Green Finance Assists Agricultural Sustainable Development: Evidence from China

Yalin Mo 1,2,*, Dinghai Sun 1 and Yu Zhang 3,*

1 School of Economics, Guangxi University, Nanning 530004, China
2 Guangxi Development Strategy Institute, Nanning 530004, China
3 International Business School, Dongbei University of Finance and Economics, Dalian 116012, China
* Correspondence: moyalin@gxu.edu.cn (Y.M.); bigdatas@163.com (Y.Z.)

Abstract: Whether green finance can promote agriculture to achieve carbon emission reduction is an important issue in agricultural sustainable development. Based on panel data on 30 provinces in China from 2011 to 2020, this paper established a mediation effect framework and employed stepwise regression and bootstrapping to study whether and how green finance can promote carbon emission reduction in China’s agricultural sector. The empirical research results indicate that the development of green finance can significantly reduce China’s agricultural carbon emission intensity. Using instrumental variables for robustness regression tests, the empirical results were also found to be robust. Further research found that green finance can not only directly promote agricultural carbon emission reduction but also indirectly facilitate it by optimizing the agricultural industrial structure and guiding agricultural technological progress. Finally, this article puts forward a number of policy recommendations to actively develop green finance, optimize the structure of the agricultural industry, and promote the progress of agricultural technology with the overarching aim of promoting the sustainable development of China’s agriculture through green finance.

Keywords: green finance; agricultural carbon emission reduction; agricultural sustainable development

1. Introduction

The concept of green finance can be traced back to the late 1980s. Under the pressure of civil society organizations, the World Bank gradually began to consider their adverse effects on ecology and nature from that time. In 1989, the International Finance Corporation established an environmental department and created an environmental and social approach to promote sustainable investment [1]. From there, the concept of green finance expanded to the fields of environmental protection, energy conservation, emission reduction, and ecological construction, among others. In fact, the “green” in green finance refers to the sustainable development of a low-carbon economy and industry, while the term “finance” emphasizes that financial capital helps the economy and industry achieve sustainable development [2].

It was not until 1995 that the concept of green finance was formally introduced to China by the People’s Bank of China. However, due to constraints in China’s economic development thinking and traditional concepts at that time, the concept of green finance was not well known among the Chinese people. Subsequently, green finance has gradually attracted the attention of governments and financial institutions in China. In 2018, the Agricultural Bank of China issued the Opinions on Comprehensively Doing a Good Job in Rural Revitalization Financial Services, providing important support for green finance from a policy perspective. It emphasized the strategic position of quality and green agriculture and at the same time incorporated the issuance of rural-inclusive financial products and the improvement of green financial services in rural areas into the banks’ work plan.

At the United Nations General Assembly in 2020, the Chinese government proposed that China strive to achieve the goal of reaching a “carbon peak” by 2030 and “carbon
neutrality” by 2060. According to the former, carbon dioxide emissions will not increase before 2030 and will gradually decrease afterward, while the latter means that enterprises, groups, and individuals will calculate the total amount of greenhouse gas emissions directly or indirectly generated within a certain period of time and then offset their own carbon dioxide emissions through afforestation, energy conservation, and emission reduction to achieve “zero” carbon dioxide emissions by 2060. In May 2021, China’s “Dual Carbon” Work Leading Group held its first plenary meeting in Beijing, marking that the dual carbon goal has been officially incorporated into China’s sustainable economic development process. Upon the background of China’s dual carbon goal, local governments, and financial institutions have encouraged green finance to help China achieve low-carbon sustainable development. At present, China has made great progress in the various areas of green finance, the green finance market, and the total amount of green finance.

