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# The Degree of Big Data Technology Transformation and Green Operations in the Banking Sector

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**Abstract:** Green finance, an essential tool for high-quality economic development, is valued by policymakers and researchers in line with the growing global concern for environmental protection, climate change, and sustainable development. The banking sector, as a major part of China's green financial system, undertakes significant responsibility for green finance while also confronting the opportunities and requirements of digital transformation. Big data technology is a major driver of digital transformation in the banking sector and can improve the green operational capability of the banking sector. The purpose of this study is to explore the ways in which the extent of big data technology transformation in the banking sector in China affects its ability to operate in a green manner and to analyze the moderating role of green credits, funds, and bonds. For this reason, this study selected A-share listed banks in China from 2015 to 2022 as research subjects and adopted a panel data regression method to study the impact of the degree of big data technology transformation on green operations. The results demonstrate that the degree of big data technology transformation in the banking sector positively influenced green operations. Green credit, funds, and bonds played a moderating role, meaning that financial products strengthened the role of the degree of big data technology transformation in green operations. This study examined the effect of big data technology transformation in the banking sector and enriches research on green finance. This study also provides practical insights for investors and regulators concerned with green development in the banking sector.

**Keywords:** degree of big data technology transformation; green operations; green credit; funds; bonds; bank sector

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**Citation:** Yun, J.; Jin, S. The Degree of Big Data Technology Transformation and Green Operations in the Banking Sector. *Systems* **2024**, *12*, 135. https://doi.org/10.3390/systems12040135

Academic Editors: Chia-Huei Wu and Wei Liu

Received: 10 March 2024
Revised: 16 April 2024
Accepted: 16 April 2024
Published: 17 April 2024



## 1. Introduction

With the rapid development of information technology, big data has revolutionized the financial industry [1]. China should accelerate the digitization process of its financial market, especially in pursuit of energy-saving and emission-reduction effects [2]. The digital transformation and efficiency improvement of commercial banks have attracted extensive attention in the financial industry [3]. Bank digitization is a ubiquitous challenge that the banking sector is currently facing [4]. The financial sector is deeply involved in the computation of big data events [5] and the development of fintech has improved the profitability of commercial banks [6]. Banks have become intrinsically linked to technology [7] and must allocate resources for the digitization of internal processes to offer new products and services [8]. FinTech development can increase banking profitability and financial innovation and improve risk control and green operations [6].

Big data analytics is necessary for every business, and the most advanced organizations, to look forward and make meaningful decisions [9]. The importance of cybersecurity has gained prominence in today's digitalized world [10]. For the banking industry, big data technology transformation not only facilitates business efficiency, but also strengthens cybersecurity [11]. Big data also exerts a significant impact on financial products and services, which also contributes to monitoring the security of green financial transactions [1].

It can assist banks in gaining a more comprehensive understanding of customer needs, accurately assessing risks, and optimizing operations. Additionally, big data technology also contributes to monitoring and responding to cybersecurity threats [12]. With the increased global concern for environmental protection and sustainable development, green finance has emerged as an essential tool for high-quality economic development [13]. Big data technology can support the development of green financial products, such as green credit, funds, and bonds [14]. Meanwhile, policymakers and researchers are increasingly concerned about green financing [15]. The banking industry, as an essential part of the green financial system, needs to respond to these policy and regulatory requirements and utilize big data technology to enhance green operations.

With increasing global attention on environmental protection, climate change, and sustainable development, policymakers and researchers have recently focused on green financing [15]. Green finance, as a major policy innovation led by high-quality economic development, can optimize the mode and structure of economic development, enhance the rationalization and advanced level of industrial structure, and improve the high-quality development of the economy through green investment [13]. The main forms of green finance include green credit, green funds, green bonds, green insurance, and so on [16]. Green economic development enhances environmental quality [17]. Asian markets are in need of green financing [18]. In international capacity cooperation, it is necessary to implement green and low-carbon construction, operation and management, and emphasize the development of green finance [19].

The Chinese government is committed to peak carbon dioxide emissions by 2030, and strives to achieve carbon neutrality by 2060. The proposal of a peak carbon neutral target has led China into an era of climate economy, setting off green change with both opportunities and challenges [20]. The Chinese government has attached great importance to green development as a national strategy and has formulated a series of policies and measures to promote the development and innovation of green finance [21]. The banking sector, as an important part of China's green financial system, undertakes the responsibility for green finance [22] (Lian et al., 2022) and also faces the opportunities and requirements of digital transformation [23]. The digitization process of the financial market should be accelerated [2] to improve the level of green operations and contribute to the development of a green economy.

Artificial intelligence can be used to predict cash demand and reduce the operational costs of ATM and branch networks [24]. Fintech innovation contributes to green economic growth by improving financial development [25]. Digital technologies have a positive impact on economic and environmental performance [26]. Green finance has the potential to reduce costs and increase efficiency [27], and the global community is gradually shifting from an industrial economy to a new era of digital economy [28].

Green technological innovation requires a large resource input [29], and the integration of fintech development and green finance should be strengthened [30]. Green finance has made a significant contribution to green innovation [31]. Although green finance has not yet been implemented in many regions of the world at this stage [15], green finance-related policies have a positive effect on environmental protection [32].

Fintech development has a significant impact on banks' capital adequacy, asset quality, management efficiency, profitability, and liquidity ratio [33]. Green operational innovations are defined as innovations that improve the efficiency of an organization in relation to its operational business activities [34]. Big data technology has become an important driver of transformation and innovation in the banking sector. Big data technology can help banks to gain a more comprehensive and in-depth understanding of their customers' needs, accurately assess their risks, and optimize their operations more effectively, thus, improving the green operational capability of the banking sector.

