Environmental risk assessment and green transformation path for sustainable development in the banking industry of Kyrgyz republic and China

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Abstract: As the global demand for sustainable development and green finance continues to increase, traditional banks have gradually exposed problems such as limited monitoring dimensions and delayed data response in environmental risk identification, green business promotion, and performance evaluation. To solve the above bottlenecks, this paper integrates artificial intelligence and Internet of Things technologies to build a green financial intelligent perception and control system. By applying an AI credit approval model, a real-time environmental data collection mechanism based on the Internet of Things, and a green performance intelligent tracking system, refined dynamic control of key indicators such as the proportion of green credit, environmental risk levels, and customer green satisfaction can be achieved. The experimental results show that the AI deep learning model performs best in green loan risk prediction, with an AUC (Area Under the Curve) value of 0.91, which is significantly higher than the 0.72 of the traditional credit scoring model and the 0.84 of the ESG enhanced model, indicating that the model has a stronger ability to distinguish between high-risk and low-risk loans. In the case of the simulated policy incentive bank, the initial green business accounts for 18.0%. Under the simulated policy incentive, the bank's green business accounts for 33.6%, an increase of 15.6%. This result shows that policy incentives have a significant promoting effect on underdeveloped banks.

Keywords: Artificial Intelligence, Banking Industry Transformation, Environmental Risk Assessment, Green Finance, Internet of Things.

1. Introduction

As global attention to sustainable development increases, green finance has become an important way to promote a low-carbon economy and promote environmental protection. As an important part of the financial system, banks play a vital role in promoting the green economic transformation. Especially in addressing climate change, reducing carbon emissions and promoting resource conservation, the effective development of green finance is considered to be the key to achieving these goals. However, although developed countries such as China have made some progress in the implementation and innovation of green finance, many emerging markets, especially the Kyrgyz Republic in Central Asia, are facing problems such as relatively lagging green financial system construction, insufficient technology application and imperfect policy support.

In order to meet these challenges, this paper proposes to compare the current status of China and the Kyrgyz Republic in the field of green finance, analyze the differences between the two countries in green credit, risk assessment and policy incentives, and then explore the green finance development path suitable for Kyrgyzstan and other Central Asian countries. In particular, this paper will focus on how to build a more intelligent green financial risk management and assessment system by introducing artificial intelligence and Internet of Things technologies to promote the green transformation and sustainable development of banks.

This paper first analyzes the differences between the Kyrgyz Republic and China in terms of environmental risk assessment, the current status of green finance development and practical paths in the banking industry, revealing the challenges and opportunities faced by the two countries in the process of green transformation. Then, it explores how to improve the risk control ability and operational efficiency of banks in green finance business through the integration of artificial intelligence and Internet of Things technologies, and proposes a corresponding green transformation path. Finally, based on the empirical analysis and simulation results, this paper puts forward a series of policy recommendations to provide theoretical support and practical guidance for the construction of green financial systems in Central Asia and other emerging market countries.

