial performance.

1.2.4(a) ESG Practice

For listed companies around the world, ESG has been put on the agenda of corporate boards and management. With pressure from regulators, shareholders, and customers to improve corporate ESG performance and reduce risk, ESG has moved from being a public relations tool to a strategic consideration at the top management and board level (Raghu Raj, 2022).

As global support for ESG surges, Chinese companies are rapidly developing ESG strategies. From reporting and recruitment to strategy development and implementation, Chinese companies are enhancing their ESG capabilities and developing the frameworks needed to integrate ESG into their operations. China's ESG reporting requirements include both mandatory and voluntary components. Government policies, regulations, and improved risk management have emerged as important ESG drivers among Chinese listed companies (*ESG Practices of Chinese Companies*, 2023).

In China, customer and investor expectations are the most common drivers of ESG strategy development. With increasing pressure from investors, consumers, employees, boards, and regulators, ESG has transformed from a functional requirement to a driver of business value (*2022 China ESG Development White*

Paper, 2023). In November 2022, China Association for Public Companies (CAPCO) established the ESG Professional Committee and proposed in its work plan to "form an ESG management system and evaluation system with Chinese characteristics and international recognition" (CAPCO, 2022).

ESG essentially emphasizes that while pursuing economic benefits, companies should systematically manage environmental responsibilities, social impacts, and governance structures. It provides companies with a practical strategic tool and an evaluation framework for achieving sustainable development goals (SDGs). By engaging in ESG practices, companies can not only enhance their sustainable competitive advantage but also contribute to fulfilling global responsibilities and shared goals.

1.2.4(b) ESG Disclosure

ESG first emerged in Europe and the United States. Some European countries have promoted the improvement of the quality of their non-financial disclosures by issuing policy documents on ESG reporting for large companies. This trend has gradually spread from Europe to the Asia-Pacific, Australia, Africa, North America, the Middle East, and other regions (*Morketing 2022 ESG Case Book*, 2022). These policy documents have become an important driver of ESG development in various countries.

At present, although China's ESG development is still in its infancy (Wang, Fan & Zhuang, 2023), its rapid development has become a general trend. Top-down policies remain the most important driver of ESG development in China (*2022 China*

ESG Development White Paper, 2023). In March 2022, State-Owned Assets Supervision and Administration Commission (SASAC) established the Social Responsibility Bureau and issued the *Work Program for Improving the Quality of Listed Companies Held by Central Enterprises*. The program requires listed companies held by central enterprises to establish a more robust ESG system, and improve ESG disclosure practices, aiming to achieve full coverage of ESG special report disclosure by 2023 (*China Sustainable Investment Review*, 2022). As of August 2023, nearly 87% of listed central enterprises had released independent social responsibility reports and ESG reports, and 54 central enterprises had achieved the "full coverage" of reports releases for their controlled listed companies (*2023 China ESG Development White Paper*, 2024).

From a macro perspective, China's ESG disclosure is still mainly driven by regulatory legal documents. However, it is expected that China will further improve the legal framework for ESG disclosure in the future (*Morketing 2022 ESG Case Book*, 2022). As shown in Figure 1.3, as of September 30, 2023, a total of 1836 Shanghai and Shenzhen A-listed companies had issued ESG reports, accounting for 35.65%. Among them, there are 1024 listed companies on the Shanghai Stock Exchange (SSE) and 812 listed companies on the Shenzhen Stock Exchange (SZSE) (*China Sustainable Investment Review*, 2023).