However, the application of big data technology can also have an impact on the environment, and there is a need to consider the balance and harmonization between big data and green operations. This study seeks to examine the impact of the extent of big data technology transformation in the Chinese banking sector on its ability to operate in a green manner, and to analyze the moderating role of green credit, funds, and bonds in this context. Currently, the Chinese banking industry is actively integrating digital technology with green finance. Through digital products, digital operations, digital risk control, and infrastructure, it effectively promotes the digital transformation of green finance. [35]. As shown in Table 1, with the digital transformation of the banking industry, the increase in non-cash payments and electronic payment services has made banking services more convenient. At the same time, it has reduced the use of physical bank branches, thereby reducing energy consumption. China is the world's largest developing country and is an important promoter and practitioner of green finance. The digital transformation and green development of its banking sector are of great theoretical and practical significance. Therefore, China's A-share listed banks from 2015 to 2022 were selected as research objects to study whether the degree of big data technology transformation in the banking sector can enhance the ability of green operations. We confirm a significant positive correlation between the degree of big data technology transformation and green operational capabilities in the banking sector. Green credit, funds, and bonds play a positive moderating role in the relationship between big data technology transformation and green operations. This study not only enriches the theoretical research on green finance, but also presents practical guidance for the green development of the banking industry.

**Table 1.** Non-cash payment services and electronic payment services from 2015 to 2022.

| Name | Non-Cash Payment Services (Billion Transactions) | Non-Cash Payment Services (Trillion Yuan) | Electronic Payment Services (Billion Transactions) | Electronic Payment Services (Trillion Yuan) |
|---|---|---|---|---|
| 2015 | 943.22 | 3448.85 | 1052.34 | 2506.23 |
| 2016 | 1251.11 | 3687.24 | 1395.61 | 2494.45 |
| 2017 | 1608.78 | 3759.94 | 1525.8 | 2419.2 |
| 2018 | 2203.12 | 3768.67 | 1751.92 | 2539.7 |
| 2019 | 3310.19 | 3779.49 | 2233.88 | 2607.04 |
| 2020 | 2547.21 | 4013.01 | 2352.25 | 2711.81 |
| 2021 | 4395.06 | 4415.56 | 2749.69 | 2976.22 |
| 2022 | 4626.49 | 4805.77 | 2789.65 | 3110.13 |

Source: Summarized based on the "Overall Operation of the Payment System" published by the People's Bank of China from 2015 to 2022.

This study focuses on two main aspects of innovation. First, it analyzes green operations in the banking sector from the perspective of big data technology transformation, which expands the research perspective and content of green finance. Second, it takes into account the moderating effect of different types of green financial products, such as green credit, funds, and bonds, on the relationship between big data technology transformation in the banking sector in relation to green operations enriches the research methods and conclusions of green finance. This study is of practical significance in promoting the digital transformation and green development of the banking sector, improving the competitiveness and social responsibility of the banking sector, and guiding the decisions of investors and regulators.

The rest of this paper is structured as follows: Section 2 is the theoretical background and hypotheses, which describe the relevant theories and the basis for the establishment of the hypotheses; Section 3 is the research methodology, which describes the data sources, the definition of variables, and the model setup; Section 4 is the empirical results and analyses, which report the regression results and the analyses; and Section 5 presents the conclusions and recommendations, which summarize the conclusions of the study and proposes the corresponding policy recommendations and research constraints.

## 2. Theoretical Background and Hypotheses

### *2.1. Impact of Degree of Big Data Technology Transformation on Green Operations in Banking Sector*

With the rapid development of information technology, big data have become an important driving force for transformation and innovation in the banking sector. Big data technology can help banks to understand customer needs more comprehensively and deeply, assess risks more accurately, and optimize operations more effectively. Big data analysis and management capabilities are instrumental in innovative green product development [36,37].Financial development can minimize energy use and pollution emissions [38], and the ability to manage big data analytics has a positive impact on innovation and greening [36]. Business model redefinition should be seen as an ongoing process [39]. The digitization of financial markets should be accelerated in terms of energy savings and emissions reductions [2]. Big data analytics has great potential to improve business operations through data-driven decision-making [40]. Traditional financial institutions should actively embrace digitization trends and enhance their green technological innovation capabilities to solve serious environmental pollution problems [37]. Thus, banks must enhance their service innovations [41]. Digitization can improve energy efficiency [42]. Artificial intelligence is the key to most operational transformations [43]. Big data analytics facilitate the green transformation of small- and medium-sized enterprises [44].

Big data is extremely useful in the field of operations management [45]. For green operations in the banking sector, attention should be paid to improving financial technology capabilities [33]. First, through big data analysis, enterprises' environmental performance and risk can be assessed more accurately so that green credit risk can be managed more effectively. Second, customers' environmental preferences and investment behaviors can be analyzed using big data to promote green products and services more accurately. Finally, operational data can be analyzed using big data to discover environmental problems and improve the operational process, thereby reducing carbon emissions and energy consumption. Thus, we propose the following hypotheses:

**Hypothesis 1 (H1).** *The degree of big data technology transformation in the banking sector enhances the ability of green operations.*

### *2.2. The Moderating Role of Green Credit*

Green credit refers to loans provided by banks to projects or enterprises that meet green environmental protection standards and are an important part of green finance [17]. The green credit policy is an important component of environmental policy [46]. China introduced many green credit policies [47], making banks dominant in credit provision [48,49]. Green credit policy is differentiated regionally [50]. Commercial banks in China can obtain larger credit lines for enterprises with comprehensive green management strategies [51].Green credit can promote the development of green industries, improve resource utilization efficiency, and reduce environmental pollution and ecological damage [50,52,53]. Green credit can also help banks to optimize their credit structure, reduce credit risk, improve credit returns, and enhance their sense of social responsibility and image [22,54–56].