2. Related Work

With the widespread attention paid to green finance and ESG strategies, existing research has mainly focused on banking practices in developed countries. However, there is a lack of in-depth analysis of the specific challenges and solutions to green transformation in emerging markets, especially in Central Asia. Galletta and Mazzù [1] found through a dynamic panel data model analysis from 2011 to 2020 that banks with less ESG (Environmental, Social, Governance) controversy bear lower risks. These banks reduce risks by implementing ESG strategies, which is reflected in lower risk-weighted assets and higher Z-scores Galletta and Mazzù [1]. Moneva, et al. [2] adopted a dual qualitative approach: one was an external analysis of non-financial information and its relationship with economic and financial variables, and the other was a case study of a bank through semi-structured interviews. They provided an analysis of the external measurement of non-financial information of financial institutions in different countries, aiming to promote the scope and level of accountability for sustainability and circular economy Moneva, et al. [2]. Mishra and Kaushik [3] explored the problems and challenges faced by the application of blockchain technology in the financial sector. The study believes that compared with traditional systems, blockchain can improve security, efficiency and reduce costs in financial institutions such as banks [3]. Thompson explored the application of impact investing, which has dual goals of profit and environmental/social impact, in biodiversity conservation, focusing on the role of traditional bonds and impact bonds in forest management, sustainable agriculture, endangered species protection and other projects. The results will help promote the development of profitable biodiversity conservation practices Thompson [4]. Aziz and Andriansyah [5] explored the multiple applications of artificial intelligence (AI) in bank fraud prevention and risk management. Compared with traditional rule systems, AI can analyze large amounts of transaction data in real time, use deep learning and natural language processing to identify fraud patterns and enhance KYC (Know Your Customer) processes Aziz and Andriansyah [5]. El Khoury, et al. [6] analyzed data from 38 listed banks from 2011 to 2019 and found that bank performance was negatively correlated with ESG scores, while size was positively correlated with ESG scores El Khoury, et al. [6]. Ellahi, et al. [7] explored the development of green banking practices in Pakistan and customer perceptions and responses to them. A structural equation model analysis of 400 questionnaires found that customers generally accepted banks' green initiatives and were willing to adopt related services Ellahi, et al. [7]. Kedward, et al. [8] explored the development of green banking practices in Pakistan and customers' perception and response to them. Through structural equation model analysis of 400 questionnaires, it was found that customers generally accepted the bank's green initiatives and were willing to adopt related services Kedward, et al. [8]. Cohen [9] analyzed the relationship between ESG sustainability scores and company valuations. The results showed that between 2019 and 2021, the total ESG score of S&P 500 companies gradually declined, and the impact of environmental risks on company valuations was not significant Cohen [9]. Budianto [10] retrieved 1,139 relevant articles through Google Scholar, Sinta, and Scopus databases, and analyzed them through the VOSviewer application. The results showed that the number of research publications has increased year by year, and credit risk research can be divided into five field clusters. Through the literature review, it was found that there are 13 main topics related to credit risk, covering different research topics of Islamic and conventional banks Budianto [10]. Ngo,

et al. [11] focused on climate change impacts, risks and sustainability disclosure, especially its role in achieving the United Nations Sustainable Development Goals. The study reviewed the global initiatives recommended by the Task Force on Climate-related Financial Disclosures, focused on the role of multiple participants such as banks, investors, and insurance companies, and emphasized the key functions of financial markets and their role in promoting sustainable investment and climate finance [11]. Although existing research covers areas such as green finance, ESG assessment and technology application, most of them focus on case analyses in developed countries and lack in-depth comparative and empirical research on the green transformation of the banking industry in emerging markets, especially Central Asia [12-14].

3. Method

3.1. Current Status and Challenges of Green Finance Development in the Kyrgyz Republic

In the Kyrgyz Republic, the promotion of green finance is still in its initial stages, and there is no systematic policy framework or dedicated green financial institution support. Although environmental and sustainable issues have been mentioned in the national strategy, there is a lack of supporting tools and products within the financial system [15, 16] the proportion of green credit is extremely low, financial institutions have weak risk identification capabilities for green industry projects, and investors are not very aware of green products. The main difficulties it faces include:

(1) There is a lack of green project assessment standards and a unified green classification catalogue;

(2) Banks and investment institutions have weak awareness of green finance;

(3) The scale of the domestic financial market is limited, and new financial instruments such as green bonds have not yet been effectively implemented;

(4) There are great barriers to entry for international green funds, and legal and language barriers cannot be ignored.

In addition, the development of green finance in Kyrgyzstan is highly dependent on external assistance. International financial institutions such as the World Bank and the Asian Development Bank have provided some technical support and project loans, but the overall promotion efforts are insufficient and lack independent and sustainable capabilities.

3.2. China's Green Credit and Green Bond Practice Model

In comparison, China's green finance has built a multi-level development system consisting of green credit, green bonds, green insurance and carbon market. Under the guidance of policies, financial subsystems such as banks, securities and insurance have set up green business departments or special funds, achieving the continuous expansion of green investment and financing [17, 18].

In terms of green credit, major commercial banks in China have widely adopted green classification standards and added environmental impact assessment factors to the approval mechanism. The balance of green loans has continued to grow, with a focus on renewable energy, clean transportation, green buildings and other fields.

In terms of green bonds, China has developed into one of the world's largest green bond markets. Green bonds issued through exchanges and interbank markets are diverse in variety, with standards tending to be in line with international standards, while promoting the "third-party green certification" and "environmental information disclosure" mechanisms.