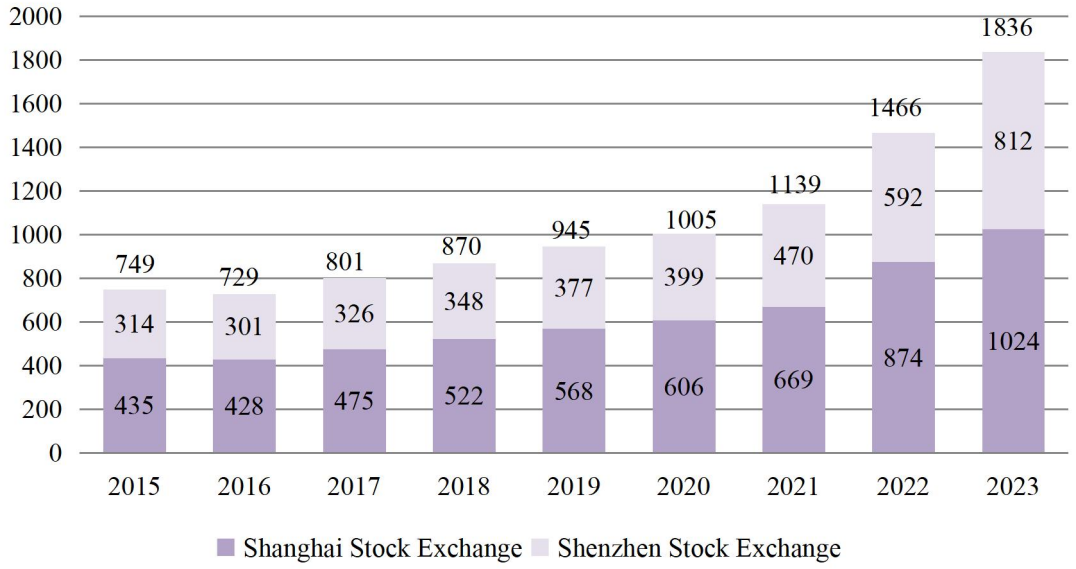

Figure1.3 ESG Reports Released by A-Listed Companies in Shanghai and Shenzhen from 2015 to 2023
Source: China Sustainable Investment Review (2023)

The number of ESG reports released by Chinese A-listed companies continued to increase between 2015 and 2023. However, external stakeholders' demand for information related to listed companies is changing—shifting from a focus on whether listed companies disclose to a focus on whether they can disclose ESG information of high quality. These shifts have reminded listed companies to focus on the quality of ESG-related disclosures and to increase the proportion of quantitative data (Huang, 2021).

1.2.4(c) ESG Rating

At present, the global rating of ESG has not yet formed a unified standard, and the trend of diversification is becoming more pronounced. Foreign ESG evaluation systems developed earlier; these systems are more mature and have greater international influence (*2023 China ESG Development White Paper*, 2024). Currently, there are more than 600 global ESG rating agencies, among which MSCI,

Bloomberg, Thomson Reuters, FTSE Russell and DJSI are the most influential (*2023 China ESG Development White Paper*, 2024). China's ESG rating system started late and has not yet formed a unified standard. The evaluation scope is basically limited to domestic listed companies. ESG ratings can help stakeholders understand, assess and manage increasingly complex and multifaceted business ethics and play an important role in sustainability (Cappucci, 2020).

Currently, there are about 20 ESG rating agencies in China (2022 ESG Practices of Chinese Companies, 2023). The mainstream ESG rating systems for A-shares include: Huazheng ESG Rating, China Securities ESG Rating, SynTao Green Finance ESG Rating, Wind ESG Rating, Harvest ESG Rating, and China Alliance of Social Value Investment (CASVI) ESG Rating (*2023 China ESG Development White Paper*, 2024). They all have a pyramidal rating system. Compared with international ESG rating systems, some Chinese rating agencies have demonstrated the relevance of the indicators. They eliminate indicators that are not applicable or for which data is not available, while adding indicators with Chinese characteristics (*2023 China ESG Development White Paper*, 2024).