The proportion of green credit reflects the importance and support of banks for green finance, as well as the green operation level of banks [22]. The higher the proportion of green credit, the more banks can meet the needs of the green economy and the more green credit can realize high-quality and efficient development of the economy [57]. The proportion of green credit can also affect the degree of big data technology transformation of banks because green credit requires banks to use big data technology to screen, evaluate, monitor, and manage green projects to improve the efficiency and effectiveness of green credit [22,58,59]. The effect of digital finance on the energy environment is more pronounced in the context of immature credit and capital markets [2]. Therefore, we believe that the proportion of green credit can modulate the impact of the degree of big data technology transformation on the green operations of the banking sector. Specifically, the higher the proportion of green credit, the greater the degree of big data technology transformation on the banking sector's green operations, and the stronger the positive impact of the degree of big data technology transformation on green operations in the banking sector. Accordingly, we propose the following hypothesis:

**Hypothesis 2 (H2).** *The green credit ratio exerts a positive impact on the degree of big data technology transformation in the banking sector to enhance green operations.*

### 2.3. The Moderating Role of the Fund

A fund is a pooled investment approach that can provide financial support for green projects [60,61]. Studies have shown that the size, structure, and performance of funds have significant impacts on the development of green finance [62]. The larger the size of the fund, the stronger the supply capacity of green finance; the more diverse the structure of the fund, the higher the risk diversification capacity of green finance, the better the performance of the fund, and the greater the market attractiveness of green finance [63,64]. Therefore, funds can promote green operations in the banking sector by providing more green financial products.

At the same time, funds can also influence the degree of big data technology transformation in the banking sector [59]. On the one hand, funds can provide the banking sector with the demand and power of big data technology. The fund's investment decisions needs to rely on the analysis and prediction of big data technology, the fund's operation and management needs to rely on the monitoring and evaluation of big data technology, and the fund's risk control must rely on the identification and prevention of big data technology. Therefore, funds can incentivize the banking sector to accelerate the application and innovation of big data technology. On the other hand, funds and digital finance can also promote green technology innovation [36,65] and provide big data technology resources and capabilities for the banking sector. The development of fintech can improve financial innovation [66] and provide the banking sector with financial and technical support for big data technologies. Therefore, funds can help the banking sector to improve the input and output of big data technology.

In summary, funds can play a positive moderating role in the degree of big data technology transformation in the banking sector and green operations. That is, the presence of funds can enhance the degree of big data technology transformation on green operations in the banking sector. Based on this, this study proposes the following hypotheses:

**Hypothesis 3 (H3).** *Fund market share positively affects the degree of big data technology transformation in the banking sector, enhancing green operations.*

### 2.4. The Moderating Role of Bonds

Bonds are important financial instruments by which banks can help to finance green projects through bond issuances and provide investors with new green assets [66,67]. Green bonds are a conservative innovation with huge market potential that is crucial for successfully promoting energy efficiency financing and green growth [68–71]. Green bonds tend to be structured in the same way as traditional investment-grade bonds, but the bond stipulates that the financing will be utilized for green investments [70]. In comparison to traditional bonds, green bonds are issued on a larger scale [72]. Banks are the main issuers of bonds and can channel funds to environmental activities and projects, attracting more green investors and promoting green operations in the banking sector [73–75].

Simultaneously, bond issuances can facilitate big data technology transformation in the banking sector. Bond issuance requires banks to collect, analyze, and disclose a large amount of data to meet the standards and requirements for green bonds [58]. These data relate to the use, benefits, risks, and returns of bonds, which require banks to use big data technology for effective management and monitoring [76]. The issuance of bonds can also provide banks with more data resources to help them better understand market dynamics, optimize the pricing and allocation of bonds, and improve their competitive advantage [15].

Therefore, bond issuances can positively moderate the relationship between the degree of big data technology transformation in the banking sector and green operations. When banks issue more bonds, the effect of the degree of big data technology transformation in the banking sector on green operations is greater. Based on the above analysis, this study proposes the following hypothesis:

**Hypothesis 4 (H4).** *Bond market share positively impacts the degree of big data technology transformation in the banking sector to enhance green operations.*

Figure 1 illustrates the model used in this study.