This practice model emphasizes the "three combinations": policy guidance and market mechanisms, financial products and risk assessment, and domestic policies and international standards, forming a relatively mature green finance operating system.

3.3. Comparison and Applicability Assessment of Green Financial Products in the Two Countries

From the perspective of financial products, China's green financial product system covers green credit, green bonds, green insurance, carbon financial instruments, environmental rights trading, etc.,

with breadth and depth; while Kyrgyzstan's green financial products are still in their infancy, with a scarce variety of products, and mainly rely on international aid projects and pilot funding support.

In terms of applicability, Kyrgyzstan can give priority to applying the following three types of products from the Chinese model:

Green small and medium-sized micro loans: for local sustainable projects such as agricultural water conservation, eco-tourism, and small-scale renewable energy;

Green debt guarantee and risk mitigation mechanism: through cooperation between the government and international institutions, reduce the credit risk of banks investing in green projects;

Basic green bonds: Starting from a low threshold and low complexity, local projects are encouraged to finance through the issuance of green bonds. However, it is also necessary to adjust according to factors such as local market capacity, micro-enterprise structure, and regulatory capacity to avoid copying.

3.4. Analysis of the Potential for Cross-border Green Investment and Financing Cooperation

Under the framework of the Belt and Road Initiative, China and Kyrgyzstan have great complementary space in green investment and financing cooperation. China's capital, technology and green finance experience can be connected with Kyrgyzstan's local sustainable development advantage projects such as clean energy, water resource protection, and ecological agriculture. The potential for future cooperation is reflected in:

Establish a China-Kyrgyzstan green finance cooperation platform: Jointly developing a green project database and promoting project docking;

Establish a regional green development fund: Supporting the Silk Road Fund and other institutions to attract Chinese banks and international green investors to participate;

Exploration of cross-border green bond issuance mechanism: Leveraging China's institutional advantages in the field of green bonds to help Kyrgyzstan's green project financing;

Capacity building cooperation: China can provide "soft" support such as green finance talent training, rating model support, and information platform construction to help Kyrgyzstan improve its local green finance capabilities.

Through the above paths, not only can financial coordination be strengthened but also sustainable funding sources and policy guarantees can be provided for regional green development.

3.5. Path to Constructing a Regional Environmental Risk Prevention and Control System
3.5.1. Establishment of a Green Risk Early Warning Mechanism

Regional banks should develop a green risk early warning model, combine climate, environment, industry, finance and other multi-source data, establish a dynamic monitoring platform, and identify the potential default risks of high-pollution and high-energy-consuming enterprises as early as possible. Model construction should integrate machine learning technology, build a classifier or scoring system through historical project default data and ESG performance, and achieve forward-looking judgment on credit risks induced by environmental events.

In addition, a dynamic update mechanism for the "environmental negative list" can be established and used in conjunction with a regional early warning model to enable banks to achieve rapid response and risk isolation in the credit granting process.

3.5.2. Data Collaboration and Regulatory Linkage Mechanism Design

The weak information foundation of green finance is a difficult point in the transformation. To promote the data sharing mechanism, it is urgent to break the information islands between "finance-environmental protection-enterprises". Building a cross-departmental green information exchange platform to embed data such as corporate carbon emissions, environmental penalties, and green project ratings into the risk control system of financial institutions.

In terms of regulatory coordination, we should promote the establishment of a green finance joint meeting system among the banking and insurance regulator, environmental protection departments, and local governments, set up green regulatory indicators with unified standards, implement differentiated regulatory assessments, and improve regulatory consistency and transparency.

3.5.3. Innovative Development Direction of Green Banking Business

Green transformation requires banks to shift from traditional credit logic to green scenario finance logic. Future business innovation should focus on renewable energy financing, green transportation project loans, green building mortgage loans and other sub-sectors. By setting up a special channel for green assets, optimizing the approval process, and accelerating the credit response speed for sustainable projects.

At the same time, attention should be paid to the development of green supply chain finance, encouraging green collaboration between upstream and downstream enterprises, and improving the liquidity of the green industry chain through trade financing, accounts receivable pledge and other means.