1.2.4(d) Three Dimensions of Environmental, Social and Governance (ESG) Performance

(1) Environmental (E) performance

Environmental (E) disclosure is the main way for companies to communicate their environmental status to external stakeholders (Zhang, Zhou, Wang & Jian, 2024). As one of the market entities, environmental resources form the basis for the

survival of companies (Akbar, Jiang, Qureshi & Akba, 2021; Li, 2022). At the end of 2021, the Ministry of Ecology and Environment (MEE) issued *the Administrative Measures for the Legal Disclosure of Environmental Information of Enterprises.* It imposed requirements on five types of companies, including certain listed companies and debt-issuing firms, to disclose E information in accordance with the law (*2022 China ESG Development White Paper*, 2023). Overall, Chinese companies still do not prioritize E issues sufficiently. Performance on climate change mitigation, resource conservation and waste reduction remains in need of improvement (*ESG Practices of Chinese Companies*, 2023).

In 2023, in terms of corporate disclosure, more than half of listed companies disclosed qualitative information on goals, policies and other information related to greenhouse gas (GHG) emissions management. This proportion increased by 20% from 2022 (33.24%) (*China Sustainable Investment Review*, 2023). Since the proposal of "dual carbon" goals, the disclosure of climate-related information by listed companies has also gradually improved. However, the disclosure of quantitative information still lags behind. Only 24.5% of listed companies actively disclose such information (*China Sustainable Investment Review*, 2023). Some companies are also coming to realize that focusing on environmental (E) issues can enhance their financial performance (Goncalves, Robinot & Michel, 2016). The E dimension focuses on carbon emissions, resource utilization, and pollution control, all of which align with sustainable development goals (SDGs) related to clean energy, climate action, and water resource protection.

(2) Social (S) performance

The most prioritized ESG issues for Chinese companies are a combination of social (S) and governance (G) issues. Employee welfare, product standards, and safety are important themes (*ESG Practices of Chinese Companies*, 2023). The social (S) dimension emphasizes employee rights, community engagement, and diversity and inclusion, which are closely related to sustainable development goals (SDGs) such as poverty eradication, good health and well-being, quality education, gender equality, and decent work.

Protecting and improving society is the social responsibility that every company must undertake in the process of its operation and development. In January 2022, the Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE) respectively updated *the Listing Rules* to include CSR-related content for the first time. *The Listing Rules* clearly stipulate that listed companies should prepare and disclose non-financial reports, such as social responsibility reports, in accordance with regulations (*China Sustainable Investment Review*, 2022).

(3) Governance (G) performance

Board composition is a key factor in measuring the health of governance. Although it has obviously improved, Chinese listed companies still need to overcome some major structural obstacles. Currently, Chinese companies tend to follow a compliance-oriented approach in the composition of their boards of directors, building their governance structures based on minimum regulatory requirements. According to Economist Impact's ESG survey of Chinese listed companies from

December 2022 to January 2023, 91% of Chinese A-share companies are "minimally compliant" (*ESG Practices of Chinese Companies*, 2023).

An area of the governance structure that is being upgraded is board committees. Current Chinese regulations only require listed companies to establish audit committees. However, in recent years, some companies have also established nomination committees and remuneration committees. This shows that governance is moving towards increased transparency and accountability. In August 2023, the China Securities Regulatory Commission (CSRC) issued the "*Administrative Measures for Independent Directors of Listed Companies*" to promote the formation of a more scientific independent director system and help improve the level of governance (*2023 China ESG Development White Paper*, 2024). ESG emphasizes the establishment of transparent, fair, and effective governance structures, which aligns with the sustainable development goals (SDGs)' call for building peaceful, inclusive, and sustainable societies.

1.2.4(e) ESG Performance and Financial Performance

ESG performance holds strong appeal in capital markets, contributing to enhanced investor confidence and improved firm valuation. Corporate ESG performance can significantly impact on financial performance. For example, implementing energy-saving systems can reduce operating costs; investing in community development projects can enhance a company's social impact; and improving governance structures can ensure transparent financial reporting, thereby attracting investors and reducing the cost of capital.