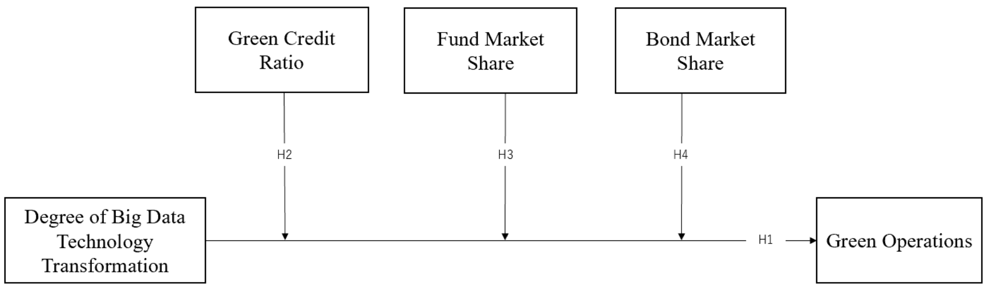


**Figure 1.** Research Model.

## 3. Methodology

### *3.1. Sample Selection and Data Sources*

In this study, Chinese A-share listed banks from 2015 to 2022 were selected for research and 235 sample values were obtained. The data on the degree of big data technology transformation in this study are taken from the China Economic and Financial Research Database (CSMAR), while other data are taken from the Wind Economic Database (WIND), Oriental Wealth Financial Data Platform (Choice), listed companies' websites, listed companies' social responsibility, and annual reports. Sample data were processed as follows: (1) Samples with missing data were excluded; (2) Excluding ST listed banks; (3) To eliminate the effects of extreme values, this study shrank all continuous variables at the 1% and 99% levels; (4) To eliminate the effects of heteroscedasticity, a logarithmic treatment was applied to the main continuous variables; (5) To avoid covariance, the continuous variables involved in the interaction terms were pooled.

### *3.2. Definition of Variables*

#### 3.2.1. Dependent Variable

Taking Industrial Bank Co., Ltd. (Fuzhou, China) as an example, green operations are in the environmental segment of the company's ESG management. Therefore, the environmental ESG score was selected for measurement. This study concerns A-share listed banks in China, therefore, drawing on Zhu and Jin [77] and others, ESG data are selected to be provided by Bloomberg. Bloomberg is a third-party data provider in China that focuses on ESG data and systematizes ESG information from public sources, such as annual reports, perpetual reports, social responsibility reports, environmental reports, announcements, circulars, and official websites. The Bloomberg Environmental (E) score is used to measure green operations.

#### 3.2.2. Independent Variable

This study drew on Feng et al. [78] and used text analysis to measure the degree of big data technology transformation. The total number of texts involving artificial intelligence, big data, cloud computing, blockchain, and digital technology applications is defined as the degree of big data technology transformation to analyze the text content of the annual reports of listed companies, extract relevant keywords, and determine word frequency.

#### 3.2.3. Moderating Variable

Green Credit Ratio

In this study, we referred to the study by Song et al. The Green Credit Loan Ratio (GCLR) under the Equator Principles, also known as the Project Finance Ratio under the Equator Principles, was calculated by dividing the green credit balance (Equator Principles Project Finance) by the total loan amount [79]. Data on the green credit ratios were obtained from the CSMAR database.

Fund Market Share

This study extends and improves the study by Le et al. Although the objectives of our study differ from theirs, we used similar measures [80]. The market share of bank funds was selected as the measure. This approach ensured that our measurements were consistent with those of Le et al. and met our research needs. Relevant data were obtained from Choice Financial Terminals.

Bond Market Share

Wang et al. [81] used the difference in yields between green and traditional bonds to measure the debt market response. In this study, both green and traditional bonds were measured, and because of the small sample size of green bonds, the market share of traditional bonds was selected as a measure. Relevant data were obtained from Choice Financial Terminals.

#### 3.2.4. Control Variable

To mitigate the effect of other possible factors, we referred to He, Guo, and Yue [82–85] and selected the following seven control variables: firm size (Size), gearing (Lev), age of the firm (AGE), firm performance (ROA), growth rate of revenue (GRO), nature of the first shareholder (SOE), and percentage of the first shareholder's shareholding (TOP1). Table 2 presents the definitions and measurements of these variables.

**Table 2.** Measurement and Definition of Variables.

| Name | Variable Name | Abbreviation | Definition of Variable |
|---|---|---|---|
| Independent Variables | Degree of Big Data Technology Transformation | FTLF | Ln (keyword word frequency + 1) |
| Dependent Variables | Green Operations | GES | Bloomberg Environmental Rating |
| Moderating Variables | Green Credit Ratio | GCR | Ln (green credit balance/total loans + 1) |
| | Fund Market Share | MSF | Ln (fund issuance/total commercial bank fund issuance + 1) |
| | Bond Market Share | BIR | Ln (bond issuance/total commercial bank bond issuance + 1) |
| control variable | Company Size | Size | Ln (book value of total assets at year-end) |
| | Gearing Ratio | Lev | Total liabilities at year-end/total assets at year-end |
| | Company Age | AGE | Ln (year of observation − year of establishment + 1) |
| | Company Performance | ROA | Net profit/total assets |
| | Revenue Growth Rate | GRO | Revenue growth rate |
| | Nature of the Largest Shareholder | SOE | 1 for state-owned enterprises, 0 for others |
| | Shareholding Ratio of the Largest Shareholder | TOP1 | Shareholding ratio of the largest shareholder |

### 3.3. Research Model

To test the effect of the degree of big data technology transformation on green operations, namely, to test the validity of Hypothesis 1, this study referred to the methodology of Wang and Irfan [31,86] and constructed a panel econometric least squares regression Model (1) as follows:

$$GES = \alpha_0 + \alpha_1 \cdot FTLF + \alpha \cdot Control + \epsilon \quad (1)$$

In Model (1), GES is the dependent variable, FTLF is the independent variable, Control represents each control variable, and $\alpha_0$ is the intercept term, and $\alpha_1$ is the coefficient of the independent variable, which indicates the degree of influence of the independent variable on the dependent variable; $\epsilon$ is the random disturbance term. If $\epsilon\alpha_1$ is positive and passes the significance test, it means that the degree of big data technology transformation positively affects green operations and research Hypothesis 1 is valid. If $\alpha_1$ does not pass the significance test or $\alpha_1$ is negative and passes the significance test, Hypothesis 1 is not valid.