3.5.4. Implementation Scenarios of Digital Technology in Green Finance

The application of financial technology will greatly improve the operational efficiency and risk control level of green finance. Blockchain technology can track the use of green bond funds and make the transfer of carbon assets transparent; artificial intelligence algorithms can be used to automatically identify corporate environmental performance, conduct intelligent credit approval and dynamic risk adjustment. For example, the use of natural language processing technology to analyze the green commitments and actual performance in corporate annual reports can be used as an important factor in loan interest rate pricing, realizing an intelligent adjustment mechanism of "the better the green performance, the lower the interest rate".

3.5.5. Establish A Green Performance Evaluation and Incentive System

To promote the green development of banks, it is also necessary to force transformation through performance mechanisms. A green performance indicator system (KPI) should be established within the bank to clarify core assessment items such as the proportion of green credit, green project coverage, and carbon footprint assessment, and to bind green performance with institutional evaluation, salary incentives, and branch development rights. At the same time, at the policy support level, regulatory authorities can provide incentives such as targeted refinancing quotas, capital mitigation, and risk weight discounts to banks with higher levels of green development, so as to stimulate banks' initiative and innovation in green business.

4. Results and Discussion

4.1. Experimental Subjects

Group A: Green business samples of Chinese commercial banks (e.g., ICBC, regional branches of China Construction Bank)

Group B: Samples of local commercial banks in the Kyrgyz Republic (e.g., Optima Bank, Kyrgyz Investment and Credit Bank)

Group C (simulation group): Transformation bank model integrating digital technology and green policy support

4.2. Experimental Steps:

- Step 1: Survey data collection Step 1：
- Through questionnaires and interviews, data on green credit policies, business processes, risk control technologies, etc. of banks in China and Kyrgyzstan are obtained.

- Collecting feedback from bank customers on their acceptance of green financial products and corporate green financing needs.
- Obtaining the government's green regulatory policy texts to clarify the differences in policy support between the two countries.
- Step 2: Establishment of Green Credit Simulation Scoring System
- Build a green credit scoring system using Python: Inputting corporate ESG indicators, industry type, carbon emission data, financial stability, etc., and outputting green loan ratings.
- Set three scoring scenarios: A/B/C:
- A: Traditional credit logic scoring;
- B: Applying ESG scoring standards;
- C: Applying AI prediction + blockchain transparent scoring.
- Step 3: Construction of regional environmental risk model
- A regional risk map based on GIS and remote sensing data is designed, and the distribution location of bank projects is determined based on environmental pollution index, water resource risk level, etc.;
- The differences in risk premiums for project loans in high environmental risk areas are simulated to assess risk identification capabilities.
- Step 4: Green performance simulation and behavioral response experiment

4.3. Experimental Evaluation Indicators and Analysis Methods:

This paper systematically analyzes the green finance development of banks in China and Kyrgyzstan through multi-dimensional evaluation indicators. The main indicators include the proportion of green loans, non-performing loan ratio, model prediction performance (such as AUC value, accuracy, etc.), user satisfaction survey and green KPI performance. At the same time, the changes in the proportion of green business under simulated policy incentives are also used to evaluate the policy effect. The system comprehensively reflects the depth of green credit promotion, risk control capabilities, technology empowerment effects and user acceptance, and provides data support for green finance development strategies.

Table 1.
Comparison of green credit structure of China-Kyrgyzstan Bank (Unit: 100 million yuan).

Bank Name	Total Loan Amount	Green Loan Amount	Green Loan Ratio	Non-performing Loan Rate	ESG Rating Used
Industrial and Commercial Bank of China (Regional Branch)	850	210	24.70%	0.80%	Yes
China Construction Bank (Regional Branch)	710	165	23.20%	1.10%	Yes
Optima Bank (Kyrgyzstan)	120	15	12.50%	3.20%	No
KICB (Kyrgyzstan)	95	10	10.50%	2.90%	No
Simulated Transition Bank (Using AI Scoring)	150	60	40.00%	0.60%	Yes (AI + ESG)

