



INSTITUTO
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Environmental Risk Evaluation of Commercial Banks: Empirical Data from the Chinese Steel Industry

SHI Jianmin

Doctor of Management

Supervisors:

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ISCTE University Institute of Lisbon

PhD XIA Hui, Professor,
University of Electronic Science and Technology of China

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BUSINESS
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Banks: Empirical Data from the Chinese Steel
Industry** SHI Jianmin

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I declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of my knowledge it does not contain any material previously published or written by another person except where due reference is made in the text.

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Abstract

As an increasing number of countries begin to pay attention to environmental protection the world has embarked on a green and low-carbon transformation, and commercial banks are paying more and more attention to environmental risk management.

For a long time, most of the Chinese commercial banks have been evaluating the environmental risks of enterprises in terms of compliance review and qualitative evaluation but have not quantified the environmental risks in their internal rating system. Therefore, there is an urgent need to build a set of quantitative standards for environmental risks evaluation of commercial banks.

This thesis first analyses the current situation of environmental risk management in commercial banks in China and abroad. Second, by constructing a two-by-two game theory model with players of governments, commercial banks, and enterprises, we discover that commercial banks play an important role and finds the influencing factors on the equilibrium. More importantly, for the first time, a commercial bank environmental risk evaluation index system and a commercial bank credit evaluation index system based on environmental risk are constructed. Furthermore, a case study of three typical listed steel companies is conducted using above evaluation model. Finally, suggestions for improving the environmental risk evaluation of commercial banks in China are put forward at the government and bank levels.

This thesis incorporates quantitative environmental risk evaluation into the credit risk evaluation system of commercial banks, and the designed steel industry environmental risk evaluation model also has practical implications for other high energy-consuming and high-emission industries.

Keywords: environmental risk, green credit, commercial banks, risk evaluation, game equilibrium

JEL: G21; G28; K23; Q01

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Resumo

À medida que um número crescente de países começa a prestar atenção à proteção ambiental, o mundo embarcou em uma transformação verde e de baixo carbono, e os bancos comerciais estão prestando cada vez mais atenção à gestão de riscos ambientais.

Há muito tempo, a maioria dos bancos comerciais chineses avalia os riscos ambientais das empresas em termos de revisão de conformidade e avaliação qualitativa, mas não quantifica os riscos ambientais em seu sistema interno de classificação. Portanto, há uma necessidade urgente de construir um conjunto de padrões quantitativos para avaliação de riscos ambientais de bancos comerciais.

Esta tese primeiro analisa a situação atual da gestão de risco ambiental em bancos comerciais na China e no exterior. Em segundo lugar, ao construir um modelo de teoria dos jogos dois a dois com atores de governos, bancos comerciais e empresas, descobrimos que os bancos comerciais desempenham um papel importante e encontramos os fatores que influenciam o equilíbrio. Mais importante, pela primeira vez, um sistema de índice de avaliação de risco ambiental de banco comercial e um sistema de índice de avaliação de crédito de banco comercial baseado em risco ambiental são construídos. Além disso, um estudo de caso de três empresas siderúrgicas típicas listadas é realizado usando o modelo de avaliação acima. Finalmente, sugestões para melhorar a avaliação de risco ambiental dos bancos comerciais na China são apresentadas nos níveis governamental e bancário.

Esta tese incorpora a avaliação quantitativa de risco ambiental no sistema de avaliação de risco de crédito de bancos comerciais, e o modelo de avaliação de risco ambiental da indústria siderúrgica projetado também tem implicações práticas para outras indústrias de alto consumo de energia e alta emissão.

Palavras-chave: risco ambiental, crédito verde, bancos comerciais, avaliação de risco, equilíbrio do jogo

JEL: G21; G28; K23; Q01

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摘要

随着越来越多的国家开始重视环境保护，提出“碳达峰、碳中和”目标，全球掀起了绿色低碳的转型大潮，商业银行越来越重视环境风险管理。

长期以来，中国的商业银行对企业环境风险的评价多数还停留在合规审查和定性评价上，在其内部评级系统中没有对环境风险进行量化，因此迫切需要构建一套商业银行环境风险量化评估标准。

本文首先分析了中外商业银行环境风险管理的现状，并通过构建政府部门、商业银行和企业两两博弈模型，分析三个博弈参与者的行为特征，发现商业银行扮演了重要的角色，并找到了对均衡的影响因素。首次构建了商业银行环境风险评估指标体系和基于环境风险的商业银行信贷信用风险评价指标体系，并运用此评估模型对三家典型的钢铁上市公司进行案例研究。最后，从政府和银行层面，提出了完善中国商业银行环境风险评估工作的对策建议。

本文将环境风险定量评估纳入商业银行信用风险评价体系，所设计的钢铁行业环境风险评估模型对推广到其他高耗能、高排放行业具有一定实践价值。

关键词：环境风险；绿色信贷；商业银行；风险评估；博弈均衡

JEL: G21; G28; K23; Q01

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In April 2016, with the doctorate dream since my youth, I came to Chengdu for the first time in my life and went to the beautiful Qingshuihe Campus of UESTC. The scene of the admission interview at the School of Economics and Management that year is still vivid. It is the love of Dean Ma, Director Xiao Wen, and Professor Sun Ping that gave me the opportunity to study for a doctorate degree so that I could have heated debates in the classroom, boldly ask questions, drill down the root causes of many problems, carefully verify evidence, strengthen exchanges ideas with students of different educational backgrounds, places and different ages, thus forging a deep friendship with them.

The reason why I chose the topic of environmental risk management of commercial banks and studied the steel industry with the largest pollution and carbon emissions six years ago stems from the heartache in my childhood when I saw the extensive development destroyed the environment. Later, I worked in bank credit and risk management. The idea that environmental factors should be considered in credit support for traditional industries was always lingering in my mind. What is gratifying is that the Chinese government has paid more and more attention to environmental protection and green finance in recent years. In the past six years, I have bought nearly 30 books, downloaded 300 papers to study this topic carefully, and applied the results of my studies in my work. The application helps me consider environmental factors before, during, and after the loan issuance, so the bank where I work avoided many risks caused by environmental factors.

My foreign supervisor, Professor Diana Mendes, is accomplished in the field of financial quantitative analysis. During the proposal of the project in Portugal in 2017, she helped me collect a lot of foreign language materials and gave me a lot of guidance and inspiration during the thesis writing process, which nurtured my academic in-depth thinking, innovation, perseverance, and resilience. Her profound knowledge and earnest academic attitude have benefited my whole life.

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The thesis is about to be defended. There must be some questions. It is the tolerance of the jury that gave me the opportunity to defend the thesis, and it is the wisdom of the jury that gave me another good opportunity to learn. Thank you.

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2016年4月，怀揣着少年时的博士梦，我人生中第一次来到成都，来到美丽的电子科技大学清水河校区。当年在经管院面试的情景至今还历历在目，是马院长，肖文主任，孙平老师的厚爱给了我攻读博士学位的机会，使我能和来自不同的地域、不同的行业、不同的教育背景、不同年龄的同学在课堂上激烈辩论、大胆设疑、刨根问底、小心求证，课后加强交流、思想碰撞，结下了深厚的友谊。

6年前我之所以选择商业银行环境风险管理这个选题，并且研究的是污染和碳排放量最大的钢铁行业，源于小时候看到粗放的发展方式对环境的破坏心痛不已，后来工作了，从事银行信贷及风险管理工作，对传统行业的信贷支持应当考虑环境因素这个思路总是萦绕于脑中。令人欣慰的是，近年来，中国政府对生态环境保护和绿色金融日益重视，这六年我买了近30本书，下载了300篇论文，认真研读，并将学习的成果在工作中加以运用，在贷前、贷中、贷后等方面考虑环境因素，使我所在的银行规避了很多环境因素导致的风险。

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List of Abbreviations

5G	the fifth generation
ABN AMRO	Algemene Bank Nederland Amsterdam-Rotterdam Bank
AHP	analytic hierarchy process
AQSIQ	Administration of Quality Supervision, Inspection and Quarantine
CBA	China Banking Association
CBIRC	China Bank and Insurance Regulation Commission
CBRC	China Banking Regulatory Commission
CCB	China Construction Bank
CDM	clean development model
CEIN	China Economic Information Network
CIB	China's Industrial Bank
CNBS	China's National Bureau of Statistics
COD	chemical oxygen demand
COVID-19	Coronavirus Disease
CPC	Communist Party of China
CRE	credit risk evaluation
CRM	comprehensive risk management
CSC	China's State Council
CSRC	China Security Regulation Commission
DJSGI	Dow Jones Sustainability Group Index
ECRM	environmental credit risk management
EIA	environmental impact assessment
EP3	the third edition of EPs
EP4	fourth edition of EPs
EPs	equator principles
ERC	environmental risk coefficient
ERCP	environmental risk contingency plans
ERE	environmental risk evaluation
ERM	environmental risk management

ESG	environmental social and governance
ESG	Global Environmental, Social, and Governance
ESRM	environmental and social risk management
ESRM	environmental and social risk evaluation
FRI	financial risk index
G20	Group 20
GDP	gross domestic product
GFA	green financial assets
HECE	high emission and consumption of energy
HSBC	Hongkong and Shanghai Banking Corporation
ICBC	Industrial and Commercial Bank of China
IFC	International Finance Corporation
IMJCCR	Inter-Ministerial Joint Conference on Capacity Removal
M&A	mergers and acquisitions
MEE	Ministry of Ecology and Environment
MEP	Ministry of Environmental Protection
MIIT	Ministry of Industry and Information Technology
MOF	Ministry of Finance
MONR	Ministry of Natural Resources
MSCI	Morgan Stanley Capital International
MWR	Ministry of Water Resource
NDRC	National Development and Reform Commission
NGOs	non-governmental organizations
NPL	non performed loans
NTCSCSAC	National Technical Committee on Social Credit of Standardization Administration of China
NUEP	United Nations Environment Programme
PBoC	the People's Bank of China
PRC	People's Republic of China
R&D	research and development
SASAC	State-owned Assets Supervision and Administration Commission
S&P	Standard and Poor's
SCR	social corporate responsibility

SEPA	State Environmental Protection Administration
SPDB	Shanghai Pudong Development Bank

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Chapter 1: Introduction

1.1 Research background

The relationship between economic development and environmental protection has always been the focus of attention of governments, enterprises, and scholars worldwide. In the past, there was a wrong development tendency to equate economic growth, especially gross domestic product (GDP) growth, purely with economic development. Indeed, some developing countries and regions achieved faster economic growth in a short time according to this tendency, but this development approach relied excessively on local natural resources and unilaterally pursued economic benefits. As a result, it consumed a large amount of fossil fuels, thus imposing adverse impacts on global warming and the frequent occurrence of extreme weather, which directly threatened the survival and development of mankind (Y. C. Chen, 2019).

The water pollution incident in the Songhua River (Sohu, 2005), a major river in northeast China, sounded the alarm for China's environmental pollution problem. This incident showed that China's rapid economic development brought severe environmental problems (Y. Lei et al., 2019; Ministry of Water Resource [MWR], 2018). Therefore, the Chinese government proposed not to follow the old path of pollution first and treatment later, and President Xi pointed out that (2014) "lucid water and lush mountains are invaluable assets" to accelerate the transformation of the economic growth mode, promote the transformation of the economy from high-speed development to high-quality development, build a resource-saving and environment-friendly society, and pay more attention to the sustainable development of the economy (Jin, 2018; Y. Li & Chen, 2021; Ning, 2018).

The Ralph Canal incident in the United States and the Superfund Act (Lan, 2012) have drawn people's attention to the enormous impacts of commercial bank lending on the environment (P. J. Liu & Zhang, 2020; Marcos, 2020). Commercial banks can be both a financier of environmental damage (Qu, 2011; Urban & Wójcik, 2019). and an essential force in solving environmental problems (Ji & Zhang, 2019; B. W. Lei & Shi, 2020). In order to direct commercial banks' loans to environmentally friendly projects and enterprises, help the development of green industries and the green transformation of traditional industries, reduce

the impacts of environmental pollution, and promote the coordinated development of environmental, social and economic benefits for society, the Chinese government required commercial banks in China to pay more attention to the development of green finance through formulating the following policies.

In August 2016, the Guidance on Building a Green Financial System was issued by China's central bank and ministries (PBoC, 2016). One month later, the Chinese government included green finance in the G20 (2016) issued and promoted the establishment of the Group 20 Green Finance Study Group to study how to encourage the development of green finance in each country according to its characteristics and improve the greening of global financial institutions and the ability of capital markets to allocate resources to green industries. China's State Council (2017) adopted the green finance reform and innovation pilot zones in five provinces (regions), namely Zhejiang, Guangdong, Guizhou, Jiangxi, and Xinjiang. The Central Committee of CPC (2017) clearly proposed the development of green finance, and elevated pollution prevention and control and the prevention and resolution of significant risks to the strategic level of the three major battles. At the general debate of the 75th session of the UN General Assembly, President Xi (2020) announced that China would increase its national contribution, adopt more robust policies and measures, and strive to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. Proposals of the Central Committee of the Communist Party of China on Formulating the Fourteenth Five-Year Plan for National Economic and Social Development and the Long-term Goals for 2035 (CPC, 2020) explicitly includes a steady decrease in carbon emissions after reaching the peak in China's 2035 visionary goals.

Commercial banks should have social responsibility while pursuing economic efficiency as a special enterprise with macroeconomic management and macro marketing functions. All banking businesses should be linked to improve and optimize the environment, such that environmental risk management (ERM) becomes one of the core tasks of commercial banks. In the early days, commercial banks focused on market risk, credit risk and operational risk, but paid less attention to the impact of environmental risk (Boateng et al., 2019). With the increasing effect of environmental factors on the sustainable development of financial institutions and the massive number of credit losses caused by environmental issues, the commercial banks will bear the joint and several responsibilities of enterprises due to environmental risks, such as credit risk, reputation risk, legal risk of third-party claims for damages and transformation risk brought about by changes in energy structure (B. Huang et al., 2020).

It can be seen that environmental factors increase the operational risk of commercial banks

in at least three ways: through credit risk, joint and several liability risk and reputation risk. Credit risk is the most important risk faced by commercial banks, and the most prominent impact of environmental factors on commercial banks is currently reflected in it. Higher environmental standards and environmental emergencies will have an impact on the cash flow and assets and liabilities of enterprises, reducing their ability to repay loans and thus increasing the credit risk faced by commercial banks. Therefore, a quantitative evaluation of environmental risks is of great importance for the objective evaluation of enterprise's credit risk.

The specific manifestation is that the lender will bear a huge amount of compensation liability for the damage caused by pollution, which may directly reduce its ability to repay the loan. The lender will face high pollution clean-up costs and administrative penalties after the environmental pollution accident, which may cause the reduction of the value of the loan collateral and pledges, thus damaging the interests of the bank. As the beneficiary or creditor of the mortgage, commercial banks will replace the lending enterprise to assume environmental liability. These risks cannot be completely avoided in advance and require commercial banks to pay great attention and incorporate environmental risks into their comprehensive risk management system (Dikau & Volz, 2018; Rahman & Barua, 2016).

Environmental risk evaluation (ERE) is the first and foremost task of ERM and the most important work of ERM. After conducting ERE, commercial banks can accurately understand the impact of the projects they lend to on the local ecological environment to make decisions on whether to lend or not based on the ERE result of the enterprise (F. Xu & Ma, 2019).

On the other hand, the development and application of ERE and its analysis methods have become an essential element in promoting the sustainable development of the banking industry and maintaining financial stability. Through environmental risk analysis, commercial banks can identify and quantify the financial risks that may be triggered by environment-related factors, and reduce the exposure to environmental high-risk assets by taking measures to mitigate the risks (J. Ma, 2020). At the same time, through environmental risk analysis, commercial banks can identify and create potential investment opportunities and obtain additional income through product innovation (X. Liu, 2015a).

Only a few financial institutions and consulting, research and development organizations in developed countries and China have developed tools and methodologies for ERE (Shi, 2002). The Dow Jones Sustainability Index, the most famous and oldest in the industry in the United States (based on which Dow Jones Group and the Financial Times compiled the Sustainability Index to reflect the development status of corporate social responsibility [CSR]) evaluates

corporate sustainability from the perspective of investments in economic, social, and environmental aspects.

The Equator Principles (EPs) are an international industry standard for financial institutions to manage environmental and social risks in project financing, but EPs focus on a comprehensive review of fixed-asset investment projects. For companies applying for liquidity loans, pre-lending due diligence and post-lending continuous monitoring and evaluation of their ERM capabilities are critical.

Most Chinese commercial banks evaluate the environmental risks in compliance review and qualitative evaluation without forming a complete evaluation system to assess the environmental risks of enterprises (Yu et al., 2020). Iron and steel enterprises are consuming significant resources and energy and are among the top industrial enterprises regarding pollutant emissions. They are a major source of pollution (W. H. Chen et al., 2017; D. Li & Xiao, 2011). However, commercial banks lack detailed criteria for ERE in the iron and steel industry. Therefore, there is an urgent need to build a complete set of ERE systems for commercial banks to help solve the environmental risks before and after lending, realize quantitative ERE, and provide technical support for the ERM work of commercial banks.

1.2 Research significance

By studying the specific practices of foreign large and medium-sized commercial banks in the field of ERM, this thesis analyzes the current development status and problems of ERM in Chinese commercial banks. It focuses on ERE system of commercial banks with the case study in the steel industry. The conclusions obtained in this study are of great significance for Chinese commercial banks to improve their ERM system and promote the green transformation for high pollution and high energy-consuming industries. The specific contributions are as follows.

1.2.1 Theoretical significance

From the perspective of ERE of commercial banks, a theoretical model is established to: (a). analyze how commercial banks can effectively implement ERE in the steel industry, (b). explore the factors influencing the implementation of balanced ERM of commercial banks in the steel industry, and (c). provide a theoretical basis for establishing an index system for ERE by commercial banks.

1.2.2 Practical significance

This study selects the shortcomings of commercial banks in conducting ERM as a starting point, constructs an index system and an evaluation method of commercial banks for environmental risks, and selects the high pollution and high energy-consuming steel industry as a representative to apply actual data to identify and assess the environmental risks of steel enterprises accurately. The study provides a specific and operable ERE standard for banks to use financial instruments to promote energy transmission and emission reduction, which has practical value in high pollution and high energy-consumption industries.

1.3 Research content

This thesis uses the analytic hierarchical process (AHP) to establish an ERE model to quantify the environmental risk of the borrowing enterprise. Furthermore, a commercial bank credit risk evaluation (CRE) model is constructed based on ERE, and ERE factors are considered when rating credit. Finally, three listed steel companies are selected to apply the ERE model. The specific research content is divided into seven parts.

Chapter One introduces the research background and research significance of ERM for commercial banks and the research methods, technical roadmap, and main innovation and characteristics of this thesis.

Chapter Two comprises the theoretical basis and the literature review. Through organizing the relevant research results at home and abroad, it is pointed out that the current research in China mainly focuses on green credit policy analysis and theoretical research. There is little research on the methods of quantitative evaluation of commercial banks' environmental risks.

Chapter Three analyzes the *status quo* of ERM of commercial banks. By comparing the good practices of environmental risks home and abroad, it is found that the ERE of China's banking industry started relatively late but progressed quickly. Some external rating agencies continue to explore ERE and achieve significant results.

Chapter Four constructs a game theory model between government departments, commercial banks, and enterprises with high pollution and emission. By analyzing the characteristics of game behavior of these three parties, the game equilibrium and the existing conditions between the government, banks, and enterprises, can be obtained. Chapter Four also analyzes the commercial banks' factors influencing their implementation ERM on industries with high pollution and emission.

Chapter Five is the environmental risk management and evaluation plan for iron and steel enterprises. It includes the qualitative assessment of the environmental impacts of iron and steel enterprises, the construction of the ERE based on the AHP, and the construction of the CRE index system. Then, the author uses this model for a comprehensive evaluation to determine the corresponding credit rating and policy.

Chapter Six gives examples of ERE programs for commercial banks. Taking the three listed steel companies of Baosteel, Baotou Steel, and Fangda Special Steel as examples, the environmental risks of the three companies and their credit risks with environmental risks are evaluated.

Chapter Seven is a summary of the entire thesis and policy recommendations. From the government and bank levels, the author puts forward countermeasures and suggestions to improve the ERE work of Chinese commercial banks in terms of policy formulation, process specifications, evaluation standards, industry guidelines, and information disclosure.

1.4 Research methods

1.4.1 Game theory approach

Environmental issues are manifested as conflicts of interest and games between various stakeholders. This study applies the game theory as the research method to construct a two-by-two game analysis by three participating subjects, government, commercial banks, and companies. Their behavior characteristics and target selection are analyzed through game analysis of the conflict of interest and game equilibrium between the three stakeholders. Based on the equilibrium of the game between government departments, commercial banks, and enterprises with high pollution and emission, this study analyzes how commercial banks can effectively implement ERM in the industry with high emission and consumption of energy (HECE), the factors influencing the implementation of by commercial banks, providing a theoretical basis for the establishment of an ERE index system for commercial banks in China.

1.4.2 Analytic hierarchy process

Saaty (1986) developed AHP. AHP is a method that divides the factors affecting the decision into multiple levels in the order of the overall objective and the sub-objectives at each level, and carries out quantitative analysis from each level in turn. In this way, the degree of influence of each factor in each level on the results is quantified. It is a clear method to show impacts. It can

turn the multi-objective and multi-criteria decision problems, which are difficult to quantify, into multi-level single-objective problems. After determining the quantitative relationship between the elements of the same level and the elements of the previous level through a two-by-two comparison, the results can be obtained by simple mathematical operations. Therefore, AHP can decompose the intertwined and complex decision-making problems into more general and straightforward sub-problems. It is easier to find the essential influencing factors of the problem and target the problem for in-depth analysis through layer-by-layer analysis. AHP is systematic, easy to understand, and has strong applicability. The method is a standard method to solve complex multi-layer decision-making factors.

The method is widely used in economic management for evaluation, and this study uses AHP to study the ERM of commercial banks by taking the steel industry as an example and constructing an ERE model and a CRE model for commercial banks. Under the premise of less quantitative data, the borrower environmental and credit risk is decomposed according to the levels of objectives, hierarchical indicators, and sub-indicators. Then weights of each hierarchical indicator and sub-indicator are scientifically determined to reasonably estimate the size of the risk. At the same time, the model established by this method improves the existing bank assessment method, which has strong practicality and operability.

1.4.3 Case study

The data of three listed steel enterprises are collected, and the ERE model and bank CRE model are applied to conduct an empirical analysis to verify whether the model meets the ERE and credit CRE criteria and whether it is effective through the ERE and CRE by commercial banks.

1.5 Technical road map

Figure 1.1 is the technical road map of this study. It demonstrates the framework of this study.

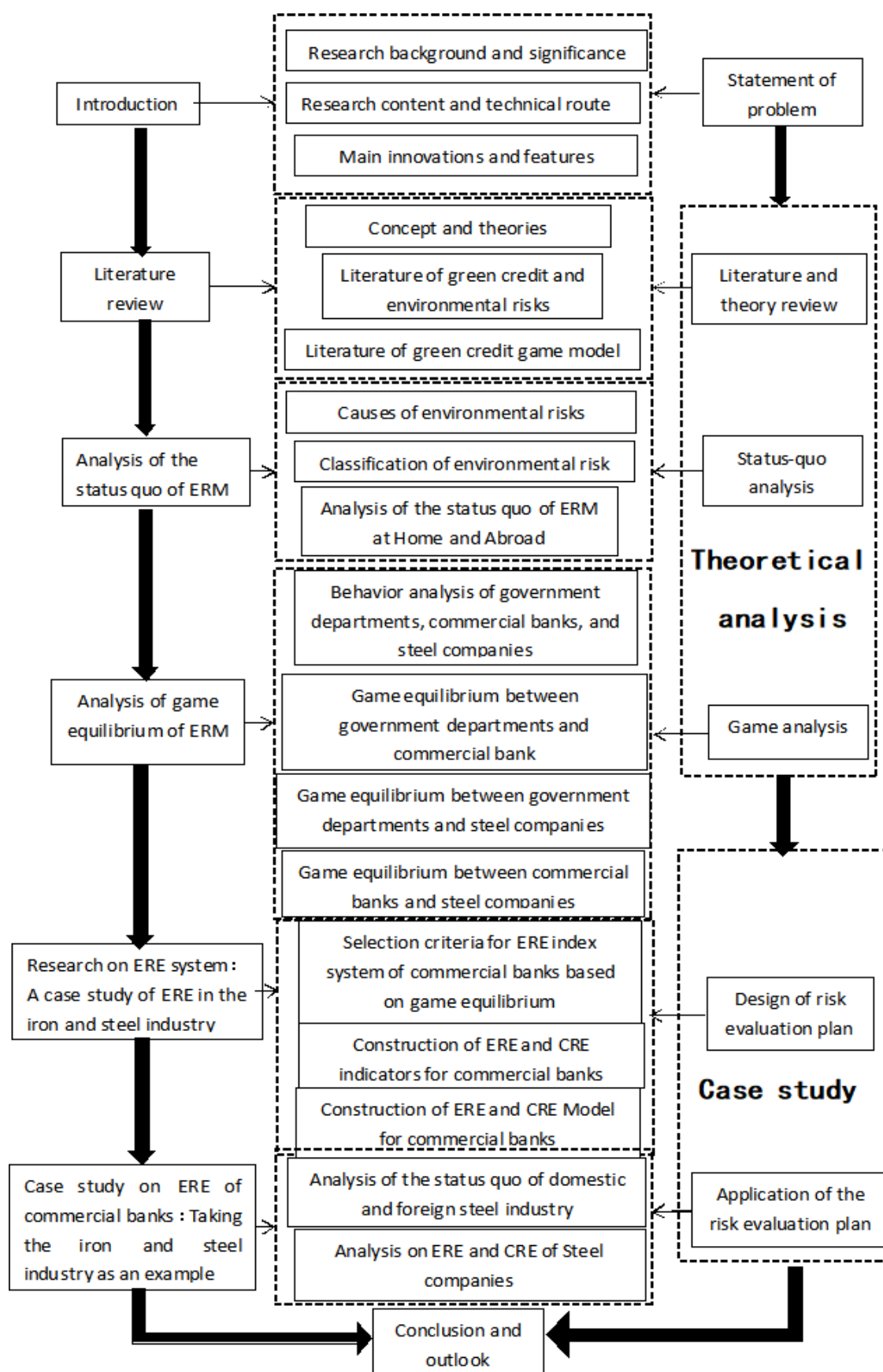


Figure 1.1 Technical road map

1.6 Innovation and features of this study

1.6.1 Main innovation

This study incorporates the quantitative evaluation of environmental risk into the CRE system of commercial banks. At present, most Chinese commercial banks' ERE of enterprises stay on a compliance review and qualitative evaluation, and this thesis introduces ERE into the CRE system of the bank to construct a complete set of enterprise ERE systems for commercial banks. It can help commercial banks realize quantitative assessment of enterprises' environmental risks and provide technical support for commercial banks' ERM.

This thesis uses AHP to construct an ERE method of steel enterprises for commercial banks, replacing the current environmental risk compliance evaluation with a quantitative ERE, and examining four hierarchical structural indicators, pollution management, environmental management, social impact, and corporate greenness. This thesis represents one of the most advanced studies in ERE of the steel industry for commercial banks in China.

1.6.2 Research features

Important banks in China's financial system are currently paying much attention to the rating research of the industry, but the research on the ERE in the steel industry is relatively rare. Therefore, this thesis takes the steel industry as the research object and identifies and evaluates the environmental risks of steel enterprises through three steps, compliance audit of environmental impact assessment, ERE, and evaluation of bank credit risk embedded with the ERE module. In this way, commercial banks can accurately evaluate the steel industry's environmental risks, and these evaluation methods can be extended to other industries with high pollution and carbon emission. Therefore, this thesis has specific practical significance in the field of industry application.

Through the use of rating results, this thesis advocates the establishment of market-based instruments, such as: differential loan pricing, provisioning, economic capital measurement and other incentive mechanisms for green credit resource allocation, to guide commercial banks to participate voluntarily rather than being intervened by administrative orders, since it can help them save cost measurement, and increase profits. Moreover, commercial banks can obtain balanced returns after adjusting to environmental risks to achieve the use of financial instruments to achieve the purpose of using financial instruments to promote energy conservation and emission reduction in industries with high pollution and emission.

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Chapter 2: Literature Review

Under the guidance of the new philosophy to develop the economy, China's banking industry is paying more attention to the development of green finance. Green credit is an important part of green finance and one of the future development trends of banks. The development of green credit also brings a variety of complex risks and challenges marked by environmental risks. The result of green credit mainly depends on the bank's capability of environmental risk management (ERM). Establishing a sound and efficient ERM is the fundamental task for banks to implement green credit. Therefore, this chapter will define the concepts of green credit, environmental risk, and ERM of commercial banks.

Meanwhile, the theoretical foundation of the ERM of commercial banks will be briefly described, including the theory of sustainable finance, corporate social responsibility (CSR), and the theory of the ERM of commercial banks. Then, this thesis will take the steel industry as an example to study the ERM of commercial banks under the implementation of green credit. This study will review the related literature and research at home and abroad from three aspects, green credit of commercial banks, ERM of commercial banks, and green credit game theory model of commercial banks.

2.1 Relevant concepts

2.1.1 Green credit

Report of the 19th National Congress of the CPC (CPC, 2017) pointed out that building an ecological civilization is a millennium plan. China is vigorously developing a green economy, and various localities are making serious efforts to curb the momentum of pollution, with green development, circular economy, low-carbon economy, and "Internet+" becoming the main elements of upgrading and transformation of industrial enterprises. China also put forward a series of policies (China's State Council [CSC], 2019; People's Bank of China [PBoC], 2016, 2017) to support the development of green finance, and green credit is an essential part of China's green financial system. The concept of green credit was first introduced in the Green Credit Guidelines (CBRC, 2012). This document aimed to promote the development of green credit business by Chinese financial institutions, thereby guiding firms to establish a green,

environmentally friendly and sustainable development concept. From the government's macro-management perspective, green credit is a brand-new credit policy to curb the blind expansion of high energy-consuming and high-polluting industries. It aims to encourage commercial banks to invest their funds in environment-friendly enterprises and projects and help enterprises reduce energy consumption and save resources, requiring commercial banks to make environmental compliance one of the necessary conditions for approving loans.

Green credit is the result of developing green finance. Since green credit in China started late, both research and practice are at the initial stage, and there is no unified definition of green credit yet. At present, most scholars believe that green credit refers to that guided by national policies from a microscopic perspective. From the standpoint of green and sustainable development, commercial banks, policy banks, and other financial institutions encourage preferential policies, such as, low-interest-rate loans for environmental friendly enterprises - to promote the transformation, the upgrading of enterprises towards a green and sustainable development model, and the control of the development of highly polluting enterprises by using loan restrictions and price increases (L. Y. Wang & Fu, 2016). The development of green credit contains two levels of meaning. First is incorporating ecological and environmental protection into the credit evaluation system, such as promoting renewable energy development, encouraging environmental protection enterprises, and creating an environment-friendly economic society. Second is controlling credit for high-energy-consuming and high-polluting enterprises, which prompts a shift to a green and environmentally friendly green economy.

Green credit emphasizes green, healthy, and sustainable development of the social economy. When evaluating loans and credit, it considers not only liquidity, safety, and profitability based on the enterprise's historical credit and financial information but also environmental factors and environmental credit. Since its introduction, green credit has received strong support from the government, banks, and enterprises. An increasing number of enterprises gradually raised their environmental awareness and investment in environmental protection as an essential financial tool to promote the development of a green economy. The implementation of green credit, raising the interest rates and loan thresholds for highly polluting and high-emitting enterprises, and incorporating environmental protection ratings and pollution control capacity assessments into loan approvals has changed the ideology obsessed with economic benefits, which helps to realize green and sustainable development through financial means. To build a beautiful society with ecological civilization and cope with global environmental risks, the implementation of green credit is an inevitable trend for the sustainable development of Chinese commercial banks. However, compared with traditional credit, the

risks faced by green credit are more diverse, so risk assessment is more complex. Conventional risk assessment models are difficult to be applied to assess green credit. Therefore, a more comprehensive and objective risk assessment model for green credit should be established.

2.1.2 Environmental risks

Environmental risks posed by corporate environmental issues have the following three connotations. Firstly, with the deterioration of the global ecological environment, sustainable and green development is promoted globally, and new environmental protection laws were issued by China, gradually increasing the requirements for the environmental protection behavior of enterprises. Secondly, suppose the borrower's production process does not meet the environmental requirements and cause severe environmental pollution and ecological damage. In that case, they will suffer penalties such as fines or suspension of business following laws and regulations, thus affecting the enterprise's profitability, cash flow, and repayment ability. Thirdly, as the lender, the bank assumes direct or indirect joint and several liabilities under the law, and the borrower will bring unknown risks and losses to the bank, such as the inability to recover the loan. Environmental risks arise from both internal and external pressures. Internal pressures refer to the requirements of risk control of commercial banks and competition among the banking industry. External pressures refer to the high national standards for the environmental competence of enterprises and the public opinion pressure on the environmental behavior of enterprises.

The environmental risk of commercial banks means the possibility of losses to commercial banks due to the environmentally harmful behavior of borrowers. The main environmental risks faced by commercial banks are direct risk, indirect risk, reputational risk, and transformation risk.

2.1.2.1 Direct risk

When a lending enterprise applies for a loan from a commercial bank, it usually pledges its factory assets or other physical collateral to the bank. Since the state and the society pay increasing attention to ecological and environmental issues, enterprises assume more responsibility for environmental protection due to changes in national environmental protection regulations when borrowing from a bank, leading to higher production costs and even penalties for shutting down production and business. As the creditor and mortgagee of the enterprise, the bank will be directly exposed to the resulting risks and losses.

2.1.2.2 Indirect risks

Many enterprises are not fully aware of the importance of environmental protection, so they ignore the damage brought to the ecological environment in production and operation. After learning that banks incorporate environmental risks into their credit evaluation system for enterprises, enterprises may deliberately conceal the actual situation of polluting the environment when applying for loans from banks to pass loan approval successfully. This will lead to the case where banks only grasp incomplete information about the enterprises and face a higher possibility of environmental risks. When the profitability of the enterprise is affected by environmental problems, it may lead to a decrease in the repayment ability and a failure of repaying the debt to the bank on time, which indirectly leads to a reduction in the profitability of the bank and even brings problems such as non-performing assets to the bank.

2.1.2.3 Reputational risk

With the gradual awakening of public awareness of environmental protection, the public will gradually prefer to consume green, healthy, and environmentally friendly products. People also have higher requirements for the environment in their daily life. Enterprises that neglect environmental protection in production and operation cause environmental problems, such as air pollution, noise pollution, and water pollution, which severely impact the lives of nearby residents. When a similar situation occurs, the enterprise will suffer penalties from law enforcement authorities and damage its corporate image and meet with public boycotts or complaints. Banks, as creditors, also bear joint and several liabilities and are implicated, and may also face legal risks, including compensation and litigation, losing potential or original customers and affecting the bank's revenue.

2.1.2.4 Transformation risk

The Fourteenth Five-Year Plan for the PRC's National Economic and Social Development and the Outline of the Long-term Goals for 2035 (National Development and Reform Commission [NDRC], 2021) made essential plans to achieve the goal of carbon emission peak and carbon neutrality. The development of clean energy will inevitably reduce the consumption of fossil fuels, and the change in carbon price will also bring substantial downside risks to high-carbon industries. With the transformation of the industrial structure to green and low-carbon, banks will also face major adjustments in the structure of credit allocation, increasing credit allocation to green and low-carbon areas, such as clean energy, green transportation, energy conservation and environmental protection, while reducing credit allocation to polluting and high-carbon

industries, such as iron and steel, thermal power, cement, electrolytic aluminium and other sectors (Y. Q. Zhou, 2021).

However, the comprehensive green transformation of banks in multiple dimensions, including industry, region, customers and products, requires adjustments to supporting customer access, economic capital take-up, authorization, pricing, scale, and incentive policies, optimization of green credit processes, innovation of green financial products, and stress testing of high-carbon industries. At the same time, there are still uncertainties about the efficiency and benefits of green, low-carbon technologies. Therefore, different banks will show more significant differences in adjusting structures, setting standards and preventing risks.

2.1.3 ERM in commercial banks

ERM is a means and measure for commercial banks to carry out comprehensive risk management to improve their operation and profitability and reduce losses caused by environmental problems. Robust control and management of environmental risks can reduce non-performing assets and enhance the operation and competitiveness of commercial banks, so banks should pay attention to ERM. Jaeggi and Shi (2009) made a basic concept definition of ERM and proposed that ERM of commercial banks refers to a series of ERM actions taken by commercial banks to reduce the losses caused by environmental problems of borrowers. Therefore, commercial banks should incorporate the environmental factors involved in the production and operation of borrowers into the risk evaluation system and integrate ERM into the credit risk management system to comprehensively and thoroughly assess the credit risks.

ERM study in China started late, and in general, ERM in banks can be divided into three stages, the initial stage, the participation stage, and the sustainable development stage (Jeucken, 2004). In the initial stage, banks are not aware of the hazards caused by environmental risks and ERM, mainly considering the profitability of borrowers. In the participation stage, banks gradually realize the risks caused by environmental issues and no longer focus only on the profitability of enterprises. They gradually pay attention to environmental risks under the guidance of national policies, consider the ERM capability of borrowers in the process of lending assessment, and actively take measures to control environmental risks. In the sustainable development stage, banks are no longer limited to controlling environmental risks but actively support the development of new energy and environmental protection industries, explore the business opportunities of green sectors, and take green and sustainable development as a long-term strategy.