To further test the moderating role of the green credit ratio, fund market share, and bond market share in the relationship between the degree of big data technology transformation and green operations, namely, to test whether Hypotheses 2 to 4 are valid, with reference to the methodology of the prior study by Liu et al. [87]. This study added the moderating variable and degree of big data technology transformation between the interaction term baseline model and constructed Models (2)–(4). If $\alpha_3$ is positive and passes the significance test, when $\alpha_1$ coefficient passes the significance test, then the green credit ratio, fund, and bond positively affect the positive impact of degree OF big data technology TRANSFORMATION on green operations, respectively, and Hypotheses 2–4 are established.

$$GES = \alpha_0 + \alpha_1 \cdot FTLF + \alpha_2 \cdot GCR + \alpha_3 \cdot FTLF \cdot GCR + \alpha \cdot Control + \epsilon \quad (2)$$

$$GES = \alpha_0 + \alpha_1 \cdot FTLF + \alpha_2 \cdot MSF + \alpha_3 \cdot FTLF \cdot MSF + \alpha \cdot Control + \epsilon \quad (3)$$

$$GES = \alpha_0 + \alpha_1 \cdot FTLF + \alpha_2 \cdot BIR + \alpha_3 \cdot FTLF \cdot BIR + \alpha \cdot Control + \epsilon \quad (4)$$

## 4. Empirical Analysis Results

### 4.1. Descriptive Statistics

The descriptive statistics of the sample data are presented in Table 3. The dependent variable—green operations (GES)—had a mean of 3.082, a standard deviation of 0.884, a minimum value of 0.0837, and a maximum value of 4.303. This indicates that there are also large differences in the performance of companies in green operations, with some companies doing a better job in green operations, and others needing further improvement. The independent variable—the degree of big data technology transformation (FTLF)—had a mean of 1.957, a standard deviation of 0.771, a minimum value of 0, and a maximum value of 3.526. This indicates that there are differences in the degree of big data technology transformation among companies. TRANSFORMATION varies somewhat, with some companies having a higher degree of transformation and others having a relatively lower degree. The moderating variable—Green Credit Ratio (GCR)—had a mean of 0.0363, a standard deviation of 0.0372, a minimum value of 0, and a maximum value of 0.171. For the bond market share (BIR) the mean was 0.00407, the standard deviation was 0.00587, the minimum value was 0, and the maximum value was 0.0438. For the market share of funds (MSF) the mean was 1.217, the standard deviation was 1.517, the minimum value was 0, and the maximum value was 7.429. This indicates that there are some differences in the green credit ratio, bond market share, and fund market share among companies, which may reflect that different companies attach different importance to and implement different efforts in the green credit market, bond market, and fund market. In addition, some control variables have large standard deviations. For example, the mean value of the proportion of shares held by the first largest shareholder (TOP1) was 24.46, the standard deviation was

17.05, the minimum value was 4.180, and the maximum value was 67.39, which suggests that there is a large difference in the proportion of shares held by the largest shareholder of each bank.

**Table 3.** Descriptive Statistics.

| Variables | N | Mean | sd | Min | Max |
| --- | --- | --- | --- | --- | --- |
| GES | 235 | 3.082 | 0.884 | 0.0837 | 4.303 |
| FTLF | 235 | 1.957 | 0.771 | 0 | 3.526 |
| GCR | 235 | 0.0363 | 0.0372 | 0 | 0.171 |
| MSF | 235 | 1.217 | 1.517 | 0 | 7.429 |
| BIR | 235 | 0.00407 | 0.00587 | 0 | 0.0438 |
| Size | 235 | 28.42 | 1.570 | 25.56 | 31.31 |
| Lev | 235 | 0.924 | 0.00972 | 0.897 | 0.947 |
| AGE | 235 | 3.253 | 0.452 | 2.079 | 4.710 |
| ROA | 235 | 0.875 | 0.176 | 0.424 | 1.437 |
| GRO | 235 | 0.0858 | 0.0864 | −0.156 | 0.428 |
| TOP1 | 235 | 24.46 | 17.05 | 4.180 | 67.39 |
| SOE | 235 | 0.630 | 0.484 | 0 | 1 |

## *4.2. Correlation Analysis*

Table 4 presents the results of correlation analyses. The data showed a significant positive correlation between the dependent variable green operations (GES) and the independent variable degree of big data technology transformation (FTLF) with a correlation coefficient of 0.211 (at the 1% level), supporting Hypothesis 1, which states that the degree of big data technology transformation in the banking sector enhances green operations. The correlation coefficients between the two explanatory variables were less than 0.8, and the variance inflation factors (VIF) were less than three, with a mean value of 1.7, indicating that there was no multicollinearity problem.