Agricultural production activities are one of the important contributors of greenhouse gases leading to the aggravation of global warming. Since 1970, global agricultural output has more than doubled. The greenhouse gas emissions of agricultural ecosystems account for 7–20% of the world’s total greenhouse gas emissions, and approximately 17% of China’s carbon emissions come from agriculture [3,4]. The agricultural industry in rural areas has a complex structure, wide distribution, and large differences in carbon emissions. In 2020, U.S. agricultural production activities directly led to approximately 594.7 million tons of carbon dioxide-equivalent emissions, with the planting industry (including urea fertilization, rice cultivation, and soil management, etc.), enteric fermentation, and manure management around 339.8, 175.2, and 79.3 million tons, respectively [5]. Therefore, reducing agricultural carbon dioxide emissions and improving the carbon productivity of the planting industry are important methods of effectively controlling greenhouse gas emissions. It should thus be asked: Can green finance help agriculture reduce carbon emissions? If so, how does green finance contribute to carbon reduction in agriculture?

To answer these questions, we established a mediation effect framework and employed panel data on 30 provinces in China from 2011 to 2020 to investigate the influence of green finance on China’s agricultural carbon emissions. Our empirical results demonstrated that the development of green finance can significantly reduce the carbon emission intensity of China’s agriculture. Further research also found that green finance can not only directly promote China’s agricultural carbon emission reduction (direct effect) but also indirectly facilitate it (indirect effect) by optimizing the agricultural industrial structure and guiding agricultural technological progress. Our research provides strong evidence that green finance can contribute to the sustainable development of agriculture in China.

The possible contributions of our article are as follows. First, compared with many studies focusing on qualitative analyses of green finance or mainly using a single indicator to study the development of green finance, our studies have used quantitative analysis methods to investigate compound green finance indicators and their effect on agricultural carbon emission reduction. Second, whether green finance can help agriculture reduce carbon emissions remains in doubt at present, our research demonstrated that the development of green finance can significantly reduce China’s agricultural carbon emissions through direct and indirect effects.

The remainder of the paper is structured as follows: Section 2 includes a literature review and hypothesis deduction, Section 3 introduces the data and econometric model, Section 4 analyzes the empirical results, and Section 5 summarizes the study and puts forward relevant policy recommendations.

2. Literature Review and Research Hypotheses

2.1. Literature Review

2.1.1. Green Finance

As a new financial model distinct from traditional finance, green finance has not yet received a unified definition, although the existing literature mainly covers three important concepts. The first is environmental finance, which helps to solve the practical problems of
environmental protection, pollution reduction, and resource conservation, along with other green issues, by providing financial services [6–8]. The second holds that green finance is a financial innovation that protects our environment by applying a variety of financial tools and products and has the important function of promoting socially sustainable development [9,10]. The third and more recent view is that green finance is a form of finance that promotes environmentally friendly investments and fosters an ecologically conscious society through green credit, securities, insurance and investment, and carbon finance [11–14].

Based on the above concepts, many studies in recent decades have focused on qualitative and conceptual analyses of green finance. For example, Salazar believes that green finance can help improve the allocation efficiency of financial resources and guide the flow of funds from high-energy-consuming and high-polluting industries to green and environmentally friendly industries, thereby improving the ecological environment [6]. Scholtens has pointed out that the development of green finance should be committed to alleviating ecological and environmental problems, and financial regulators should pay attention to the allocation of scarce social resources and actively guide financial institutions to develop their businesses in the direction of energy conservation and environmental protection [7]. By optimizing resource allocation and guiding consumption and investment behavior, green finance not only promotes the adjustment of the industrial structure but also plays an important role in improving the ecological environment.

However, compared with the previous qualitative analyses, there are few studies on the issue of green finance that use quantitative analysis methods. Those that do exist have mainly used a single indicator to study the development of green finance, such as low-carbon capital flow progress [15] and loans borrowed by environmental enterprises [16], or used green credit and green investment to represent the development of green finance [17]. Although these single indicators can reflect the development level of a certain aspect of green finance to some degree, they do not reveal the entire picture. To overcome the limitations of a single indicator, some scholars have further constructed evaluation systems to measure the comprehensive level of green finance development. The present paper referred to the composite green finance development system established by Fu and Peng to measure the development level of China’s green finance [18].