2.2 Theoretical foundations of ERM in commercial banks

2.2.1 Theories of sustainable finance

Norwegian Prime Minister Brundtland put forward the concept of sustainable development that gradually awakened the awareness of environmental protection and social responsibility in various industries. The concept of sustainable development was progressively extended to the financial industry, resulting in the theory of sustainable finance. The study of sustainable finance can be traced back to the “Superfund Act” promulgated by the United States at the end of the 20th century. The theory of sustainable finance, also known as environmental finance, is a practice of sustainable development in the financial industry. It emphasizes combining economic development and environmental protection by considering the current economic benefits of projects, and paying more attention to the protection and maintenance of environmental resources, and investing more economical and financial support into green projects or enterprises with sustainable development such that the development of the current economy does not harm the long-term development interests (World Commission on Environment and Development, 1987).

The essence of developing sustainable finance is to develop the financial industry and ecological sustainability. The theory puts forward two levels of requirements. First is a reconsideration of the relationship between finance and the environment. Ecological sustainability and financial development are intertwined, and the financial industry can guide other sectors to develop in a green and sustainable direction with low energy consumption and high quality. The second is that the financial sector should strongly support green industries, advocate green finance, and encourage the development of green industries that protect the ecological environment through policy guidance, following the principles of environmental protection and low energy consumption.

Sustainable finance, mainly through the guidance and improvement of national policies, promotes the innovation and improvement of banking financial services and products in accordance with the development of the ecological and environmental industries. It is the basic theory of ERM for commercial banks, and it indicates the direction and trend of the financial industry. The implementation of sustainable finance is of great significance to the banking industry, as it can not only prompt banks to implement ERM in pursuit of a strategic vision for long-term sustainable development but also improve the image of banks and gain public support and trust.

2.2.2 Corporate social responsibility

CSR means that while creating profits and taking responsibility for shareholders, companies should also take responsibility for consumers, employees, communities, and the environment. CSR requires corporate to abandon the traditional concept of profit as the only goal and emphasize the concern for human values and the contribution to consumers, society, and the environment. The World Bank defines CSR as the collection of policies and practices related to a corporate relationship with key stakeholders, values, compliance with the law, and respect for people, society, and the environment.

Small (1895) pointed out that apart from the public sector, such as the government, private corporate should gain the public's trust, which became the starting point of the CSR concept. Sheldon (1924) explicitly introduced the concept of CSR and linked CSR with the various responsibilities of business operators to meet the needs of industry and beyond for the first time. He argued that CSR included ethical factors and that business operations should contribute to the promotion of community services and interests, and that community interests, as a measure, should be much higher than corporate profits. Carroll (1979) thought that the earliest available literature dealing with CSR is *The Functions of Executives* by Barnard.

By the 1970s in the United States, the interrelationship between corporate social commitment (responsibility) and corporate interests had taken on epochal significance. Mainstream economics argued that socially responsible corporate behavior ultimately resulted in market returns for the firm, and thus corporate social responsibility is considered an effective management strategy (R. J. Zheng, 2006). CSR naturally becomes a valid long-term proposition when short-term giving practices do not bring the most effective and far-reaching social benefits to the corporate. Thus, CSR practices are investments that the corporate makes for the future and have become a mainstream international trend of thought along with concepts such as sustainable development.

CSR of a commercial bank is a concept derived based on CSR theory. As a special public corporate, the banking industry must assume more social responsibility due to its unique role in resource allocation. As the core and hub of the modern economy and an important lever for the redistribution of social resources, commercial banks have unique characteristics and historical missions which determine that they should have higher requirements for financial morality and financial ethics. It is an integral part of the social responsibility of the financial corporate.

The theory of CSR of commercial banks has been studied systematically in China, and a theoretical system of CSR of commercial banks based on Chinese characteristics has been

formed. According to Y. G. Cui and Yuan (2005), in addition to general corporate responsibilities, banks should also consider the following special social responsibilities. First is protecting the safety of depositors' funds. The second is allocating credit resources fairly. The third is ensuring the smooth implementation of national economic policies and industrial policies. Influenced by Jamili and Carroll's (2017) four-level theory, Y. T. Cao and Wang (2008) proposed that the social responsibility of commercial banks includes economic responsibility, legal responsibility, moral responsibility, and philanthropic responsibility by nature. Economic responsibility requires banks to maximize shareholders' interests and provide products or services needed by society. Legal responsibility requires banks to bear the corresponding burdens according to the law and fulfil their economic responsibilities within the legal framework. Ethical and philanthropic responsibilities have not yet been explicitly formed into legal texts by society but are expected by society.

J. J. Gong (2007) further pointed out the interrelationship of these four responsibilities. Economic and legal responsibilities constitute the primary responsibilities of commercial banks, which are the "hard constraints" imposed by society on commercial banks. Moral and philanthropic obligations comprise the high-level responsibilities of commercial banks as the "soft constraints" imposed by society on commercial banks.

Guidelines on Corporate Social Responsibility of Banking Financial Institutions in China (China Banking Association [CBA], 2019) refers to CSR as economic, social, charitable, and environmental responsibilities of financial institutions towards their stakeholders, including shareholders, employees, consumers, business partners, government and society, as well as the promotion of sustainable social and environmental development. The social responsibilities of financial institutions shall at least include the economic responsibility to create a fair, safe, and stable competitive order in the industry under the conditions of compliance with the law and to continuously create economic value for the state, shareholders, employees, customers, and the public with high-quality professional operations. Guided by a business philosophy that meets the requirements of social ethics and public welfare, social responsibility should require the financial institutes to actively safeguard the public interests of consumers, employees, and the general public. Philanthropic responsibility encourages financial institutes to engage in social welfare activities to build a harmonious society and promote social progress. Environmental responsibility supports the national industrial policy and environmental protection policy through saving resources, protecting and improving the natural ecological environment, and supporting sustainable social development. Environmental responsibility directly promotes commercial banks to carry out ERM.

2.2.3 Comprehensive risk management (CRM)

CRM was proposed by scholars in the late 1990s in the context of problems with long-term capital management (Tang & Li, 2003). In this context, they found that banks' risk can be seen as a combination of multiple risks and factors. There is more than a single form of risk in banks but interactions and linkages between different risks. Thus, the theory of CRM emerged. As the global financial environment becomes more complex and diversified, the risks faced by the financial industry showcase a trend of diversity and complexity, claiming banks to pay more attention to consider various risks in their process of development comprehensively. The core element of CRM is the careful consideration of risks. It is no longer only considering one or several aspects of risks, such as environmental risks or credit risks. In the development process, banks should consider seemingly independent risks in an integrated manner, explore the correlation between each risk, and conduct comprehensive control of cross risks. From the process point of view, the CRM of commercial banks mainly includes setting the objectives of risk management, setting the risk management index system, comprehensively assessing risk factors, and proposing risk response measures.

At present, some enterprises in China are still in the crude mode of high pollution, high consumption and low output because they neglect the protection of the ecological environment and natural resources. Enterprises mainly pursue economic benefits in the production process, ignoring environmental issues. This way, they conduct on the road of foreseeable or unforeseeable environmental problems that bring environmental risks.

However, China's laws and regulations on environmental protection are becoming increasingly stricter, and the environmental requirements for enterprises are gradually tighter. Enterprises that cause severe environmental pollution and ecological damage in the production process face high illegal costs and severe penalties, and banks may also face joint and several liabilities or difficulties in recovering payments for goods. Environmental risks of the borrower increase the possibility of losses for commercial banks, reducing their profitability and capacity or even leading to non-performing assets. The theory of CRM enables the banking industry to realize that environmental risk is also an essential factor to be considered in the assessment process and the consideration of common traditional risks, such as credit risk and operational risk. Commercial banks carry out ERM as an important means to avoid economic losses due to environmental risks.

In order to improve their competitiveness, commercial banks should fully consider environmental risks in the loan approval process and establish ERM processes in three stages,

before, during and after lending, which is essentially an internalization of the externalities of environmental risks. In summary, CRM theory emphasizes the control and management of all types of risks in commercial banks. It provides a theoretical basis for commercial banks to carry out ERM, making the development of a sound and feasible ERM system an important work for banks to carry out loan reviews.

2.3 Studies on green credit by commercial banks

2.3.1 Status of foreign studies

As people's awareness of environmental protection gradually rises, more environmental protection policies and regulations are in place, and scholars are conducting much research on environmental protection to guide the flow of funds of financial institutes, promote the greening of industries and optimize environmental quality. The main themes of these studies are "green finance", "sustainable finance", and "environmental finance".

White (1996) first proposed "green finance", pointing out that green finance raises society's awareness and promotes ecological and environmental protection through financial instruments. They also argued that the banking industry should incorporate the environmental risks of projects or enterprises into the financial risk assessment system, emphasizing that environmental factors also play a crucial role in affecting finance. The environment and finance are closely intertwined, and that green finance should be developed in the context of the global emphasis on sustainable development.

Labatt and White (2002) pointed out that environmental finance is used to reduce the environmental risks faced by banks. With the emergence of the Equator Principles in 2002, countries worldwide paid more attention to environmental finance and began to study in-depth some of the problems in the development of environmental finance in practice.

Jeucken (2004) proposed that sustainable finance is the allocation of funds by commercial banks to those businesses and industries that meet the requirements of sustainable development. He thought that financial institutions are a vital factor in the progress of society towards sustainable development through comprehensively discussing the basic meaning of sustainable finance, its theory, and its importance. It was argued that there is a need to support the development of environmentally friendly businesses by applying different lending rates to them in response to their environmental performance. Such differentiated interest rates would reduce the benefits of banks in the short term but increase their long-term benefits.

Cilliers et al. (2010) conducted a study to verify that green credit is a criterion for assessing the value of green spaces and addressing how to compensate for the value of green spaces in urban planning projects. The results indicated that green planning in cities is not only related to flora and fauna but also economic benefits. Green credit plays an important role in solving environmental problems and can raise the public's awareness of environmental protection, enhance the sense of CSR, guide the improvement of an urban environment, create economic by-products, and promote the quality of urban planning and sustainable economic development.

Given the essential role of the government in promoting the development of green finance, some foreign scholars explored the effectiveness of green credit policies and put forward suggestions to encourage the development of green credit based on their findings.

Criscuolo and Menon (2015) analyzed venture capital investments in the green sector in 29 countries based on a database of transactions by firms seeking financing. He combined the data with renewable energy policies and government R&D expenditure indicators and identified the possible role of policies in explaining the observed cross-country differences. The study results showed that both supply-side and environmental policies were for long-term considerations for creating markets for environmental technologies. Compared to short-term fiscal policies, the higher level of risk capital makes long-term policy stability, sustainability, and credibility. It is an important policy feature to support the development of green innovation.

Soundarrajan and Vivek (2016) validated green finance in the industry in India and argued that green finance is a market-based investment or loan program that incorporates environmental impacts into risk assessment. Green finance identifies the value of the environment itself and seeks to improve human well-being and social equity while reducing corporate environmental risk and advancing ecological integrity.

Ziolo et al. (2019) argued that banks focused on the security of the transaction to issue loans. Still, it is different that environmental, social, and governance (ESG) factors have become a significant source of threat to the financial system's stability in the context of the increasing non-financial risks. Therefore, banks should incorporate the risks arising from ESG factors into their decision-making process. They argued that incorporating ESG factors into the decision-making process of financial institutions makes the financial system more sustainable.

China's green credit policy proposed integrating corporate ESG performance into financial policy and regulation. Weber (2017) thought that commercial banks in China had made significant environmental and social performance progress between 2009 and 2013. Given that a green financing system can be effectively established through a top-down approach, Ng (2018)

pointed out that green credit policies are a successful approach and suggested that ERM can be incorporated into financial credit risk assessment through mandatory regulations. Aizawa and Yang (2010) proposed that green credit policies have helped banks to reduce credit risk and achieve better financial performance as a practical tool for financial stability sustainability. In addition, Qi and Xie (2021) considered that a green credit policy could create opportunities for bank-wide credit restructuring. Establishing a green credit policy system requires disclosure of the ESG efforts of the banking sector while calling on self-regulatory organizations to appoint green assessment mechanisms, drawing on international practices. Ho (2018) thought that banks in China display more interest in increasing brand awareness and improving reputation as market incentives rather than responding to policies.

Few studies have been conducted on the impact of green credit policies on the market performance of the Chinese banking sector.

Weber (2017) investigated the interaction between sustainability performance and financial performance of Chinese commercial banks. Using panel data regression analysis, a positive cyclical causal relationship was found between the financial performance and sustainability performance of Chinese commercial banks. This result is consistent with the institutional theory that Chinese lending institutions gain two benefits from implementing green credit policies. First, Chinese commercial banks' improved environmental and social performance increases their total assets, net profits, return on total assets and return on net assets. Second, the institutional pressure from China's green credit policies positively affects both Chinese commercial banks' environmental and financial performance.

2.3.2 Current status of China's research

Chinese scholars have started their research on green credit relatively late compared with foreign studies. The connotation of green credit, according to Chinese scholars, is more similar to that of "green finance", "sustainable finance", and "environmental finance" studied by foreign scholars. Chinese scholars emphasize introducing environmental factors into the sustainable operation of financial institutions. Green credit refers to the consideration of the potential of financial institutions in the sustainable operation of financial institutions and the decision-making process of financial institutions in financing based on the review of potential environmental impacts. By integrating environmental and ecological factors into the bank's credit decision-making system and focusing on environmental protection and ecological issues, borrowing firms can generate high environmental and social benefits, thus supporting the

sustainable development of the bank's credit business. Despite its relatively late start in China, China firmly supports its growth. As a result, many studies have analysed significant issues related to green credit and how to promote relevant green credit policies in China.

As the world's second-largest economy, China has been experiencing rapid economic growth for more than 30 years. During the early years of rapid economic growth, the problems of environmental pollution and resource depletion were neglected. Fortunately, environmental protection and the efficient use of resources have attracted more attention. The Chinese government proposed to shift economic development to a more environmentally friendly, resource-saving and low-carbon way. Establishing a green financial system will be an essential approach in this transformation. Over the past decade, China has made outstanding achievements in building a sustainable economy through a green financial system. In contrast to the Western "bottom-up" approach, the Chinese government took decisive steps to implement sustainable economic policies to achieve internal stability and maintain China's international standing.

The Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks (State Environmental Protection Administration [SEPA] et al., 2007) was issued, encouraging financial institutions to transfer credit support from industries with HECE to environmentally friendly enterprises and green projects that comply with environmental laws and regulations. Five years later, the Green Credit Guidelines was issued (CBRC, 2012).

Some scholars have used the Green Credit Guidelines (CBRC, 2012) as a research context to study the role of these policies on the implementation of green credit programs by banks and their effectiveness. Bai et al. (2014) evaluated that these guidelines have positively contributed to the ESG performance of the banking sector and enhanced the responsibility of banks in facilitating the transition of the economy to a green, low-carbon and circular use model. In this context, major commercial banks were required to disclose environmental information in their regular ESG performance reports, as called for by the Chinese government and stock exchanges in Mainland China and Hong Kong, concerning corporate sustainability reporting.

Regarding the research on green credit in China, S. S. Ba et al. (2018) reviewed the current status of Chinese research in the field of green credit, sorted out the current status and development trend of research in this field, and divided the relevant research into five major categories, the definition and origin of green credit, research on the practical benefits of green credit, analysis of the development necessity of green credit, research on the policy direction of green credit, research on development issues of green credit, and the prospect of green credit research.

Some scholars have studied the current situation of green credit development in China and put forward suggestions to promote the development of green credit in China based on the reality of the development of the Chinese banking industry. L. X. Li and Huang (2010) described and analyzed seven types of risks, such as policy risk, climate risk, technology risk, and clean development model (CDM) risk, faced by Chinese commercial banks in implementing green credit in response to the uncertainties that exist in the primary stage of sustainability development. After the analysis, it was found that green credit in China is still at the stage of social response and call and has not been promoted from the institutional level.

Fan and Li (2012) analyzed the basic environment for banks to implement green credit and explored innovative ways to promote green credit development. In addition, they proposed increasing loans to certain industries and refusing to lend to others and differential credit to gradually phase out loans to high-polluting and energy-intensive industries.

X. Y. Gong and Chen (2018) pointed out that despite the policies in place to control the flow of funds to highly polluting, energy-intensive and overcapacity industries, there is still much room for improvement in green credit with regard to the share of loan balances of the four major state-owned banks in China (i.e., Industrial and Commercial Bank of China, China Construction Bank, Agricultural Bank of China and Bank of China).

Zuo and Guo (2010) used the SWOT to analyze the opportunities and challenges that Chinese commercial banks may face in implementing green credit and the strengths and weaknesses of the banking industry itself. The study results illustrated the strategies that Chinese commercial banks should adopt to develop green credit and corresponding countermeasures for the development strategies, which provided a theoretical reference.

H. R. Chen (2010) reviewed theories related to green credit and explained the connotation, development and current practice of green credit. The mainstream environmental risk assessment (ERA) index system of green credit at home and abroad was introduced. The current practice of green credit in China was elaborated from the perspectives of both the financial industry and banks. Based on that, relevant opinions and suggestions were put forward for the development and application of green credit in China.

Taking famous banks such as Citibank in the United States as an example, Q. Ma and Liu (2013) researched CSR, risk assessment indicators, and credit business products for the implementation of green credit. After the analysis, countermeasures and suggestions were proposed for the implementation of green credit by Chinese commercial banks to establish a risk assessment system and improve the access mechanism for enterprises and projects.

X. Huang and Zhong (2014) thought that the enthusiasm of Chinese financial institutions to

implement green credit is generally not high, and the national management system about green finance is not yet perfect. They suggested that to develop green credit vigorously, should be established and improved the institutional system related to green finance, coordination between major ministries should be employed, and the role of green credit in guiding the development of ecological and environmental protection industries should also be considered.

Mo et al. (2015) verified the risk characteristics of the green credit business, using data from two energy industry companies of wind power and photovoltaic. The results found that the risk of green credit business differed significantly for the same industry, but the risk of industries supported by the government is lower than that of traditional industries, and national policies have a greater impact on the development of green credit.

Kong (2015) proposed that green credit is a concrete manifestation of the green economy in the financial sector, and commercial banks have an important responsibility in promoting a green economy. By analyzing the practice of green credit of the five major banks in China, it was concluded that although the five major banks have outstanding lending and financing results, the banks' green credit-related policies still lack scientificity and innovative green credit-related services and products.

C. F. Ba (2016) thought that the development of green credit in China is still at the primary stage due to the following reasons. The national mechanism for the development of green credit is not perfect. The cost of developing green credit is high, and the government should promote the development of green credit by improving relevant mechanisms and supporting preferential policies.

H. Chen (2019) adopted the differences-in-differences method to explore whether Chinese commercial banks have implemented the Green Credit Guidelines (CBRC, 2012) from the firm's perspective. They found that loans to high pollution, high energy consumption, and overcapacity industries in China significantly decreased. The cost of loans significantly increased after introducing the Guidelines. Therefore, they concluded that the green credit policy could effectively limit credit financing for enterprises with HECE.

H. F. Huang and Ren (2010) analyzed the current situation of the practice of green credit policy in China, studied the specific content and characteristics of green credit policy in China, and summarized the practice model of green credit policy. He also researched the problems faced by the current implementation of green credit policy and put forward the prospect on the development of green credit.

Y. Q. Zhou et al. (2017) led a green credit research group of ICBC and put forward that although green credit in China started early, green credit is still in its infancy. Commercial

banks should actively implement green credit to achieve green development and pay attention to many aspects such as corporate culture and organizational structure to build a green financial system.

In order to understand the development of green finance, W. J. Wang et al. (2021) assessed the green finance development at the provincial level in three provinces (Beijing, Tianjin and Hebei) in northern China from 2007 to 2018, relative development level, and input-output efficiency in China. Based on the Tobit model, this study investigated the influencing factors, and empirical results demonstrated that the level of green finance development in Beijing, Tianjin and Hebei is uneven, but the development trend is positive.

Some Chinese scholars have discussed the role of implementing green credit in promoting the sustainable development of Chinese commercial banks. A study by Tan and Fu (2010) concluded that green credit is a powerful financial tool for energy conservation and emission reduction. Vigorously developing green credit is an important way for Chinese commercial banks to achieve sustainable development.

Y. H. Chen (2012) proposed that green credit brings both opportunities and challenges to the development of commercial banks. The conflict between the risk management system of green credit and shareholders' interests is an important factor affecting the development of green credit. However, a green economy is an inevitable trend of green credit development. In the process of green credit development, people can adopt the construction of a risk assessment system, build an organizational management system, and develop innovative special credit products to actively deal with the risks and challenges that may accompany the development of green credit.

T. Qin and Liu (2012) believed that green credit is an inevitable trend of sustainable development. The problems of contradictory local interests, banking industry efficiency problems, risk evaluation standards, and difficulties in collecting data and information are all problems in developing green credit. In order to solve these problems, they proposed that the banking industry needs to establish an environmental information database and build a comprehensive risk assessment system including environmental risks, innovative and diverse credit services. In this way, the system can guide firms to establish social responsibility and an intelligent environmental assessment platform as countermeasures.

X. Ma and Chen (2015) argued that the banking industry should set up environmental risk warnings. Otherwise, it is impossible to develop a green credit business. In order to ensure the effectiveness of green credit risk control, risk warning indicators should take into account the commonality and individuality of green credit risks, ensuring both scientific and operability

aspects. At the same time, they proposed that the active development of green credit is of great significance to promote the transformation of economic structure and economic growth mode to green ecology and environmental protection.

G. L. Sun et al. (2017) found that green credit is conducive to reducing the overall credit risk of banks and reducing NPL of commercial banks by analyzing the relevant data of commercial banks from 2008 to 2016. In addition, the vigorous development of green credit can also improve banks' profitability.

Guang et al. (2017) explored whether the green credit behavior of commercial banks helps mitigate their own credit risk. To assess banks' green credit behavior in detail, they proposed an indicator called "loan carbon intensity" to measure the carbon emissions associated with commercial banks' loans. Then, a panel data model was used to explore the relationship between "loan carbon intensity" and the NPL ratio to measure banks' credit risk. An empirical study was conducted to examine the impact of credit guarantees on NPL rates from a micro perspective based on data from Chinese commercial banks from 2007 to 2014. The results showed that "loan carbon intensity" positively impacts the NPL ratio. Since "loan carbon intensity" is considered an important indicator of banks' green credit, it is concluded that green credit policies help achieve the emission reduction targets and promote the control of banks' credit risk.

X. N. Wang and Zhu (2017) analyzed data of 12 commercial banks from 2009 to 2015. They found that the implementation of green credit business by commercial banks may reduce profitability in the short term, but it is beneficial to improve the profitability of commercial banks and increase their earnings in the long term.

S. Li et al. (2017) attempted to assess and analyze the impact of green credit policies that the Chinese government issued on banks' operational performance and risk by collecting data from the annual reports and CSR reports of 16 Chinese listed commercial banks. After obtaining these data, they analyzed whether the green credit policy in China has enhanced the sustainability of commercial banks. It was found that commercial banks engaged in green credit are positively correlated with their operating performance, and green credit is negatively correlated with commercial bank risk, indicating that the implementation of green credit is conducive to improving banks' operating performance and reducing risk.

L. Y. He et al. (2018) collected data, including green credit balances and financial information of nine listed commercial banks, and empirically analyzed the relationship between the competitiveness of commercial banks and their implemented green credit using the generalized method of moment regression. They concluded that the implementation of green

credit by commercial banks could improve the total return on assets of banks to a certain extent, enhancing the competitiveness of commercial banks.

Gao and Gao (2018) used 20 banks as examples to analyze the relationship between the scale of green credit development of commercial banks and bank competitiveness through principal component analysis and regression. The result found that when the confidence level is 95%, the larger the scale of green credit of commercial banks, the stronger the bank's competitiveness. They conclude that vigorous promotion of green credit is beneficial to improving the competitiveness of commercial banks.

Mei et al. (2018) found a non-linear and asymmetric relationship between the development of green credit on promoting the development of the environmental protection industry. When the amount involved in green credit is higher than the threshold, the development of green credit has a small impact on the environmental industry. Conversely, when the amount is lower than the threshold, the development of green credit has a larger impact on the development of the environmental industry.

S. Xu et al. (2018) adopted grey correlation analysis to analyze relevant data from 31 provinces in China from 2004 to 2015. They found that green credit has a certain impact on industrial structure through the capital channel. They also found through regression analysis that the degree of development of green credit in different regions of western, central and eastern China has different degrees of influence on industrial structure upgrading, suggesting that the role of green credit in promoting industrial structure upgrading should be emphasized.

X. L. Liu and Wen (2019) explored whether financial institutions in China should bear environmental responsibility using facts, conceptual models and empirical tests. They applied the framework of economic growth theory to study the issue of financial institutions' commitment towards the environment. They concluded that financial institutions aiming at profit maximization had caused huge environmental costs while bringing about economic growth, thus arguing that financial institutions should assume environmental responsibility. In addition, they empirically examined whether the current resource allocation of financial institutions in China impacts the environment and the quality of economic growth. The results show that the resource allocation of financial institutions has a significant impact on the environment and the quality of economic growth, which leads to the conclusion that financial institutions should assume environmental responsibility.

H. Yin et al. (2019) found that green credit can reduce carbon emissions and promote the development of a green economy by promoting the development of high-tech industries by analyzing relevant data from 23 provinces and municipalities in China from 2006 to 2015.

Y. N. Wang (2020) constructed a competitiveness assessment system of four aspects of commercial banks, including social impacts and liquidity and analyzed relevant data of 17 companies between 2012 and 2017 using principal component analysis. Findings present that the amount of green credit is positively related to the competitiveness of commercial banks.

Y. Li et al.(2020) analyzed relevant data from various provinces in China and found that the development of green credit can effectively promote the upgrading of China's industrial structure. However, there are regional differences in this promotion effect from an overall perspective. She suggests that a sharing system will improve the development of green credit among regions and promote the coordinated development of green credit among regions.

In response to the reality of the development of China's banking sector, Chinese scholars analyzed the positive factors that promote the implementation of green credit and provided path support for the implementation of green credit in China. Through a joint analysis approach, Mai and Xu (2015) analyzed the factors that influence commercial banks' enthusiasm in promoting green credit implementation. They found that financial institutions still aim at profit maximization and are relatively less enthusiastic about promoting green credit.

L. Y. Han and Wang (2014) pointed out that green credit is an inevitable trend for sustainable finance in the global calling for sustainable development. By comparing the characteristics of the development of green credit in the United States and other representative countries, they analyzed various factors affecting the development of green credit and put forward theoretical references for the development of green credit in China in terms of legal construction, policies and regulations, and innovative approaches.

Y. Y. Li and Yin (2017) analyzed the green credit risk transfer problem by constructing a conceptual model and pointed out that can be adopted, the method of transferring green credit risks from commercial banks to non-bank financial institutions, in order to reduce the risks borne by banks and enhance the stability of green credit, to further promote commercial banks to actively develop green credit.

H. Chen (2019) combined the current practical achievements of major domestic banks in developing green credit, put forward references on the risk assessment and product design of green credit. He also proposed a series of measures to promote the development of green credit, arguing that environmental risk control should be applied throughout all aspects of the green credit business.

Ren (2020) explored the critical factors that determine the level of green finance development across China. She proposed a method to measure the level of green finance development across regions and analyzed green finance policies using text mining techniques

via a panel data model to test the impact of four major categories of factors, policy promotion, financial development, ecological environment and economic-based, on the level of green finance development across regions. She also set out indicators for assessing green financial development in China. It was found that policy promotion is a key factor in the level of green financial development in each locality, but the influence of the level of financial development is unstable and depends on the promotion of local financial policies. Economic growth and the degree of environmental pollution contribute to and stimulate the development of green finance in various places to a certain extent.

In summary, Chinese research on green credit mainly covers the study of the current status and problems of green credit development in China, the study of the effectiveness of green credit policies, the role of green credit in promoting the sustainable development of Chinese commercial banks, the analysis of factors affecting the implementation of green credit, and finally, the recommendations for promoting the development of green credit in China based on the reality of the development of the Chinese banking industry.

2.4 Studies on ERM in commercial banks

ERM is the process of identifying, assessing, controlling, transferring, and monitoring environmental risks in commercial banks, enabling commercial banks to avoid environmental risks and improve their operational efficiency. Therefore, ERM has become an indispensable management activity for commercial banks. ERM of commercial banks refers to the incorporation of environmental risks into their comprehensive risk management system, including the formulation of the Green Credit Guidelines (CBRC, 2012), the incorporation of environmental risks into their rating system, the establishment of a green credit identification and statistical approach, the incorporation into the whole credit process, the establishment of an assessment and evaluation system, the establishment of a green guarantee system, the establishment of a green insurance system, and the establishment of differentiated capital take-up and pricing policies.

2.4.1 Status of foreign studies

Foreign research on ERM started early since foreign financial institutions, mainly represented by large international commercial banks, realized the importance of environmental risk management. In 2002, international commercial banks, represented by Citibank, developed an ERM framework to manage environmental risk.

Breitenstein et al. (2021) conducted a systematic literature review of studies on ERM in financial institutions. The current literature is divided into three categories. First is the impact of environmental risk on the financial performance of financial institutions, second is the current state of environmental risk management in financial institutions, and last are methods for assessing environmental risk. They found that financial institutions can reduce risk exposure by prioritizing environmental responsibility and performance, prompting corporate managers to adopt more proactive environmental measures.

Through reading and organizing the literature, this thesis divides the foreign studies on ERM of commercial banks into studies on the EPs, studies on the current situation of ERM of commercial banks in various countries, studies on the impact of ERM on the development of commercial banks, and studies on credit assessment models based on environmental risk.

2.4.2 Studies of EPs, international guidelines for ERM in commercial banks

Eshet (2017) examined the environmental impact of EPs, looking at the environmental performance of members and non-members implementing EPs concerning projects with extreme adverse environmental effects. The study found that EPs members were not less involved in environmentally unfavorable projects than non-members. In addition, a comparison of EPs members' loan projects before and after the adoption of EPs showed that members were involved in more environmentally unfavorable projects after the adoption of EPs.

Monaghan (1993) suggested that EPs can be applied to the entire process of credit approval in the banking sector to reduce the environmental risks faced by commercial banks in their investments and to achieve environmental protection based on ensuring the interests of banks. It was also pointed out that the complexity of green credit requires banks to be more rigorous and comprehensive in their risk assessment, and many scholars have conducted studies accordingly and proposed a series of green credit risk evaluation systems for different environments.

As an important specific practice of green finance, EPs aim to ensure the sustainability of project finance as an essential assessment system for commercial banks to manage environmental risks. EPs can provide environmental guidelines for project finance. Macve and Chen (2010) and Scholtens and Dam (2007) considered EPs as a set of best practice principles for commercial banks in ERM.

Williams (2013) briefly described EPs, discussed the critical role of banks in promoting sustainable development globally, and suggested that the banking sector plays an important role in promoting sustainable development and environmental protection regulation. Finally, he

argued that green credit could lead the way forward.

Contreras et al. (2019) examined the adoption of EPs in countries worldwide by collecting data on 18,729 financial institution lending programs worldwide from 2003 to 2014. The result presented that once some participants in the market have adopted EPs, these participants promote the adoption of EPs by the banks with which they work closely. External pressure from public awareness campaigns positively impacted the adoption of EPs by commercial banks, but the huge and influential banks were less affected by this external pressure.

Several research papers have been written about the impact of EPs on the business performance of financial institutions. Eisenbach et al. (2014) used an event study approach to explore the impact on financial institutions after they voluntarily joined EPs. They found that financial institutions that voluntarily adopted EPs experienced positive abnormal returns, consistent with the hypothesis that banks' adoption of EPs enhances their reputation.

Scholtens and Dam (2007) analyzed the characteristics of commercial banks that have adopted EPs as a sign of responsible behavior. The analysis concluded a significant difference in the environmental and social responsibility policies of commercial banks that have adopted EPs for financing firms compared to commercial banks that have not adopted EPs. They have significantly higher environmental and social responsibility requirements for firms. There are no significant differences between commercial banks in terms of other characteristics.

Wright (2012) assessed the changes that existed in commercial banks' lending policies after joining EPs and found that the development of lending policies was highly uneven across commercial banks after joining EPs. Commercial banks do not stop lending support to projects or enterprises with significant environmental problems.

Finger et al. (2018) used comparative analysis, an event study approach and a two-stage selection model for the examination. A distinction was made between banks in developed and developing countries, and the impact of the equatorial principle on them was studied separately. The study concluded that banks in developing countries adopted EPs as a strategic decision of their own, while banks in developed countries adopted EPs only to hoodwink the public under the pretense of being green, but in fact, had ulterior motives and even ran counter to environmental protection.

2.4.3 Studies on the status of ERM in commercial banks in various countries

Some scholars have studied the current development of ERM conducted by commercial banks worldwide. Weber et al. (2010) analyzed the current situation of ERM in European commercial

banks. They selected the European banking sector as an example, noting that ERM in banks is mainly considered at the risk identification stage, but less at the risk assessment and risk control stages. They argued that it is important to integrate ERM into the entire risk management process of credit operations in the banking sector, suggesting the importance of ensuring adequate risk management. The findings indicated that the banking industry should integrate ERM into the whole credit management process rather than incorporating it only into the initial evaluation stage. In addition, they suggested that there is a large gap between banks that have signed a statement of adherence to sustainable development and protection of the environment with the environmental sector and those that have not signed it.

Weber (2012) analyzed the social responsibility reports of nine Canadian commercial banks and found that all nine banks take environmental risks into account in their credit risk management. He argued that Canadian banks perform better in ERM compared to other countries because most Canadian commercial banks systematically examine environmental risks in their loans.

Jeucken (2010) delineated the development process of ERM in commercial banks and subdivided the banking industry's attitude towards ERM into four stages. In the first stage, banks are concerned about environmental risks, only increase costs without any benefits, and thus adopt a resistant attitude. In the second stage, environmental factors pose potential risks to banks' operations when risk aversion strategies are welcome. In the third stage, banks have identified business opportunities from ERM, therefore actively engaging in related business. In the fourth stage, all banks' business activities are aligned with sustainable economic and social development.

M. Z. Hu and Li (2015) thought it is of great significance to integrate standardized ERA procedures into the credit rating process and thus implement ERM. Environmental credit risk management (ECRM) can reduce banks' environmental risks, enrich government policy tools for environmental management, and promote local green growth. They constructed a bank ECRM performance evaluation criterion containing 32 ECRM indicators and selected 120 sample banks from 12 countries in the Asia-Pacific region for a comparative study. The results demonstrated that commercial banks in different countries have different levels of ECRM performance. Canada, the United States and Japan have the best ECRM performance. Australia, Korea, China, and Thailand have average ECRM performance, and the other five countries have low ECRM performance.

Y. Xu et al. (2018) explored the link between environmental risk and banks' loan covenants and loan costs by conducting semi-structured interviews with senior bankers from major

Australian banks. The results showed that when banks manage environmental risk by setting environmental covenants in their loan agreements, the bank's lending costs will not reflect environmental risk unless the environmental risk affects the firm's credit rating.

2.4.4 Impacts of ERM on the development of commercial banks

Monaghan (1993) pointed out that bank needs to review corporate environmental risks before issuing a loan. "Greening" should be a key concept for commercial banks in conducting credit operations, and the risks posed by the environment deserve to be assessed together, as do traditional risks. Only by examining the various risks in an integrated manner can credit be accurately assessed and unnecessary losses in the lending process be reduced. Suggestions for improvement are made on how banks can reduce environmental risks.

Some scholars have studied the impact of environmental risks faced by commercial banks on the development of commercial banks. Both Thompson (1998) and Cowton and Thompson (2000) considered that lending from banks could significantly impact the environment, and the environment can pose a significant risk to banks. They also argued that banks can play an important role in helping to improve environmental standards and that stricter lending conditions can force firms to invest in environmentally friendly technologies and pollution control measures. There is a growing awareness that social, environmental and sustainability risks represent an increasing proportion of the overall risks faced by financial institutions.

Cowton and Thompson (2000) said that banks take three types of risks associated with environmental risk due to lending, direct, indirect, and reputational risks. They suggested that even if banks are not directly concerned with environmental issues, they have an incentive to understand the environmental impact of their lending decisions.

Scholars have explored the role of ERM by commercial banks. Scholtens (2006) addressed that as society becomes more concerned about environmental issues, banks are more inclined to lend to environmentally friendly and pollution-controlled businesses. He said that bank financing of projects that consider environmental issues will not undermine other development goals but will result in better environmental and economic returns.

Goss and Roberts (2011) and Nandy and Lodh (2012) pointed out that banks may value corporate environmental responsibility because firms that perform well in environmental responsibility are more likely to receive lower bank loan costs.

Sharfman and Fernando (2008) empirically explored the relationship between corporate ERM and economic performance using 267 listed companies in the United States. They found

that firms can achieve improved economic performance from ERM because firms can reduce the cost of equity capital. The reason is that by enhancing their ERM capabilities, firms can gain economic benefits from ERM. The reason is that firms can reduce the cost of equity capital, increase debt financing capabilities, and obtain higher tax incentives after improving debt financing capabilities by improving ERM capabilities. As a result, the business economic performance of the firm can be enhanced.