**Table 4.** Correlation Analysis.

| | GES | FTLF | GCR | MSF | BIR | Size | Lev | AGE | ROA | GRO | TOP1 | SOE |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| GES | 1 | | | | | | | | | | | |
| FTLF | 0.211 *** | 1 | | | | | | | | | | |
| GCR | 0.152 ** | 0.0300 | 1 | | | | | | | | | |
| MSF | 0.166 ** | 0.110 * | 0.126 * | 1 | | | | | | | | |
| BIR | 0.221 *** | 0.162 ** | 0.486 *** | 0.180 *** | 1 | | | | | | | |
| Size | 0.474 *** | 0.179 *** | 0.00700 | 0.0520 | 0.0410 | 1 | | | | | | |
| Lev | −0.215 *** | 0.157 ** | −0.0830 | −0.190 *** | −0.0420 | −0.0640 | 1 | | | | | |
| AGE | 0.309 *** | 0.116 * | 0.0100 | 0.140 ** | 0.0350 | 0.682 *** | −0.281 *** | 1 | | | | |
| ROA | −0.0910 | −0.117 * | −0.0490 | 0.0810 | 0.00200 | 0.202 *** | −0.111 * | 0.306 *** | 1 | | | |
| GRO | −0.155 ** | 0.0870 | −0.0190 | −0.0400 | −0.00700 | −0.218 *** | 0.245 *** | −0.184 *** | 0.202 *** | 1 | | |
| TOP1 | 0.308 *** | 0.266 *** | 0.0920 | 0.0590 | 0.148 ** | 0.659 *** | −0.0240 | 0.648 *** | 0.0100 | −0.151 ** | 1 | |
| SOE | 0.131 ** | 0.0250 | −0.0130 | 0.0390 | 0.0220 | 0.250 *** | −0.00600 | 0.137 ** | 0.141 ** | −0.0860 | 0.193 *** | 1 |

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## *4.3. Analysis of Empirical Results*

(1) Benchmark Regression

According to the Hausman test results, the p-value is less than 0.05. Accordingly, this study refers to Wang et al. [88] and selects a fixed year and a fixed city for empirical analysis. The results of the benchmark regression analysis are illustrated in Table 5. In column (1), under the condition of not adding control variables, there is a significant positive correlation between the degree of big data transformation (FTLF) and green operations (GES), with a correlation coefficient of 0.194. Column (2) adds control variables to column (1), where there is a significant positive correlation between the degree of big data transformation (FTLF) and green operations (GES), with a correlation coefficient of 0.134. There is a significant positive correlation between the control variable size and green operations (GES), with a correlation coefficient of 0.374, with larger banks having more resources to invest in green development. The R-squared increased from 0.311 to 0.440, which demonstrates that the inclusion of control variables influenced the relationship between the dependent variable green operations (GES) and the independent variable degree of big data transformation (FTLF). As a consequence, Hypothesis 1 is supported that the degree of big data technology transformation in the banking sector enhances green operations. Through data analysis, banks are in a position to identify and assess environmental risks more accurately and take appropriate measures for green operations.

**Table 5.** Benchmark Regression.

| Variables | (1)<br>GES | (2)<br>GES |
|---|---|---|
| FTLF | 0.194 *** | 0.134 * |
| | (2.76) | (1.88) |
| Lev | | −7.295 |
| | | (−1.02) |
| AGE | | −0.081 |
| | | (−0.47) |
| Size | | 0.374 *** |
| | | (6.41) |
| ROA | | −0.465 |
| | | (−1.34) |
| GROWTH | | 0.550 |
| | | (0.78) |
| SOE | | 0.014 |
| | | (0.14) |
| TOP1 | | −0.002 |
| | | (−0.51) |
| Constant | 1.921 *** | −0.659 |
| | (8.36) | (−0.10) |
| City fixed | Yes | Yes |
| Year fixed | Yes | Yes |
| Observations | 235 | 235 |
| R-squared | 0.311 | 0.440 |
| F test | 0 | 0 |
| r2_a | 0.277 | 0.393 |
| F | 9.158 | 9.431 |

Note: t-statistics in parentheses; *** $p < 0.01$, * $p < 0.1$.

(2) Robustness Tests

To verify the reliability of the findings, this study drew on [89] variable substitution measures in existing research. Data technology application (DTA) replaces the independent variable degree of big data technology transformation (FTLF). Text analysis was used to measure data technology applications to analyze the textual content of the annual reports of listed companies, and keywords were extracted to determine word frequency. The regression analysis model is consistent with the original model, which verifies the robustness and reliability of the results obtained in this study, and the results of the robustness test are shown in Table 6.

**Table 6.** Regression Analysis.

| | (1)<br>GES | (2)<br>GES |
|---|---|---|
| FTLF | 0.134 * | |
| | (1.88) | |
| DTA | | 0.529 * |
| | | (1.90) |
| Lev | −7.295 | −7.376 |
| | (−1.02) | (−1.03) |
| AGE | −0.081 | −0.081 |
| | (−0.47) | (−0.47) |
| Size | 0.374 *** | 0.374 *** |
| | (6.41) | (6.41) |
| ROA | −0.465 | −0.465 |
| | (−1.34) | (−1.34) |
| GROWTH | 0.550 | 0.550 |
| | (0.78) | (0.78) |
| SOE | 0.014 | 0.015 |
| | (0.14) | (0.14) |
| TOP1 | −0.002 | −0.002 |
| | (−0.51) | (−0.52) |
| Constant | −0.659 | −0.585 |
| | (−0.10) | (−0.09) |
| City fixed | Yes | Yes |
| Year fixed | Yes | Yes |
| Observations | 235 | 235 |
| R-squared | 0.440 | 0.440 |
| F test | 0 | 0 |
| r2_a | 0.393 | 0.394 |
| F | 9.431 | 9.441 |

Note: t-statistics in parentheses; *** $p < 0.01$, * $p < 0.1$.

(3) Regression Analysis of Moderation Effect

The results of Model (1) in Table 7 indicate that there is a significant positive correlation between the degree of big data transformation (FTLF) and green operations (GES). Namely, the higher the degree of big data transformation, the higher the level of green operations. Therefore, Hypothesis 1 is supported.