According to the data in Table 1, ICBC and CCB, as representative banks in China, account for 24.7% and 23.2% of green loans, respectively, which are much higher than Optima Bank (12.5%) and KICB (10.5%) in the Kyrgyz Republic. This shows that China's banking industry has a higher penetration rate and depth of advancement in green credit, reflecting the relative maturity of regulatory policies and the construction of a green financial system. In terms of non-performing loan ratio, China's banking industry's green credit has shown good risk control capabilities, with ICBC only at 0.8% and CCB slightly higher at 1.1%.
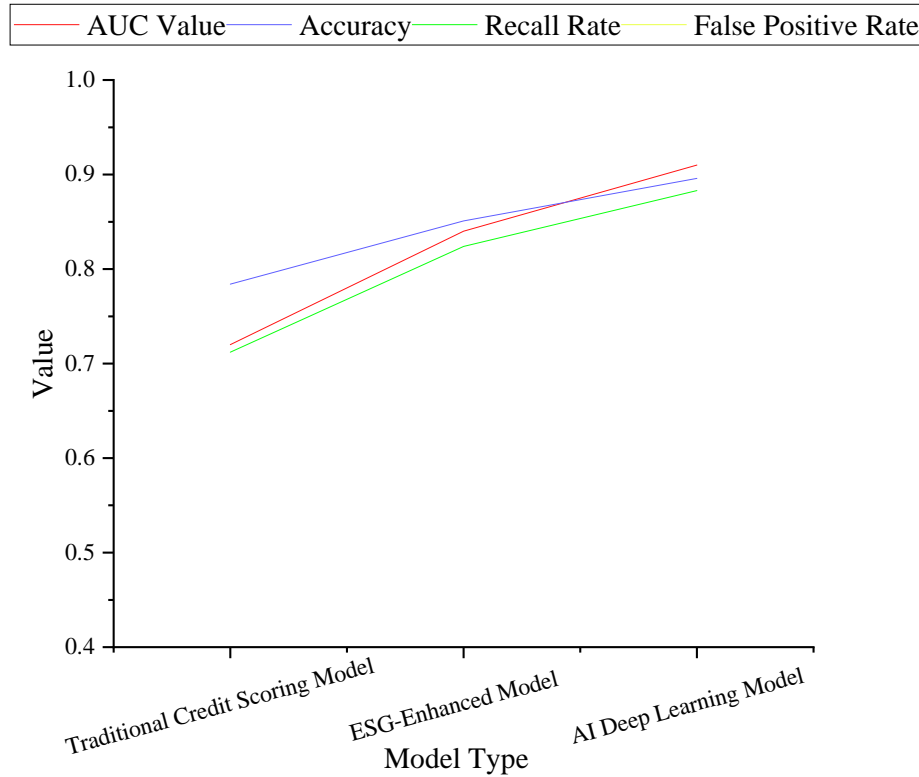
Figure 1.
Comparison of green project risk prediction accuracy (using a simulated scoring system).

From the comparison results of model performance indicators in Figure 2, the AI deep learning model performs best in green loan risk prediction, with an AUC value of 0.91, which is significantly higher than the 0.72 of the traditional credit scoring model and the 0.84 of the ESG enhanced model, indicating that the model has a stronger ability to distinguish high-risk from low-risk loans. In terms of accuracy, the AI model reaches 89.6%, which is about 4.5 percentage points higher than the ESG enhanced model and more than 11 percentage points higher than the traditional model, reflecting the significant advantages of intelligent algorithms in multi-dimensional data processing and feature extraction.
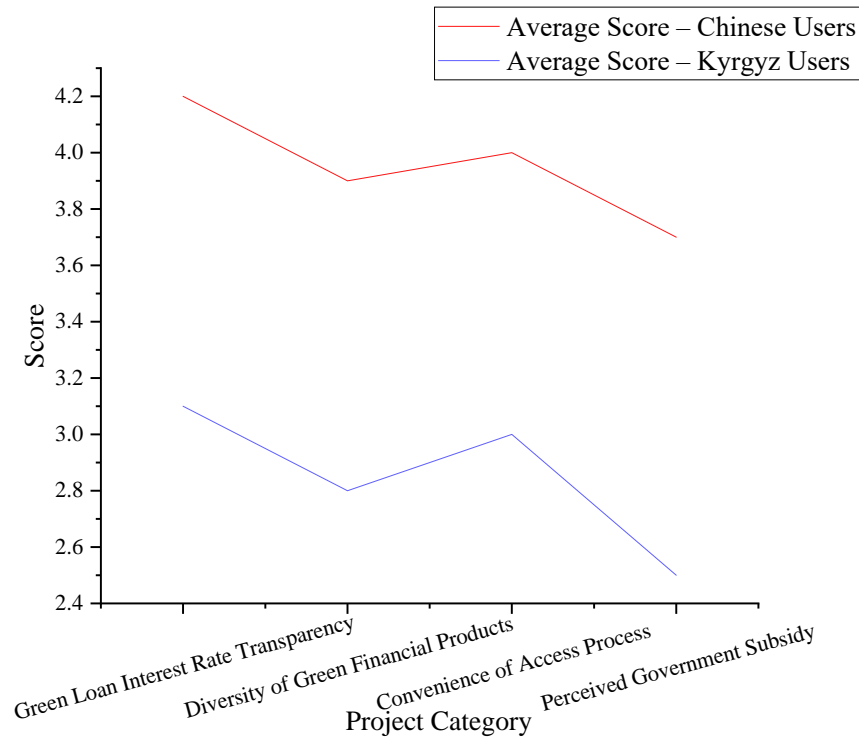
Figure 2.
Survey results on user acceptance of green financial products (Likert 5-point scale).