2.4.5 Studies on credit evaluation models based on environmental risks

Some scholars incorporate corporate economic, environmental, and social indicators into environmental risk and credit assessment qualitative and quantitative methods. C. C. Yang et al. (2019) developed a hybrid multi-objective decision model based on grey correlation analysis, decision laboratory analysis, network analysis method, and technique for order preference by similarity to an ideal solution, which led to the establishment of a green credit rating mechanism for commercial banks. To test the validity of the model, credit risk and economic, environmental, and social performance evaluation indicators were selected as evaluation criteria, and 55 high-tech listed companies in Taiwan were used as evaluation objects to validate the model for their credit levels.

Some scholars have also added corporate social, environmental, and sustainability indicators to credit risk evaluation and have drawn some conclusions. Weber et al. (2010) explored whether sustainability indicators of borrowing firms affected their credit risk rating and concluded that when sustainability criteria were added to traditional credit risk indicators, commercial banks' credit default predictions for borrowing firms' correctness improved by about 7.7%. B. Zhang et al. (2011) and Nandy and Lodh (2012) argued that environmental risk appears increasingly essential in the total risk faced by financial institutions. Buxton (1997), Case (1996), Coulson and Dixon (1995), and Thompson (1998) all said that environmental risks need to be monitored and assessed to mitigate the impact of environmental risks.

Gaganis et al. (2021) thought that an assessment framework that considers the borrower's financial information and socio-environmental performance is of significant value to bank managers. Therefore, an assessment framework was proposed to evaluate the firm's performance by including not only financial information but also information related to the environment and CSR in the assessment framework.

Escriing-Olmedo et al. (2010) provided a detailed description of the different evaluation criteria through a sample of six indexes of sustainable development and ten ESG institutions.

They concluded that due to the increasing importance of social responsibility in the financial markets, sustainability indexes and ESG rating agencies have an important role in encouraging the implementation of environmental protection policies. It was also noted that although there are various evaluation methods and evaluation indexes used by ESG rating agencies, the evaluation criteria lack standardization.

Several previous studies evaluate the sustainability of firms. For example, in the academic field, Oliveira et al. (2019), Puggioni and Stefanou (2019), Ortas et al. (2015), Cheung et al. (2010), Y. Cai et al. (2011) created comprehensive indicators to evaluate corporate sustainability or CSR. Gutiérrez-Nieto et al. (2016) used hierarchical analysis to complete an evaluation system for bank credit loans based on social responsibility. The evaluation system assesses the impact of the business on social aspects, including the effects of the business on employment, the impact of the business on education, the impact of the business on health, and the impact on the business environment.

In order to improve ERM capabilities, the focus is on establishing and implementing a sound risk management process. In the ERM process of commercial banks, ERA is an extremely important link. In addition to the studies mentioned above, foreign institutions have developed a series of index systems for quantitative assessment of environmental risks, such as The Dow Jones Sustainability Indexes, the most famous and oldest in the industry. It evaluates the capability of firms to develop sustainably and their sense of environmental responsibility from the perspective of investment, mainly from three aspects, economic, social and environmental. The FTSE Domini 400 Social Index evaluates the performance of enterprises in social and environmental aspects, and the Advanced Sustainable Performance Indices evaluates the financial performance of enterprises in the Eurozone. These evaluation systems are important for foreign scholars to conduct environmental risk pricing and related empirical studies.

2.4.6 Current status of Chinese studies

In recent years, along with the further promotion of the green credit policy, Chinese financial institutions, mainly represented by large and medium-sized commercial banks, have realized the importance of ERM, and it is an inevitable trend for commercial banks to develop practical ERM approaches for the proposed lending enterprises. From the current situation in China, research on ERM for commercial banks has focused on the following three aspects.

2.4.6.1 Studies of ERM in commercial banks concerning the current development of green credit

The strength of commercial banks' ERM capability directly determines the development of green credit business, and the ERM system of commercial banks is regarded as the foundation of green credit implementation. After analyzing the current situation and problems of ERM of 10 large commercial banks in China, Q. J. Ma and Liu (2013) built a complete set of ERM systems of commercial banks suitable for China's national conditions by drawing on the advanced experience of foreign Citibank's ERM. They divided commercial banks' green credit loan process into the pre-loan review, mid-loan confirmation, and post-loan management. The pre-lending audit includes ERA, enterprise environmental audit, and output environmental impact assessment (EIA) reports. The mid-lending confirmation includes incorporating the EIA report into credit audit, determining the loan interest rate and formulating loan agreement. The post-lending management is a regular audit.

After analyzing the current situation of ERM in Chinese commercial banks, X. Liu (2015b) concluded that Chinese commercial banks are not proactive enough in ERM. The content of their ERM still stays in the policy formulation stage and lacks concrete operational measures for effective ERM. After analyzing the ERM situation of commercial banks at home and abroad, policy recommendations for constructing an ERM system in the Chinese banking industry were proposed.

D. X. He and Zhang (2007) pointed out that from China's national conditions, ERM should be elevated to the strategic level of bank operations, and commercial banks should prepare ERM programs with their realities.

M. Chang et al. (2008) said that the over-reliance of Chinese commercial banks on environmental information provided by environmental protection departments and their lack of initiative is the main reasons limiting the development of green credit in China. Chinese commercial banks should change their development mindset and establish internal bank criteria for judging green credit, i.e., ERM systems, as soon as possible.

D. F. Feng (2008) proposed that the lack of effective implementation of the national green credit policy by environmental protection departments and commercial banks results in the absence of assessment of environmental risks by commercial banks and significant regional differences in ERM. Therefore, China faces both pressures and challenges in implementing green credit under the combined effect of pressure from all parties.

Jaeggi and Shi (2009) pointed out that commercial banks take social and environmental

factors into account when assessing credit operations to minimize the risks faced by banks and customers. This is the essence of ERM of commercial banks, and the implementation of ERM can reduce the risks of commercial banks in credit operations and improve the profitability of commercial banks.

C. Zheng (2012) realized that environmental pressure gradually increases in China, and environmental protection is imminent. Therefore, he argued that Chinese commercial banks should learn from the practical experience of foreign commercial banks in ERM. Several aspects should be controlled together in order to improve the risk management capabilities of commercial banks.

H. J. Cai (2013) analyzed the practical effects of green credit policies in China in recent years and found that commercial banks pay more attention to the repayment ability of enterprises when approving loans to enterprises or projects. Although commercial banks also consider borrowing firms' capability to protect the environment when approving loans, which is in line with the national green credit policy, the effect of the difference in borrowing costs is not apparent enough.

Lin (2018) suggested that there are still many problems in the ERM of commercial banks. She argued that the laws related to ERM of commercial banks should be improved, and a good corporate environmental information platform should be built to promote the practice of EPs and green credit.

ERM in Commercial Banks (Lan, 2012) systematically studies and introduces ERM techniques, processes and methods in commercial banks. The close connection and difference between commercial banks' ERM and China's green credit policy are elaborated. She argued that, on the one hand, commercial banks' ERM is the risk management measures and instruments adopted by bankers to avoid the loss of credit and reputation brought by environmental risks from the perspective of maximizing their interests. On the other hand, the green credit policy is a macro-management policy adopted by the government to conduct commercial banks to invest their funds in environmentally friendly enterprises and projects. The government's green credit policy can influence the cost and benefit of implementing ERM for commercial banks. Suppose the government enacts a strict green credit policy. In that case, the benefits of implementing ERM for commercial banks will outweigh the costs, and commercial banks will actively introduce, identify, research and adopt various techniques, processes, and tools for ERM to maximize their interests.

2.4.6.2 Studies of ERA methods in the ERM process of commercial banks

From the advanced experience of large foreign commercial banks in ERM, ERA is the critical link in the whole ERM process. The ERA of commercial banks for lending projects reflects a high degree of integration between environmental science and financial risk management.

M. Chang et al. (2010) constructed two sets of ERA processes for two models of project financing and corporate financing and rated the environmental risks contained in the financing projects or enterprises comprehensively through two steps of qualitative and quantitative assessment. Their study offered high reference value for commercial banks to manage the environmental risks in the steel industry.

From banks' perspective, Fu and Tan (2011) first constructed an ERA index system, then determined the specific index weights through a questionnaire survey of risk management experts in several Chinese commercial banks. Then, they built a hierarchical analysis assessment model and illustrated the model's application process using the bank's project cases. This study can guide commercial banks to construct their ERA model.

N. Y. Hu and Cao (2011) realized the importance of transforming the economic development model in the context of the gradual deterioration of the global climate and environmental problems and believed that the implementation of green credit by commercial banks is an important support to the transformation and upgrading of the economy and sustainable economic structure. They proposed that commercial banks should closely integrate ERM with green credit business, build an environmental risk evaluation system, and actively promote ERM in the green credit business.

2.4.6.3 Studies on the accession of Chinese commercial banks to EPs

As an essential practice of green finance, EPs are an important assessment system for commercial banks to manage environmental risks, and EPs are used to judge and assess the environmental risks of loan projects. The implementation of EPs is conducive to commercial banks' capabilities of enhancing comprehensive risk management, improving sustainable development, and strengthening CSR.

However, in response to the slow implementation and application of EPs in China, A. Y. Jiang and Hu (2021) studied the impact of EPs on the operational level of Chinese commercial banks from three perspectives, profitability, credit, and management, to test the applicability of EPs in China. F. Xu and Ma (2019) used Industrial Bank, the first Chinese bank to commit to EPs, to study EPs' impact on commercial banks' operating performance level with a synthetic control method. They found that the implementation of EPs is beneficial in providing the

business performance of commercial banks in the short run. However, over time, the costs associated with the implementation of EPs for risk management gradually exceed the benefits obtained, and, in the long run, EPs have a negative impact on the operating performance of commercial banks.

Eps: The Practice of Sustainable Development in the Banking Sector (S. Z. Feng et al., 2011) explained the basic theory and operational framework of EPs, analyzed the specific application practice of EPs in project financing, and put forward specific suggestions for the localization of EPs in the context of China's green credit policy. He expected that it could be helpful in the theoretical study of EPs and the upcoming practice of EPs financing in China and a guide for banking financial institutions on green credit.

J. M. Zhang et al. (2017) analyzed the current situation of implementing EPs for ERM in Chinese and foreign commercial banks and concluded that there are still many shortcomings in the practice of ERM in Chinese commercial banks compared with well-known foreign commercial banks. Commercial banks are less likely to establish a complete ERM system, and EPs have not yet been popularly applied in Chinese commercial banks. They recommended strengthening the legal construction of ERM and green credit in various aspects, improving the incentive and restraint mechanism, and enhancing the enthusiasm and initiative of commercial banks to carry out ERM and green credit.

Guang et al. (2017) analyzed the necessity of commercial banks to implement green credit, summarized the development of EPs and the problems and difficulties currently faced by Chinese commercial banks in implementing green credit business. They also proposed that China should develop green credit countermeasures suitable for China's national conditions to implement ERM.

S. Liu (2018) selected the Industrial Bank's practice of EPs as an example and concluded that banks in China should actively respond to new policies and concepts, consciously implement green credit, manage environmental risks well, and promote the development of a green economy.

D. He (2020) summarized the origin and development of EPs and argued that in the context of the development of the Belt and Road Initiative, commercial banks should pay attention to the application of EPs, establish ERA and management systems, and promote green credit.

2.5 Studies related to green credit game theory models of commercial banks

2.5.1 Status of foreign studies

Game theory is the study of conflict and equilibrium between rational decision makers and the theory of conflict and cooperation between rational decision makers. Game theory attempts to rationalise and abstract these complex relationships in order to provide a more precise picture of the logic of change and to provide guidance for solving practical problems.

Von Neumann and Morgenstern (1963) published the classic book *Game Theory and Economic Behaviour*, which is considered to be a significant work in the history of game theory and is considered to be the first sign of its formation. The book argued that game theory in mathematics would become the best way to study economic theory.

The 1950s saw the culmination of game theory research. In 1950 and 1951, John Nash published two papers called “Equilibrium in N-Person Games” and “Non-Cooperative Games”, which introduced and defined the concept of “Nash Equilibrium”, the cornerstone of non-cooperative games. Nash Equilibrium considers that each player in the one-strategy set is confident that he has chosen the best set of strategies given his competitors., and it describes a world where no one makes mistakes.

In 1994, the American mathematician and economist Nash, the Hungarian-American economist Harsanyi and the German economist Selten were awarded the Nobel Prize in Economics that year for their outstanding contributions to game theory.

Since the 1980s, game theory has become increasingly sophisticated and has been used in many fields of research, including environmental economics. The use of game theory to abstract the behaviour of subjects and rationally analyse the behaviour of green credit transactions is highly applicable.

Inefficient energy consumption is the primary source of environmental pollution, and improving energy efficiency through green technology innovation is an effective way to reduce harmful emissions. Most game theory model studies on green credit focus on the impact of green credit on firms' green technology innovation.

After reviewing a large amount of foreign literature, the writer has found that Chinese have published many theses in foreign journals that use game theory to study green credit, while there are few studies done by foreign researchers. For example, H. R. Cui et al. (2020) set up a tripartite evolutionary game theory model with government, financial institutions and enterprises to conduct game equilibrium analysis by constructing replicated dynamic equations

to derive evolutionary stabilization strategies. They used numerical simulations to analyze the impact of each parameter on the change and development of green financial markets. They found that the integrity of the green financial system has a substantial positive impact on sustainable development and clean production. To promote the establishment of a green financial system, it is necessary to strengthen government regulation, significantly cut the green economic production costs of financial institutions and enterprises, increase consumer pollution compensation, and reduce the cost of government regulation.

S. L. Chen et al. (2019) focused on two important factors in green credit, loan interest rate and loan size. The impact of these factors on green innovation was explored, and a green innovation game theory model involving three participants, government, banks, and enterprises, was constructed. It was found that the incentive effect of loan interest rate and loan size on green innovation has a strong dependency. They proposed that the green loan interest rate should be below a particular threshold value. Otherwise, green loans will not stimulate enterprises to engage in green technological innovation. In addition, the loan size offered by the bank should be between the two loan size thresholds at a loan interest rate below a given threshold, thus incentivizing firms to engage in green technology innovation.

D'Orazio and Valente (2019) discussed the role of financial institutions in providing green funding to firms to promote green technological innovation in green firms. Findings suggested that state-owned commercial banks are beneficial to economic development when they are used as a tool to promote innovation and industrial policy. Firm green quality reaches its highest level when state-owned commercial banks explicitly support green investments combined with strong consumer preferences for environmental quality.

The results of the studies by relevant scholars indicate that green credit from banks or government subsidy policies provides start-up capital for green innovation, making companies more willing to engage in green technology innovation and thus reducing the environmental risks faced by banks.

2.5.2 Current status of Chinese studies

In recent years, the game analysis among the participating subjects under green credit has become a prevalent issue for Chinese scholars. The relevant studies mainly focus on the quantitative analysis of the game between the government and banks and between banks and enterprises in the process of green credit implementation and explore the optimal strategies of each subject under different situations and scenarios.

X. S. Zhang and Li (2009) addressed the contradiction between local officials' performance appraisal system and local government in environmental protection. Then, they constructed a dynamic game theory model between local government and local commercial banks that revealed the contradiction of interests in implementing "green credit". They argued that changes in the utility function under different institutional arrangements affect the external conditions of green credit execution. From the perspective of sustainable development, they conclude that changing government functions is an effective way to improve the efficiency of executing green credit.

In response to the government's expectation to promote the implementation of a green supply chain of enterprises by supervising the implementation of green credit from the supply of funds, Y. S. Zhou et al. (2015) incorporated the government into the evolutionary game. They considered the situations when the government, through the implementation of green credit to banks, implemented green supply chain inspection and supervision of enterprises and gave corresponding rewards and punishments. They constructed a three-party evolutionary game theory model between the government, banks, and enterprises. By creating a copying dynamic equation to analyze the game equilibrium and deriving an evolutionarily stable strategy, the study found that, in the short term, whether the government chooses a "regulation" or "non-regulation" strategy, commercial banks will decide not to implement green credit. Enterprises will decide to "not adopt" a green supply chain strategy. When the government does not implement supervision, both banks and companies will choose environmental protection strategies in the long run.

X. L. Jiang et al. (2016) used the current situation of green credit development in Beijing's new energy industry as a background and constructed a game between commercial banks and the new energy industry with an evolutionary game theory model to carry out equilibrium analysis by constructing replicated dynamic equations and derived four equilibrium strategy combinations for enterprises and banks. Finally, they offered suggestions on improving the bank's credit system and how the government can play a benign supervisory function.

Wen et al. (2019) analyzed the behavior of decision strategies and stability strategies of multi-entity participation in risk prevention and control by building an evolutionary game theory model of banks, guarantee institutions, and micro and small enterprises under government environmental regulation. They also discussed the impact of key decision parameters through numerical simulation experiments.

B. Ma et al. (2017) constructed a dynamic stochastic general equilibrium model containing four sectors, households, manufacturers, commercial banks, and the central bank. The results

presented that the financial support behavior of commercial banks can influence firm output, and commercial bank loans promote economic growth and industrial structure optimization by expanding or reducing the size of firm financing.

F. X. Han et al. (2017) analyzed the motivation for developing green credit and then constructed a three-party game theory model with the government, banks, and enterprises to explore the game between the government and banks, which parsed out the background of the release of green credit policy. The game between enterprises and banks was also considered, and the gains and losses of banks in implementing green credit were analyzed to clarify the decision mechanism of commercial banks in implementing green credit. Finally, the factors affecting the implementation of green credit by commercial banks are analyzed, and countermeasures were proposed.

H. B. Zhang and Sun (2019) explored a three-way green credit development game among government, banks and enterprises. They found that the government can effectively improve the green input behavior of enterprises and commercial banks by sharing certain green costs through subsidies or tax breaks. The relevant cooperation among the government, banks, and enterprises is the optimal way to promote the development of green credit.

H. J. Cao and Chen (2010) considered the situation that financial regulators might punish banks for not implementing green credit, and enterprises may be administratively punished by the government for polluting the environment in an uncertain environment. They analyzed the behavioral choices of banks and enterprises for environmental protection using a static game with complete information, a repeated game, and a static game with incomplete information. Results showcased that banks will choose not to implement green credit without external supervision and restraint, and enterprises will choose environmental pollution behavior. Therefore, they believed that the government should tighten pollution penalties and improve the bank's green credit incentive and restraint mechanism as important measures to achieve environmental protection.

Ye and Fang (2020) constructed a three-party evolutionary game theory model to explore the game of environmental management by government, banks and enterprises. With the government's strict environmental regulation and relaxed environmental regulation, banks will change their strategies accordingly from charging higher interest rates to lower interest rates, while enterprises will change their strategy from governing the environment to not governing the environment. They discussed that strict environmental constraints could induce firms to engage in environmental management behavior. Environmental management by firms helps improve the level of ERA of firms by banks, which leads banks to offer interest rate concessions

to firms with sound environmental management.

Z. Y. Hu et al. (2013) considered the change of the cumulative pollution in the river and constructed a green credit differential game theory model based on continuous-time water pollution control between enterprises and banks, where the bank used the credit scale as the decision variable, and the enterprise used water pollution discharge as the decision variable. Both parties aimed to maximize the objective function. They obtained the feedback Nash equilibrium solution of banks and enterprises under the dynamic framework and the dynamic equation of river pollution over time. Through numerical simulation, it was found that the implementation of green credit improves the control effect of enterprises on pollutants. The scale of green credit of commercial banks is directly proportional to the degree of corporate environmental governance and is positively related to the incentive mechanism for environmental control.

G. Wu and Shi (2017) took the evolutionary game analysis between commercial banks and firms in the presence or absence of government subsidies. Commercial banks decide whether to establish an ERM system, and firms make environmental governance inputs. They found that when the government does not subsidize the environmental strategies of firms and commercial banks, it will not be an evolutionarily stable strategy for commercial banks to establish ERM systems and for firms to invest in environmental management. When government subsidies exist, under certain conditions, commercial banks establishing ERM systems and firms supporting environmental management can be stable evolutionary strategies.

C. D. Wang et al. (2012) summarized the main difficulties and problems in implementing green credit in China. Then, under the assumption of limited rationality of banks, they set up an evolutionary game theory model among banks, which imitates the dominant strategies of other banks in their decision-making to reach equilibrium. They analyzed the impact of changes in the main parameters on the evolution of equilibrium and identified the key factors that determine the implementation of green credit. Results revealed that an increase in the efficiency of regulatory supervision drives the evolutionary game theory model to reach a steady state. Finally, an optimization path for the green credit implementation mechanism was proposed.

H. Li and Li (2015) established a static game theory model with incomplete information. They conducted a game analysis on the competition between government regulation, bank green loans and environmental management of enterprises with HECE. At the same time, they added reputation mechanism to government regulation and contingency cost to enterprise cost and derived the Nash equilibrium under different participants. The corresponding suggestions were made for the implementation mechanism of green credit.

Xue and Wei (2020) discussed the strategy choice of commercial banks in different situations and established an evolutionary game theory model among banks for the competitive relationship between commercial banks. Banks will imitate the advantageous strategies of other banks and select an evolutionary game theory model between banks. A complete information static game theory model was established for the different market positions and returns of polluters and commercial banks. In addition, the repeated game theory model was used to explore the existence of multiple games between banks and enterprises. The strategic choices of commercial banks in implementing green credit were analyzed from various perspectives to provide strategic suggestions for the practice of green credit in commercial banks. They found that to ensure the effective supply of green credit, the additional benefits brought by green credit to commercial banks should be increased, the cost of issuing green credit should be appropriately reduced, and the supervision of the environmental performance of commercial banks should be strengthened.

M. Liu and Hao (2018) set up a tripartite dynamic evolutionary game theory model of banks, government and enterprises. They discussed the strategic choice of each participant under the condition of tripartite information asymmetry to analyze the mechanism of mutual influence tripartite decision making. The research results showcased that based on the environmental externalities and rational human assumptions, enterprises and banks will not take the initiative to carry out green technology innovation to reduce environmental pollution, and commercial banks will not take the initiative to implement green credit. In order to achieve the goal of sustainable development, the government should strengthen the supervision and punishment of enterprises' behavior of polluting the environment and improve the incentive mechanism of green credit.

X. Zhao et al. (2018) constructed a tripartite evolutionary game theory model of government, banks, and enterprises to derive the equilibrium strategy choice of the three parties in the credit market. They analyzed the stability of the evolutionary game of banks and enterprises under the government incentive strategy choice and the main factors affecting the strategy choice of banks and enterprises. They found that the main factors influencing the choice of green production by enterprises are the green production subsidies provided by the government, the cost of green transformation of enterprises, expected benefits, and indirect benefits. The main factors influencing banks' strategy choice are the cost, indirect benefits, and direct benefits of green financial services provided by banks.

2.6 Literature observation and evaluation

In summary, regarding the studies on green credit and ERM of commercial banks, domestic and foreign scholars have emphasized that ERM is the foundation of the development process of green credit. Foreign scholars mainly research the link between financial sustainability and the ERM of commercial banks from environmental finance and sustainable finance, the impact of green finance implementation on commercial banks, and empirical studies on green finance and environmental risk evaluation. Their research results have strong operability. From the Chinese perspective, the research on green credit and commercial banks' ERM by domestic experts and scholars started only after the joint issuance of the Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks by the State Environmental Protection Administration of China (PBoC & CBRC, 2007). In terms of research content, Chinese scholars have mainly focused on green credit policy analysis and related theoretical research. However, there is less research on methods and systems for quantitative assessment of environmental risks in commercial banks and further research on quantitative ERM in Chinese commercial banks, especially industry-specific assessment systems. That can be a future research direction.

Theoretically, most game theory studies on green credit mainly examine the influencing factors of implementing green credit policies, the implementation mechanism of green credit, and how banks exercise their agency supervision rights. However, they neglect the fact that, at present, most commercial banks only carry out ERM based on the environmental compliance information provided by the ecological environment department in implementing green credit policies and seldom consider the need for commercial banks to establish an ERM system.

This thesis constructs a two-two game theory model between the government, banks, and enterprises, adds environmental risk penalty coefficients to commercial banks' ERM, explores commercial banks' decision to establish ERM systems, enterprises' environmental governance decisions, and the government's regulatory decisions, and finally proposes recommendations to promote banks' ERM and enterprises' environmental governance.

In reality, ERE by Chinese commercial banks is mainly confined to a compliance review. Commercial banks have not yet considered the degree of impact of environmental risks on credit risk in lending to steel enterprises and have not yet formed a complete evaluation system to evaluate the environmental risks of steel enterprises. Therefore, there is an urgent need to build a complete set of commercial banks' evaluation systems for environmental risks of iron and steel enterprises to help solve the problems of environmental and multiple uncertain risk

factors faced by commercial banks before and after lending to this sector. In this way, it can help realize quantitative evaluation of commercial banks' environmental risks of iron and steel enterprises and provide technical support for commercial banks' ERM. In this thesis, the author uses the hierarchical analysis method to establish an environmental risk evaluation method for Chinese iron and steel enterprises to quantitatively evaluate the environmental risks of iron and steel enterprises.

Chapter 3: Analysis of the Current Situation of ERM of Commercial Banks

With the introduction and increasing stringency of international and domestic laws and regulations and environmental standards, enterprises' production and operation activities have been subject to more constraints. The risk of uncertainty in business prospects has greatly increased, thus making environmental risk an essential object of risk assessment and risk management in the credit activities of commercial banks. ERM of commercial banks refers to the incorporation of environmental factors into the scope of risk management and the formulation of related ERM policies, systems, processes, and management methods to identify, warn, assess, and mitigate environmental risks, and to effectively prevent, control, and dispose of the environmental risks. This chapter focuses on the comparative analysis of foreign and Chinese commercial banks' ERM practices and identifies the main problems of ERE in Chinese commercial banks.

3.1 The practice of ERM in foreign commercial banks

3.1.1 Origin and practices of the EPs initiators

In October 2002, ten banks, including the International Finance Corporation (IFC) of the World Bank Group and Algemene Bank Nederland Amsterdam-Rotterdam Bank (ABN AMRO), met in London to discuss the establishment of guidelines for environmental and social issues caused by financing in projects for all industries worldwide. After the meeting, the EPs were drafted. The EPs were officially launched in Washington, D.C. by the ten banks, including the four initiators (S. Z. Feng et al., 2011). Currently, the EPs have been adopted by all major international banking institutions. By March 2018, the EPs had been adopted by 37 countries and 94 financial institutions worldwide (Lu, 2019).

On January 1, 2014, the third edition of EPs (EP3) was fully implemented. EPs are a complete environmental and social risk composed of ten basic principles, eight performance standards, and environmental, health and safety guidelines for 63 industries. The ten basic principles stipulate the code of conduct to manage environmental issues in project financing; the eight performance standards help banks identify and analyze environmental and social risks

in project financing. Environment, Health and Safety Guidelines (IFC, 2007) were officially issued to control and eliminate various risks in the financing process of multiple industries.

The latest fourth edition of the EPs (EP4) has been officially put into use since July 1, 2020. Compared with the EP3, the main content of the EP4 includes expanding the scope of reviewing projects, new content compatible with international emission reduction targets, the disclosure of climate change and greenhouse gas emissions, and improving environmental and social risk management (ESRM). The EP4 pays more attention to strengthening the connection with international emission reduction agreements. At the same time, it requires financial institutions to actively participate in and maintain ESRM, actively intervene in project-related risks, and list the Equator Principles Action Plan to improve and reduce risk.

The EPs are an important milestone in the history of international financial development since they established the minimum industry standards for environmental and social aspects of project financing for the first time. Therefore, it serves as a guide to action and quantitative indicators for sustainable financial operations by banks worldwide.

Barclays, one of the initiators of the EPs, has integrated environmental and social risks into its risk controls, making environmental and social risk assessments an integral part of its due diligence risk assessment. Barclays has developed an integrated social and environmental credit guideline that covers all financing terms and over 50 industries by engaging external consultants and industry environmental experts. The guidelines assess and determine different levels of environmental risk based on the client's ERM profile to facilitate the review and assessment of loans (L. Y. Wang & Fu, 2016). At the same time, in order to share Barclays' experience with its peers, Barclays and the United Nations Environment Program have provided the guidelines to more than 170 financial institutions around the world, providing strong guidance for other banks in the world to evaluate and review loans. Barclays supports the entire banking environmental and social risk control system with its sound policy system and scientific management process.

Citibank in the United States is an important initiator and active practitioner of the EPs. It established an environmental and social management system for Citibank's global transactions, and this management system serves as a guarantee for the implementation of the EPs. Operationally, Citibank has embedded ESRM principles in its credit system, established a strict ERM process and a series of criteria to assess the impact arising from environmental issues, and set up a committee to review environmental and social risk policy. Citibank has adopted a four-step review and approval process in terms of financing procedures. The first step is an initial assessment of risks, then a classification of project risks into categories A, B, and C based

on the magnitude of environmental risks. The next step is the risk assessment stage, where senior credit risk officers review and submit project proposals. The final step is conducting a full review of the project as required by the EPs.

ABN AMRO is a bank with rich experience in the EPs. Its prominent feature is that ABN AMRO has gradually shifted the strategic objective of sustainable development from risk management to the exploration of business opportunities. In the field of carbon trading, ABN AMRO is a top 10 dealer in the world. Moreover, the bank has designed the climate index and water resources index by studying the share price performance of various listed companies and launched sustainable financial products whose returns are linked to the indices mentioned above. In this way, ABN AMRO has formed a product service system covering various forms of wealth management products, loan financing, investment funds.

Mizuho Bank in Japan is the first bank in Asia to join the EPs and is the best practitioner of the EPs. Mizuho Corporate Bank Equator Principles Implementation Manual was completed for 38 industries, and Mizuho Bank set up a Sustainability Office in March 2006 to screen projects and offer the EPs screening report accordingly. Mizuho Bank localized the EPs by translating them into Japanese and formulating specific rules. The implementation of the EPs has enabled Mizuho Bank to seize business opportunities, thus rising from 18th place in 2003 to third place in the world in 2006 in terms of financing (CIB, 2017).

3.1.2 Comparison and analysis of ERM practices in major developed countries

3.1.2.1 Comparison of legislation

In the United Kingdom, the guiding ideology of legislation focuses on preventing pollution, following the three basic principles of green development, polluter pays, and pollution prevention (F. B. Sun, 2010). Under these principles, the United Kingdom has developed an environmental impact assessment system, comprehensive pollution control, and environmental management standards. The core of the British environmental control system is to avoid pollution by setting strict standards through legislation, including the Pollution Prevention Act, which controls pollution by setting systematic technical standards and issuing permits for 9,000 processes that companies need to apply to the environmental authorities (An & Cao, 2017).

The sound legal system of the United States is the most prominent feature of the development of green credit in the United States. Since the 1970s, the United States Congress has passed 26 laws related to environmental protection, involving water environment, air pollution, waste management, contaminated site cleanup. Environmental law enforcement has

been continuously increased to raise the cost of environmental violations by enterprises, and then, the consequences of environmental violations have been indirectly transformed into credit risks related to financial institutions so that enterprises can set up self-regulatory organizations and generate incentives to control environmental risks. For example, the Comprehensive Environmental Response, Compensation, and Liability Act stipulated that financial institutions must take responsibility for environmental damage caused by lending enterprises and pay the corresponding restoration and remediation costs. Banks share information on environmental protection data with environmental protection departments. The federal government attaches great importance to transferring risk through environmental liability insurance and the role of environmental non-governmental organizations (NGOs) in exerting pressure on governments, businesses, and banks. The impacts of NGOs in the United States are the strongest worldwide (L. Y. Wang & Fu, 2016).

German environmental legislation emphasizes administrative procedures, public participation, and environmental prevention, thereby effectively coordinating the relationship between environmental protection and economic development.

Since the 1950s and 1960s, Japan has enacted several laws and regulations on environmental protection, which have effectively curbed the severe environmental pollution in areas where industrial pollution is concentrated and protected the people's right to live and their health requirements.

3.1.2.2 Comparison of environmental policies at the bank level

The Hongkong and Shanghai Banking Corporation (HSBC) has clear lending standards and adheres to the highest international standards in its lending process, including the EPs, according to Principles for Responsible Banking (United Nations, 2019), and the relevant guidelines of the World Bank and the International Finance Corporation. HSBC has formulated a series of credit policies covering environmentally sensitive industries. HSBC has clarified that it does not grant loans to the industries and areas, including energy, chemicals, minerals and metals, forest land, and forest products. During loan due diligence, client managers usually use environmental monitoring checklists to comprehensively assess their environmental risks. For industries defined by the government as HECE, a comprehensive and detailed assessment is required.

Citibank strictly controls the direction of credit and reduces the proportion of high-risk loans. It has adjusted its credit structure based on ERE, reduced the proportion of loans to lenders with environmental risks, and scaled down loans to environmentally sensitive areas and

industries. For enterprises or areas where pollution has already occurred, loans are strictly controlled. For enterprises or regions where environmental pollution has already occurred, the loan will not be issued after the loan is recovered. The initiatives mentioned above significantly reduce the impact of environmental risks on loans and have also prompted lending enterprises to strengthen their pollution control efforts, thus effectively facilitating the flow of bank assets from areas with high environmental risks to areas with lower environmental risks.

3.1.2.3 Comparison of evaluation process and methods

Barclays has a dedicated environmental and social risk evaluation system involving the borrower, the internal rating department, the environmental and social risk evaluation department and the reputation committee. General lending involves only the borrower and the internal rating department. However, if a borrower is considered to have potential environmental risks, the environmental and social risk evaluation department will step in and provide guidance. If significant risks could affect the bank's reputation, the reputation committee will decide the highest level. Each project is subject to an evaluation process. If the loan is approved, the company should follow environmental policy requirements during project execution and construction. These requirements will be written into the loan contract. The evaluation system is also applicable to bond underwriting of its investment department.

Citibank has established a strict environmental affairs management mechanism, and the ESRM system (Citibank, 2003) has been integrated into its entire credit system, forming a series of green financing standards and guidelines. The evaluation process of environmental and social risk is rigorous. According to the transactions stipulated by ESRM, environmental and social risks are classified into type A, B, and C according to their size. As long as the risk is considered as type A, it should be jointly evaluated by the ESRM department director and the senior credit officer.

Citibank's ERE has four steps. The first step is initial inspection. Past and present environmental information of the company is collected, and the site visit is conducted and verified by professional staff. The second step is detailed environmental evaluation. Professionals conduct a careful environmental evaluation of the project, based on the initial inspection results. The third step is environmental testing. Based on the above, the bank decides whether to conduct environmental testing to eliminate existing and potential environmental risks. The fourth step is post-lending management. To track and manage their potential environmental risks, regular environmental reviews are conducted on borrowers. Citibank incorporates the results of the environmental and social risk evaluation (ESRE) into the

project's annual portfolio evaluation. In addition, Citibank has established a regular early warning system for emerging risks to conduct in-depth studies on emerging risks. Together with its clients, peer banks and regulators, Citibank has measured the global capacity for ESRM, providing a bottom line of what environmental risks can be tolerated.

The Environmental and Social Reputational Risk Framework (Deutsche Bank, 2011) was developed to guide the ESRM process. It is incorporated in the Reputational Risk Management Framework. Deutsche Bank is required to submit quarterly reports to the Group Reputation Risk Committee on its environmental risk exposures, environmental risk controls, environmental risk trends and management. Deutsche Bank also classifies different industries according to environmental and social risk sensitivity.

In March 2006, Japanese Mizuho Bank set up a Sustainability Office, incorporating the EPs into its business processes and establishing a new project financing approval process. Mizuho Bank conducts the ERE for each financing of its customers. The ERE includes firstly whether the borrower's environmental management system is sound, whether the borrower's environmental management system is ISO14001 certified, whether the environmental responsibilities between various departments of the enterprise are clear, and whether the enterprise regularly publishes its environmental report to the public. Secondly, the process also evaluates the borrower's production situation and environmental compliance.

3.1.2.4 Comparison of green indices

Green indices are receiving increasing attention from all parties. Representative ones are the Standard and Poor's (S&P) Dow Jones Sustainability Group Index (DJSGI) and the Morgan Stanley Capital International (MSCI) Global Environmental, Social, and Governance (ESG) Index.

(1) The DJSGI

On September 8, 1999, Dow Jones Index, STOXX, and Swiss Sustainable Asset Management Group jointly launched the DJSGI, which has been expanded into a system of indicators with regional characteristics. As the first global system of indicators to track the financial performance of major companies, the DJSGI ranks these companies according to their sustainability criteria. The goal is to bridge the companies living up to sustainability principles and the investors who want to profit from risk-return investments and the shareholder value created by companies that prioritize environmental and social factors.

The DJSGI has received widespread acclaim since its publication. The DJSGI is published on a daily basis, so its timeliness is very strong. The DJSGI is based on rules reviewed by a third

party, which is open and transparent. The DJSGI also provides investors, companies and financial institutions with quantification of corporate sustainability finance in a unified structure, so many large banks and insurance companies use it.

(2) The MSCI ESG

The MSCI ESG rating is based on the analysis of 37 indicators and thousands of data from its vast database by more than 140 experienced analysts. The rating methodology measures the performance of each company in 10 themes under the 3 ESG pillars and 37 key ESG issues. Moreover, it concerns the degree of risk exposure under each article in each company's industry and the transferring strategy for that risk. The degree of risk exposure is divided into 11 levels from zero to ten. Zero means that the company has no risk exposure under this indicator, and ten represents the highest risk exposure. According to the company's risk exposure in each indicator and the weighted average of the risk transfer strategy, the company's rating is finally obtained.