The results of Model (2) in Table 7 show that the coefficient of the interaction term between the green credit ratio (GCR) and the degree of big data transformation (FTLF) was 3.764, which is positively correlated at the 5% level, suggesting that the impact of the degree of big data transformation positively influences the change in the green credit ratio. This is in line with the expectations of Hypothesis 2. Therefore, Hypothesis 2 is supported.

The results of Model (3) in Table 7 indicate that the coefficient of the interaction term between the market share of funds (MSF) and the degree of big data transformation (FTLF) was 0.063, which is a significant positive correlation at the 10% level, suggesting that the change positively influences the impact of the degree of big data transformation in the market share of funds. This is in line with the expectations of Hypothesis 3; therefore, Hypothesis 3 is supported.

The results of Model (4) in Table 7 indicate that the coefficient of the interaction term between bond market share (BIR) and the degree of big data transformation (FTLF) was 0.353, which is significantly positively correlated at the 1% level, suggesting that the degree of big data transformation positively influences the change in bond market share. This is in line with the expectations of Hypothesis 4; therefore, Hypothesis 4 is supported.

Different financial products respond variously to the degree of transformation of big data technology, which requires a localized green development strategy. With regard to green credit ratios, the impact of the degree of transformation of big data technology may be influenced by market demand and policy support. In the case of fund market share and bond market share, they may be more influenced by investor preferences and market structure. Accordingly, the characteristics and needs of different markets need to be fully taken into account in the greening strategy of the banking sector.

**Table 7.** Regression Results.

| Variables | (1) GES | (2) GES | (3) GES | (4) GES |
|---|---|---|---|---|
| FTLF | 0.169 ** | 0.179 *** | 0.150 ** | 0.135 ** |
| | (2.52) | (2.69) | (2.22) | (2.04) |
| GCR | | 1.975 * | | |
| | | (1.93) | | |
| GCR x FTLF | | 3.764 ** | | |
| | | (2.08) | | |
| MSF | | | 0.001 | |
| | | | (0.39) | |
| MSF x FTLF | | | 0.063 * | |
| | | | (1.92) | |
| BIR | | | | 0.003 |
| | | | | (0.66) |
| BIR x FTLF | | | | 0.353 *** |
| | | | | (3.42) |
| Size | 0.308 *** | 0.289 *** | 0.314 *** | 0.317 *** |
| | (6.48) | (6.00) | (6.60) | (6.80) |
| Lev | −22.933 *** | −19.883 *** | −21.375 *** | −21.617 *** |
| | (−4.10) | (−3.54) | (−3.77) | (−3.93) |
| AGE | −0.067 | −0.050 | −0.087 | −0.011 |
| | (−0.38) | (−0.28) | (−0.49) | (−0.06) |
| ROA | −1.105 *** | −1.072 *** | −1.159 *** | −1.202 *** |
| | (−3.37) | (−3.32) | (−3.50) | (−3.70) |
| GRO | 0.437 | 0.389 | 0.437 | 0.433 |
| | (0.68) | (0.61) | (0.68) | (0.69) |
| TOP1 | −0.004 | −0.005 | −0.004 | −0.007 |
| | (−0.89) | (−1.09) | (−0.91) | (−1.51) |
| SOE | 0.078 | 0.057 | 0.071 | 0.077 |
| | (0.75) | (0.55) | (0.68) | (0.75) |
| Constant | 16.383 *** | 14.040 *** | 14.886 *** | 14.772 *** |
| | (3.11) | (2.68) | (2.79) | (2.84) |
| Observations | 235 | 235 | 235 | 235 |
| R-squared | 0.329 | 0.355 | 0.340 | 0.363 |
| r2_a | 0.31 | 0.33 | 0.31 | 0.33 |
| F | 13.841 | 12.304 | 11.550 | 12.765 |

Note: t-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## 5. Conclusions and Implications

### *5.1. Discussion*

In recent years, the digital transformation of the financial industry has emerged as a focus of attention. Big data technology is becoming the engine of economic development in many countries, including China [90]. Most scholars agree that the application of big data technology can help banks to improve efficiency, optimize services, reduce risks, and achieve the goal of green operations [6,24,42,43,78,91,92]. Nevertheless, technological advances can affect the environment [93]. Big data technology can bring about the value of data and information, but it also requires a large amount of input and consumption of resources, equipment, and energy, which improves cost-effectiveness [94]. Financial resources in the banking sector are devoted to developing energy-efficient technologies which are negatively correlated with environmental sustainability [36]. Therefore, the introduction of big data technology into the banking sector has both positive and negative effects on environmental performance. This study examined the degree of big data technology transformation in the banking sector and its impact on green operations. It verified the moderating role of green credits, funds, and bonds by taking into account the role of green financial products to explore this issue in depth. These findings are consistent with most studies, indicating that big data technology provides more opportunities for green finance [15]. Big data technology can improve the accuracy of credit assessments, reduce credit risk, and promote the development of green credit [95]. The development of fintech can increase profitability and financial innovation and improve risk control [6]. Therefore, this study concludes that big data technology transformation meets the sustainability and transparency requirements of green finance, and can help green technological innovation [37].