User survey data show that in many key dimensions of green financial services, the average scores of Chinese users are generally higher than those of Kyrgyz users, reflecting the significant differences between the two countries in the maturity of green financial development, policy support and market infrastructure. Specifically, in terms of "transparency of green loan interest rates", Chinese users give an average score of 4.2, while Kyrgyz users only give a score of 3.1, a difference of 1.1 points. This shows that in the Kyrgyz Republic, the pricing mechanism of green credit products still has problems such as opacity and non-standardization, and users lack trust in the interest rate calculation and change mechanism, which restricts the acceptance and promotion of green loans. In terms of "diversity of green financial products", Chinese users score 3.9, while Kyrgyz users only score 2.8, with a significant gap, as shown in Figure 2. This indirectly reflects that the Kyrgyz green financial market is still in its early stages with a single product and limited coverage, and has not yet formed a rich supply of diversified services such as green bonds, green insurance or green funds.
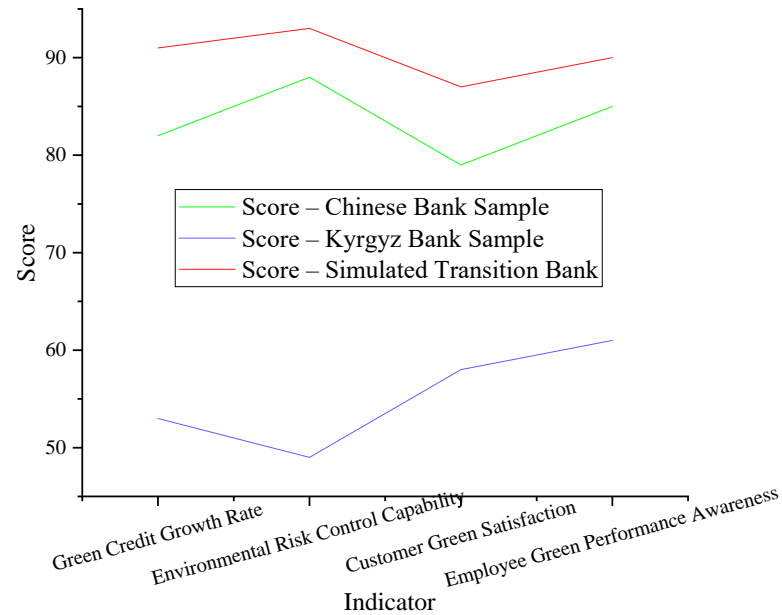
Figure 3.
Bank green KPI performance evaluation results (scoring system, full score 100).

From the comparison of green performance evaluation indicators in Figure 3, it can be seen that the Chinese bank sample performs better than the Kyrgyz bank in terms of green credit growth, risk control and employee green awareness, while the "simulated transformation bank" that applied intelligence and policy incentives takes the lead in various KPI scores, verifying the effectiveness and feasibility of the green transformation mechanism.