The above studies found that in decades of international practice, governments in developed countries have gradually recognized the relationship between the banking sector and sustainable development, clarified the environmental responsibilities of banks at the legal level, and encouraged commercial banks to pay attention to environmental risk management. A large number of environmental events are having an impact on banks' operations. Stakeholders, especially NGOs, have demanded banks for environmental management. An increasing number of internationally renowned financial institutions are involved in researching quantitative systems, models, and methods for ERM via establishing ERM systems in their business processes. In this way, they have accumulated a wealth of conceptual awareness, system construction, process design, and implementation measures in management experience, thus gaining more business opportunities and improving the public image of the society.

3.2 ERM practice in Chinese commercial banks

In this thesis, four Chinese commercial banks are selected. They are the Industrial and Commercial Bank of China (ICBC), China Construction Bank (CCB), China's Industrial Bank (CIB), and Shanghai Pudong Development Bank (SPDB), the best joint-stock bank. This thesis compares and analyzes their strategy of green credit plan, credit and industry policy, ERM process, product system and research results, and the green credit balance.

3.2.1 Strategic planning for green credit

ICBC is characterized by the establishment of a comprehensive ERM system. Firstly, it clarified the direction of green credit at the strategic level and issued the Opinions on Further Strengthening Green Finance Construction (ICBC, 2020) as a planning document in green finance. This document specified the objectives, main working lines, and key measures for green finance development. ICBC has assumed international environmental responsibility by establishing a sound, comprehensive management mechanism for ecological and environmental protection, exerting financial leverage, and shifting away from reliance on traditional development paths, and promoting economic restructuring.

At present, ICBC has established a relatively sound mechanism for the long-term development of green credit. This mechanism has been integrated into its corporate vision, development strategy, credit culture, policy system, management process, and product services. According to Principles for Responsible Banking (United Nations, 2019), ICBC has joined the financial action led by United Nations Environment Programme (UNEP) and agreed to disclose its carbon information.

The Green Credit Development Strategy of China Construction Bank (CCB, 2016) set out the short, medium, and long-term development goals of green credit around three significant tasks, promoting the development of green business, preventing environmental and social risks, and improving social responsibility performance.

CIB took the adoption of the EPs as an entry point and formulated a series of organizational structures, management methods, operational guidelines and supporting policies related to the EPs. As the first EPs bank in China, CIB used the EPs as a tool to set out its environmental and social risk-related policies, specify process operations and strategic objectives, incorporate environmental and social risk management into its core business processes. Corporate Finance Business Development Strategic Plan 2011-2015 (CIB, 2010) included the concepts and connotations related to sustainable finance, and the Environmental and Social Risk Management Strategy (CIB, 2011) was formulated. CIB agreed to join the responsible banking led by UNEP (United Nations, 2019).

As the first Chinese-funded commercial bank to publish the CSR Report (SPDB, 2021a), SPDB's layouts in green finance are inseparable from the support of top-level design. SPDB took the lead in the industry to launch the Green Credit Comprehensive Service Plan (SPDB, 2008). In November 2021, SPDB officially released the "SPDB Green Innovation" brand (China Daily, 2021), iterating the Green Credit Comprehensive Service Plan (SPDB, 2008) to

version 3.0. The Financial Helping Carbon Neutral Development and Achieving the Blue Book (SPDB, 2021b) was also released, which included the development of green finance as its 14th Five-Year strategic plan. It showcased SPDB's clearly following the transformation towards carbon commission peak and carbon neutrality and its determination to serve industry transformation and upgrading as a green bank.

3.2.2 Credit and industry policies

ICBC took the lead in issuing the Opinions on Promoting the Construction of Green Credit (ICBC, 2007), strengthening risk management in environmentally sensitive industries, proposing the establishment of an environmental protection veto system for credit, and not granting loans to projects that do not comply with environmental protection policies, thus curbing environmental pollution at source.

In accordance with national industrial policies, environmental protection standards and industry operation conditions, ICBC has formulated green credit policies covering multiple industries and set different economic capital adjustment coefficients according to industry classifications to encourage and guide the entire bank to invest limited credit resources in ecological protection, clean energy, energy-saving, and environmental protection, circular economy, and other green economy fields.

ICBC has actively supported key green industries, such as new energy power generation, green infrastructure construction, and ecological and environmental protection. ICBC embeds its clients' environmental protection technology and other indicators into project access standards to systematically guide the green adjustment of investment and financing structure. ICBC issued quota management plans for key domestic industries, and implemented maximum quota management for the enterprises with high emissions and pollution (ICBC, 2021a).

CCB incorporated environmental and climate risks into its comprehensive risk management system. ERM has been incorporated into its risk management process, and the environmental protection veto system has been implemented for loans to enterprises and projects that do not meet environmental protection requirements. CCB also adjusted the approval authority for certain credit businesses following the national policy guidance, adopted differentiated industry authorization management, and strictly approved the approval of high-energy-consuming and high-polluting industries such as ferroalloys and calcium carbide (CCB, 2021).

CCB has increased its credit support for green, energy-saving, and emission-reduction

projects and strictly restricted credit allocation to high-energy-consuming, high-polluting, and overcapacity industries. CCB channeled most of its loans to the areas, such as ecological protection, environmental governance, sewage treatment and other environmental protection industries, the transformation and upgrading of traditional industries, and green environmental protection. CCB supported clients and projects with commercial sustainability, good market prospects, and meeting the circular economy and green economy requirements (CCB, 2021).

CCB has stepped up its research on green credit-related industries' approval and formulated approval guidelines covering high-energy-consuming, high-polluting, and overcapacity industries such as iron and steel, and cement. They issued guidelines on the consent of high-environmental-risk industries and energy-intensive industries such as waste incineration and power generation, modern coal chemical industry, production and supply of tap water, sewage treatment and its recycling, photovoltaic industry, new energy auto parts, water conservancy projects, modern agricultural machinery, new rural loans industries, and environmental protection-related industries. CCB formulated detailed credit guidelines for specific industries and developed an early warning system to automatically alert branches when loan amounts in the two high-risk sectors are within industry limits. In 2020, CCB proposed incorporating environmental and climate risks into a comprehensive risk management system (CCB, 2021).

The adoption of the EPs is a milestone in developing CIB's green finance. The EPs have brought a set of environmental and social risk management systems to Industrial Bank, and a series of guidelines for lending to energy-saving and emission reduction projects have been issued, such as Management Measures for Energy-saving and Emission Reduction Business, Rules for Access to Energy-saving and Emission Reduction Projects, and Criteria for Determining the Attributes of Energy-saving and Emission Reduction Projects in Environmental Finance (Xinhua, 2012).

In 2020, CIB continued to adopt the principle of controlling the incremental volume of credit outstanding, optimizing the stock and adjusting the structure in the field of overcapacity, and implemented a differentiated credit policy for overcapacity industries such as iron and steel, coal, and non-ferrous metals, taking into account the national industrial policy, regional resource endowment, and environmental protection compliance. During the implementation of strict control, CIB actively grasped business opportunities in the supply-side structural reform and optimized its business structure by strengthening business access management and industry limit management following the strategy of advantageous regions and high-quality leaders to help China's supply-side reform.

At the same time, CIB's credit business paid more attention to non-financial factors such as the environment, society, and corporate governance and actively guided credit resources to industries with low energy consumption, low emissions, low pollution, high efficiency, and good market prospects.

SPDB launched Green Future: Green Finance Integrated Service Solution 3.0 (China Daily, 2021), forming a green credit product and service system covering the upstream and downstream of the low-carbon industry chain. SPDB's green credit business has covered more than 20 industries, such as construction, electricity, steel, cement, petrochemical, renewable energy, emission rights, and carbon trading, involving more than 60 technology types, such as oil saving and replacement, coal-fired boiler renovation, waste pressure, and waste heat utilization. All projects were relatively mature in energy saving and emission reduction technology and can yield high economic and social benefits.

3.2.3 ERM process

Firstly, ICBC strengthened the whole process of ERM. It prudently controlled risks in all aspects of due diligence, project evaluation, rating and credit, review and approval, contract signing, fund allocation, lending, and post-investment management. Strictly abide by the ecological protection red line. Secondly, ICBC focused on post-credit environmental monitoring, requiring account managers to keep an eye on the environmental protection status of enterprises to maximize the prevention of risks that may arise from unexpected environmental events. ICBC's internal credit management system also carried out "environmental protection information labelling" for corporate clients, classifying all enterprises according to environmental protection requirements into environmentally friendly, environmentally qualified, environmentally concerned, and potentially risky; and implemented different credit policies for other categories, initially forming a database of clients' environmental protection risks.

Based on the EPs and the International Finance Corporation (IFC) Performance Standards and Guidelines, ICBC issued the Green Credit Classification Management Measures (ICBC, 2021b), which divided domestic corporate loan customers and projects into four levels and 12 categories and embedded them into ICBC's asset management system to achieve scientific and quantitative management of environmental and social risks.

CCB classified clients into three categories, A, B, and C, according to the level of their environmental and social risks. CCB integrated environmental and social management into the

entire credit business process. CCB also developed an early warning tracking system for post-credit management, integrating information from external environmental monitoring and its asset portfolio. They focus on regions and industries with severe pollution and major environmental violations, pinpointing the “black swans” of environmental problems.

CCB achieved these by optimizing proactive control, actively applying new achievements in environmental protection information technology development, strengthening the identification of environmentally sensitive areas and industries, proactively adjusting credit structures, strengthening intelligent control, making full use of big data tools, identifying risk hazards in advance through risk warning platforms, pushing risk information in a targeted manner, and classifying and managing graded warnings.

CIB independently developed the “Green into Gold” system to ensure its business group and large-scale development. The system consisted of five functional modules, green customer management, green business identification, environmental benefit measurement, green asset management, and evaluation of equatorial principles. This system highlighted five major perspectives. First, it independently developed 40 sets of environmental benefit measurement modules, covering dozens of industries related to a low-carbon economy, circular economy, and ecological economy, with a broad scope of application and realizing accurate assessment of environmental benefits. Secondly, it added a green asset management module to meet regulatory requirements. Thirdly, the system can centralize the management of green loans of the CBRC and green financial debt assets. Fourthly, artificial intelligence models were introduced for the first time. Fifthly, the timeliness and accuracy of green business identification were significantly improved through keyword recognition, deep machine learning, and other digital technologies, which can substantially accelerate the efficiency of manual operations.

CIB used big data analysis technology and customer relationship network algorithms to collect and analyze a large amount of operational data from enterprises, analyzed and evaluated target lenders’ social and environmental risks in quasi-real-time, and efficiently developed a green finance customer sandbox.

In its credit business, SPDB strictly followed the requirements on ERM proposed in interim measures on social and environmental risk management of SPDB and strengthened ERE for environmentally sensitive industries in terms of process level, geographic location, enterprise employment. Following China’s environmental laws and regulations, industrial policies, the List of Excluded Activities, SPDB increased support for renewable energy and clean energy projects, invested heavily in energy-saving and consumption-reducing

technological improvement projects, harmless treatment of pollutants and waste recycling and reuse projects, and promoted the production and application of environmentally friendly products and equipment (Liang, 2014).

3.2.4 Product system and research results

ICBC and CCBC were able to leverage their group strengths to actively build a diversified green financial service system in product innovation, providing total product and comprehensive support to the green economy. These were done through financial advisory, bond underwriting, project loans, leasing, factoring, financial investment, industrial funds, and other means.

CIB promoted a specialized green finance operation system, innovated product systems and service models in energy conservation and environmental protection, and formed financial service solutions in the field of emission rights. In terms of green financial product innovation, CIB transformed national and local support policies for green development into products and services that facilitate green financing through the advantages of its professional capabilities in green finance, and innovatively launched “environmental protection loan”, “water conservation loan”, “green ticket pass” and “green creation loan”. CIB released the first ESG financial product. These measures effectively alleviated the problems of lack of collateral, difficulty in the financing, and expensive funding in enterprises’ green transformation and development and enhanced the quality and effectiveness of the guidance and leveraging effect of special government green funds.

SPDB’s green credit products and service system comprise five major segments and ten innovative products. The five segments were energy efficiency financing (industrial and building energy efficiency), clean energy financing, environmental finance, carbon finance, and green equipment supply chain financing. The ten special products were: IFC energy efficiency loan, French Development Agency green intermediate credit, Asian Development Bank building energy efficiency loan, contract energy management future income right pledge financing, clean development model factoring financing.

The Stress Test Study on the Impact of Environmental Factors on Commercial Banks’ Credit Risk (ICBC, 2016) was released. This study fills the gap in China’s banking industry in environmental risk quantification and transmission mechanism research and plays a leading role in the global banking industry to carry out green finance and environmental risk quantification research. On the other hand, CCB chose the thermal power and chemical sectors

for its stress tests.

3.2.5 Green credit balances

According to the Notice on the Work Related to the Green Financing Statistical System (China Bank and Insurance Regulation Commission [CBIRC], 2020), ICBC green loans to energy conservation, environmental protection, clean production and other green industries had a balance of RMB 1.845719 trillion, and the total amount of loans to the industries with high emission and pollution remained stable or declined slightly for many years as of the end of 2020.

By the end of 2020, the balance of green credit of CCB was RMB 1.342707 trillion, which strongly supported green projects such as industrial energy conservation and emission reduction, comprehensive environmental management, clean energy utilization, inhibited the start of production of polluting projects, and created good economic and social benefits. The green credit projects supported by CCB in 2020 saved 35.0648 million tons of standard coal, reduced 73.8866 million tons of carbon dioxide, and saved 113.3387 million tons of water (CCB, 2021).

By the end of 2020, CIB had a balance of RMB 1.15576 trillion million in green finance financing, serving a total of 29,829 green finance clients. The balance of loans to the industries with high emissions and pollution accounted for 2.62% of the total public loans, down by 0.11% from the same period of the previous year (CIB, 2021).

By the end of 2020, the balance of financing in the green finance sector of SPDB and banks reached RMB 500 billion, including a balance of over RMB 260 billion in green credit, RMB 33.855 billion in green bond underwriting, and RMB 34.531 billion in green bond investment, including self-management and wealth management (SPDB, 2021a).

3.2.6 Green rating and green index development

ICBC and Shanghai China Securities Index Company jointly developed and released the CSI 180 ESG Index (ICBC, 2018), the first ESG index in China. On the basis of research and experience of international rating agencies, fully considering the characteristics of China's national conditions and Chinese enterprises, ICBC combined their internal client data with environmental data and public information of customers held by Trucost, a subsidiary of S&P, to build the first ESG green rating system among Chinese commercial banks. ICBC conducted trial calculations on a sample of CSI 180 enterprises to form the Green Development Index and

Green Investment Index. The ESG rating system is the first one among domestic commercial banks. The ESG evaluation system has good application value for banks to identify clients and guide sustainable investment.

The above analysis shows that, in terms of ERM level, state-owned commercial banks are better than joint-stock commercial banks. A relatively complete system of ERM characterizes ICBC. CCB is more prominent in the analysis of environmental risks in the industry. CIB has accumulated rich experience in the adoption and practice of the EPs. SPDB has developed a large number of green financial products. The contribution made by large state-owned commercial banks to the field of green finance is greater than that of joint-stock commercial banks.

3.3 Main issues about ERE facing commercial banks in China

3.3.1 Inadequate quantitative analysis

Quantitative research and assessment can help to improve rational decision-making and thus avoid costly mistakes in decision-making. While internationally advanced banks generally value the importance of quantitative analysis of environmental risks, Chinese commercial banks mainly rely on compliance approvals and environmental information blacklists, which only represent whether a company meets national environmental standards at a certain point in time. However, a company's environmental condition is dynamic. It may either be improving or deteriorating as time goes by, so relying solely on this limited information to make decisions is unscientific. Few Chinese commercial banks have developed separate ERM procedures, lacking a strict combination of quantitative and qualitative ERE methods and models and failing to make a reasonable and detailed evaluation of the environmental risks contained in the project during the pre-lending due diligence stage. Borrowing companies are not required to continuously submit their environmental evaluation reports to banks during the use of green credit funds, making it difficult for banks to continuously track the environmental risks of the borrowing companies.

3.3.2 Inconsistent evaluation criteria

The mainstream commercial banks abroad have all joined EPs and have widely applied the EPs to ERM in project financing, including classifying and evaluating the environmental risks of projects, assessing the feasibility of clients' environmental risk prevention and control plans,

requiring environmental clauses to be included in loan contracts when approving loans, and conducting environmental risk tracking and monitoring after loan issuance. However, only CIB and Bank of Jiangsu are EPs banks in China (Xinhua, 2017).

Apart from that, on the one hand, a relatively unified and authoritative standard for ERE has not been formulated. As different companies or projects have their own specificity and complexity, ERE is difficult, professional, and involves various fields. Therefore, it isn't easy to unify evaluation standards. On the other hand, the indicator settings of different institutions lack comparability. If functional departments, such as CBIRC and PBoC, can take the lead in researching ERE, formulate unified evaluation standards and rules, and promote them in various financial institutions, they will play a good role in guiding other banks.

3.3.3 Lack of data availability and reliability

The construction of ERE indicators and the evaluation results are limited by corporate environmental information disclosure quality. Information disclosure is mandatory for listed companies and debt-issuing companies in China. In terms of public environmental data, many data are too costly to search and poorly available, and there is much room for improvement. The sources of environmental information are diverse, a large number of companies select some types of information to disclose. Information about the environment is highly specialized and not updated on time. There is no information sharing among banks and between banks and environmental protection departments. The information obtained by banks still needs to be interpreted and screened by internal specialized departments and professionals. Nonetheless, a few commercial banks have made efforts to get corporate environmental information through multiple channels, paving the way for the construction of ERE criteria in the future.

3.3.4 Lack of fine-grained industry guidelines

Some large foreign commercial banks have formulated fine-grained industry guidelines for environmentally sensitive industries, such as iron and steel, chemical and electric power. These guidelines include the environmental issues that may arise from the industry's production and operation and the corresponding regulatory requirements, which greatly saves the cost and time of pre-lending due diligence and creates convenient conditions for commercial banks to conduct ERE. Chinese commercial banks still lack internal ERE methods for different industries. Although some industry guidelines have been formulated, they are somewhat general, only possessing a certain degree of guidance from a macro perspective. These industry

guidelines are not refined to the various processes in the industry sector. Referring to the experience of advanced foreign banks, proposing targeted ERE criteria for environmentally sensitive industries, such as steel, chemical, and coal, is the main task for Chinese commercial banks to improve their ERM capabilities in the future.

3.4 Chapter summary

This chapter compares the practice of ERM of Chinese and foreign commercial banks. It can be seen that developed foreign countries, Europe, the United States, Japan, and Germany, attach great importance to legislation to clarify the environmental legal responsibilities of commercial banks and companies. They are concerned with disclosing information to stakeholders and establishing a comprehensive set of internal institutions, mechanisms, and processes.

On the other hand, Chinese commercial banks have different capabilities of ERM and are not very active in ERM due to the lack of clarity on the environmental legal responsibilities of banks. However, they are still very cautious in adopting international initiatives such as EPs. Most banks have much room for improvement in institutions, mechanisms, and internal processes.

A comparison of ERE practices of banks in different countries around the world and various systems in China shows that ERE is a major step in managing environmental risk, and this chapter leads to the following conclusions.

Firstly, compared with the international banking industry, ERM in China's banking sector is at an intermediate level, lagging behind the banking sector in developed countries. In general, the state-owned banks outperform joint-stock banks, urban commercial banks, and agricultural commercial banks. The Chinese banking industry was slow in launching ERM but caught up. Most of the progress is manifest in policy guidance from regulators, but the banking industry still lacks awareness of ERM.

Secondly, given the strict provisions of the relevant laws, the banking sector in developed countries has defined strategic objectives, equipped with a sound organizational management structure. They integrated ERM into business processes and established rules and measures to monitor and manage implementation, with relatively strong ERM expertise for environmentally sensitive industries.

Thirdly, a comparative analysis shows that Chinese commercial banks lack specific operational rules and evaluation methods. However, an increasing number of Chinese banks are paying attention to developing quantitative tools and models for environmental risk based on

their development situation combined with policies. How to measure environmental risk becomes the key to ERM in Chinese commercial banks.

Chapter 4: Game Equilibrium Analysis of ERM of Commercial Banks

From the perspective of ERM of commercial banks, this chapter analyzes the evolutionary game equilibrium of government departments, commercial banks, and steel companies, and analyzes theoretically how commercial banks can effectively implement ERM for the steel industry, and explore influencing factors of commercial banks when implementing ERM for the steel industry, which provides a theoretical basis for the establishment of ERM indicators for China's steel industry by commercial banks.

4.1 Behavioral characteristics of game participants

According to the theory of sustainable financial development, social responsibility theory, and ERM from the theoretical analysis section of Chapter Three, it can be seen that ERM of commercial banks involves all levels of government departments (the People's Bank of China [PBoC], Ministry of Finance [MOF] of the People's Republic of China, China Banking Regulatory Commission [CBRC], Ministry of Land and Resources of the People's Republic of China), commercial banks and steel companies, and it is a three-party game. Therefore, it is necessary to analyze the behavior characteristics of the above three participants who engage in the game.

4.1.1 Goals and behavioral characteristics of government departments

Documents including Guiding Opinions on Credit Granting for Energy Conservation and Emission Reduction (CBRC, 2007), Green Credit Guidelines (CBRC, 2012), Energy Efficiency Credit Guidelines (CBRC & NDRC, 2015), Guidance on Building a Green Financial System (PBoC, 2016) clearly defined green credit and green financial systems, and put forward the vigorous efforts in contributing for the development of green credit. According to the policies mentioned above, government departments' work objectives are as follows: One is to prevent and defuse major financial risks to prevent and control environmental pollution, and the other is to achieve sustainable economic and social development. Therefore, its behavioral characteristics are embodied as follows: On the one hand, they encourage (regulate)

steel companies and commercial banks to maximize profits and taxes while meeting the constraints of sustainable development. On the other hand, they restrict and punish (do not regulate) iron and steel enterprises and commercial banks to maximize profits under the production model of HECE.

4.1.2 The goals and behavioral characteristics of commercial banks

At present, China has established a green credit system framework with the Green Credit Guidelines (CBRC, 2012) as the core and has stipulated the policy boundaries, management methods, and assessment policies for commercial banks and other financial institutions to carry out energy conservation and environmental protection credit and green credit, so as to ensure that credit funds are channeled to low-carbon, recycling, and ecological fields. Therefore, commercial banks need to weigh their credit funds' expected benefits and risks when performing risk management on steel companies. The goal of allocating credit funds is to actively manage and avoid the environmental factors that steel companies face (such as air pollution, water pollution, and solid waste pollution) and risks caused by macroeconomic, policy, and industry changes to achieve the maximum return of credit funds. Due to the lack of credit evaluation systems to assess potential environmental risks caused by steel companies in commercial banks, the behavioral characteristics of commercial banks are as follows. On the one hand, they build an ERE system for the steel industry. Carry out ERM and allocate credit funds to iron and steel enterprises and projects that meet the principle of sustainable development. On the other hand, ERM is hardly implemented according to the existing credit evaluation indicators, and loans are granted to high-energy, high-polluting iron and steel enterprises and projects. Judging from the cooperation projects between major commercial banks and steel enterprises in 2019, banks' credit strategy to support the development of the steel industry is mainly based on strategic cooperation with leading enterprises in the steel industry, with credit allocation focused on deleveraging, going global, asset management, upgrading and transformation.

4.1.3 The goals and behavioral characteristics of iron and steel enterprises

The iron and steel industry is specific in China with high energy consumption, high pollution, and serious overcapacity. According to the Central Bank's 2019 Financial Stability Work Conference, preventing and resolving financial risks, especially avoiding systemic financial risks, is the fundamental task of financial work. Therefore, despite years of supply-side reforms,

the steel industry has completed the elimination goal proposed in the “13th Five-Year Plan” two years ahead of schedule and 2019 Notice on the Work of Dismantling Excess Capacity in Key Areas (Inter-Ministerial Joint Conference on Capacity Removal [IMJCCR], 2019, 2020) has not removed the iron and steel industry from industries with excess production capacity. As a result, commercial banks are still cautious in granting credit to the iron and steel industry.

Faced with the regulations required for the development of the green economy and with the continuous improvement of environmental protection standards in the steel industry, China’s steel companies need to manage their risks caused by changes in macroeconomic, policy, and industry related to environmental factors (such as air pollution, water pollution, and solid waste pollution) in order to achieve the maximum profits for the output value. Therefore, their behavioral characteristics are reflected in: on the one hand, they cooperate with the regulation and management of the government and commercial banks, and invest in upgrading and transforming high-energy, high-polluting production processes and production models to reduce the risks caused by changes of macroeconomic, policy, and industry related to environmental factors (such as air pollution, water pollution, and solid waste pollution), so as to maximize the profits under the sustainable development model of steel enterprises. On the other hand, they avoid (escape) the regulation and management of the government and commercial banks and continue the production process and production model with HECE to pursue profit maximization blindly.

4.2 The game theory model between governments and commercial banks

4.2.1 Analysis of game equilibrium between government departments and commercial banks

For the government, the game’s goal is to fight against pollution, solve significant environmental problems that the people have strongly reflected, and improve the level of economic development. The behavioral characteristics are reflected in: on the one hand, it supports (regulates) steel companies and commercial banks to maximize their profits and taxes under sustainable development constraints. On the other hand, it punishes (does not regulate) commercial banks for lending to high-energy, high-polluting steel companies and projects, aiming at extensively pursuing profit maximization. The game strategy is the implementation of regulation or not.

For commercial banks, the goal of the game is to actively manage, avoid risks changes of

macroeconomic, policy, and industry related to environmental factors (such as air pollution, water pollution, and solid waste pollution), and maximize the return on credit funds. Due to the lack of existing credit evaluation systems to evaluate potential environmental risks caused by steel companies in commercial banks, the behavioral characteristics of commercial banks are as follows. On the one hand, they build an ERE system for the steel industry, carry out ERM and allocate credit funds to iron and steel enterprises and projects that meet sustainable development. On the other hand, the ERM is not implemented to lend to high-energy, high-polluting iron and steel enterprises and projects according to the existing credit evaluation indicators. The game strategy is the implementation of ERM or not.

The game theory model between commercial banks and government departments is as follows.

Table 4.1 can be further illustrated by that R_1 ($R_1 > 0$) is the green financial asset income obtained by the commercial bank through ERM, R_2 ($R_2 > 0$) is the green financial asset income obtained by the commercial bank without ERM, and $R_1 > R_2 > 0$. σ_1 is the financial risk index of commercial banks, and σ_2 is the environmental risk index of the steel industry faced by commercial banks. K_1 ($K_1 > 0$) is the financial risk coefficient, and K_2 ($K_2 > 0$) is the environmental risk coefficient (ERC) for commercial banks to implement ERM. Finally, K_3 ($K_3 > 0$) is the ERC for commercial banks not implementing ERM, and where we have that $K_3 > K_2 > 0$.

Table 4.1 The game between governments and banks

Commercial banks Government departments	With ERM	Without ERM
Regulation	$(0, R_1 - K_1 * \sigma_1 - K_2 * \sigma_2)$	$(0, R_2 - K_1 * \sigma_1 - K_3 * \sigma_2)$
No regulation	$(-K_2 * \sigma_2, R_1 - K_1 * \sigma_1 - K_2 * \sigma_2)$	$(-K_3 * \sigma_2, R_2 - K_1 * \sigma_1 - K_3 * \sigma_2)$

Proposition 4.1: The equilibrium of the game between governments and commercial banks is given by the following state: (regulation, implementation of ERM).

It can be observed from the game theory model that, on the one hand, from the perspective of commercial banks' game analysis, commercial banks choose between two strategies of either implementing ERM or not implementing ERM. When implementing ERM, commercial banks will obtain a return represented by R_1 . The expression, $-K_1 * \sigma_1 - K_2 * \sigma_2$, reflects the risks brought by macroeconomic, policies, and industry changes, including environmental factors (such as air pollution, water pollution, and solid waste pollution) involved in the allocation of credit resources to steel companies when commercial banks implement ERM. If ERM is not implemented, the commercial bank will get a return of R_2 . The expression, $-K_1 * \sigma_1 - K_3 * \sigma_2$, reflects the risks that commercial banks would face if they allocate credit to steel companies

involving environmental factors (e.g. air pollution, water pollution, solid waste pollution) caused by macroeconomic, policy, and industry changes when ERM is not implemented. On the other hand, from the government's game analysis perspective, governments choose between the two game strategies: regulation and not regulation for the green development goals. By regulating, governments can achieve the performance goal of mitigating financial environment risks to zero. However, without regulation aiming at green development, when the credit resources of commercial banks are allocated to steel companies, the governments will face the environmental risks ($-K_2 \cdot \sigma_2$ or $-K_3 \cdot \sigma_2$) caused by macroeconomic, policy, and industry changes.

The government's risk of implementing regulation for green development is zero, while the risk of non-regulation is $-K_2 \cdot \sigma_2$ or $-K_3 \cdot \sigma_2$, so the government's optimal strategy is to regulate. At the same time, because $K_3 > K_2 > 0$, $R_1 > R_2 > 0$, $(R_2 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$ is less than $(R_1 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2)$, which means that commercial banks choose to implement ERM, since they tend to obtain higher benefits and lower risks. Therefore, their optimal strategy of the game is to implement ERM. The above-mentioned game between governments and commercial banks attains the equilibrium for the following strategy pair: (regulation, implementation of ERM), and its risk and the return value is $(0, R_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$.

4.2.2 Game equilibrium analysis among commercial banks

In order to promote sustainable development, governments at all levels follow the principle that lush mountains and lucid water are invaluable assets (Xi, 2014). At the same time, they have implemented institutional incentives for governments and commercial banks Punishment mechanism. In the context of increasing RA_1 , RB_1 (incentivizing commercial banks to conduct ERM), and K_3 (punishing government non-regulatory behavior and commercial banks not performing ERM) by administrative means, the strategies of governments at all levels will choose to regulate. The game analysis of ERM among commercial banks is shown in Table 4.2.

Table 4.2 The game between commercial banks A and B

Commercial bank B	Implement ERM	Not implement ERM
Commercial bank A		
Implement ERM	$(RA_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2, RB_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$	$(RA_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2, RB_2 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2)$
Not implement ERM	$(RA_2 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2, RB_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$	$(RA_2 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2, RB_2 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2)$

RA_1 ($RA_1 > 0$) is the green financial asset income obtained by Commercial Bank A from ERM. RA_2 ($RA_2 > 0$) is the green financial asset income obtained by commercial bank A without implementing ERM, and $RA_1 > RA_2 > 0$. σ_1 is the financial risk index of Commercial

Bank A. $\sigma A2$ is the environmental risk index of the steel industry faced by Commercial Bank A. $RB1$ ($RB1 > 0$) is the green financial asset income obtained by commercial bank B's ERM. $RB2$ ($RB2 > 0$) is the green financial asset income obtained by commercial bank B without implementing environmental risks, and $RB1 > RB2 > 0$. $\sigma B1$ is the financial risk index of Commercial Bank B. $\sigma B2$ is the environmental risk index of the steel industry faced by Commercial Bank B.

$K1$ ($K1 > 0$) is the financial risk coefficient. $K2$ is the environmental risk moderation coefficient for Commercial Banks A and B to implement ERM. $K3$ is the environmental risk penalty coefficient for Commercial Banks A and B that do not implement environmental risk management, and $K3 > K2 > 0$.

Proposition 4.2: The equilibrium state of the game between Commercial Banks A and B is: (implementation of ERM, implementation of ERM).

From the game theory model, it can be observed that Commercial Banks A and B choose between two game strategies of implementing ERM and not implementing ERM. When implementing ERM, Commercial Banks A and B will obtain the benefits $RA1$ and $RB1$. $(-K1 \cdot \sigma A1 - K2 \cdot \sigma A2)$ and $(-K1 \cdot \sigma A1 - K2 \cdot \sigma A2)$ reflect the environmental factors (such as air pollution, water pollution, solid waste pollution) caused by macroeconomic, policy, and industry changes. If ERM is not implemented, Commercial Banks A and B will receive $RA2$ and $RB2$. In this case, $-K1 \cdot \sigma A1 - K3 \cdot \sigma A2$ and $-K1 \cdot \sigma B1 - K3 \cdot \sigma B2$, reflect the macroscopic view of the environmental factors (such as air pollution, water pollution, solid waste pollution) involved in the allocation of credit resources to steel companies when commercial banks A and B do not implement environmental risk management Risks caused by economic, policy, and industry changes.

Since $K3 > K2 > 0$, $RA1 > RA2 > 0$, $RA1 > RA2 > 0$, we have that:

$$(RA2 - K1 \cdot \sigma A1 - K2 \cdot \sigma A2) < (RA1 - K1 \cdot \sigma A1 - K3 \cdot \sigma A2) \text{ and} \\ (RB2 - K1 \cdot \sigma B1 - K2 \cdot \sigma B2) < (RB1 - K1 \cdot \sigma B1 - K3 \cdot \sigma B2),$$

which means Commercial Banks A and B choose to implement ERM to obtain higher benefits and lower risks than not to implement ERM. Therefore, the optimal strategy of the game between Commercial Banks A and B is to implement ERM. The equilibrium of the game between the Commercial Bank A and B is (implementing ERM, implementing ERM), and its risk and the return value is $(RA1 - K1 \cdot \sigma A1 - K2 \cdot \sigma A2, RB1 - K1 \cdot \sigma B1 - K2 \cdot \sigma B2)$.

4.3 The game theory model between government and steel enterprises

4.3.1 Analysis of game equilibrium between government departments and steel companies

For the government, the game's goal is to fight pollution, solve significant environmental problems that the people have strongly reflected, and improve economic development. Its behavioral characteristics are reflected in: On the one hand, it supports (regulates) steel companies to maximize profits and tax revenues while meeting sustainable development. On the other hand, it punishes and restricts (not regulates) the behavior of steel enterprises in pursuit of profit maximization under the production mode of high energy and high pollution. The game strategies are to implement and not implement the regulation.

The behavioral characteristics of steel companies are reflected in the following: on the one hand, they cooperate with the government and commercial banks, invest funds to upgrade and transform high-energy, high-polluting production processes and production models, and reduce risks caused by environmental factors (such as air pollution, water pollution, solid waste pollution) and changes in macroeconomic, policy, and industry to maximize the profits under the sustainable development model. On the one hand, it evades (avoids) the regulation and management of the government and commercial banks. It sticks to high energy and high-polluting production technology and mode in the pursuit of profit maximization blindly. Its game strategies include control pollution, not control pollution.

The game theory model between government departments and steel companies is analyzed in Table 4.3.

Table 4.3 The game between government departments and steel companies

	Steel companies Control pollution	Not control pollution
Government		
Regulate	$(0, RG1-C1*\sigma2)$	$(0, RG2-C2*\sigma2)$
Not regulate	$(-C1*\sigma2, RG1-C1*\sigma2)$	$(-C2*\sigma2, RG2-C2*\sigma2)$

$RG1$ ($RG1>0$) is the output income of the iron and steel enterprise for environmental pollution control. $RG2$ ($RG2>0$) is the output income of the iron and steel enterprise without environmental pollution control, and $RG1>RG2>0$. $\sigma2$ is the ERI of steel enterprises. $C1$ is the risk cost coefficient of the steel enterprise implementing environmental pollution control. $C2$ is the risk penalty coefficient of the steel enterprise not implementing environmental pollution control, and $C2>C1>0$.

Proposition 4.3 The equilibrium state of the game between the government and steel companies is: (regulation, implementation of environmental pollution control).

From the game theory model, it can be seen that, on the one hand, from the perspective of the game of iron and steel enterprises, they choose between the two game strategies of controlling pollution and not controlling pollution. When controlling pollution, the iron and steel enterprise will receive a profit of $RG1$. $-C1*\sigma2$ reflects the risk cost input of macroeconomics, policies, and industry changes involving environmental factors (such as air pollution, water pollution, solid waste pollution) when iron and steel companies control pollution. When pollution control is not implemented, the iron and steel enterprises will gain $RG2$. $-C1*\sigma2$ reflects the risk penalty cost caused by changes in macroeconomics, policies, and industries that involve environmental factors (such as air pollution, water pollution, solid waste pollution) when iron and steel companies do not control pollution. On the other hand, from the perspective of the government game, the government chooses between two game strategies of implementing supervision and not implementing supervision. By implementing supervision and pursuing green development goals, the government can achieve performance in pollution treatment and solve financial environmental risks. Without supervision on whether iron and steel companies conduct green production, the government will face risk penalty costs $-C1*\sigma2$ or $-C2*\sigma2$. The risk penalty cost $-C1*\sigma2$ or $-C2*\sigma2$ is caused by macroeconomic, policy, and industry changes involving environmental factors (air pollution, water pollution, solid waste pollution) faced by steel companies.

The government's risk of supervising the green development goal is zero, while non-supervising will face the risk penalty cost at $-C1*\sigma2$ or $-C2*\sigma2$, so the government's optimal strategy is to conduct regulation. At the same time, because $C2>C1>0$ and $RG1>RG2>0$, we have that: $(RG1-C1*\sigma2) < (RG2-C2*\sigma2)$. It means that iron and steel enterprises that choose to implement environmental pollution control need invest more in the short term, but the long-term benefits are higher than those that do not conduct the pollution control. The optimal strategy of the game is to implement pollution control. Therefore, the game equilibrium between the government and steel enterprises is (regulation, implementation of pollution control), and its risk and return value are $(0, RG1-C1*\sigma2)$.