The novelty of this study is two-fold. First, it analyzes the green operation of the banking sector from the perspective of big data technology transformation, which expands the research perspective and content of green finance. Second, it considers the moderating effect of different types of green financial products, such as green credits, funds, and bonds, on the relationship between big data technology transformation in the banking sector in relation to green operations, which has enriched the research methods and conclusions of green finance. The innovation points of this study fill the deficiencies or gaps in prior studies and provide new perspectives and bases for understanding and evaluating digital transformation and green development in the banking sector. Prior studies have primarily focused on the impact of big data technology on banking sector performance [6], the impact of green financial products on banking sector performance [22,54–56], and the convergence of fintech development and green finance [30]. By constructing a panel data regression model, this study examined the impact of the degree of big data technology transformation and green financial products on the green operations of the banking sector, as well as the interaction effect between them, thereby revealing the intrinsic connection and mechanism between digital transformation and green development of the banking sector. The results of this study contribute to improving the awareness and utilization of big data technology and green financial products in the banking sector, facilitating green innovation and competitiveness in the banking sector, and contributing to the development of a green economy.

In the meantime, the government can regulate the financial market in an effective manner through intervention policies to ensure the stability of the market. [96]. This serves as a significant guideline for the banking industry in undertaking big data technology transformation and facilitating green operations. The impact of policy factors may vary by region. Therefore, this study conducted a lagged one-period analysis through a fixed-region approach to verify the impact of big data technology transformation on green operations when regional differences in the impact of policy factors are considered. This indicates the need to take into account the specific conditions of different regions when implementing relevant policies to ensure the effectiveness and adaptability of policies.

### *5.2. Conclusions*

This study selected Chinese A-share listed banks from 2015 to 2022 as research subjects to investigate the relationship between the degree of big data technology transformation in the banking sector and green operations and how green financial products, such as green credit, funds, and bonds, can regulate this relationship. The results of the study indicate the following. (1) Big data technology transformation enhances green operational capabilities. The degree of big data transformation in the banking sector is positively correlated with green operations, indicating that big data technology can help banks to assess environmental risks more accurately and optimize green operations more effectively. In other words, in the banking sector, the extent of big data technology transformation enhances the ability to green operations. Aggressive big data technology transformation enables banks to assess environmental risks with greater precision and implement more effective green strategies in their operations. (2) Green financial products have a positive moderating role. Green credit, funds, and bonds have a significant positive moderating effect on the relationship between the degree of big data technology transformation in the banking sector and green operations. Green credit ratio positively affects the degree of big data technology transformation in the banking sector to empower green operations. The higher the green credit ratio, the more the degree of big data technology transformation contributes to green operations. (3) Fund market share positively influences the degree of big data technology transformation in the banking sector to enhance green operations. The higher the fund market share, the greater the contribution of the degree of data technology transformation to green operations. (4) Bond market share positively affects the extent of big data technology transformation in the banking sector to enhance green operations. The higher the bond market share, the more the degree of data technology transformation contributes to green operations. This demonstrates that financial products can provide greater financial support for green projects and facilitate green investments and risk management in banks.

This study provides instructions for the green development of the banking sector. This study examines the effect of big data technology transformation in the banking sector and enriches the research on green finance. This study is also instructive for investors and regulators concerned about the green development of the banking sector and provides theoretical guidance and practical reference for the green transformation of the banking sector.

Based on the above analysis, this study has both theoretical and practical implications. This supports the degree of big data technology transformation in the banking sector to enhance green operational capabilities.

With regard to theoretical significance, this study explores the influencing factors and mechanisms of green operations in the banking sector from the perspective of big data technology transformation, which expands the research scope of green finance and enriches related theories of big data technology transformation. This study not only provides a new dimension and index for understanding and evaluating the level of green operations in the banking sector, but also provides a new perspective and idea for exploring and optimizing the banking sector's green operation mode. In addition, this study provides beneficial insights and suggestions for the diversified development and innovation of green finance, which contributes to the theoretical system and practical application of green finance.

With regard to practical significance, this study provides a reference basis for government departments to formulate relevant policies. It suggests that government departments should strengthen support and guidance for big data technology transformation in the banking sector, as well as increase supervision and incentives for green finance, thereby facilitating the banking sector to realize green development. Meanwhile, big data technology transformation in the banking industry plays an essential role in improving service efficiency, risk management, and customer experience. Green operations have also received increasing attention as a sustainable business model. The level of economic development, market maturity, and policy environment in different regions may affect the effectiveness of policy implementation. As a consequence, there is a real need to take these factors into account when formulating and implementing policies to ensure that they are targeted to address issues and maximize benefits. This study also provides practical suggestions for managers in the banking sector to accelerate the application and innovation of big data technology and to actively develop and promote green financial products and services to enhance the level and competitiveness of green operations. This study also provides lessons and references for all sectors of society to increase awareness and participation in green finance, boost its popularization and the development of green finance, and promote sustainable development.

### *5.3. Limitations and Future Outlook*

This study has the following limitations. First, the sample includes only Chinese A-share listed banks, which may introduce some selection bias. This fails to fully represent the overall situation in China's banking sector. Second, the data sources of this study are mainly publicly available secondary data, which may have certain data quality and reliability issues, and may fail to reflect the internal data and information of banks. Future research could expand the coverage of the research sample and adopt more methods and techniques to supplement and improve relevant theories. In addition, due to limitations in data collection, the study was unable to categorize the research subjects in detail, so it did not consider default risk and rating factors when discussing green loans and green bonds. Future research can strive to overcome the challenges of data collection by conducting a more comprehensive analysis of the impact of default risk and low-rated bonds on the expansion of green finance, in order to better assess the impact of green finance on the economy and the environment.

**Author Contributions:** Data curation and draft, J.Y.; methodology, review, and editing, S.J. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Data Availability Statement:** The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author/s.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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