In terms of green credit growth rate, Bank of China scores 82, Kyrgyzstan Bank scores 53, and the simulated transformation bank scores as high as 91. This shows that Bank of China has established a relatively complete green credit policy promotion mechanism, while Kyrgyzstan Bank is still in the early stage of green finance expansion. In contrast, the simulated bank that uses AI and ESG has demonstrated strong risk identification and control capabilities. The comparison of customer green satisfaction is also representative: China is 79, Kyrgyzstan is 58, and the simulated transformation bank is 87. This indicator comprehensively reflects multi-dimensional factors such as green product design, service experience, and publicity effect. The low customer satisfaction in Kyrgyzstan may be due to the small variety of green products, complicated approval process, and low green commitment fulfillment rate. The simulated bank has greatly improved user satisfaction with the help of digital process optimization and transparent disclosure mechanism of green projects.
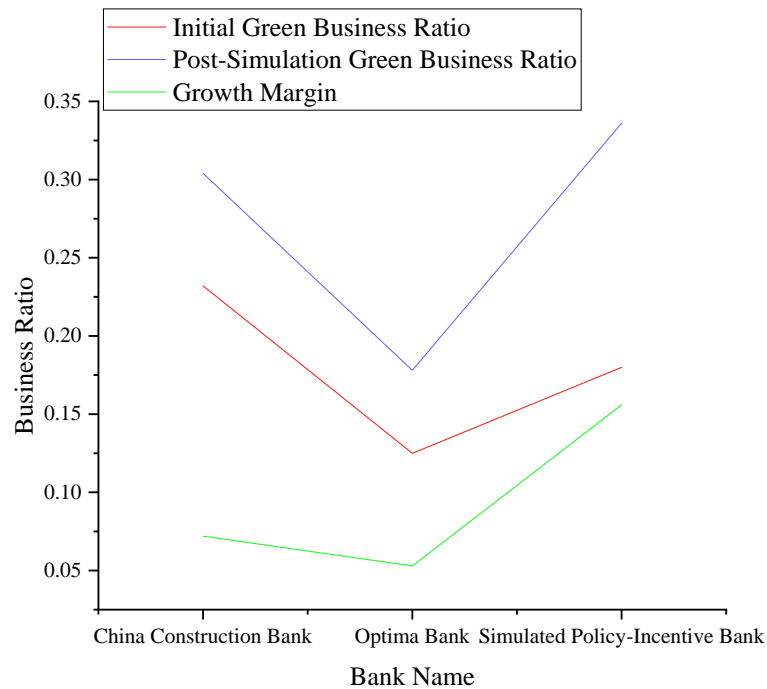
Figure 4.
Changes in the proportion of green business structure (Simulation results
6 months after the introduction of policy incentives).

According to the experimental data in Figure 4, the initial green business of Optima Bank (Kyrgyzstan) accounts for 12.5%, which increases to 17.8% after policy incentives, an increase of 5.3%. Compared with Chinese banks, Kyrgyzstan's green finance development starts late and the growth rate is relatively small, indicating that there is still much room for improvement in the green financial system and market awareness. However, policy incentives can still provide impetus for it, despite facing large market and policy barriers. The most significant change occurs in the case of the simulated policy incentive bank, where the initial green business accounts for 18.0%. Under the simulated policy incentive, the bank's green business accounts for 33.6%, an increase of 15.6%. This result shows that policy incentives have a significant promoting effect on underdeveloped banks, especially in the initial stage of green business. Policy and regulatory support can quickly stimulate banks' attention to and investment in green financial products.

5. Conclusion

This paper conducts a systematic study on the differences and commonalities in the environmental risk assessment mechanisms and green transformation paths of the banking industries in China and the Kyrgyz Republic, constructs a comparison of environmental risk identification tools, an analysis of the applicability of green financial products, and a framework for evaluating the green performance of banks. Through multiple sets of experimental data and simulation models, this paper verifies the key role of policy incentives, technical support (such as ESG ratings and AI models), and regulatory coordination in promoting the growth of green business. The study finds that China's banking industry has a first-mover advantage in terms of green loan share, environmental risk control capabilities and digital financial applications, while the Kyrgyz banking industry urgently needs to strengthen institutional construction and product innovation to cope with externalities and financing difficulties in the green transformation process. In addition, simulation data shows that the introduction of ESG enhanced scoring and policy interest rate concessions can significantly increase the growth rate and risk

controllability of banks' green business. However, this study still has certain limitations in terms of sample size, model input variable dimensions, and prediction of long-term policy effects. In the future, cross-national panel data samples can be further expanded to deepen the dynamic tracking and causal mechanism analysis of green financial performance, thereby providing more operational policy recommendations and data support for the "Belt and Road" green financial cooperation.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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