Government departments should take scientific, green, and sustainable development at all levels. They should be guided by the principle that lush mountains and lucid water are invaluable assets (Xi, 2014) to prevent and defuse major financial risks and win the battle against environmental pollution. They should use reform and innovation to stimulate endogenous economic power, and promote the steel industry to enter a high-quality, green development model, and satisfy the people's pursuit of a better life. Therefore, in order to ensure the stable and lasting realization of equilibrium in the game between the government and

steel companies (regulation, implementation of pollution control), it is necessary to establish an incentive and punishment mechanism for governments at all levels and steel companies, which is to increase RG1 (encourage iron and steel companies to carry out pollution control) through administrative policies, and C2 (punish government non-regulatory behavior and steel enterprises for not carrying out pollution control). Then the game mechanism will help realize the game equilibrium results that governments at all levels regulate proactively, and iron and steel enterprises take the initiative to implement pollution control.

In the same way, to implement the incentive and punishment mechanism for pollution control of governments at all levels and steel companies (adjusting RG1 and C2 indicators), the key point is to accurately and effectively evaluate and measure the environmental risk index σ_2 involving the ERI of steel companies. However, there is insufficient research on the evaluation system of σ_2 , ERI in HECE industries. It is urgent to establish an evaluation system for σ_2 , ERI for the steel industry, which will be presented in the next chapter.

4.3.2 Analysis of game equilibrium between steel companies

Governments at all levels set the goal of advocating scientific, green, and sustainable development and winning the battle against environmental pollution. They should follow the principle that lush mountains and lucid water are invaluable assets (Xi, 2014). At the same time, incentive and punishment mechanisms are implemented for governments at all levels and commercial banks via increasing RG1 (incentivizing steel companies to conduct pollution control) and C2 (punishing government non-regulatory behavior and steel companies for not performing pollution control) through administrative means. Then governments at all levels will choose to regulate. The game analysis of pollution control among steel companies is presented in Table 4.4.

Table 4.4 Game between steel companies

Steel Company A	Steel Company B	Control pollution	Not control pollution
Control pollution		$(RGA1-C1*\sigma A2, RGB1-C1*\sigma B2)$	$(RGA1-C1*\sigma A2, RGB2-C2*\sigma B2)$
Not control pollution		$(RGA2-C2*\sigma A2, RGB1-C1*\sigma B2)$	$(RGA2-C2*\sigma A2, RGB2-C2*\sigma B2)$

In this case, $RGA1$ ($RGA1>0$) is the income of steel enterprise A from environmental pollution control. $RGA2$ ($RGA2>0$) is the benefit of steel enterprise A when it does not control pollution and $RGA1>RGA2>0$. $\sigma A2$ is the pollution risk index of Steel Company A. $RGB1$ ($RGB1>0$) is the income of Steel Company B's when it does pollution control. $RGB2$ ($RGB2>0$)

is the benefit of Steel Company B not controlling pollution, and $RGB1 > RGB2 > 0$. $\sigma B2$ is the ERI of Steel Company B.

$C1$ is the cost coefficient for Steel Company A and B to control pollution, $C2$ is the penalty cost coefficient for Steel Company A and B when they do not control pollution, and $C2 > C1 > 0$.

Proposition 4.4: The game equilibrium between Steel Company A and B is (controlling pollution and environmental governance, controlling pollution and environmental governance).

It can be seen from the game theory model that Steel Company A and B choose between the two strategies of either implementing pollution control or not implementing pollution control. When implementing pollution control, Steel Company A and B will obtain the benefits of $RGA1$ and $RGB1$. $(-C1 \cdot \sigma A2)$ and $(-C1 \cdot \sigma B2)$ reflects the cost of environmental governance input by Steel Company A and B. Steel companies A and B that do not implement ERM receive $RGA2$ and $RGB2$ as their benefits. $(-C2 \cdot \sigma A2)$ and $(-C2 \cdot \sigma B2)$ reflect the penalty cost of Steel companies A and B for not controlling pollution.

Obviously, $RGA1 > RGA2 > 0$, $RGB1 > RGB2 > 0$, and $C2 > C1 > 0$, so $(RGA1 - C1 \cdot \sigma A2) > (RGA2 - C2 \cdot \sigma A2)$ and $(RGB1 - C1 \cdot \sigma B2) > (RGB2 - C2 \cdot \sigma B2)$. It means that if Steel companies A and B choose to control pollution, the short-term cost of pollution control is higher than not to control pollution, but the long-term benefits are higher. Therefore, the optimal strategy of the game between Steel Companies A and B is to implement pollution control. Therefore, the game equilibrium between Steel Companies A and B is: (controlling pollution and environmental governance, controlling pollution and environmental governance), and its output income and cost input are $(RGA1 - C1 \cdot \sigma A2, RGB1 - C1 \cdot \sigma B2)$.

4.4 Analysis of game equilibrium between iron and steel enterprises and commercial banks

For commercial banks, the objective of the game is to actively manage and hedge the risks faced by steel enterprises concerning environmental factors (such as air pollution, water pollution, solid waste pollution) caused by macroeconomic, policy, and industry changes in order to maximize the return on credit funds. As the existing credit evaluation system of commercial banks lacks evaluation of potential environmental risks caused by steel enterprises, the behavior of commercial banks is characterized by the following. On the one hand, they construct an ERE system for the steel industry, carry out ERM and allocate credit to steel enterprises and projects that meet sustainable development goals. On the other hand, they do not implement REM and lend to steel enterprises and projects with HECE. Their game strategy

is implementing ERM, not implementing ERM.

The behavior of steel enterprises is characterized by the following: on the one hand, they cooperate with the regulation and management of the government and commercial banks, invest in upgrading their high energy-consuming and high-polluting production processes and production modes, reduce the risks caused by macroeconomic, policy and industry changes in terms of environmental factors (e.g., air pollution, water pollution, solid waste pollution.), and maximize profits under the sustainable development model. On the other hand, they evade (avoid) the regulation and management of the government and commercial banks, and continue their HECE production processes and production patterns in a one-sided pursuit of profit maximization. Their game strategy is controlling pollution or not controlling pollution, which can be seen in Table 4.5.

Table 4.5 Game equilibrium between commercial banks and iron and steel companies

Steel companies	Commercial banks	implement ERM	not implement ERM
Control pollution		$(RG1-C1*\sigma2, R1-K1*\sigma1-K2*\sigma2)$	$(RG1-C1*\sigma2, R2-K1*\sigma1-K3*\sigma2)$
Not control pollution		$(RG2-C2*\sigma2, R1-K1*\sigma1-K2*\sigma2)$	$(RG2-C2*\sigma2, R2-K1*\sigma1-K3*\sigma2)$

Where $RG1$ ($RG1>0$) is the return of steel enterprises to control pollution, $RG2$ ($RG2>0$) is the return of steel enterprises not to control pollution, and $RG1>RG2>0$. $R1$ ($R1>0$) is the return of green financial assets (GFA) acquired by commercial banks for managing environmental risks. $R2$ ($R2>0$) is the return of GFA earned by commercial banks for not managing environmental risks, and $R1>R2>0$. Finally, $\sigma1$ is commercial banks' financial risk index (FRI), and $\sigma2$ is the ERI of steel enterprises faced by commercial banks.

$K1$ ($K1>0$) is the FRI for commercial banks. $K2$ ($K2>0$) is the environmental risk moderation coefficient for commercial banks implementing ERM. $K3$ ($K3>0$) is the environmental risk penalty coefficient for commercial banks not implementing ERM, and $K3>K2>0$. $C1$ is the cost coefficient for steel companies controlling pollution. $C2$ is the penalty cost coefficient for steel companies not controlling pollution, and $C2>C1>0$.

Proposition 4.5: The equilibrium state of the game between steel companies and commercial banks and is: (controlling pollution, implementing ERM).

From the game theory model, it can be seen that on the one hand, the steel company chooses between two game strategies: controlling pollution or not controlling pollution. Treating pollution results in a gain of $RG1$ for the steel company, and $(-C1*\sigma2)$ reflects the steel company's cost of pollution treatment. When ERM is not implemented, the profit of the steel

company is RG_2 , and $(-C_2 \cdot \sigma_2)$ reflects the penalty cost of the steel company for not controlling pollution. On the other hand, the commercial bank chooses between implementing ERM and not implementing ERM. When implementing ERM, the income obtained by commercial banks is R_1 . At this time, $-K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2$ reflects the risks caused by changes in macro-economy, policy, and industry related to environmental factors (air pollution, water pollution, solid waste pollution), when they allocate credit to iron and steel enterprises, in the context of implementing ERM. If the commercial bank does not implement ERM, the gain of commercial banks is R_2 . The expression, $-K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2$, reflects the risks caused by changes in macro-economy, policy, and industry that relate to environmental factors (such as air pollution, water pollution, solid waste pollution) when they allocate credit to iron and steel enterprises in the context of not implementing ERM.

Since $RG_1 > RG_2 > 0$ and $C_2 > C_1 > 0$, we have that: $(RG_1 - C_1 \cdot \sigma_2) > (RG_2 - C_2 \cdot \sigma_2)$. It means that steel companies' short-term cost of investment to treat pollution is greater than that of not treating pollution, but the long-term benefits obtained are higher. Therefore, the optimal game strategy for steel enterprises is to control pollution. The same reason is that $K_3 > K_2 > 0$, $R_1 > R_2 > 0$, so $(R_1 - K_1 \cdot \sigma_1 - K_3 \cdot \sigma_2) > (R_2 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$, which means that commercial banks that choose to implement ERM will obtain higher benefits and lower risks than not implementing EMR. The optimal strategy of the game is to implement ERM. Therefore, the game equilibrium between the above-mentioned steel companies and commercial banks is (implementing ERM, managing environment risk), and its output income and cost input are $(RG_1 - C_1 \cdot \sigma_2, R_1 - K_1 \cdot \sigma_1 - K_2 \cdot \sigma_2)$.

Through the above five sets of game equilibrium analysis, we deduce that in order to maintain stable and lasting gaming between the government and commercial banks, government departments and steel companies, steel companies, and commercial banks in the form of (regulation, implementation of ERM), (regulation, pollution control), (pollution control, implementing ERM), it is necessary to reform and innovate in the system, and establish incentive and punishment mechanisms for governments at all levels, commercial banks, and steel companies. For example, administrative measures should: increase R_1 (incentivizing commercial banks to conduct ERM), increase K_3 (punishing government non-regulatory behavior and commercial banks not performing ERM); increase RG_1 (incentivizing steel companies to treat pollution), increase C_2 (punishing the government for non-regulatory behavior and steel companies for not conducting environmental pollution control behaviors), and reduce C_1 (incentivizing steel companies to control pollution control) through policy subsidies. In this case, through the game mechanism, the active supervision of governments at

all levels will be realized, the commercial banks will take the initiative to implement ERM, and the iron and steel enterprises will take the initiative to control pollution, thus leading to game equilibrium. To implement the incentive and punishment mechanism for government departments at all levels, commercial banks and steel companies, R_1 , K_3 , RG_1 , C_2 , and C_1 should be adjusted. The critical point is to accurately and effectively evaluate and measure the environmental risk index σ_2 involving steel companies. However, there is insufficient research on the evaluation system of the environmental risk index σ_2 of the steel industry featuring high energy and high pollution. There is an urgent need to establish an evaluation system for the environmental risk index σ_2 of the steel industry. It is precisely the research topic carried out in the next chapter.

4.5 Chapter summary

From the perspective of risks and benefits, this chapter analyzes the game equilibrium between the government and commercial banks, government departments and steel companies, steel companies and commercial banks (regulation, implementation of ERM), (regulation, pollution control), (pollution control, implementation of ERM). In this chapter, the author also proposes an incentive and punishment mechanism for government departments at all levels, commercial banks, and steel companies. On the premise of accurate and practical assessment of the ERI σ_2 of steel companies, the equilibrium can be stably attained by adjusting R_1 , K_3 , RG_1 , C_2 , and C_1 . The next chapter provides a theoretical basis for the commercial bank's ERM index system of the steel industry.

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Chapter 5: Environmental Risk Evaluation for Steel Companies

At present, China is considering optimizing and upgrading its industrial structure as an important way of transforming economic development. At the same time, there is a real need to protect the ecological environment in China. This thesis considers this as a starting research point, taking into account the Guidance Catalogue for Industrial Structure Adjustment (NDRC, 2019), the Guidelines for Disclosure of Environmental Information of Listed Companies (Ministry of Environmental Protection [MEP], 2010) and the current situation of highly polluting and energy-consuming industries. We can find that the industries facing severe environmental risks are mainly iron and steel, thermal power, cement, and coal. The steel demand is increasing in all sectors, with high resources and energy consumption, but its pollutant emissions are among the highest in the industrial sector. Good environmental risk management (ERM) in the steel industry can guide the steel industry to rationalize its industrial layout, improve investment in environmental technology, and significantly improve the actual effect of energy saving and emission reduction in steel enterprises.

More importantly, good ERM in the steel industry can lead other highly polluting and energy-consuming industries to save energy and reduce emissions. In previous years, China's air pollution has become increasingly severe, with frequent hazy weather in the north and a year-on-year increase in the number of environmental disputes. Atmospheric pollution has seriously affected people's health and quality of life. Among all industrial sectors in China, the iron and steel industry ranks third, third and first in terms of sulfur dioxide emissions, nitrogen oxides, and particulate matter, respectively. The iron and steel industry emissions are one of the most important causes of air pollution (Zhao et al., 2018). In this context, it is of great environmental importance to use the steel industry as a target ERE by commercial banks. It is conducive to promoting energy-saving and greening in the steel industry, which is crucial to the quality and efficiency of enterprises and their high-quality development.

Since 2020, supply and demand in the steel industry have been tightened due to the impacts of the Coronavirus Disease (COVID-19), the market downturn, and China's "carbon emission peak and carbon neutrality" policy. Raw material prices, such as iron ore, have continued to rise, resulting in a significant decline in industry profitability. The steel industry's asset and liability ratio are still high, and financial risks remain. In the next few years, China will continue the

macro-control of the industry with serious overcapacity. The era of high growth and high profits in the steel industry will end, and uncertainties in the industries will increase. Enterprise restructuring and integration will become the central theme for the development of the industry. Therefore, commercial banks should pay close attention to the various risks involved in granting credit to the steel industry. This study adopts the steel industry as the subject of the study, which is of great relevance to reduce the credit risk of commercial banks and prevent loan defaults and damage to the reputation of commercial banks.

ERE is the first and foremost task of ERM and the most important link of ERM. After conducting ERE, commercial banks can accurately understand the project's impacts on the local ecology, environment, and the human and social environment to make decisions on whether to lend based on the ERE. In summary, this study uses the analytic hierarchy process (AHP) to design an evaluation model of the ERM performance and a credit evaluation model for iron and steel enterprises. The purpose of this study is to evaluate the environmental risks and creditworthiness of a steel company's loan application and help commercial banks decide whether to lend and how much to lend, in the hope of providing a reference for ERM of steel companies loan projects. The aim is to provide a reference for ERM for lending to steel enterprises.

As shown in Figure 5.1, a commercial bank's ERE program consists of three main steps: the first step is to conduct a qualitative environmental evaluation of the steel company. This step is necessary to determine whether the steel company complies with environmental regulations based on the principles of environmental impacts approval for steel projects. The second step is to assess the ERM performance of the steel company using the constructed AHP-based evaluation model of the ERM performance of steel companies. Commercial banks will not lend to steel companies that do not meet the criteria of ERM performance. The third step is to assess the creditworthiness of those companies that pass the ERM performance evaluation. In this step, AHP is used to determine the creditworthiness of the steel company, take into account the environmental, financial, and non-financial information of the steel company, and make decisions on how much to lend.

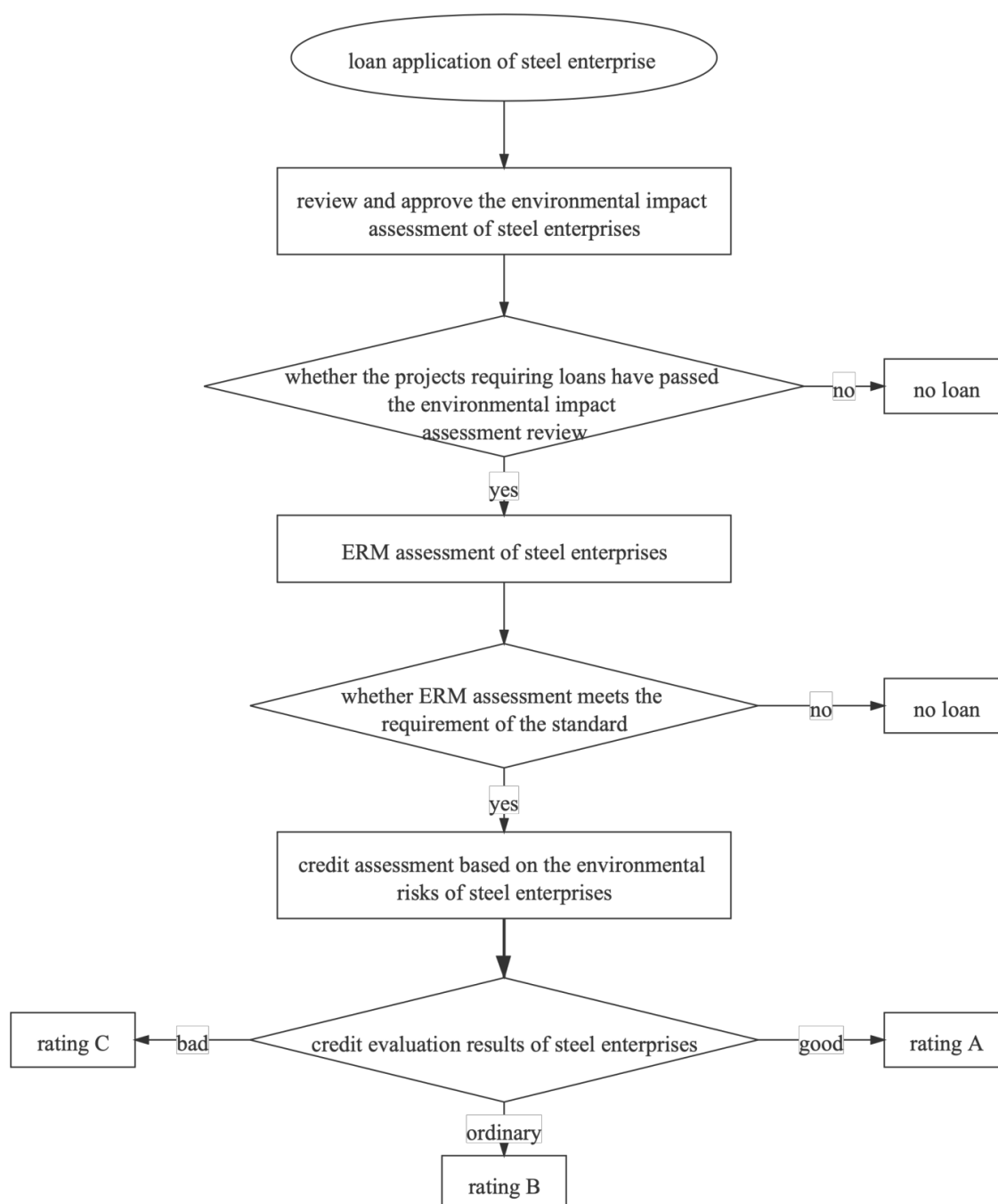


Figure 5.1 Framework for an ERE program for commercial banks

5.1 Reference standards for the approval of EIA in the steel industry

The ERM for steel companies is based on the emission standards issued by the Ministry of Environmental Protection (MEP) of the People's Republic of China (PRC) and the General Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ) of PRC. The relevant laws and regulations on environmental protection reflect the requirements of China's

laws and regulations on pollution emissions, serving as an essential legal basis for commercial banks in China to manage environmental risks. At the same time, the principles for environmental impacts evaluation and approval of steel construction projects issued by China are important references (MEP, 2015).

The Principles for Environmental Impact Evaluation and Approval of Steel Construction Projects (MEP, 2015) stated that physical sites for steel enterprises are not allowed to be located in nature reserves, scenic spots, protected areas of drinking water sources or permanent agricultural land. The Principles require that the total amount of pollutants discharged by the enterprise meet the relevant national and local targets. The enterprise specifies the total amount of pollutants, sources, and the specific balance plan. New projects that emit pollutants over the total pollutant emission targets or in areas that have not achieved the environmental quality improvement targets will not be approved.

According to the Principles (MEP, 2015), steel enterprises must collect, control, and treat - organized and unorganized waste gas - in terms of waste gas treatment. All sintering (pellet) roasting flue gases must be collected and constructed simultaneously with advanced and efficient desulphurisation, dust removal, and necessary denitrification facilities. Sintering and electric furnace processes should take the necessary dioxin control measures. Where necessary, coke oven flue gases should be treated with sulphur and nitrogen oxide control facilities. Low-NO_x combustion technology should be used for steel rolling heating furnaces and heat treatment furnaces. Cold rolling acid mist, oil mist, and organic waste gases also need to be cleaned.

In terms of wastewater treatment, the principle of “separate wastewater, treatment according to different qualities, and graded utilization” requires establishing a comprehensive wastewater collection, treatment, and reuse system. Coking phenol-cyanide wastewater, oil-containing wastewater, emulsion wastewater, acid-base wastewater, and chromium-containing wastewater will be collected and treated separately. Phenol-cyanide wastewater must not be discharged. At the same time, net and turbidity ring wastewater treatment systems and plant-wide wastewater treatment stations need to be constructed to provide support.

As for the solid waste treatment, in the principle of “resourcefulness, minimization and harmlessness”, solid waste should be treated and disposed of with effective measures to improve the overall rate of utilisation. The storage, treatment, and disposal of hazardous waste should comply with the relevant requirements. Tar slag, bitumen slag, biochemical sludge, and treated coking desulphurisation waste liquor should be used for comprehensive utilisation

through measures such as the reuse of coking coal without causing any damage to the environment in the process of reuse. Sintering (pellet) desulphurisation slag, blast furnace slag, and pre-treated steel slag must be disposed of properly.

In terms of the environmental risk contingency plan, the Principle (MEP, 2015) required enterprises to propose reasonable environmental risk contingency plans and effective environmental risk prevention and response measures. These plans and measures must be integrated into the regional environmental risk emergency response mechanism.

The Principle (MEP, 2015) stipulated specific pollutant emissions to meet the following standards: Exhaust gas and wastewater emissions must meet the Emission Standards for Pollutants in the Coking Chemical Industry (MEP & AQSIQ, 2012), the Emission Standards for Air Pollutants in the Iron and Steel Sintering and Pelletizing Industry (MEP, 2012a), the Emission Standards for Air Pollutants in the Ironmaking Industry (MEP, 2012b), the Emission Standards for Air Pollutants in the Steelmaking Industry (MEP, 2012c), the Emission Standards for Air Pollutants in Steel Rolling Industry (MEP, 2012d) and the Emission Standards for Water Pollutants in Iron and Steel Industry (MEP, 2012e). Solid waste storage and disposal facilities and sites shall meet the requirements of the General Industrial Solid Waste Storage and Disposal Sites Pollution Control Standards (MEP & AQSIQ, 2002) and Hazardous Waste Storage Pollution Control Standards (MEP, 2002) and their requirements.

Before approving credit granting, commercial banks need to obtain approval opinions on environmental impact assessment documents issued by MEP based on the principles mentioned above.

5.2 Construction of indicators for the ERM model of commercial banks

After reviewing the evaluation of the environmental impacts of the steel companies, companies that have passed the assessment can have access to credit. Lending to companies that do not pass the review will be rejected outright. This study begins with constructing an index system of ERE for commercial banks in this subsection.

The study identifies a system of indicators for evaluating the environmental risks of commercial banks by reviewing relevant information and laws and regulations mentioned above. The system is divided into four criteria levels: pollution management, environmental management, social impacts, and corporate greenness. The indicator level has selected 14 indicators to form the indicator system for the ERE of commercial banks, as shown in Table 5.1. The indicators can be obtained from the company's annual report, the steel company's local

official environmental website, or the company's annual environmental report.

Table 5.1 ERE AHP indicators of commercial banks

Guideline level	Indicator level
pollution control	exhaust emissions
	wastewater discharge
	solid waste disposal
	disclosure of environmental statistics
environmental management	pollution permit management
	environmental management system certification
	environmental personnel, departments, and environmental management systems
	environmental administrative penalties
social impacts	significant environmental violations
	environmental emergencies
	public complaints
	resource and energy consumption
corporate greenness	process equipment level
	green spending

5.2.1 Pollution control

Based on the emissions, wastewater discharge, and solid waste treatment of the iron and steel enterprises, the pollution management of the enterprises will be taken into account.

5.2.1.1 Exhaust emissions

As an important source of air pollution, emissions are mainly toxic and harmful gases emitted by enterprises or residents in production and living. The main types of exhaust gases include carbon monoxide, hydrocarbons, nitrogen oxides, sulphur dioxide, and fine particulate matter.

The “exhaust emission” indicator in the indicator level considers whether an iron and steel company treats the emissions generated during the production process before they are released into the atmosphere. The primary method of evaluating these indicators is to determine whether the concentration of emissions meets the standard and whether the total annual emissions exceed the permitted emissions.

5.2.1.2 Wastewater discharge

Wastewater discharge mainly refers to the discharge of sewage from enterprises or residents in production and living. It generally refers to water that cannot be recycled after specific specialized treatments or does not meet certain standards after primary pollution and purification. The “wastewater discharge” indicator in the indicator level considers whether the coking and steel wastewater generated by the production process is treated before being discharged by the steel company. The main method of evaluating this indicator is to determine whether the concentration of wastewater discharged by the company meets the standard and

whether the total annual volume of wastewater discharged by the company exceeds the permitted volume.

5.2.1.3 Solid waste disposal

Solid waste is defined as solid and semi-solid pollutants generated by residents and enterprises in the course of production and living that have lost their original use value or have not lost their use value but have been abandoned or discarded. The “solid waste disposal” indicator in the indicator level refers to whether or not steel companies dispose of solid and semi-solid pollutants generated during the production process. The treatment methods used are physical methods such as incineration, drying, shredding, and landfill, and chemical methods such as oxidation, decomposition, and absorption to change the waste’s polluting properties. The main process of evaluating this indicator is to determine whether the enterprise meets the national standards for the discharge of pollutants from solid waste, whether it actively promotes the rotary bottom furnace process and whether the solid waste is stored in a compliant and reasonable manner.

5.2.2 Environmental management

The main objective of involving “environmental management” is to assess the environmental management behaviour of an enterprise from the perspective of its internal environmental management. It includes the disclosure of environmental statistics, the management of pollution permits, the certification of environmental management systems (ISO14001), the environmental protection staff, the environmental protection organisation and the environmental management system, and the standardised management of outfalls. These four indicators can be used to assess the environmental management performance of steel companies.

5.2.2.1 Disclosure of environmental statistics

The disclosure of “environmental statistics” in the indicator level examines whether enterprises comply with the regulations of local environmental protection authorities, whether they report environmental statistics honestly and whether they disclose their environmental information in designated public channels.

5.2.2.2 Emission permit management

The Regulations on the Administration of Emission Permits (CSC, 2021) require enterprises and operators to obtain an emission permit when discharging pollutants and to discharge

pollutants under the relevant regulations. No pollutant may be discharged without a discharge permit. The indicators for the management of emission permits mainly consider whether the enterprise has obtained an emission permit, whether it has paid the emission fee on time and whether it has completed the annual emission declaration on time.

5.2.2.3 Environmental management system certification status

ISO14001 environmental management system certification is based on a third-party notary's publicly available environmental management system standards (ISO14001 environmental management series standards). It can be used to certify whether a manufacturer's environmental management practices are qualified. If a company is licensed to ISO14001, it meets the requirements of environmental protection legislation and establishes an excellent corporate image. This indicator specifies whether a company is ISO14001 certified.

5.2.2.4 Environmental protection personnel, environmental protection department, and environmental protection management system of the enterprise

The three indicators, environmental protection personnel, environmental protection department and environmental protection management system, are mainly evaluated in term. The environmental protection personnel indicator is based on whether the company employs full-time or part-time environmental protection personnel and whether regular environmental protection training is provided to relevant personnel. The "environmental protection department" indicator examines whether the company has a dedicated or part-time environmental protection department. The "environmental protection system" is an indicator of whether the company has set up a system to meet its environmental management needs, such as: an environmental protection job responsibility system, an environmental protection facility operation management system, an environmental behaviour reporting system, and an environmental protection file management system.

5.2.3 Social impacts

The criteria tier of "social impacts" examines the environmental behaviour of the enterprise in terms of social impacts, including administrative penalties, substantial environmental violations, environmental emergencies, and public complaints. The above four indicators are used to assess the social implications of the environmental management of steel companies.

5.2.3.1 Environmental administrative penalties

According to the Measures on Administrative Environmental Penalties (MEP, 2012f), relevant

government departments should impose administrative environmental penalties on enterprises that violate the laws, regulations, or rules on environmental protection. This indicator mainly examines whether the enterprise has received environmental penalties such as warnings, fines, and orders to make corrections in the course of production.

5.2.3.2 Significant environmental violations

Significant environmental violations are examined to see whether there are serious environmental violations in the course of the enterprise's production activities, such as whether the enterprise discharges wastewater in a way that circumvents environmental supervision; whether there are pollution prevention and control facilities that have been dismantled or left idle for an extended period or the pollution prevention and control capacity is seriously inadequate; and whether there is a certain environmental violation that has been ordered to be rectified but has not yet been rectified.

5.2.3.3 Environmental emergencies

An environmental emergency is a situation where pollutants are discharged into the air, water, or soil during the production process due to substandard discharge of pollutants or natural disasters or production safety accidents, causing ecological and environmental damage or significant social impact. Environmental emergencies are classified into four categories: general, major, significant, and especially significant, based on the number of fatalities, the severity of environmental pollution, the harm caused to society, and economic losses. The environmental emergencies indicator examines whether an enterprise has caused an environmental emergency.

5.2.3.4 Public complaints

The situation of public complaints examines the number of public complaints and the social impact caused by non-compliance of environmental management during the production process. This indicator mainly reads the number of effective public complaints against companies and causes certain environmental impacts and harms.

5.2.4 Corporate greenness

The greenness of a company is considered in terms of resources and energy consumed by the steel company, level of processes and equipment, and greenness expenditure.

5.2.4.1 Resource and energy consumption

Resource and energy consumption refers to the resources and energy consumed by an enterprise in the production process. In the past, Chinese steel enterprises have been characterised by a pattern of “high input, high consumption and high pollution”. The investigation of the company’s resource and energy consumption can help understand the company’s energy-saving and emission-reduction capabilities and the intensity of energy and resource consumption, which can support commercial banks in measuring the company’s environmental risks. This indicator mainly examines the comprehensive energy consumption per ton of steel in iron and steel enterprises. The comprehensive energy consumption per ton of steel is the total energy consumption per ton of crude steel produced by the enterprise.

5.2.4.2 Level of process equipment

The process equipment owned by an enterprise is one of the most critical factors in the production of products and plays an important role in the development of the enterprise. The improvement of the level of enterprise process equipment can not only improve the production efficiency of the enterprise but also provide important support for the enterprise to achieve low energy consumption, low emission and high efficiency. The inspection of this indicator is mainly carried out through a series of national standards concerning the evaluation index system of cleaner production in the iron and steel industry.

5.2.4.3 Green expenditure

Green expenditure refers to all expenditure related to environmental resources in the production and operation process, including resource consumption costs, environmental expenditure costs, environmental damage costs, environmental management costs and environmental protection support costs. This indicator examines the cost per tonne of steel. The cost per tonne of steel is the proportion of a steel company’s environmental protection costs and capitalisation to crude steel production. Costs include environmental protection tax, environmental system audit fees, environmental monitoring fees, environmental protection facility operation fees, environmental protection facility depreciation fees, environmental protection labour fees, hazardous substance transportation fees, greening fees, solid waste disposal fees, environmental protection maintenance project inputs, environmental research and development fees, and others (environmental protection training fees, environmental protection publicity fees, environmental protection administrative penalties). Calculation formula is (annual environmental protection cost input + capitalised input) / crude steel production.

5.3 Indicator system of the CRE model for commercial banks

Credit risk is the highest one in commercial banks' risk management and has a high potential for loss. The majority of risk in the credit evaluation of commercial banks is due to environmental risk. ERM in commercial banks is designed to prevent corporate credit risk. However, environmental risk has not been considered a factor in previous CRE. Therefore, based on the previous evaluation models that only incorporated financial and non-financial indicators, this section will add indicators to assess the environmental risk of enterprises and construct a CRE model for commercial banks. The model will then evaluate steel companies and determine the appropriate rating and credit policy.

In this study, the environmental risk factor is still included in the CRE model in the third step, based on the ERE model applied in the second step. It is mainly to avoid commercial banks from lending high amounts to companies that have passed the environmental rating but have poor environmental ratings for maximal profits. Will increase the credit risk banks face and reduce their profitability and ability to manage environmental risks. The three-step model developed in this chapter is a practical approach to ERM process of commercial banks. It provides a methodology and a way of thinking about ERM for commercial banks.

The following is an indicator system of CRE for commercial banks, which incorporates ERE indicators into the model based on the traditional commercial bank credit evaluation system. Financial indicators include 11 indicators in four standard layers, regarding solvency, growth, profitability and operational capacity. Debt servicing capacity mainly includes gearing, current, and quick ratios. Growth capacity includes sales revenue growth rate, net profit growth rate, and net asset growth rate. Profitability includes net sales margin, the net profit margin on total assets, and returns on net assets. Operating capacity incorporates total assets turnover ratio, accounts receivable turnover ratio and inventory turnover ratio.

Non-financial indicators include historical credit, business environment, competition strength, and management level. The specific descriptions are as follows.

5.3.1 Historical credit

The credit history of an enterprise determines to a certain extent how easy it is to obtain a loan from a bank. Commercial banks can use an enterprise's credit history to determine the enterprise ability and speed of repayment of interest on previous loans before deciding whether to lend to the enterprise. Therefore, when assessing the credit risk of an enterprise, it is crucial

for commercial banks to measure the risk based on the enterprise's loan repayment history.

5.3.2 Business environment

The profitability and operating ability of an enterprise are primarily influenced by the business environment of the enterprise, so assessing the business environment of the industry to which the enterprise belongs can, to a certain extent, determine the repayment ability of the enterprise. At the same time, the influence of macroeconomic policies and industrial policies introduced by the State on the development of the industry should also be taken into account.

5.3.3 Competition strength

Competition strength is the life of a company and is essential for it to overcome hardship and grow. For the development of an enterprise, innovation is of great importance. Competition strength is an important means of improving the production and operation of an enterprise, enhancing its competitiveness in the market, and will also improve its profitability and solvency in the future.

5.3.4 Management level

The management level means that the company's managers assign people to the correct positions according to their abilities and job content so that the characteristics of each employee can be fully exploited. This facilitates the creativity of the staff and enables the company's various departments to function quickly, thus increasing the company's economic efficiency. The main objective of this indicator is to find out whether the management team has extensive management experience and experience in the field.

The above analysis shows that the index system of the CRE model for commercial banks contains 29 indicators. Based on the environmental, financial, and non-financial indicators, the CRE model's index system for commercial banks constructed in this study is shown in Table 5.2.

Table 5.2 The index system of CRE model for commercial banks

Target level	Guideline level		Indicator level
credit risk evaluation for commercial banks	environmental indicators	pollution control	exhaust emissions
			wastewater discharge
			solid waste disposal
		environmental management	disclosure of environmental statistics
			pollution permit management
			environmental management system
			certification
			environmental personnel, departments, and environmental management systems
			environmental administrative penalties
			significant environmental violations
	Financial indicators	social impact	environmental emergencies
			public complaints
		corporate greenness	resource and energy consumption
			process equipment level
		solvency	green spending
			gearing ratio
			current ratio
			quick ratio
		growth capacity	sales revenue growth rate
			net asset growth rate
	Non-financial indicators	profitability	net sales margin
			total net asset margin
		operating capacity	return on net assets
			total asset turnover ratio
			accounts receivable turnover ratio
			inventory turnover rate
		historical credits business environment competition strength management level	

5.4 ERE models for commercial banks

Based on the index system of CRE model for commercial banks constructed in the previous subsection, this subsection uses AHP in the Yaahp analysis software to create the hierarchical structure of the ERE model, as shown in Figure 5.2. Yaahp is a professional software that provides technical support for AHP and fuzzy comprehensive evaluation, which functions include model construction, calculation and analysis for the decision-making process using AHP and fuzzy comprehensive evaluation (Metadecsn, 2021).

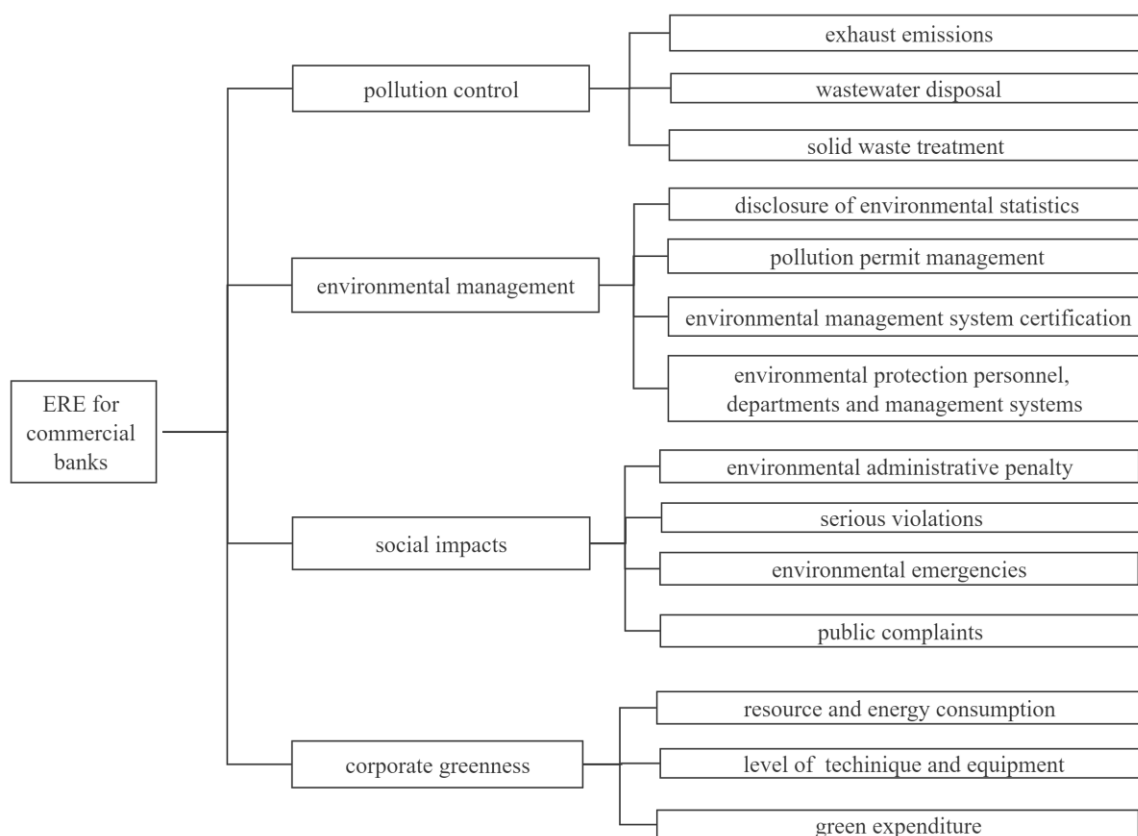


Figure 5.2 Hierarchy of ERE for commercial banks

In order to obtain a matrix of judgments between the levels and find the weights of each indicator, Questionnaire Star, an online tool for questionnaire survey was conducted. In this questionnaire, the results of the two-way comparison of the indicators are divided into nine categories. Indicator A is absolutely important, very important, relatively important, slightly important, equally important, slightly unimportant, relatively unimportant, very unimportant and absolutely unimportant compared to Indicator B. As scoring is highly subjective, the author interviewed and distributed questionnaires to experts in various fields, including credit departments of commercial banks, environmental rating agencies, environmental protection bureau staff, loan company customers, and university professors. A total of 30 responses were received in the form of the questionnaire, of which 28 were valid. After analysing and collating the score matrices of experts from various fields on the hierarchy of environmental risk ratings of commercial banks, the study identified the required judgment matrix. The matrix was then imported into yaahp for consistency testing to obtain the weights of the evaluation indicators. The specific judgment matrices are shown in Table C.1 to Table C.5 in Annex C.

Yaahp was adopted to test the consistency on the judgment matrices as shown from Table C.1 to Table C.5 in Annex C. The judgment matrices' consistency test results under these levels were less than 0.1, indicating that these judgment matrices all passed the consistency tests.

Therefore, this study applies yaahp to conduct weight analysis and obtain the weights of each ERE index, as shown in Table 5.3.

Table 5.3 ERE indicator weights

Indicators	Weighting
pollution control	0.3207
environmental management	0.1884
social impacts	0.114
corporate greenness	0.3769
exhaust emissions	0.6
wastewater discharge	0.2
solid waste disposal	0.2
disclosure of environmental statistics	0.2115
pollution permit management	0.2308
environmental management system certification	0.4711
environmental personnel, departments, and environmental management systems	0.0866
environmental administrative penalties	0.1788
significant environmental violations	0.3198
environmental emergencies	0.3632
public complaints	0.1382
resource and energy consumption	0.4
process equipment level	0.4
corporate green spending	0.2

The weights of each indicator for ERE were obtained based on the weights of the above factors, detailed in Table 5.4.

Table 5.4 Indicator weights for ERE of commercial banks

Target level	Guideline level	Indicator level
ERE for commercial banks	pollution control (0.3207)	exhaust emissions (0.1924)
		wastewater discharge (0.0641)
		solid waste disposal (0.0641)
	environmental management (0.1884)	disclosure of environmental statistics (0.0399)
		pollution permit management (0.0435)
		environmental management system certification (0.0888)
		environmental personnel, departments, and environmental management systems (0.0163)
		environmental administrative penalties (0.0204)
	social impact (0.114)	significant environmental violations (0.0364)
		environmental emergencies (0.0414)
	corporate greenness (0.3769)	public complaints (0.0157)
		resource energy consumption (0.1507)
		level of process equipment (0.1507)
		green spending (0.0754)

In applying the weight of the environmental indicators to the case companies, the environmental indicators were scored by experts according to the Enterprises Environmental Credit Evaluation Measure (for Trial Implementation) (MEP, 2013). Each indicator is scored out of 100, with higher scores indicating that the company has an advantage in that indicator. The expert score is multiplied by the weight of each environmental indicator and then summed

to give the enterprise's ERE score. The higher the score, the lower the environmental risk of the enterprise. According to the Enterprises Environmental Credit Evaluation Measure (for Trial Implementation) (MEP, 2013), the environmental risk rating is divided into four levels: excellent environmental protection, good environmental protection, warning environmental protection and bad environmental protection, and the corresponding rating colors are green, blue, yellow, and red, respectively. The specific rating criteria are shown in Table 5.5. Commercial banks will not grant loans to enterprises with a red rating by the ERE model. For enterprises with yellow, blue, and green ratings by the ERE model, commercial banks will evaluate the credit risks based on the environmental risk based CRE model.

Table 5.5 Enterprise ERE criteria

Colors	Score	Environmental Risk Rating
green	91~100	excellence
blue	81 ~ 90	good
yellow	61 ~ 80	warning
red	0 ~ 60	bad

Source: *Enterprises Environmental Credit Evaluation Measure (for Trial Implementation)* (MEP, 2013)

5.5 CRE model for commercial banks

Based on the indicator system of CRE model for commercial banks, this subsection will process the questionnaire data through AHP in the yaahp to create the indicators' weights of CRE. The hierarchical structure of the model is shown in Figure 5.3.

In order to obtain a matrix of judgments between the levels and to find the weights of each indicator, a questionnaire was designed and distributed on the platform Questionnaire Star, an online questionnaire tool. In this questionnaire, the results of the two-way comparison of each evaluation indicator are divided into nine categories, i.e., indicator A is: absolutely important, very important, relatively important, slightly important, equally important, slightly unimportant, relatively unimportant, very unimportant, and absolutely unimportant compared to indicator B. As scoring is highly subjective, the author conducted interviews and distributed questionnaires to experts in various fields, including commercial banks' credit departments, environmental rating agencies, staff of environmental protection bureaus, customers of lending companies and professors from universities, and finally received a total of 30 questionnaire survey responses, of which 28 were valid. After analyzing and collating the score matrices of experts from various fields on commercial banks' credit risk evaluation hierarchy, the author obtained the judgment matrix required for this study. The specific judgment matrix and indicator weights are shown from Table C. 6 to Table C. 12 in Annex C.

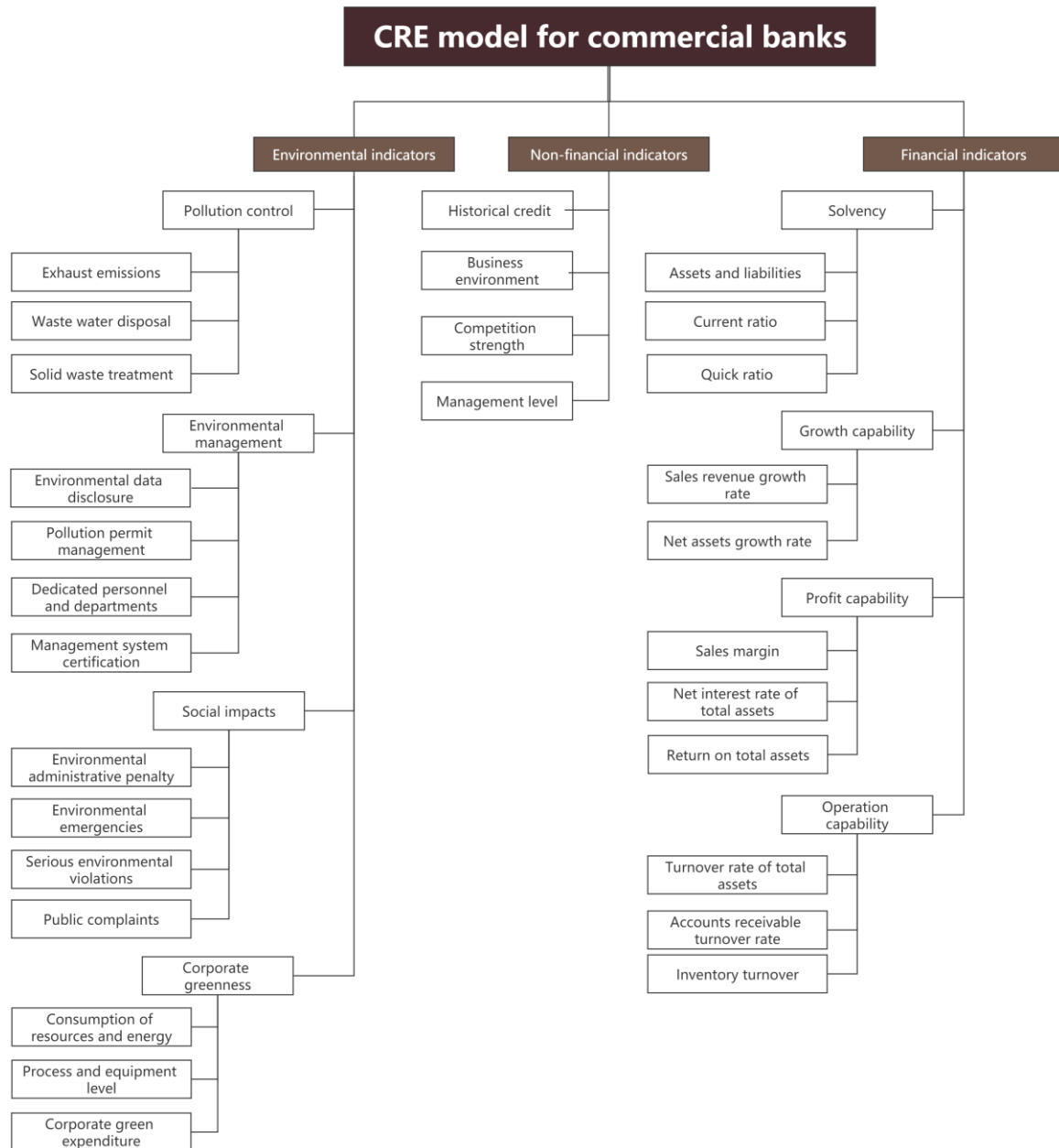


Figure 5.3 Hierarchy of CRE model for commercial banks

Using yaahp to conduct consistency tests on the judgment matrices as shown from Table C. 6 to Table C. 12 in Annex C, the author obtained that the consistency test results of the judgment matrices under these levels were all less than 0.1, indicating that these judgment matrices all passed the consistency tests. Therefore, this study applies yaahp to perform a weighting analysis to obtain the weights of the financial and non-financial CRE indicators, as shown in Table 5.6.

Table 5.6 Weights of financial and non-financial CRE indicators

Indicators	Weighting
gearing ratio	0.4934
current ratio	0.1958
quick ratio	0.3108
sales revenue growth rate	0.6667
net asset growth rate	0.3333
net sales margin	0.5
total net asset margin	0.25
return on net assets	0.25
total asset turnover ratio	0.25
accounts receivable turnover ratio	0.25
inventory turnover rate	0.5
historical credits	0.2975
business environment	0.1126
competition strength	0.3326
management level	0.2572

After deriving the weights of each factor based on the above judgment matrix, the weights of each indicator for the credit risk evaluation of commercial banks can be obtained, as detailed in Table 5.7.

Table 5.7 Indicator system of CRE for commercial banks

Target level	Guideline level	Indicator layer
environmental indicators (0.297)	pollution control (0.0952)	exhaust emissions (0.0571)
		wastewater discharge (0.019)
		solid waste disposal (0.019)
	environmental management (0.0559)	disclosure of environmental statistics (0.0118)
		pollution permit management (0.0129)
		environmental management system certification (0.0263)
		environmental personnel, departments and environmental management systems (0.0048)
		environmental administrative penalties (0.006)
	social impacts (0.0338)	significant environmental violations (0.0108)
		environmental emergencies (0.0122)
		public complaints (0.0046)
		resource and energy consumption (0.0447)
	corporate greenness (0.1119)	level of process equipment (0.0447)
financial indicators (0.5396)	solvency (0.2457)	green spending (0.0223)
		gearing ratio (0.0722)
		current ratio (0.0286)
	growth capacity (0.076)	quick ratio (0.0455)
		sales revenue growth rate (0.055)
		net asset growth rate (0.0275)
	profitability (0.1418)	net sales margin (0.117)
		total net asset margin (0.0585)
		return on net assets (0.0585)
	operating capacity (0.0767)	total asset turnover (0.0192)
		accounts receivable turnover ratio (0.0192)
		inventory turnover rate (0.0384)
non-financial indicators (0.1634)	historical credit (0.0486)	
	business environment (0.0184)	
	competition strength (0.0544)	

management level (0.042)

A questionnaire survey was conducted to determine the weights of each indicator in the credit risk evaluation model for commercial banks based on environmental risk. When applied to the case companies, the indicators were scored according to the GB/T CCA9002-2009 China Credit Industry Standard (National Technical Committee on Social Credit of Standardization Administration of China, 2019). Each indicator is scored out of 100, with higher scores indicating that the company has an advantage in that indicator. The expert's score for each indicator is multiplied by the weight of each indicator to arrive at the credit risk evaluation score of the enterprise, with a higher score indicating a lower credit risk. After calculating the overall score of an enterprise through this evaluation model, this study refers to the GB/T CCA9002-2009. It classifies the credit evaluation of an enterprise into ten grades, as shown in Table 5. 8. Commercial banks determine the enterprises' loan amount and interest rate according to the different credit grades.

Table 5.8 Classification of credit risk ratings of commercial banks

Grade	Marks	Definition
AAA	[90,100]	High degree of creditworthiness, excellent credit record, strong financial strength, excellent quality of assets, obvious economic benefits, minimal impact of uncertainties on its operation and development, and strong performance capability
AA	[80,90)	The enterprise has a high degree of creditworthiness, strong financial strength, good asset quality, good business management, stable economic efficiency, low impact of uncertainties on its operation and development, and strong performance capability
A	[70,80)	Good creditworthiness, medium to high level of capital strength, asset quality, economic efficiency and other indicators, generally in a virtuous cycle of operation, there may be uncertainties but no major risks, and the ability to perform is reasonable
BBB	[60,70)	Average creditworthiness, average assets and financial position, medium level of economic indicators, subject to uncertainties and fluctuations in development, with certain risks
BB	[50,60)	Poor creditworthiness, poor assets and financial position, low economic indicators, poor performance capability, susceptible to uncertainties, risky, uncertain future development prospects, high level of poor credit history
B	[40,50)	Poor creditworthiness, poor asset and financial position, weak performance and potential for insolvency in the event of a more adverse economic environment, but currently able to
CCC	[30,40)	Poor corporate creditworthiness, weak corporate performance, significant risk and instability
CC	[20,30)	Very poor creditworthiness of the enterprise, which is already in a loss-making situation and has no performance capability
C	[10,20)	No credit for the business, the business is heavily loss making and close to bankruptcy
D	[0,10)	The business is on the verge of bankruptcy

5.6 Chapter summary

This chapter is the design of ERM plan for commercial banks. First of all, this chapter determines the standards for the qualitative assessment of the environmental impacts of steel companies, mainly based on the approval of the environmental impacts assessment of steel construction projects, to determine whether the lending company meets the environmental protection regulations. Secondly, this chapter builds a steel enterprise ERM evaluation index system, which mainly includes four indicators: pollution control, environmental management, social impacts, and corporate greenness. Finally, this chapter adds corporate ERE indicators based on previous financial indicators and non-financial indicators of credit evaluation models. Based on that, this chapter builds a credit risk evaluation indicator system based on commercial banks' environmental risks and obtains data through expert interviews and questionnaire surveys. With the help of AHP, it determines the weight of each indicator and uses the model for a comprehensive evaluation to determine the corresponding credit rating and policy. The ERM assessment plan for commercial banks constructed in this chapter provides a path and support for the steel industry environmental risk assessment case analysis provided in the next chapter.

Chapter 6: Discussion Case Studies of Environmental Risks in the Steel Industry

In order to demonstrate the feasibility of the environmental risk evaluation (ERE) scheme for commercial banks, this chapter selects the data of three listed companies in the steel sector, Baosteel Co., Ltd., Baotou Steel Co., Ltd. and Fangda Special Steel in 2019 as examples for horizontal comparison and program application. In addition, the information of 2017, 2018, and 2019 of Baotou Steel Co., Ltd. was also collected for vertical comparison. According to the approval and review of environmental impacts, environmental risk management (ERM) performance evaluation, and commercial bank credit risk assessment (CRA) model based on environmental risks, the first step is to conduct a qualitative evaluation of environmental impacts approval for steel companies, and no loans will be granted to companies that have not obtained environmental impacts approval. The second step is to use the constructed AHP model of ERM performance evaluation of steel companies to evaluate the ERM performance of steel companies. Commercial banks will not grant loans to steel companies whose ERM performance does not meet the standards. The third step is conducting credit evaluations for companies that have passed the ERM performance evaluation to determine their credit ratings.

6.1 Current development of the steel industry at home and abroad

The iron and steel industry is a pillar industry of China's national economy and a primary industry that bears the people's livelihood. The steel industry has played an irreplaceable role in China's industrial modernisation. China's steel production increased year-on-year in 2020. Crude steel, steel, and pig iron production were 1.065 billion tonnes, 1.325 billion tonnes, and 888 million tonnes, respectively, increasing 6.5%, 7.7%, and 4.3% year-on-year, respectively. Carbon emissions from the iron and steel industry accounted for about 15% of China's total carbon emissions, making it the most significant carbon-emitting industry (China Economic Information Network [CEIN], 2020).

The layout of China's steel industry is characterised by the fact that most steel firms are located in coastal cities in the east of China, and a few are in western inland cities. In addition,

most heavy industry is in northern towns and most light industry in southern cities of China. The number of enterprises with crude steel production exceeding 30 million tonnes in China is about five, and 24 enterprises are producing more than 10 million tonnes (CEIN, 2020). China is a large country in terms of crude steel production and international market share. However, China is not a country with strong capacity for trade competitiveness index, display comparison index, and quality competitiveness.

China is rapidly developing its steel industry with advantages such as low labour costs and easy access to transport, but the disadvantages are also prominent. First, there is a shortage of quality steel resources. The iron ore required for production is heavily dependent on imports, resulting in domestic steel enterprises losing the right to speak in iron ore pricing. Secondly, the product structure is unreasonable, and the quality and grade of products are not high. China mainly imports high value-added steel while mainly exporting low value-added products. Thirdly, the layout of enterprises is scattered. Although the number of steel enterprises is large, the concentration of the industry is low. The chaotic competition among steel enterprises of different sizes has dramatically reduced the steel industry's profitability. Fourthly, the technology has been accumulated for a short period, with insufficient investment in research and development (R&D) and a lack of independent innovation. Some of the core technologies are still mastered by foreign companies, such as SMS DEMAG (CEIN, 2020). Most advanced equipment still relies on imports. Overall, the competitiveness of the Chinese steel industry still needs to be further improved.

6.1.1 Policies in China's steel industry

China's economy is currently operating at a "stable in the long run" level, and the trend has not changed. In the future, China's economic growth will continue to firmly grasp the "four insurances", namely, insisting on the leadership of the party, everything starting from reality, people-oriented, and the correct handling of the relationship between reform, development, and stability to promote the high-quality development (Xi, 2014). Under the guidance of macroeconomic policies, China's steel industry will continue to focus on supply-side structural reform in the coming years. The "eight-character policy" refers to "consolidate, strengthen, improve, and unblock" (Xi, 2014). It will be an important guideline for orienting the steel industry's policy.

6.1.1.1 Encourage strategic mergers and acquisitions (M&A) to optimize the national production capacity layout

Since the 21st century, China's steel industry has entered a phase of rapid development. A large amount of private capital flooded into the steel industry, and the industry's layout went out of control. In addition, for historical reasons, there has been a long-standing imbalance between the supply and demand of steel in the southern region and the developed steel industry in the northern region. As China's steel industry enters a new phase of quality upgrading, optimizing the steel industry layout is also on the agenda. According to Steel Industry Adjustment and Upgrading Plan (2016-2020) (NDRC, 2017), the layout of China's steel industry will be further adjusted and improved during the 13th Five-Year Plan period. Combined with the elimination of excess capacity, China's steel industry will deepen its regional layout and reduce the number of enterprises. According to Key Points of Work to Resolve Excess Steel Production Capacity in 2020 (NDRC & Ministry of Industry and Information Technology [MIIT], 2019), the Chinese government will encourage enterprises to implement strategic M&A, particularly cross-regional and cross-ownership M&A, and promote industrial concentration through the promotion of strategic M&A of firms in the steel industry.

6.1.1.2 Revise and improve the capacity replacement program and strengthen the supervision of capacity replacement projects

Measures for the Implementation of Capacity Swap in the Steel and Iron Industry (MIIT, 2021) reaffirmed the market-based principle of capacity swap. They rationalised the power and responsibility relationships between builders, grantors, and government departments. *This document* served as a guide for compliant capacity swap projects and accelerated implementation. In early 2020, the NDRC and MIIT jointly issued a document to urgently call a halt to the public announcement of capacity swap projects and revised the original implementation measures. The new version of Measures for The Implementation of Capacity Swap in the Iron and Steel Industry (MIIT, 2021) was released on 6 May 2021 and came into effect on 1 June.

6.1.1.3 Guide the development of short process steelmaking and optimise the industrial process structure

Guidance on Guiding the Development of Short Process Steelmaking in Electric Arc Furnaces (MIIT, 2019) encouraged the development of short process steelmaking. A series of

encouraging policies are proposed to guide short process steelmaking in an orderly manner.

6.1.1.4 Promoting green development in the steel industry

Accelerating the green development of the iron and steel industry is a requirement for constructing ecological civilization and an essential task for the high-quality development of the industrial economy in the new era. Guidance catalogue for industrial structure adjustment (NDRC, 2019) put forward a total of 15 encouraged technologies for the steel industry, 10 of which involve energy-saving and environmental protection technologies. It is expected that the relevant ministries and commissions will focus on the following areas to introduce a series of policies to promote the green development of the steel industry in the future. Firstly, accelerating green transformation. Take the industry-wide ultra-low emission transformation currently being implemented to improve the industry's resource and energy use and clean production. Secondly, improving the list of green factories. These factories play the exemplary role that encourages steel companies to promote coupled development with industries and cities such as building materials, electricity, and chemicals. Building green industrial parks will help improve the overall greenness of the industry. Thirdly, speeding up the formulation and revision of standards relating to energy consumption, water consumption, and clean production. Encouraging industry associations and leading enterprises to participate in developing corporate standards that are stricter than national and industry standards can help improve the standardisation of green development in the steel industry.

6.1.2 Technical environment

The mainstream steelmaking process in developed Western countries is to scrap steel as raw material for the electric furnace short process steelmaking, while China's current mainstream steelmaking process uses iron ore as the primary raw material for the converter long process steelmaking. During the Outline of the 13th five-year plan for national economic and social development of the People's Republic of China (2016-2020) (NDRC, 2016) period, China has to realize the transformation from a big steel country to a strong steel country. From the perspective of reducing dependence on imported ore, reducing carbon emissions, increasing the proportion of special steel and the proportion of electric furnace steel in developed countries, developing a short process electric furnace steelmaking process is a must. China will promote the transformation of long process steel plants in the future. Implementing the change of the stock of long process capacity is critical to increasing the proportion of short process steelmaking. In the future, relevant support policies are expected to be introduced in

order to promote the transformation of two types of long-process steel plants, namely those in environmentally sensitive areas and urban steel plants, to short-process processes, and to optimise the industrial layout and encourage the development of the scrap steel processing industry.

Under the global trend of developing a low-carbon circular economy, countries are seeking new development ideas with low energy consumption, low pollution, and low emissions. According to current technical conditions, the technology for reducing carbon dioxide emission in the iron ore smelting process is close to its limits. Only a real technological breakthrough can bring carbon dioxide emissions down even further. For this reason, many countries are actively pursuing research into hydro-metallurgical technology. KOBELCO, for example, is working with Arcelor Mittal to develop hydrogen steelmaking technology and plans to build the world's most extensive hydrogen steelmaking validation line in Germany. The Japanese steel industry is developing environmentally harmonious ironmaking process technology (COURSE50) to significantly reduce greenhouse gas emissions. The second phase of this project was conducted in 2018. The project team will develop technology for practical use, combining the technologies identified in the test blast furnace and those identified in the actual blast furnace section.

Currently, steel companies worldwide are working to apply technologies such as big data and artificial intelligence (AI) to steel production sites to significantly improve production efficiency and build a system for mass production of high value-added products. In 2019, Pohang Iron and Steel Co. Ltd and the Korea Small and Medium Enterprises Central Association jointly established the 2019 Mutual Smart Factory Support Project, setting up 500 smart plants in the next five years. In April 2020, JFE introduced the fifth generation (5G) technology at East Nippon Steel Works and promoted stable production and smart factories at JFE Steel through 4K resolution imaging and other technologies.

The pace of innovative technology in steel companies has been accelerated. In February 2019, the second steelmaking iron pre-treatment intelligent centralized control center project was successfully hot-tested in Shanghai Meishan iron and steel Limited, creating the first one-key automatic tank dumping technology in China. In April, Shagang successfully built the first industrialized ultra-thin belt production line in China by introducing the American Nucor ultra-thin belt CASTRIP technology and combining independent innovation. In July, Baosteel Co., Ltd. successfully broke the foreign technology blockade, mastered the automatic tapping technology of large-scale 300-ton converters, and successfully realized remote steelmaking using 5G technology. In September, Northeastern University released

AluSlim® high toughness Al-Si coating, breaking the 20-year patent monopoly of ArcelorMittal. In November, Zhongtian Iron & Steel independently developed the technology of “dual-furnace bottom plate structure to restrain the rise of blast furnaces”, which solved the stubborn blast furnace rise problem in the ironmaking process steel industry. In December, Baosteel developed a new material for tube bundles, which solved the global problem of short tube bundle life due to leakage of anticorrosive materials due to pickling and descaling. In January 2020, Xingtai Iron and Steel Co., Ltd. won the first prize of National Science and Technology Progress Award for the “Development and Application of Key Technologies for Green and High-efficiency Electros slag Remelting of High-quality Special Steel”. This project has achieved a historic leap from a follower to a leader in China’s electros lag technology, and it is also the first time that the national steel industry has won this honor in 15 years. In January, “Key Technologies for Efficient and Green Smelting of Clean Steel in Large Converters” jointly completed by the Institute of Iron and Steel Research, Maanshan Iron and Steel, Baosteel and Anshan Iron and Steel passed the scientific and technological achievement evaluation meeting, breaking through the key technical bottleneck for the efficient and stable production of clean steel by large converters.

6.1.3 Import and export status of China’s steel industry

In 2020, China’s steel exports continued the downward trend of the previous year, and imports increased compared with last year, continuing the net export trend.

China’s steel import market is mainly concentrated in the Asian region on the import side. Japan, South Korea, Taiwan, and other Asian regions are the most important sources of steel imports into China. Imported steel products are plated plates, medium-thickness wide steel strips, cold-rolled thin and wide strip steel, and other high value-added automotive plates. High-end plates are still the most important species of steel imported into China. It is expected that imports may reverse the downward trend due to global overcapacity overlaid with the impact of the new crown epidemic.

On the export side, the United States has steel trade conflicts with China, and the COVID-19 pandemic led to a global supply chain shakeup. Therefore, China’s steel product exports continue to face more significant pressure. The main flow of Chinese steel exports is still Southeast Asia and the Middle East, especially South Korea, Vietnam, the Philippines, Thailand, and Indonesia. Export concentration has declined. Products such as plates and bars are still the main products exported. Steel exports are expected to continue their downward

trend as the global market is in the doldrums.

6.1.4 Bank credit situation

The steel industry is a typical industry in China with high energy consumption, high pollution, and serious overcapacity. Despite years of supply-side reform, the steel industry has completed the phase-out targets set out in the 13th Five-Year Plan two years ahead of schedule. In addition, the iron and steel industry has not been removed from the list of sectors with excess capacity, despite the joint release of 2019 and 2020 Notice on the Work of Dismantling Excess Capacity in Key Areas (IMJCCR, 2019, 2020), which both delete the phrase “further implement a financial policy of retaining pressure”. However, the steel industry has not been removed from the list of sectors with excess capacity. Therefore, commercial banks are cautious in extending credit to the steel industry. Judging from the projects between major commercial banks and steel enterprises, the banks’ credit strategy to support the development of the steel industry is based on strategic cooperation with leading steel enterprises. Credit is primarily invested in deleveraging, going global, asset management, upgrading and transformation. Commercial banks need to restrict credit to steel enterprises with low technology, low value-added products, and high levels of backward production capacity, especially to smaller steel enterprises that are on the verge of elimination or restriction.

Opinions on Promoting the Implementation of Ultra-low Emission in the Iron and Steel Industry (Ministry of Ecology and Environment [MEE], 2019) proposed “incentive + push” measures. In terms of “incentives”, the preferential tax treatment is given to iron and steel enterprises that meet the conditions for ultra-low emissions. The eligible iron and steel enterprises are supported to issue corporate bonds for direct financing to raise funds for ultra-low emission renovation and other areas. In terms of “push”, differentiated electricity pricing policies and differentiated environmental management policies are implemented. The opinion requires each region to establish a differentiated electricity pricing policy and emergency emission reduction measures based on the performance of steel enterprises in terms of pollutant emissions.

In the next few years, the state’s macro-control policies for industries with serious overcapacity will continue to remain stable and continuous. The era of high growth and high profits in the steel industry will end, and the uncertainties in the development of the sector will increase. Enterprise restructuring and integration will become the central theme of

industrial restructuring. A percentage of the steel enterprises that do not have competitive advantages will be eliminated from the market. The banking industry should pay great attention to the various types of risks in steel crediting.

In 2020, China continued to introduce counter-cyclical economic adjustment policies in the face of the impact of COVID-19 pandemic on the economy. By introducing new infrastructure and increased investment, a “dual domestic and international economic cycle” is being built to enhance the stability and competitiveness of China’s supply chain and strengthen the economy’s resilience to risk. This creates a favorable macroeconomic environment for the steel industry. At the same time, 2020 is also a pivotal year for consolidating and improving the capacity of China’s steel industry. Industry mergers and restructuring, steel mill relocation and renovation, and the cleaning up of zombie enterprises are all entering the assault phase. These actions will push the steel industry to upgrade its industrial structure and achieve high-quality development. However, it should be noted that the Chinese steel industry is still facing tremendous development pressure. The uncertainty over the trend of trade friction between China and the United States has led to a rise in global trade protectionism, which has also negatively impacted the global steel trade. The impact of a prolonged COVID-19 pandemic on steel consumption will continue. The battle against pollution and the promotion of ultra-low emission transformation in the whole industry put forward higher requirements for environmental governance in the industry. Raw material prices such as iron ore continue to run at high levels, compressing the steel industry’s profitability. China’s steel demand will develop in customisation, greening, and high-end in the long run. From a comprehensive perspective, deepening supply-side reform in the steel industry will rationalise the industry’s supply structure. The transformation and upgrading of downstream industries will open up space for high-end demand in the industry. It is expected that the steel industry will continue to be in a stable and mature phase in the next three to five years, with the Prosperity index of China’s ferrous metal smelting and rolling processing manufacturing enterprises (China’s National Bureau of Statistics [CNBS], 2020) remaining at 110 to 120 points.

6.2 EIA review of steel enterprises

6.2.1 EIA review of Baosteel

Baosteel Corporation (with the full name Baoshan Iron and Steel Co., Ltd., starting now

referred to as Baosteel), is a leading global mega steel conglomerate. As one of the world's most complete steel enterprises in carbon steel varieties, Baosteel has significant production bases such as Shanghai Baoshan, Wuhan Qingshan, Zhanjiang Dongshan, and Nanjing Meishan. Baosteel's total revenue in 2019 was RMB 292.06 billion, with a total profit of RMB 14.99 billion and sales of 47.185 million tonnes of commodity billets (Baosteel, 2019a). The company has always adhered to innovation, coordination, green, openness, and sharing development path. Baosteel has a world-renowned brand and world-class technology and service capabilities.

2019 Baosteel Corporation Annual Report (Baosteel, 2019a) and 2019 Baosteel Corporation Sustainable Development Report (Baosteel, 2019b) both mentioned that the Baosteel's new, renovated, and expanded projects had implemented the "three simultaneous" regulations for environmental protection of national and local construction projects. The above projects have gone through environmental impact evaluation procedures and completion acceptance procedures. Baosteel has obtained environmental protection evaluation approvals for 64 key projects, such as the new metallurgical iron-containing dust sludge resource recycling plant, the second-step blast furnace gas cabinet renovation project, and the first and second sintering integration overhaul and renovation project. Accordingly, it can be concluded that Baosteel's environmental impact assessment (EIA) review complied with the relevant national requirements (Baosteel, 2019b).

6.2.2 EIA review of Baotou Steel

Baotou Steel Corporation is known as Inner Mongolia Baotou Steel Corporation (hereinafter referred to as Baotou Steel). The company is mainly engaged in the production and sales of steel products. Its main products include steel for construction, cold and hot rolled coils, galvanized steel sheets, medium thick plates, seamless pipes, heavy rails, section steel, and other steel products. Based on the principle that ironmaking is the center and that efficiency determines sales and sales determines production, Baotou Steel achieved stable and smooth overall production by reasonably allocating iron and water resources, scientifically preparing the sequence of casters to maintain production, and effectively organising iron balance and transportation between the old and new systems. The following section will review the environmental impact evaluation approvals of Baotou Steel for 2017, 2018, and 2019.

According to Supplementary Announcement on the Correction of the 2017 Inner Mongolia Baotou Steel Corporation Annual Report (BaotouSteel, 2017a), the post-evaluation

of environmental impact shall be carried out three years after the project is officially put into operation. In 2017, the company actively organised the post-evaluation of the environmental impact of relevant projects and completed four environmental impact evaluations. Five transformation projects are in the process of acceptance. The environmental impact evaluation review is in line with the relevant national requirements.

According to 2018 Inner Mongolia Baotou Steel Corporation Annual Report (BaotouSteel, 2018), the company organised the completion of the acceptance of environmental protection of 11 projects, such as the new Baotou Steel New System Railway Dedicated Line Project and the renovation project of the de-dusting system of the steelmaking system of Baotou Steel Sheet Plant. The company organized and completed the EIA of five projects, including the ADA desulphurization process for the ex-factory gas of Baotou Steel coking plant and Baotou Steel domestic waste transfer station. In 2018, Baotou Steel successfully passed the environmental management system audit work, and the EIA approval review of Baotou Steel complied with the relevant national requirements.

According to the 2019 Inner Mongolia Baotou Steel Corporation annual report (BaotouSteel, 2019a) and the 2019 Inner Mongolia Baotou Steel Corporation Sustainable Development Report (BaotouSteel, 2019b) stated in 2019, Baotou Steel organised the completion of the environmental protection acceptance of 11 projects, including the chromium-free passivation renovation project of the galvanising line of the thin plate plant, the environmental impact evaluation of seven projects, including the 159 heat treatment line 2 project of the steel pipe company, and the Baoshan Mining Branch, the Coal Coking Chemical Branch, the thin plate plant, the inspection and acceptance work for the networking of automatic monitoring facilities for pollution sources of 4 units of Rare Earth Steel Refinery. At the same time, Baotou Steel's head office and all subsidiaries passed the ISO14001 environmental management system certification, which improved the environmental management level of the enterprise and achieved remarkable results. 2019 Baotou Steel successfully passed the environmental management system audit work, and the EIA approval review of Baotou Steel complied with the relevant national requirements.

In summary, Baotou Steel passed the EIA review in 2017, 2018, and 2019.

6.2.3 EIA review of Fangda Special Steel

Fangda Special Steel is known as Fangda Special Steel Technology Corporation (hereinafter referred to as Fangda Special Steel). The company has a complete industrial chain of “mining

- smelting - rolling of spring flat - plate spring”. Its domestic market share of spring flat steel and automobile leaf spring ranks at the forefront of the industry. In 2019, the company achieved an operating income of RMB 15.38 billion, realized a total profit of 2.34 billion yuan, and total assets of RMB 12.49 billion (Fangda Special Steel, 2019a). Fangda Special Steel implemented differentiated, high-quality, distinctive, and low-cost competition strategies and insists on optimizing product structure. According to China Iron and Steel Association statistics, Fangda Special Steel’s profit per ton of steel in 2019 was RMB 623, which was RMB 413 more than the average per ton of steel of the benchmarking company, RMB 209.59. It has maintained the second level of the industry, and the profitability is significantly better than the industry average.

2019 Fangda Special Steel Corporation Technology Annual Report (FangdaSpecialSteel, 2019a) and 2019 Fangda Special Steel Corporation Sustainable Development Report (FangdaSpecialSteel, 2019b) illustrated that the Company carried out environmental impact evaluation in strict accordance with the requirements of environmental protection laws and regulations, obtaining approvals of environmental impact evaluation for various projects. In 2019, the Company successively carried out environmental impact evaluation for the 600TPD sleeve kiln active lime construction project, the VPSA variable pressure adsorption oxygen generator project, the coke oven flue gas desulphurisation denitrification project, and the post-sintering desulphurisation wet power and white mist removal transformation project of the iron-making plant, all obtaining approvals of environmental impact evaluation. As required, the company has promptly registered the environmental impact evaluation for the coking coal yard shed project, the iron-making raw material yard closed transformation project, and the three times de-dusting of the converter. In summary, it can be seen that the approval and review of environmental impact evaluation of Fangda Special Steel comply with the relevant national requirements.

6.3 Application of ERE models for commercial banks

6.3.1 ERE of Baosteel

The environmental status of Baosteel is disclosed in detail in the 2019 Baosteel Corporation Annual Report (Baosteel, 2019a). This section provides a comprehensive analysis of environmental information based on publicly available corporate-related environmental information of Baosteel, press reports, emission concentrations and emission limits set by the

state.

Firstly, this section examines Baosteel's environmental management performance from the perspective of pollution management. Baosteel has proactively carried out the treatment of pollution emissions following the requirements of the environmental protection authorities for pollution emissions in the steel industry. The author obtained information from its annual Report, public information on emission concentrations, and emission limits set by the state, as shown in Table 6.1. As can be seen from Table 6.1, the emission concentrations on air pollutants and water pollutant emissions are in line with the relevant standards, and the total annual emissions of the company have not reached the total permitted emissions. Regarding solid waste disposal, the company actively promoted solid waste processing and disposal, insisted on classification and control of solid waste at source, compliant and reasonable storage of solid waste, and actively promoted the application of the rotary bottom furnace process. The company commenced construction of two rotary bottom furnaces with an annual processing capacity of 250,000 tonnes, which significantly enhanced the company's ability to dispose of metallurgical dust containing zinc and iron. In terms of compliant and reasonable storage of solid waste, the company centralised solid waste in two solid waste flow turnover areas, namely the dry coal shed and the new coking coal yard, to achieve compliance in solid waste storage.

Table 6.1 Pollutant emission compliance of Baosteel Corporation

Company	Major Pollution	Outfall Distribution	Number of outfalls	Emissions Concentration	Total emissions (tonnes/year)	Permitted emissions Total volume (tonnes/year)	Exceeding emission standards
Baoshan Steel Limited Shares Company	by Particulate matter	Ironmaking, steelmaking, rolling	464	All comply with the relevant standards	4,725	8,894	None
	Sulphur dioxide				5,499	7,576	None
	Nitrogen oxides				10,093	13,796	None
	Chemical oxygen demand (COD)	Wastewater treatment outfall	7		147.2	189.74	None
	Ammonia nitrogen				7.14	14.77	None

Source: Baosteel 2019 Annual Report 2019 (Baosteel, 2019a)

Secondly, this section examines Baosteel's environmental risks from an environmental management perspective. In terms of disclosure of environmental statistics, Baosteel has continued to increase its efforts to disclose information. Following the emission permit requirements, Baosteel has made all production information of the units involved in all wastewater and exhaust gas outfalls, information on treatment facilities, and monitoring information public. At the same time, Baosteel also monitors soil, groundwater, and surface through a pilot scheme. The results show no exceedances throughout the year, which indicates that Baosteel's pollutants are discharged according to the standards. At the beginning of each year, Baosteel draws up a plan for self-monitoring and information disclosure and reports it to the Environmental Protection Bureau for the record. At the end of each year, Baosteel completes its self-monitoring report and reports it to the local environmental protection management government agency for the record. In respect of emission permit management, Baosteel has carried out the application for emission permits in accordance with the requirements of Interim Provisions on the Administration of Emission Permits (MEP, 2016) and Technical Specification for Application and Issuance of Emission Permits: Iron and Steel Industry of the PRC (MEP, 2017), and has obtained the emission permits for pollutants issued by the local environmental protection bureau. On the National Emission Permit Management Information Platform, it is also clear that the bases have applied for the corresponding emission management permits following the relevant requirements, declared the emission permits promptly, and paid the emission fees.

In terms of environmental management system certification (ISO14001), Baosteel was the first in China's metallurgical industry to be certified to the ISO14001 environmental compliance standard. In addition, Baosteel has trained most of its employees in the skills of internal auditors of enterprises approved by the national environmental supervision and management system. In terms of environmental protection personnel, departments and environmental protection management systems, all managers and employees strengthen their knowledge of environmental protection management, focus on promoting key remediation in highly polluted areas, and enhance the prevention of environmental disasters and emergency response capabilities. Special training on the interpretation of Opinions on Promoting the Implementation of Ultra-Low Emission in the Iron and Steel Industry (MEE, 2019) was conducted to enhance the environmental protection awareness of employees. Baosteel established a special energy and environmental protection department responsible for inspecting and improving environmental pollution in the enterprise. Baosteel revised and improved the Environmental Factor Identification and Control Procedures and signed the

Energy Conservation and Environmental Protection Target Responsibility Letter to implement the Party and government accountability system, double accountability for one post and accountability for failure.

Secondly, this section examines Baosteel's environmental performance in terms of social impact. Baosteel has not been subject to administrative penalties from the environmental protection authorities for substandard pollutant emissions. There have also never been any environmental emergencies or significant environmental violations at Baosteel. Baosteel has not been condemned or complained about by the public for environmental issues. In addition, Baosteel has established a comprehensive emergency response plan mechanism for environmental emergencies as required.

Finally, this section explores Baosteel's environmental performance in terms of corporate greenness. In terms of resource and energy consumption, Green Manufacturing Project Implementation Guide (2016-2020) (SPDB, 2008) required steel enterprises to reduce their integrated energy consumption to 0.57 tonnes of standard coal per tonne of steel. Its annual comprehensive energy consumption was 0.578 tonnes of standard coal per tonne of steel (Baosteel, 2019a), which means that in terms of energy consumption, Baosteel has basically met the requirements of the green manufacturing. In terms of process equipment level, all three coal-fired units and one gas-fired unit at Baosteel have completed the ultra-low transformation. The pollutant emission concentration of the two sintering units is far below the national emission standard. Baosteel has actively promoted the source emission reduction of wastewater, implemented lye recovery technology for rolling steel, and has an industrialized unit with a low discharge of coking wastewater. In terms of green spending, Baosteel's environmental protection cost per tonne of steel is RMB 180. Based on the current environmental protection facilities in the steel industry, the average environmental protection cost per tonne of steel in the steel industry is approximately RMB 80. The above information about Baosteel's process equipment level shows that Baosteel's environmental protection cost per tonne of steel is much higher than the average level of its peers.

The above-detailed analysis of Baosteel's pollution management, environmental management, social impact, and corporate greenness, combined with Enterprise Environmental Credit Evaluation Measures (for Trial Implementation) (MEP, 2013) for expert scoring, the final scoring results are shown in Table 6.2.

Table 6.2 Baosteel's environmental indicator scores

Environmental indicators	Score	Environmental indicators	Score
Exhaust emissions	100	Environmental administrative penalties	100
Wastewater discharge	100	Significant environmental violations	100
Solid waste disposal	100	Environmental emergencies	100
Disclosure of environmental statistics	100	Public complaints	100
Pollution permit management	100	Resource and energy consumption	100
Environmental management system certification	100	Process equipment level	100
Environmental personnel, departments, and environmental management systems	90	Green spending	100

Based on the AHP model's weights for commercial banks' environmental risk assessment and Baosteel's environmental protection index score, Baosteel's overall ERE score was calculated as 99.817. Baosteel is an enterprise with excellent environmental protection regarding the enterprise ERE standard.

6.3.2 ERE of Baotou Steel

Baotou Steel Corporation has disclosed its environmental status in detail in the 2017 Inner Mongolia Baotou Steel Corporation Annual Report (BaotouSteel, 2017b), 2018 Inner Mongolia Baotou Steel Corporation Annual Report (BaotouSteel, 2018), and 2019 Inner Mongolia Baotou Steel Corporation Annual Report (BaotouSteel, 2019a). This section provides a comprehensive analysis of Baotou Steel's environmental information based on its publicly available corporate environmental information and news reports.

Firstly, this section examines the environmental risks of Baotou Steel from the perspective of pollution management. Baotou Steel is proactive in managing its pollution emissions by the requirements of the environmental protection authorities for the steel industry. This study obtains information from publicly available information such as Baotou Steel's various annual reports and national regulations on emission concentrations and emission limits. Baotou Steel's key emission branches are its sheet metal plant, Guyang Mining Company, and Iron Reduction Company.

The actual emissions of Baotou Steel's flue gas in 2017 were 19,729.15 tonnes of nitrogen oxides, 9,074.5 tonnes of sulphur dioxide, and 8,356.69 tonnes of particulate matter. The total emissions were less than the permitted emissions, but there were gas emissions exceeding the standard in some periods. The company's 2017 actual emissions of water pollutants were 374.79 tonnes of chemical oxygen demand (COD) and 16.97 tonnes of ammonia nitrogen. Baotou Steel's wastewater and gas emissions met the requirements of the total emission control index of the emission permit (Baotou Steel, 2017b).

The actual emissions of Baotou Steel's flue gas in 2018 were 26,853 tonnes of nitrogen oxides, 14,054 tonnes of sulphur dioxide, and 11,483.5 tonnes of particulate matter. The actual emissions of water pollutants in 2018 were 457.969 tonnes of COD and 27.183 tonnes of ammonia nitrogen. These meet the requirements of the total emission control index of the discharge permit (BaotouSteel, 2018).

The actual emissions of flue gas from Baotou Steel JSC in 2019 were 24,441.2 tonnes of nitrogen oxides, 13,820.4 tonnes of sulphur dioxide and 10,401.2 tonnes of particulate matter. The total emissions were less than the permitted emissions. The 2019 actual emissions of water pollutants from Baotou Steel were 482.38 tonnes of COD and 26.55 tonnes of ammonia nitrogen (BaotouSteel, 2019a), which were in line with the requirements of the total emission control index of the emission permit. Still, there were cases that gas emissions exceeded the permitted quantity. In respect of solid waste disposal, Baotou Steel has enhanced the comprehensive utilisation rate of solid waste such as steel slag, converter sputtering slag and blast furnace water slag by strengthening the amount of comprehensive utilisation of solid waste resources, optimising the route of resource utilisation, and broadening the way of resource utilisation. These practices have gradually reduced the number of historical stockpiles and substantially reduced the environmental risks of open piles.

Secondly, this section examines the environmental risks of Baotou Steel from the perspective of environmental management. In terms of disclosure of environmental statistics, Baotou Steel has monitored all of its subsidiary branches that are included in the need for state-controlled pollution sources. The monitoring program is uploaded to the website of the Environmental Protection Department of Baotou, Inner Mongolia, for public display. Baotou Steel conducted monitoring of its subsidiaries in accordance with the points, content, and frequency set out in the monitoring program. The monitoring results are published on the website of the Inner Mongolia Environmental Protection Department in accordance with the monitoring reporting timelines. Baotou Steel has built the first domestic enterprise emissions permit management platform in terms of emissions permit management. The platform is based on the management of emission permits and uses management tools to manage pollution sources and the collaborative control of multiple pollutants. In 2017, 2018 and 2019, Baotou Steel carried out the application for emission permits as required and successfully obtained them. In addition, the company successfully passed the environmental management system (ISO 14001) certification work in 2017, 2018 and 2019.

In terms of environmental protection personnel, departments and environmental protection management systems, according to the environmental risk sources that exist,

Baotou Steel formulated corresponding environmental risk emergency response plans, set up emergency response facilities and equipment, and conducted regular drills. At the same time, following the requirements of Measures for the Management of Environmental Emergencies (Baotou Steel, 2019c), Baotou Steel revised and prepared new emergency plans for environmental emergencies. Several environmental risk emergency plans and reports were completed, such as the “Comprehensive Emergency Plan for Sudden Environmental Events”, the “Special Emergency Plan for Sudden Environmental Events”, the “Risk Assessment Report for Sudden Environmental Events,” and the “Emergency Resource Survey Report for Sudden Environmental Events”. In addition, Baotou Steel conducted environmental protection technical training for environmental protection technicians who managed pollutants once or twice a year to enhance their staff’s awareness of environmental protection.

Secondly, this section examines Baotou Steel’s environmental performance from the perspective of social impact. In terms of administrative penalties, the author checked the enforcement information disclosure platform of the Kundulun District Branch of the Baotou Ecological and Environmental Protection Bureau. The results showed that Baotou Steel was fined RMB 250,000 as an administrative penalty for exceeding 0.13 times the standard for sulphur dioxide at the No. 9 coke oven waste gas vent on 7 October 2019. Baotou Steel received no environmental administrative penalties in 2018. In 2017, Baotou Steel received 36 environmental penalties from the Kundulun District Branch of the Baotou Environmental Protection Bureau. The penalties were for abnormal operation of air pollution prevention and control facilities, failure to take airtight measures to prevent dust pollution from the coke stored in the ironmaking plant, and excessive coke oven exhaust gas emissions. Apart from the administrative penalties, Baotou Steel did not have any environmental emergencies or significant environmental violations. Baotou Steel was not subject to public censure or complaints about environmental issues.

Finally, this section considers the environmental performance of Baotou Steel in terms of corporate greenness. In terms of resource and energy consumption, 2017 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2017b), 2018 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2018) and 2019 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2019a) showed that Baotou Steel integrated energy consumption per tonne of steel was 0.84, 0.81 and 0.78 tonnes of standard coal, respectively. This is still short of the 0.57 tonnes of standard coal required in the Green Manufacturing Project Implementation Guide (2016-2020) (MIIT, 2016).

In terms of process equipment level, in 2017, Baotou Steel invested about RMB 800

million in 25 environmental management projects, including the project of adding a catalyst to have stretford process desulphurization for coking ex-gas, the project of expanding the capacity of three recycling saturators, and increasing the desulphurization capacity of the coking plant, and the treatment of No.2 desulphurization purification plume in the second part of the sintering plant of the iron-making plant, to further improve Baotou Steel's environmental protection level. Baotou Steel won second place in the 2017 World Steel Association Life Cycle Assessment "Steelie" Award and was named a national "Pilot Enterprise of Eco (Green) Design for Industrial Products". Baotou Steel was the only steel company to pass the first acceptance assessment (Baotou Steel, 2017b).

In 2018, Baotou Steel invested RMB 834 million for the implementation of the Barun coal-fired boiler renovation project, the Guyang Mining Company coal-fired boiler renovation project, the Guyang Mining Company pellet production line resumption of environmental protection upgrade and renovation, the Baiyun beneficiation branch coal yard closure, the storage center No.1 steam unloading dust removal renovation, the coking, and rare earth steel coking department No.1 to No.4 coke oven additional desulfurization and denitrification device project, and the coking factory gas other stretford process. The project included 25 environmental management projects, such as: the expansion of saturator in the gas purification department of Coking New District Rare Earth Steel, the expansion of saturator and increase of desulphurization capacity of three recycling saturators in coking plant, the volatile organic compounds treatment project of gas purification system in coking plant, the deep treatment and reuse of phenol and cyanide wastewater, and the project of a domestic waste transfer station in the plant (Baotou Steel, 2018).

In 2019, Baotou Steel eliminated outdated production equipment through structural adjustment. Baotou Steel successively stopped four 4.3-meter coke ovens, four 90-square-meter sintering machines, one 162-square-meter belt pellet machine, four 8-square-meter pellet shaft furnaces, two 80-ton converters, four 250-meter lime shaft kilns, five iron blending furnaces, four 90-square-meter tunnel kilns, and other equipment with low environmental protection level. Baotou Steel completed the elimination or clean transformation of 37 coal-fired boilers. At the same time, arrangements were made to implement the coal coke chemical branch one to ten coke ovens ultra-low emission transformation project, fine coal crushing, coke screening and transfer, coke pushing, ammonium sulphide crystallization, and drying. Thirty-seven sets of dust removal - facilities transformation projects enhanced the environmental protection level and ensured that pollutants were discharged following the standards (Baotou Steel, 2019a).

In terms of green spending, the average tons of steel environmental protection costs for Baotou Steel in 2017, 2018, and 2019 were RMB 124, RMB 135, and RMB 140, respectively (Baotou Steel, 2019a). Based on the current environmental protection facilities in the steel industry, the average environmental protection cost per tonne of steel is approximately RMB 80. Therefore, Baotou Steel's green expenditure is higher than the steel industry average.

Through the above-detailed analysis of Baotou Steel's pollution management, environmental management, social impact, and corporate greenness, combined with the expert scoring of Enterprise Environmental Credit Evaluation Measures (for Trial Implementation) (MEP, 2013), the scoring results of each environmental protection indicator of Baotou Steel were obtained for each year, as shown in Table 6.3.

Table 6.3 2017-2019 Baotou Steel's environmental indicator scores

Environmental indicators	2017	2018	2019	Environmental indicators	2017	2018	2019
Exhaust emissions	60	85	80	Environmental administrative penalties	20	90	80
Wastewater discharge	60	85	85	Significant Environmental Violations	70	90	100
Solid waste disposal	80	80	80	Environmental emergencies	100	100	100
Disclosure of Environmental Statistics	100	100	100	Public Complaints	100	100	100
Pollution permit management	100	100	100	Resource and energy consumption	70	75	80
Environmental Management System	100	100	100	Process equipment level	70	75	80
Environmental Certification							
Environmental personnel, departments, and environmental management systems	80	80	80	Green spending	70	75	80

According to the weights in the commercial bank's ERE AHP model and Baotou Steel's environmental protection indicator scores for 2017, 2018, and 2019, can be calculated that Baotou Steel's overall ERE scores for each year are: 74.08, 84.53, and 85.61, respectively. Baotou Steel's environmental protection rating for 2017 is a warning regarding the enterprise ERE criteria, but Baotou Steel's environmental protection rating for 2018 and 2019 is good.

6.3.3 ERE of Fangda Special Steel

Fangda Special Steel disclosed its environmental status in the 2019 Fangda Special Steel Technology Corporation Annual Report (Fangda Special Steel, 2019a). This section provides a comprehensive analysis of environmental information based on Fangda Special Steel's publicly available corporate-related environmental details, news reports, and nationally

prescribed emission concentrations and emission limits.

Firstly, this subsection examines the environmental management performance of Fangda Special Steel from the perspective of pollution management. From the 2019 Fangda Special Steel Technology Corporation Annual Report (Fangda Special Steel, 2019a) and Discharge Standard of Pollutants for Iron and Steel Industry (MEP, 2012g), it is clear that Fangda Special Steel had 64 existing exhaust gas emission outlets, which were distributed in the coking plant, ironmaking plant, steelmaking plant, rolling mill and power plant, with the emission going to the atmosphere through the chimney (exhaust pipe). Fangda Special Steel had two outlets to emit wastewater, divided into the broad emission and the water emission outlet of the coking plant. The central discharge was located to the south of the special steel plant, and the wastewater was discharged intermittently, with the unstable and irregular flow during the discharge period. However, it is not an impact-type discharge, and the wastewater was discharged to the Changdong drainage channel. The coking plant water discharge was distributed in the coking plant, and the wastewater was discharged continuously with a stable flow rate. The wastewater was discharged directly to the Yaohu Wastewater Treatment Plant through the drainage pipe. Fangda Special Steel had successively arranged online monitoring facilities at 14 major emission outlets, such as sintering and pellet flue gas desulphurization emission outlets, sintering machine tail, and blast furnace iron output field, in order to implement 24-hour real-time monitoring. Once there was a tendency for the emission to exceed the standard, immediate measures would be taken to ensure that waste gas emission is lower than the national standard. The testing data from the exhaust gas and wastewater discharge outlets showed that Fangda Special Steel had maintained compliance with the emission standards. The total emissions were less than the permitted emissions. In terms of solid waste treatment, Fangda Special Steel used a combination of hot stewing + crushing and magnetic separation to treat steel slag. However, due to site constraints, the hot stewing treatment line for liquid steel slag from the converter was arranged separately from the cold steel slag crushing and magnetic separation line, and the hot stewed slag was transported by car to the steel slag crushing and magnetic separation line outside the plant for processing and recycling. The extensive use of steel slag had always remained in the internal cycle, collecting iron-containing materials and using them back to steelmaking iron recycling. However, the deep processing technology and the recycling of tailings were rarely adopted.

Secondly, this section examines the environmental risks of Fangda Special Steel from the perspective of environmental management. In terms of disclosure of environmental statistics, Fangda Special Steel installed online monitoring devices for pollutant emissions at the

discharge ports of important facilities such as sintering and pellet desulphurisation facilities, sintering machine tail de-dusting, blast furnace iron output yard de-dusting and converter secondary de-dusting, which were networked with environmental protection departments. Fangda Special Steel's environmental protection facilities were in good condition and operating normally, with a 100% compliance rate of emission from each facility and a 100% effective transmission rate of online monitoring data. In terms of emission permit management, Fangda Special Steel applied for the declaration of emission permit following the corresponding requirements and passed the audit of the environmental protection department. Fangda Special Steel passed the certification of quality, environmental, occupational health and safety and measurement management systems in terms of environmental management system certification. Fangda Special Steel prepared the Emergency Response Plan for Environmental Incidents in the Production Area of Fangda Special Steel Technology Company Limited in terms of environmental protection personnel, departments, and environmental protection management system. This plan specified the level of warning and early warning measures after an environmental pollution incident according to the degree of harm, the scope of influence, the internal ability to control the state of affairs, and the emergency resources to be mobilised.

Thirdly, the environmental performance of Fangda Special Steel was examined from the perspective of social impact. Fangda Special Steel was given administrative penalties for environmental protection by the national, provincial, municipal, and district environmental protection authorities on many occasions. In the meantime, the company was involved in open-air storage of lump ore raw materials, quicklime and coke, and inadequate measures in "prevention of dispersion, loss and leakage" according to Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste, which are suspected of environmental violations.

In 2019, a gas leak occurred in the No. 2 blast furnace of Fangda Special Steel's coking plant during maintenance, resulting in a fire and explosion that killed two workers and injured eight. In addition, the public often reports Fangda Special Steel for environmental issues. Report on the "Voice of the People" (NCNews, 2014) showed that the environment of Qianwan Village, a wall away from Fangda Special Steel, had deteriorated, with a strong smell of coal smoke and tar, and severe dust and powder. Report on the "Local Leaders' Message Board" (People Net, 2022) showed that the environmental pollution problem in the area around Fangda Special Steel was worsening, and dust was flying all over the sky. More and more deaths from particular diseases such as cancer and leukaemia among nearby

residents, possibly related to environmental pollution.

Finally, this section considers the environmental performance of Fangda Special Steel in terms of corporate greenness. In terms of resource and energy consumption, Fangda Special Steel's annual integrated energy consumption of 0.97 tonnes of standard coal per tonne of steel (Fangda Special Steel, 2019a), which is a large gap from the 0.57 tonnes of standard coal required in Green Manufacturing Project Implementation Guide (2016-2020) (MIIT, 2016). In terms of process equipment level, Fangda Special Steel had a complete set of pollution prevention and control facilities. By the end of December 2019, Fangda Special Steel had 160 sets of environmental protection facilities, including 65 sets of waste gas treatment facilities, 10 sets of water treatment facilities, 84 sets of noise management facilities, and 1 set of slag treatment facilities. The pollution prevention and control equipment enhanced Fangda Special Steel's environmental protection level. In terms of green expenditure, the average environmental protection cost of Fangda Special Steel was RMB 94 per tonne of steel. In contrast, the average environmental protection cost of the steel industry is approximately RMB 80 per tonne of steel according to the current environmental protection facilities in the steel industry (Fangda Special Steel, 2019a). The green expenditure of Fangda Special Steel was slightly higher than the average level of the steel industry.

Through the above-detailed analysis of pollution management, environmental management, social impact, and corporate greenness, Fangda Special Steel's environmental performance is not satisfactory, and its performance is poor. Combined with Enterprise Environmental Credit Evaluation Measures (for Trial Implementation) (MEP, 2013) for expert scoring, the final scoring results are shown in Table 6.4.

Table 6.4 Fangda Special Steel environmental indicator scores

Environmental indicators	Score	Environmental indicators	Score
Exhaust emissions	50	Environmental administrative penalties	20
Wastewater discharge	50	Significant environmental violations	20
Solid waste disposal	50	Environmental emergencies	20
Disclosure of environmental statistics	70	Public complaints	20
Pollution permit management	70	Resource and energy consumption	50
Environmental management system certification	80	Process equipment level	50
Environmental personnel, departments, and environmental management systems	60	Green spending	70

According to the weightings in the commercial banks' ERE AHP model and the environmental indicators score of Fangda Special Steel, the overall ERE score of Fangda Special Steel is 52.57. Concerning the enterprise ERE criteria - Fangda Special Steel is a non-performing enterprise in terms of environmental protection - and its environmental

performance has not met the standards. Although its profitability is super strong and can bring considerable profits to the bank, commercial banks should not grant loans to the enterprise based on corporate environmental risks.

6.4 Application of CRE models for commercial banks

6.4.1 CRE of Baosteel

By reviewing the 2019 Baosteel Corporation Annual Report (Baosteel, 2019a), the financial information required for this paper can be obtained, as shown in Table 6.5.

Table 6.5 2019 Baosteel share financial information

Financial Indicators	Numerical values	Financial Indicators	Numerical values
Net profit	14,270,692,982	Total liabilities	85,646,574,295
Net profit for the previous year	9,401,183,384	Quick-acting assets	47,676,670,401
Other current assets	28,827,643,909	Prior year operating income	125,587,444,953
Prepayments	1,517,502,941	Operating income for the year	131,362,437,134
Current assets	93,606,995,375	Operating costs	114,206,599,679
Current liabilities	76,298,221,330	Accounts receivable at the beginning of the year	10,835,531,758
Inventory at the beginning of the year	11,103,486,717	Accounts receivable at the end of the year	17,056,459,620
Year-end inventories	13,521,669,741	Owner's equity at the beginning of the year	148,964,244,252
Total assets at the beginning of the year	243,018,625,689	Owner's equity for the year	153,439,402,514
Total assets at the end of the year	239,085,976,809	Non-current assets due within one year	2,063,508,380

The above financial information allows for calculating specific values for each financial indicator, as shown in Table 6.6.

Table 6.6 Specific values of Baosteel's financial indicators for 2019

Indicators	Calculation formula	Numerical values
Gearing ratio	Total liabilities/total assets	35.53%
Current ratio	Current assets/current liabilities	1.23
Quick ratio	Quick assets/current liabilities	62.49%
Sales revenue growth rate	Sales growth for the year/sales in the previous year	4.60%
Net asset growth rate	Increase in net assets for the year / prior period net assets	3.00%
Net sales margin	Net profit/sales revenue	10.86%
Return on net assets	Net profit/average shareholders' equity	9.44%
Total net asset margin	Net profit/average total assets	5.92%
Total asset turnover ratio	Sales revenue/average total assets	0.54
Accounts receivable turnover ratio	Average sales revenue/accounts receivable balance	9.42
Inventory turnover rate	Cost of goods sold/average balance of inventory	9.28

After collating Baosteel's financial information, this study requires collecting and analyzing its non-financial information by consulting annual reports, industry information, credit records, and other publicly available information.

From the perspective of historical credit, this study focuses on Baosteel's historical credit information through the Baosteel Corporation Basic Credit Information Report (National Enterprise Credit Information Public Display System, 2020). From the website, the author found that Baosteel had no administrative penalties, had not been listed in the business exception list, and the list of enterprises in serious breach of law and default. Baosteel had no outstanding non-performing credit information, so the enterprise had good credit.

In terms of the business environment, carbon dioxide emissions will peak by 2030 and become carbon neutral by 2060 in China's carbon neutral policy. The steel industry already leads all industries in carbon emissions as an important body responsible for achieving carbon neutrality. At the same time, China's steel industry has entered a long cycle of capacity removal and structural adjustment, and the industry is facing more prominent contradictions and problems. Ecological civilisation, the upgrading of material demand, and the transformation of the industry into a service industry have put forward higher requirements for the development of the steel industry. With the continued deepening of supply-side structural reform and the introduction of more stringent environmental protection measures, the overall supply of steel fell back. The steel industry shows a double downward trend in demand and capacity, so it is difficult to reverse the overcapacity situation in the short term. However, China is currently accelerating the elimination of steel enterprises with backward production capacity, accelerating the M&A of steel enterprises, which is conducive to enhancing upstream and downstream bargaining power. As the number one steel enterprise in China, Baosteel still has excellent opportunities.

In terms of competitiveness, Baosteel continued to implement a development strategy characterised by technological leadership. Baosteel focused on the cultivation of innovative capabilities. It actively developed and applied advanced manufacturing, energy-saving, and environmental protection technologies. Baosteel established a nationwide and worldwide marketing and processing service network. Baosteel continued to implement a development strategy characterised by technological leadership, focusing closely on China's high-end manufacturing industries, such as nuclear power, high-speed rail, offshore equipment, and new energy vehicles. Baosteel developed high-end products, including ultra-high-strength steel and oriented silicon steel. Baosteel developed and stockpiled higher-end new material technologies, gradually shifting its focus from steel to materials. Baosteel proposed

transforming its main business from steel to materials, and from manufacturing to service. Baosteel increased its investment in technological innovation and continued to progress in product development and technological advancement in 2019. The R&D investment rate was 2.3% and the percentage of invention patent applications was 88%. Seven products: thin gauge oriented silicon steel B18P080, quenched ductile steel QP1500, high strength and high precision magnetic yoke steel SXRE750, non-quenched high strength geological drilling pipe BGR950, hot rolled double-sided clad aluminium substrate steel BFA280S, deep-drawn DRD beverage can clad iron, and 2205 duplex stainless steel marine composite plate, achieved world premiere. Baosteel was included in the first Innovation China Top 100 Listed Companies released by Panorama.com and the School of Economics of Fudan University. Compared with its competitors, Baosteel enjoyed a strong capacity for innovation and development.

In terms of management level, Baosteel established a sound corporate governance structure and formulated a precise performance evaluation and remuneration management system for senior management. These systems were effectively implemented after being considered and approved by the Remuneration and Evaluation Committee of the Board of Directors and the Board of Directors. The remuneration of Baosteel's senior management was closely linked to Baosteel's performance and their performance. The mechanisms from the determination of performance targets, daily remuneration management, performance evaluation, and remuneration all operated under a standardised process. At the 5th Annual China Conference and the 2nd Ram Charan Management Practice Awards held on the theme of "New Technology: New Management," the Company was awarded the "Special Award for Management Practice in the 40 Years of Reform and Opening Up", the first place of "Best Investor Relations Company" of Institutional Investor's 2018 "Asia Pacific Corporate Management Team" ranking in the primary materials category, and the first "New Fortune Best Listed Company", the "Top 50 Best Boards in China" jointly selected by Fortune China and Aon Hewitt Management Consulting, and the "Innovation China: Top 100 Listed Companies" title (Baosteel, 2018). The company has strong team management capabilities.

Standard Values for Enterprise Performance Evaluation (State-owned Assets Supervision and Administration Commission [SASAC], 2019) considered steel enterprises to be in the ferrous metal smelting industry, so this study uses the average value of the ferrous metal smelting industry as a reference for expert scoring. Based on the above given financial indicators and non-financial indicators of Baosteel, the financial and non-financial indicator scores for the enterprise are shown in Table 6.7.

Table 6.7 Baosteel share scores for financial and non-financial indicators

Indicators	Numerical values	Average	Score
Gearing ratio	35.53%	60.1%	100
Current ratio	1.23	1.12	90
Quick ratio	62.49%	38.7%	90
Sales revenue growth rate	4.60%	-15.4%	100
Net asset growth rate	3.00%	7.6%	100
Net sales margin	10.86%	4.6%	100
Return on net assets	9.44%	5.1%	100
Total net asset margin	5.92%	3.4%	100
Total asset turnover ratio	0.54	0.4	80
Accounts receivable turnover ratio	9.42	11.4	60
Inventory turnover rate	9.28	5.7	85
Historical credits			100
Business environment			75
Competition strength			90
Management level			100

Based on Baosteel's scores on financial, non-financial, and environmental indicators, the AHP model for credit assessment of commercial banks constructed in the previous chapter was applied, and Baosteel's overall score is 95.91 through yaahp software. Against the credit assessment criteria, it can be determined that Baosteel's credit rating is AAA, namely excellent credit. It is in line with the A3 long-term credit rating given to the company by the international rating agency Moody's (Baosteel, 2019a). The company is currently the best steel mill in China in terms of green steel mills and city-production integration.

6.4.2 CRE of Baotou Steel

By reviewing the 2017 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2017b), the 2018 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2018), and the 2019 Inner Mongolia Baotou Steel Corporation Annual Report (Baotou Steel, 2019a), it was obtained the financial information required for this study, as shown in Tables 6.8, 6.9 and 6.10.

Table 6.8 Financial information of Baotou Steel in 2017

Financial Indicators	Numerical values	Financial Indicators	Numerical values
Net profit	2,141,872,051	Total liabilities	96,071,395,111
Net profit for the previous year	252,112,387	Quick-acting assets	18,923,741,265
Other current assets	1,887,385,355	Prior year operating income	30,882,187,260
Prepayments	790,410,832	Operating income for the year	53,375,100,599
Current assets	40,486,105,566	Operating costs	45,197,979,227
Current liabilities	87,853,394,420	Accounts receivable at the beginning of the year	1,740,264,102
Inventory at the	14,240,540,249	Accounts receivable at the	3,092,168,118

beginning of the year		end of the year	
Year-end inventories	18,884,568,114	Owner's equity at the beginning of the year	47,522,367,272
Total assets at the beginning of the year	140,587,517,587	Owner's equity for the year	49,701,253,709
Total assets at the end of the year	145,772,648,820	Non-current assets due within one year	---

Table 6.9 Financial information of Baotou Steel in 2018

Financial Indicators	Numerical values	Financial Indicators	Numerical values
Net profit	3,081,168,208	Total liabilities	95,417,558,380
Net profit for the previous year	2,141,872,051	Quick-acting assets	42,992,150,283
Other current assets	777,999,136	Prior year operating income	53,375,100,599
Prepayments	434,276,414	Operating income for the year	69,745,049,506
Current assets	62,405,518,589	Operating costs	59,996,146,540
Current liabilities	79,185,530,999	Accounts receivable at the beginning of the year	3,092,168,118
Inventory at the beginning of the year	18,884,568,114	Accounts receivable at the end of the year	3,440,691,124
Year-end inventories	18,201,092,756	Owner's equity at the beginning of the year	49,701,253,709
Total assets at the beginning of the year	145,772,648,820	Owner's equity for the year	52,596,181,376
Total assets at the end of the year	148,013,739,756	Non-current assets due within one year	---

Table 6.10 Financial information of Baotou Steel in 2019

Financial Indicators	Numerical values	Financial Indicators	Numerical values
Net profit	3,245,262,540	Total liabilities	86,205,090,213
Net profit for the previous year	3,081,168,208	Quick-acting assets	32,050,708,974
Other current assets	1,408,543,240	Prior year operating income	69,745,049,506
Prepayments	744,408,355	Operating income for the year	63,074,845,682
Current assets	51,502,037,057	Operating costs	57,437,984,283
Current liabilities	68,165,489,964	Accounts receivable at the beginning of the year	3,440,691,124
Inventory at the beginning of the year	18,201,092,756.30	Accounts receivable at the end of the year	5,401,970,322
Year-end inventories	17,298,376,488	Owner's equity at the beginning of the year	52,596,181,376
Total assets at the beginning of the year	148,013,739,756	Owner's equity for the year	52,279,928,045
Total assets at the end of the year	138,485,018,258	Non-current assets due within one year	---

Source: Calculated based on the financial data of Baotou Steel's 2017-2019 annual report

Considering the above information is possible to calculate the specific values for Baotou Steel's indicators for 2017, 2018, and 2019, as presented in Table 6.11.

Table 6.11 Specific values for each financial indicator for 2017, 2018 and 2019

Indicators	Calculation formula	2017	2018	2019
Gearing ratio	Total liabilities/total assets	67.10%	64.96%	60.18%
Current ratio	Current assets/current liabilities	0.46	0.79	0.76
Quick ratio	Quick assets/current liabilities	21.54%	54.29%	47.02%
Sales revenue growth rate	Sales growth for the year/sales in the previous year	72.83%	30.67%	-9.56%
Net asset growth rate	Increase in net assets for the year / prior period net assets	4.58%	5.82%	-0.60%
Net sales margin	Net profit/sales revenue	4.01%	4.42%	5.15%
Return on net assets	Net profit/average shareholders' equity	4.41%	6.02%	6.19%
Total net asset margin	Net profit/average total assets	1.50%	2.10%	2.27%
Total asset turnover ratio	Sales revenue/average total assets	0.37	0.47	0.44
Accounts Receivable Turnover Ratio	Average sales revenue/accounts receivable balance	22.09	21.35	14.27
Inventory turnover rate	Cost of goods sold/average balance of inventory	2.73	3.24	3.24

After collating and analysing Baotou Steel's financial information, non-financial information was collected and analysed by searching annual reports, industry information, credit records, and other publicly available information.

Baotou Steel's historical credit was checked through Inner Mongolia Baotou Steel Corporation Basic Credit Information Report (National Enterprise Credit Information Public Display System, 2020), and Baotou Steel was not listed in the abnormal business list, nor was it included in the blacklist of enterprises in serious breach of law and default. Baotou Steel had no outstanding non-performing credit information and good credit standing.

In terms of industry development prospects, the Chinese government attaches great importance to supply-side reform and mergers and acquisitions in the steel industry. In recent years, it has continued to guide the steel industry to eliminate backward production capacity and improve environmental protection, energy consumption, quality, and other related requirements. The steel industry shows a downward trend of both demand and capacity. Therefore, it is difficult to reverse the overcapacity situation in the short term. In addition, the price of iron ore, coal, and other raw materials has risen in recent years, putting certain pressure on enterprises to control costs, and the industry is not optimistic about its development prospects.

In terms of innovation and development capability, Baotou Steel had developed rare earth steel with unique ductility, high strength, and toughness, and drawing properties to strengthen the performance of steel products. Baotou Steel had cooperated with the Institute of Metals of the Chinese Academy of Sciences and Inner Mongolia University of Science and Technology to carry out full process research and development of high-quality rare-earth steel products such as rare-earth rails and rare-earth steel for wind power. Baotou Steel developed a full

range of rare earth steel products such as plates, pipes, rails, and wires, fully highlighting the advantages of rare earth steel, optimising outcomes, and improving product quality in order to expand the product variety structure. Baotou Steel actively promoted management innovation and business model transformation and development to enhance competitiveness. Baotou Steel also strengthened energy conservation and environmental protection to build green steel. By changing its development philosophy, Baotou Steel transformed from a steel producer to a quality product supply service provider and urban service provider, highlighting the characteristics of rare earth steel. Baotou Steel has a more prominent competitive advantage than other companies in the same industry.

In terms of management level, Baotou Steel established a sound organisational structure, including a corporate management structure, a performance evaluation system for managers, and a remuneration management system. Regarding the management incentive system, the remuneration of senior management is linked to the production and operation performance of Baotou Steel, which enables the responsibilities, risks, performance, and benefits of senior management to be fully reflected. The daily work and annual performance of senior management personnel needed to be assessed and evaluated, and then the remuneration of senior management personnel was paid in accordance with Baotou Steel's remuneration appraisal procedures and related systems. However, it was learned through the Decision on Announcement and Criticism of Inner Mongolia Baotou Steel Corporation and Relevant Responsible Persons (Shanghai Stock Exchange, 2018) that Baotou Steel had concealed the fact that the subsequent progress of major fundraising projects had stalled in 2018 due to a long period. At the same time, Baotou Steel failed to reveal the risks of major fundraising construction projects, which undermined investors' right to information and reasonable expectations. Baotou Steel's chairman and secretary of the board of directors were therefore notified of their criticism and recorded in the integrity file of the listed company. In 2021, the Intermediate People's Court of Bayannur City, Inner Mongolia Autonomous Region publicly sentenced Meng Zhiquan, former deputy secretary of the Party Committee of Baotou Steel (former general manager of Inner Mongolia Baotou Steel Union Co., Ltd.) on the crime of accepting bribes, and sentenced to 11 years in prison and fined RMB one million.

In summary, based on the financial and non-financial indicators of Baotou Steel, combined with the fact that steel enterprises belong to the ferrous metal smelting industry as proposed in the Standard Values for Enterprise Performance Evaluation (SASAC, 2019), this study uses the average value in the performance evaluation of the ferrous metal smelting industry as the standard for expert scoring to arrive at the financial and non-financial

indicators of the enterprise scores, as shown in Table 6.12.

Table 6.12 Financial and non-financial indicator scores for Baotou Steel from 2017 to 2019

Indicators	Average	2017	2017 Score	2018	2018 Score	2019	2019 Score
Gearing ratio	60.1%	67.10%	65	64.96%	70	60.2%	75
Current ratio	1.12	0.46	60	0.79	70	0.756	65
Quick ratio	38.7%	21.54%	60	54.29%	95	47%	90
Sales revenue growth rate	-15.4%	72.83%	100	30.67%	100	-9.6%	80
Net asset growth rate	7.6%	4.58%	65	5.82%	70	0.6%	50
Net sales margin	4.6%	4.01%	60	4.42%	75	5.1%	90
Return on net assets	5.1%	4.41%	65	6.02%	85	6.2%	90
Total net asset margin	3.4%	1.50%	60	2.10%	65	2.3%	70
Total asset turnover ratio	0.4	0.37	60	0.47	80	0.44	75
Accounts receivable turnover ratio	11.4	22.09	100	21.35	100	14.266	95
Inventory turnover rate	5.7	2.73	60	3.24	65	3.236	65
Historical credits			90		90		90
Business environment			70		70		70
Competition strength			85		90		95
Management level			50		50		50

We applied Baotou Steel's financial, non-financial, and environmental indicator scores to the AHP model for credit assessment of commercial banks constructed in the previous chapter, and finally calculated Baotou Steel's comprehensive scores of 70.41, 80.18, and 80.47 for 2017, 2018, and 2019 respectively through yaahp software. Against the credit assessment criteria, its credit rating can be determined. Baotou Steel's creditworthiness is average in 2017 and high in 2018 and 2019, marked by AA. The credit rating of Baotou Steel for the years 2017-2019 shows that the credit rating of Baotou Steel rose in these three years, from credit rating A to AA. It is inextricably linked to the introduction of green lending by commercial banks in recent years. It is also consistent with the conclusions drawn from the game theory model in the previous two chapters, namely that the alignment of environmental credit rating and credit rating encourages steel companies to improve their own ERM to obtain credit funding. The credit ratings that consider corporate ERM have raised the importance of corporate ERM. At the same time, as more credit funds enter environmentally friendly steel plants, these companies will develop better and faster, and they will also serve as a good example for other steel companies, enabling more steel companies to join in improving production processes and complying with cleanliness. In the trend of production standards, the influence weight of environmental credit has significantly been increased, and financial guidance and leverage have been brought into play.

6.5 Chapter summary

This chapter presents an example of an ERE scenario for commercial banks. After a brief introduction to the development status of the steel industry, this chapter applies the program to three selected listed companies in the steel industry, namely Baosteel Corporation, Baotou Steel Corporation, and Fangda Special Steel. Firstly, the EIA of the three steel companies is reviewed and it is obtained that the EIA approvals of all three companies meet the relevant requirements. Secondly, the ERM performance evaluation AHP model constructed in the previous chapter was used to evaluate the ERM performance of the three steel companies. The analysis concluded that Baosteel is an excellent environmental protection enterprise and Baotou Steel is a good environmental protection enterprise. However, Fangda Special Steel is a bad environmental protection enterprise that does not meet the environmental performance standards. Commercial banks should not grant loans to this enterprise according to the requirements. Finally, the CRE AHP model constructed in the previous chapter was used to assess the credit risk of the enterprises that passed the ERM performance evaluation test, i.e., Baosteel and Baotou Steel, and to determine their credit ratings. The results show that Baosteel has a credit rating of AAA, which is excellent, and Baotou Steel has a credit rating of AA, which is a high degree of corporate credit. Under the bank's supervision, Baotou Steel continuously improved its processes and equipment. It increased its investment in environmental protection, which improved its ERE results and positively enhanced its credit assessment results. This has enabled Baotou Steel to receive more support from the bank in terms of credit size and loan interest rates. The determination of credit rating in this chapter provides the basis for commercial banks to determine the loan amount, loan interest rate, and lending policy.

Chapter 7: Conclusions and Suggestions

As the main body of the market economy, commercial banks should consider the environmental factors involved in the allocation of credit resources under the requirements and supervision of green economy policies and the ever-changing environmental protection standards (such as air pollution, water pollution, soil pollution) and other aspects of macro-policies, industry changes caused by risks, to achieve the maximum profit after risk adjustment. Therefore, commercial banks need to weigh the benefits and risks of credit when lending to enterprises with high emissions and pollution, especially the substantial environmental risks of high energy consumption and high emission production methods. However, the existing credit evaluation system cannot accurately evaluate these potential environmental risks. There is a lack of theoretical and empirical research on the ERE system in China. The thesis research provides an important reference for establishing the ERE system of Chinese commercial banks and a theoretical basis for commercial banks to comprehensively consider environmental risks to determine loan issuance, interest rates, and policies for enterprises with HECE.

7.1 Main conclusions

This thesis takes the ERM system of commercial banks as the research object and deeply studies the ERE index system and methods of Chinese commercial banks from both theoretical and case study points of view.

First, by comparing the environmental risk and green credit practices of domestic and foreign commercial banks, the study has found that the ERM of Chinese commercial banks is generally at a medium level, lagging behind that of banks in developed countries. There are still shortcomings in specific business processes, evaluation standards, and industry guidelines. Most of the progress of commercial banks comes from the policy guidelines of government regulatory agencies. The banks themselves still have insufficient awareness of ERM. Overall, the ERM level of state-owned banks is better than that of joint-stock banks, and the performance of joint-stock banks is better than that of city commercial banks.

Secondly, a two-by-two game theory model was established with the following players: government departments, commercial banks, and steel companies. The behavior

characteristics of the participants were analyzed through the game equilibrium. On this basis, suggestions are given to establish institutional incentives and punishment mechanisms for government departments at all levels, commercial banks, and steel companies. Furthermore, this study provides a theoretical basis for constructing an ERE index system by analyzing the influence of the environmental risk index and ERC on the game equilibrium.

Thirdly, this study establishes a commercial bank's ERE index system for companies with HECE. Based on the previous credit evaluation models of financial and non-financial indicators, through expert interviews and questionnaire surveys, AHP was used to add enterprise ERE indicators, including pollution control, environmental management, social impact, and corporate greenness. Moreover, this study determines the weight of each indicator, and establishes a commercial bank CRE indicator system based on environmental risks to determine the corresponding credit rating and credit policy under the comprehensive ERE.

Lastly, this study uses the ERE model to conduct case studies on three listed companies, Baosteel, Baotou Steel, and Fangda Special Steel. The study finds that Baosteel is an excellent environmental protection enterprise with a credit rating of AAA and excellent credit. Baotou Steel is an environmentally sound enterprise with a credit rating of AA and a relatively high degree of credit. Under the supervision of the bank, Baotou Steel has continuously improved its processes and equipment to increase investment in environmental protection. It improved the results of ERE and played a positive role in improving its credit rating, enabling it to gain more support in terms of credit scale and loan interest rates from banks. Fangda Special Steel is an environmentally poor company. Its ERE does not meet the standards, so commercial banks should not grant loans to Fangda Special Steel.

7.2 Suggestions

In order to actively promote ERE work for Chinese commercial banks and narrow the gap with commercial banks in foreign countries, Chinese commercial banks need to launch the following three tasks.

The first is to formulate unified ERE standards in line with China's national conditions so that commercial banks can accurately classify levels of corporate environmental risk, thus making correct credit decisions.

The second is to establish an environmental information collection and transmission channel among corporate, bank, and environmental protection departments so that commercial banks can obtain accurate, comprehensive, and timely corporate environmental

information to effectively evaluate their environmental risks.

The third is to improve the ERE work process and methods, expand the scope of evaluation objects to other environmentally sensitive industries and customers, refine industry rules, and establish a dynamic environmental risk monitoring mechanism.

To this end, it is recommended that the government and commercial banks take the following specific measures.

7.2.1 At the government level

7.2.1.1 Encourage financial institutions to actively adopt the international initiatives of sustainable finance

The international community's well-known sustainable finance initiatives include the EPs, the Principles of Responsible Banking, and the United Nations Global Compact (Liang, 2014). By participating in the Sustainable Finance Initiative, Chinese banks can promptly obtain advanced experience from foreign banking, thus laying a solid foundation for the development of sustainable finance. At present, many Chinese commercial banks have conducted special research on the International Sustainable Finance Initiative, but a limited number of them have joined it. This reason severely restricts the improvement of the ERM capabilities of Chinese commercial banks and causes a considerable gap in ERE capabilities between Chinese commercial banks and well-known banks abroad. Relevant government departments should issue policies to encourage Chinese commercial banks to join the International Sustainable Finance Initiative to make up for the lack of Chinese ERE standards and industry guidelines.

7.2.1.2 Establish and improve the environmental information database, and strengthen the collection and sharing of environmental information

The environmental data of a company is an essential element for commercial banks to conduct ERE. Its authenticity and comprehensiveness directly affect the final results of commercial banks' evaluation of corporate environmental risks. Due to the lack of normative constraints on disclosing environmental information, most companies self-disclose their environmental compliant indicators through CSR reports or sustainability reports. These reports disclose what is good while concealing what is unpleasant. The behavior will not be published, resulting in the lack of some key environmental data and evaluation deviation. Therefore, the environmental protection department and the CBIRC should establish a unified standard for the disclosure of environmental information of enterprises as the mandatory

environmental information disclosure system for listed companies (China Security Regulation Commission [CSRC], 2019), and require enterprises to publish environmental reports on a regular basis to ensure that environmental information and indicators of enterprises are open, transparent, and standardized.

Regarding the sharing of corporate environmental information, environmental protection departments should establish effective communication channels with commercial banks and third-party rating agencies to strengthen the exchange and sharing of corporate environmental information through environmental information databases. This measure can ensure that commercial banks obtain accurate, comprehensive, and effective data of environmental indicators when conducting ERE.

In addition, most of the corporate environmental information provided by the environmental protection department is highly specialized, such as pollutant emission concentration, resource consumption. This information normally cannot be quickly converted into sample data for commercial banks to conduct ERE. Therefore, commercial banks should establish their own corporate environmental information database, reasonably incorporate corporate environmental data in accordance with the needs of CRE, and process them into ERE information that commercial banks can directly use.

7.2.2 At the bank level

7.2.2.1 Establish relatively unified ERE standards and models

Loans for enterprises are mainly divided into two categories, project financing, and corporate loans, with different ERE focuses. The former focuses on the impact of new projects on the environment, and the latter considers corporate environmental risks and the level of pollution prevention and control. Therefore, it is inappropriate to use the environmental review procedures for project financing to review corporate loans. There should be two different sets of ERE standards and procedures. We can learn more from advanced international experience for project loans, such as the social and environmental sustainability policies and performance standards and environmental, health, and safety guidelines system proposed by IFC (CIB, 2017). Issuance of corporate loans should carefully consider China's actual situation and adapt measures to local conditions, and we should not blindly copy international experience.

The banks themselves formulate evaluation standards of commercial banks for corporate environmental risks. The banking regulatory authorities have not issued a unified evaluation specification or grading standard, resulting in differences in the results of ERE by banks.

Some enterprises cannot get a loan from one bank, but they can get it when they turn to another bank. Banks with low environmental standards are more likely to obtain customers and higher profits quickly than banks with high environmental standards, which causes unfair competition.

Therefore, it is recommended that the PBoC and CBIRC take the lead in establishing a unified banking ERE standard in line with China's national conditions to guide commercial banks in terms of process methods, evaluation basis, and selection of key indicators. For different environmentally sensitive industries, the content and the weight of the specific indicators in the system can be adjusted according to the various sectors being evaluated, making different industries more comparable and the evaluation method more general and common.

7.2.2.2 Improve the ERM workflow and methods

To integrate ERM into the bank's core business, firstly, it is necessary to establish a corporate ERE indicator system and review process to pre-evaluate the environmental risks involved in the credit business and formulate possible risk mitigation measures. The specific content includes risk identification, risk evaluation, formulation of response measures, interactive communication with stakeholders, post-event supervision. When an enterprise submits a loan application, the commercial bank shall conduct a detailed evaluation of its environmental risk based on the established ERE index system and screen out the non-creditable enterprises with greater environmental risks. Secondly, the CRE model that incorporates environmental factors can effectively evaluate the borrowers' environmental risk level, financial and non-financial factors, make scientific and reasonable credit decisions, and avoid losses caused by credit risk. Last but not least, commercial banks should establish a continuous evaluation and monitoring mechanism for post-loan environmental risks, grasp the dynamic changes of corporate environmental risks, and formulate corresponding early warning mechanisms and emergency plans.

Precisely, based on the Green Credit Guidelines (CBRC, 2012), commercial banks should further refine their operations in all aspects of before, during, and after lending.

(1) Pre-lending stage

Commercial banks should earnestly collect information of their clients in environmentally sensitive industries. Customer environmental risk information can be collected through online media, the MEE, and the NDRC website. Credit should be resolutely withdrawn, and new credit support shall not be granted to clients in the scope of strict control of green credit.

These clients have the following features: not meeting environmental protection standards, violating environmental laws and regulations, possessing HECE, high environmental risks, and outdated production capacity and technology.

At the same time, commercial banks shall carry out environmental risk investigations per relevant regulations on pre-lending due diligence in the credit business and truthfully reflect the investigations into the corresponding credit approval requirements.

Firstly, for existing clients that have environmental risks, if it is necessary to continue their business (the amount does not exceed the previous credit balance), banks should focus on investigating the rectification of existing risks, grasp the degree of rectification and estimate the completion time of rectification, and evaluate and analyze the negative impacts of the risk on the overall corporate operation. The branch leader in charge of the corporate loans should sign an opinion on the client's environmental risk rectification evaluation opinion.

Secondly, we have the client ERE. The pre-loan risk evaluation staff shall verify the authenticity of the environmental information provided by the client, process and sort the data, substitute it into the rating system, and write the results into the credit business risk evaluation opinion. They can seek qualified and independent third-parties and relevant authorities for support if necessary.

(2) During-lending stage

Firstly, the compliance review link. Compliance examiners should focus on documents of credit rating reports, investigation evaluation reports, credit quota or credit business request, whether the client's environmental risk is disclosed and whether the credit business risk evaluation opinion assesses the environmental risk.

Secondly, credit approval link. The examiners shall fully consider the environmental risks borne by the client and the risk tolerance ability. If the environmental protection fails to meet the standards, no new credit shall be granted. Those eligible for rectification and reform will be given a 6-month observation period. At the same time, attention should be paid to transition risks. There shall be a certain reasonable ratio between new energy credit and traditional credit in allocating credit resources.

Thirdly, contract signing link. The client manager should truthfully inform the client (including the guarantor) when signing the loan contract, mortgage contract, and other business contracts and remind the statement clause in the contract. If the client involves in environmental risks, the bank has the right to stop the credit extension to the customer or announce the early maturity of the principal and interest of the creditor's rights.

Fourthly, the lending link. The client's environmental risk status is important for the loan review. If any risk is found, the operating department should be notified to carry out the verification. If it is verified that the client cannot meet the bank's ERM requirements, the loan shall not be issued.

(3) Post-lending link

The early warning and tracking system is used to establish a continuous monitoring mechanism for post-loan environmental risks. Collecting client's environmental risk information in a usual manner and regularly carrying out post-loan inspections and credit rating re-inspections. Hidden environmental risks should be detected early with early warning, early resolution, and early disposal. For existing clients who have environmental risks, the business department and the risk department of banks shall negotiate, communicate, and coordinate to jointly supervise and urge the client to complete rectification and resolve risks. Through regular inspection and improvement, the ERM capabilities can be enhanced continuously.

7.2.2.3 Formulate more comprehensive and detailed industry guidelines

The Green Credit Guidelines for China's Iron and Steel Industry (MEP & CBRC, 2011) is the first national-level credit guidance for the steel industry. ICBC (2016) has conducted stress tests in the steel, cement, and other industries, referring to the experience of advanced foreign banks, and put forward targeted ERM requirements and detailed credit access standards for environmentally sensitive industries such as steel, chemical, and coal. However, most of China's commercial banks only formulate industry policies for the sectors with HECE. They do not cover most environmentally sensitive industries or update dynamics as mainstream international banks do. It is recommended that China's commercial banks prioritize the formulation of industry guidelines for the major ten industries with high pollution and high environmental risk load, namely iron and steel, power, cement, chemical, textile, papermaking, pharmaceutical, coke, non-ferrous metals, petroleum.

It is also recommended that the national authoritative department compare the environmental standards of each industry one by one, formulate a credit management guideline of the sectors with HECE, unify ERM standards, and implement list management. In this way, clients can be divided into four categories: encouraging, maintaining, and withdrawing, and prohibiting restricting the financing of enterprises with HECE. Credit can be increased for environmentally friendly and resource-saving enterprises to help the superior and eliminate the inferior.

It is worth noting that although developed countries have rich experience and mature technology in the field of ERE, this does not mean that China needs to copy foreign standards and models. China should absorb and improve in practice and strive to explore a set of ERE systems suitable for China's national conditions.

7.3 Limitations and prospects

This thesis adds a module to quantify environmental risks in the internal rating system of commercial banks, which enriches the rating system for the sustainable development of commercial banks. There is enormous room for improvement in this area. At the same time, the progress of the ERM level of commercial banks is a gradual process, and the ERE work is also in continuous improvement. To find a CRE method based on the environmental perspective that meets China's national conditions requires continuous research and practice.

Moreover, we should play the role of the market as an invisible hand and use market mechanisms to promote green credit rather than administrative orders. The application of rating results should be promoted in the business development of commercial banks as the basis of client selection, credit pricing, credit resource allocation, economic capital occupation, bank interest discount, and stress test. Efforts should be put to internalize the externalities of environmental risk in an attempt to internalize the externality of environmental risks. In the future, further research can consider these perspectives.

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Annex A: Questionnaire 1 Social Survey Questionnaire on AHP Model for Environmental Risk Assessment in Commercial Banks

Distinguished experts.

Hello, thank you for filling out this questionnaire in your busy schedule! The purpose of this questionnaire is designed to determine the weights of each indicator in the environmental risk assessment model of commercial banks through the hierarchical analysis method. The indicator system is divided into four guideline layers, namely pollution management, environmental management, social impact, and corporate greenness. The indicators in pollution management include: exhaust gas emission, wastewater emission, solid waste disposal, and you will be asked to judge the relative importance of each two indicators based on historical experience; the indicators in environmental management include: environmental statistics disclosure, emission permit management, environmental management system certification, environmental protection personnel, departments and environmental management system, and you will also be asked to judge the relative importance of each two indicators; the indicators in social The indicators in Social Impact include environmental administrative penalties, important environmental violations, environmental emergencies, and public complaints, and you are also asked to judge the relative importance of each of the two indicators. Finally, the indicators in the greenness of the enterprise include resource and energy consumption, process and equipment level, and green expenditure, and you are also invited to judge the relative importance of the two indicators. This questionnaire is a matrix single-choice question, please tick the option you think. Thank you very much for your participation!

If you are not sure about the above indicators, please see the following indicators.

(1) Exhaust gas emissions: This refers to whether the iron and steel enterprise treats the exhaust gas generated during the production process before it is emitted into the atmosphere. The evaluation of this indicator is mainly based on whether the concentration of exhaust gas emitted by the enterprise meets the standard.

(2) Wastewater discharge: It refers to whether the iron and steel enterprises treat the coking wastewater and iron and steel wastewater generated during the production process before discharging them. The wastewater discharge indicator is evaluated mainly on whether

the concentration of wastewater discharged by the enterprise meets the standard.

(3) Solid waste treatment: This refers to whether the steel enterprise treats the solid and semi-solid pollutants generated during the production process, and the evaluation of this indicator is mainly based on whether the enterprise meets the national emission standards for solid waste pollutants.

(4) Disclosure of environmental statistics: The main purpose is to examine whether enterprises comply with the regulations of local environmental protection departments, fill in environmental statistics truthfully and disclose their environmental information in designated public channels in accordance with their requirements.

(5) Emission permit management: mainly to see whether the enterprise has obtained the emission permit management certificate, paid the emission fee on time, and completed the annual emission declaration and registration on time.

(6) Environmental management system certification: The main focus is on whether the company has passed ISO14001 certification.

(7) Environmental protection personnel, environmental protection departments and environmental protection management system: environmental protection departments are mainly to see whether the enterprise has a full-time or part-time environmental protection department. The environmental protection personnel is mainly to see whether the enterprise has full-time or part-time environmental protection personnel and regular training of relevant personnel in environmental protection expertise. The environmental protection system is mainly to see whether the enterprise has set up a corresponding system to meet the needs of the enterprise's environmental management.

(8) Administrative penalties for environmental protection: The main examination is whether the enterprise has received environmental penalties during production, such as warnings, fines, and orders for corrections.

(9) Important environmental violations: The main examination is whether there are important environmental violations in the course of the enterprise's production activities.

(10) Environmental emergencies: The main examination is whether the enterprise has ever had an environmental emergency.

(11) Public complaint situation test: mainly examines the number of effective complaints from the public against the enterprise, and causes certain environmental impact and harm.

(12) Resource and energy consumption: It refers to the energy resources consumed by the enterprise in the production process, and this indicator mainly examines the size of the enterprise's comprehensive energy consumption per ton of steel.

(13) Level of process equipment: The examination is mainly conducted through the

series of national standards on the clean production evaluation index system of the steel industry, whether there is an industrialized device for low discharge of coking wastewater and whether there is an industrialized device for low discharge of steel wastewater.

(14) Enterprise green expenditure: refers to all the expenditure related to environmental resources involved in the production and operation process of the enterprise, and the examination is mainly through the size of the enterprise's environmental protection cost per ton of steel.

1. For the four indicators affecting the environmental risk of commercial banks (pollution management, environmental management, social impact, and corporate greenness), what do you think is the relative importance of the two two indicators for environmental risk assessment?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Corporate pollution management as compared to corporate environmental management	☐	☐	☐	☐	☐	☐	☐
Corporate pollution control compared to corporate social impact	☐	☐	☐	☐	☐	☐	☐
Corporate pollution management compared to corporate greenness	☐	☐	☐	☐	☐	☐	☐
Corporate environmental management versus corporate social impact	☐	☐	☐	☐	☐	☐	☐
Corporate environmental management as compared to corporate greenness	☐	☐	☐	☐	☐	☐	☐
Corporate social impact compared to corporate greenness	☐	☐	☐	☐	☐	☐	☐

2. For each indicator under the "pollution control" level, what do you think is the relative importance of the two indicators for environmental risk assessment?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Corporate exhaust emissions compared to corporate wastewater emissions	☐	☐	☐	☐	☐	☐	☐
Corporate emissions compared to corporate solid waste disposal	☐	☐	☐	☐	☐	☐	☐
Corporate wastewater discharge compared to corporate solid waste disposal	☐	☐	☐	☐	☐	☐	☐

3. For each indicator under the "environmental management" level, what do you think is the relative importance of the two indicators for environmental risk assessment?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Corporate environmental statistics disclosure compared to corporate emissions permit management	☐	☐	☐	☐	☐	☐	☐
Corporate environmental statistics disclosure compared to corporate environmental management system certification	☐	☐	☐	☐	☐	☐	☐

Environmental Risk Evaluation of Commercial Banks

Disclosure of corporate environmental statistics as compared to corporate environmental personnel, departments and environmental management systems	☐	☐	☐	☐	☐	☐	☐
Enterprise Emission Permit Management Compared to Enterprise Environmental Management System Certification	☐	☐	☐	☐	☐	☐	☐
Enterprise emission permit management compared to enterprise environmental protection personnel, departments and environmental management systems	☐	☐	☐	☐	☐	☐	☐
Enterprise environmental management system certification compared to the enterprise environmental protection personnel, departments and environmental management system	☐	☐	☐	☐	☐	☐	☐

4. For each indicator under the "social impact" level, what do you think is the relative importance of the two indicators for environmental risk assessment?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
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Environmental Risk Evaluation of Commercial Banks

Administrative penalties for corporate environmental protection compared to significant corporate environmental violations	☐	☐	☐	☐	☐	☐	☐
Administrative penalties for corporate environmental protection compared to corporate environmental emergencies	☐	☐	☐	☐	☐	☐	☐
Administrative penalties for corporate environmental protection compared to corporate public complaints	☐	☐	☐	☐	☐	☐	☐
Significant environmental violations by enterprises compared to corporate environmental emergencies	☐	☐	☐	☐	☐	☐	☐
Significant environmental violations by enterprises relative to public complaints by enterprises	☐	☐	☐	☐	☐	☐	☐
Corporate environmental emergencies relative to corporate public complaints	☐	☐	☐	☐	☐	☐	☐

5. For each indicator under the "greenness of the enterprise" level, what do you think is the relative importance of the two indicators for environmental risk assessment?

Environmental Risk Evaluation of Commercial Banks

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Enterprise resource and energy consumption relative to the level of enterprise process equipment	☐	☐	☐	☐	☐	☐	☐
Corporate resource and energy consumption compared to corporate green spending	☐	☐	☐	☐	☐	☐	☐
Level of enterprise process equipment relative to enterprise green spending	☐	☐	☐	☐	☐	☐	☐

Annex B: Questionnaire 2 Social Survey Questionnaire on AHP Model for CRE of Commercial Banks

Distinguished experts.

Hello, thank you for filling out this questionnaire in your busy schedule! The purpose of this questionnaire is to determine the weights of each indicator of the AHP model for credit risk assessment of commercial banks through hierarchical analysis. The indicator system is divided into three criteria layers, namely financial indicators, non-financial indicators and environmental indicators. The growth capacity indicators in the financial indicators include: sales revenue growth rate, net asset growth rate, and you will be asked to judge the relative importance of each two indicators according to the historical experience; the solvency indicators in the financial indicators include: gearing ratio, current ratio, and quick ratio, and you will be asked to judge the relative importance of each two indicators; the profitability indicators in the financial indicators include: net sales margin, total assets net margin, net asset return rate, and the profitability indicator. The profitability indicators in the financial indicators include net sales margin, net profit margin of total assets, return on net assets, and please judge the relative importance of each two indicators Importance.

Since the judgement of the weighting of each environmental indicator has been determined in another questionnaire, it is not repeated here, and only the importance of the financial and non-financial indicators in relation to the environmental indicators is judged.

This questionnaire is a matrix of single choice questions, please tick the option you think is appropriate. Thank you very much for your participation!

1. For each indicator under the "growth capacity" level, what do you think is the relative importance of the two indicators for the credit risk assessment of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Growth rate of enterprise sales revenue compared to the growth rate of enterprise net assets	☐	☐	☐	☐	☐	☐	☐

2. For each of the indicators under the "solvency" level, what do you think is the relative importance of the two indicators for the assessment of credit risk of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Corporate Gearing Ratio Compared to Corporate Current Ratio	☐	☐	☐	☐	☐	☐	☐
Corporate Gearing Ratio Compared to Corporate Quick Ratio	☐	☐	☐	☐	☐	☐	☐
Corporate current ratio compared to corporate quick ratio	☐	☐	☐	☐	☐	☐	☐

3. For each indicator under the "profitability" level, what do you think is the relative importance of the two indicators for the credit risk assessment of commercial banks?

Environmental Risk Evaluation of Commercial Banks

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Net sales margin of a business compared to net assets of a business	☐	☐	☐	☐	☐	☐	☐
Corporate net sales margin compared to corporate return on net assets	☐	☐	☐	☐	☐	☐	☐
Corporate net asset margin compared to corporate return on net assets	☐	☐	☐	☐	☐	☐	☐

4. What do you think about the relative importance of the indicators under the "operational capacity" level for the credit risk assessment of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Business total asset turnover compared to business accounts receivable turnover	☐	☐	☐	☐	☐	☐	☐
Business total asset turnover compared to business inventory turnover	☐	☐	☐	☐	☐	☐	☐
Business accounts receivable turnover ratio	☐	☐	☐	☐	☐	☐	☐

Environmental Risk Evaluation of Commercial Banks

compared to business inventory turnover ratio							
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5. For each indicator at the level of "financial indicators", what do you think is the relative importance of the two indicators for credit risk assessment of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Business solvency compared to business growth	☐	☐	☐	☐	☐	☐	☐
Corporate solvency as compared to corporate profitability	☐	☐	☐	☐	☐	☐	☐
Corporate solvency versus corporate operating capacity	☐	☐	☐	☐	☐	☐	☐
Business growth capacity compared to business profitability	☐	☐	☐	☐	☐	☐	☐
Business growth capacity versus business operating capacity	☐	☐	☐	☐	☐	☐	☐
Corporate profitability versus corporate operating capacity	☐	☐	☐	☐	☐	☐	☐

6. For each indicator under the level of "non-financial indicators", what do you think is the relative importance of the two indicators for the assessment of credit risk of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Corporate history of credit relative to the growth prospects of the industry in which the business operates	☐	☐	☐	☐	☐	☐	☐
Historical corporate credit compared to the ability of companies to innovate and grow	☐	☐	☐	☐	☐	☐	☐
Corporate history credit compared to corporate team management capabilities	☐	☐	☐	☐	☐	☐	☐
Prospects for the development of the industry in which the company is located relative to its ability to innovate and develop	☐	☐	☐	☐	☐	☐	☐
The growth prospects of the industry in which the business is located relative to the management capabilities of the business team	☐	☐	☐	☐	☐	☐	☐

Environmental Risk Evaluation of Commercial Banks

Corporate innovation and development capacity compared to corporate team management capacity	☐	☐	☐	☐	☐	☐	☐
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7. For the three guideline level indicators (financial indicators, non-financial indicators, and environmental indicators) that affect the credit risk assessment of commercial banks, what do you think is the relative importance of the two two indicators for the credit risk assessment of commercial banks?

	entirely important	utterly important	a little bit important	the same as important	a little bit unimportant	utterly unimportant	entirely unimportant
Enterprise financial indicators versus enterprise non-financial indicators	☐	☐	☐	☐	☐	☐	☐
Enterprise financial indicators versus enterprise environmental indicators	☐	☐	☐	☐	☐	☐	☐
Enterprise non-financial indicators versus enterprise environmental indicators	☐	☐	☐	☐	☐	☐	☐

Annex C: Other Tables

Table C.1 Judgement matrix under the environmental risk assessment hierarchy

Environmental risk assessment	Pollution control	Environmental management	social influence	Corporate greenness
Pollution control	1	0.5	0.5	0.25
Environmental management	2	1	0.5	0.5
social influence	2	2	1	1
Corporate greenness	4	2	1	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.2 Judgement matrix under the social impact hierarchy

social influence	Environmental administrative penalties	Significant environmental violations	sudden environmental incident	Public complaints
Environmental administrative penalties	1	0.5	0.33	2
Significant environmental violations	2	1	1	2
sudden environmental incident	3	1	1	2
Public complaints	0.5	0.5	0.5	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.3 Judgement matrix under the environmental management hierarchy

Environmental management	Disclosure of environmental statistics	of Pollution permit management	Environmental Management System Certification	Environmental personnel, departments and environmental management system
Disclosure of environmental statistics	1	1	0.3333	3

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Pollution permit management	1	1	0.5	3
Environmental Management System Certification	3	2	1	4
Environmental personnel, departments and environmental management system	0.3333	0.3333	0.25	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.4 Judgment matrix under pollution control levels

Pollution control	exhaust emission	Wastewater discharge	Solid waste disposal
exhaust emission	1	3	3
Wastewater discharge	0.33	1	1
Solid waste disposal	0.33	1	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.5 Judgement matrix under the corporate greenness hierarchy

Corporate greenness	Resource and energy consumption	Level of equipment	process	Corporate spending	green
Resource and energy consumption	1	1		2	
Level of equipment	1	1		2	
Corporate green spending	0.5	0.5		1	

Source: Compiled from the results of the Questionnaire Star survey

Table C.6 Judgment matrix under the credit risk assessment hierarchy

Credit assessment	risk	Environmental indicators	Financial indicators	Non-financial indicators
Environmental indicators		1	0.33	0.5
Financial indicators		3	1	2
Non-financial indicators		2	0.5	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.7 Judgement matrix at the level of financial indicators

Financial indicators	Operating capacity	solvency	growth capacity	profitability
operating capacity	1	0.33	1	0.5
Profitability	2	3	2	1
growth capacity	1	0.5	1	0.5
solvency	3	1	2	0.33

Source: Compiled from the results of the Questionnaire Star survey

Table C.8 Judgment matrix under the operating capacity hierarchy

operating capacity	Total asset turnover ratio	Accounts receivable turnover rate	Inventory turnover rate
Asset turnover rate	1	0.5	1
Accounts receivable turnover rate	2	1	2
Inventory turnover rate	1	0.5	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.9 Judgement matrix under the growth capacity hierarchy

growth capacity	Sales revenue growth rate	Net asset growth rate
Sales revenue growth rate	1	2
Net asset growth rate	0.5	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.10 Judgment matrix under the profitability hierarchy

Profitability	Net sales margin	Total net asset margin	ROAN
Net sales margin	1	2	2
Total net asset margin	0.5	1	1
return on net assets (ROAN)	0.5	1	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.11 Judgment matrix under solvency hierarchy

solvency	gearing	current ratio	quick ratio
gearing	1	2	2
Current ratio ratio	0.5	1	0.5
quick ratio	0.5	2	1

Source: Compiled from the results of the Questionnaire Star survey

Table C.12 Judgement matrix at the level of non-financial indicators

Non-financial indicators	Historical credit	Industry Development Prospects	Capacity for innovative development	Team management skills
Historical credit	1	3	1	1
Industry Development Prospects	0.33	1	0.5	0.33
Capacity for innovative development	1	2	1	2
Team management skills	1	3	0.5	1

Source: Compiled from the results of the Questionnaire Star survey