2.1.2. The Relationship between Financial Development and Carbon Emissions

The existing literature on the relationship between financial development and carbon emission reduction is mainly divided into the following three categories. First, there is the literature pointing out that financial development can effectively promote carbon emission reduction. For example, Shahbaz et al. found that financial development can reduce carbon emissions by increasing foreign investment, encouraging technological innovation, and promoting carbon trading [19], while Tamazian found that in the BRIC (Brazil, Russia, India and China) countries, a higher level of economic and financial development leads to a lower degree of environmental degradation and lower carbon emissions [20]. Second, there is the literature focusing on the fact that financial development has a significant inhibitory effect on carbon emission reduction; that is, financial development tends to boost carbon emissions. For example, Sadorsk’s research showed that, whether in developed countries or developing countries, the development of the financial sector is often accompanied by an increase in energy consumption and carbon emissions, which is detrimental to the country’s environment [21]. Nasir et al. found that the financial development of countries in the Association of Southeast Asian Nations (ASEAN) can boost regional economic growth but at the cost of sacrificing the environment and increasing carbon emissions [22]. In addition, Ye and Ye also found that financial development significantly inhibits carbon emission reduction [23]. Third, there is research pointing out the nonlinear correlation between financial development and carbon emissions, that is, that the two have an inverted U-shaped nonlinear relationship. For example, Charfeddine et al. believe that this type of relationship between financial development and carbon emissions exists in some Middle Eastern
countries, suggesting that a country’s financial development will promote carbon emission reduction in the early stage and will then, with the deepening of financial development, inhibit carbon emission reduction [24]. Peng et al. also found an inverted U-shaped relationship between financial development and carbon emissions in the Yangtze River Delta region of China [25]. At present, academic circles have come to inconsistent conclusions on the relationship between financial development and carbon emission reduction, which may be due to differing green finance practices in different countries, different regional economic structures, different levels of technological development, and an inconsistent selection of variable indicators in the studies.

2.1.3. The Relationship between Green Finance and Sustainable Development

Reviewing the existing literature, most articles have not only explored the relationship between traditional financial development and carbon emission reduction but also studied the relationship between green finance and economic growth. For example, Ruiz et al. and Chen et al. believe that there is a highly significant positive correlation between green finance and economic development [26,27]. At the same time, Ning and She believe that green finance will restrict economic growth, that is, that there is a negative correlation between the two [28]. There have also been some studies discussing the relationship between green finance and total factor productivity. For example, Li and Chen found that green credit can significantly improve green total factor productivity, while Lee and Lee further pointed out that the government’s implementation of green financial policies and higher social conditions tend to enhance the effect [29,30].

In addition to investigating green finance and economic growth, existing studies have been highly concerned with the relationship between green finance and sustainable development. For example, Mara et al. found that the development of green finance is positively correlated with the demand for clean energy and that green finance enhances environmental responsibility by funding green technologies for successful energy transition and sustainable development goals [31]. Zhang et al. conducted an empirical study using financial data from Bangladesh from 2015 to 2020 and found that the social, economic, and environmental dimensions of green finance have a strong positive impact on banks’ sustainability performance [32]. Cui et al. also studied the equilibrium strategies and influence mechanisms of the government, financial institutions, enterprises, and consumers by constructing an evolutionary game model and found that the integrity of the green financial system has a positive impact on sustainable development and cleaner production [33]. Green finance is an inevitable trend of future financial development, and the innovative development of green finance is a powerful driving force for sustainable development and social progress [34].

At present, there is a dearth of literature exploring the relationship between the development of green finance and agricultural carbon emission reduction, and few studies have used quantitative analysis methods to investigate compound green finance indicators and their effect on agricultural carbon emission reduction. In view of this, this paper focuses on sustainable agricultural development and empirically investigates the direct and mediating effects of green finance development on agricultural carbon emission reduction in China based on provincial panel data from 2011 to 2020. The study hopes to provide theoretical references and empirical evidence for achieving sustainable agricultural development and the dual carbon goal in China.

2.2. Research Hypotheses

2.2.1. Direct Effect: The Agricultural Carbon Reduction Effect of Green Finance

In the context of responding to the Chinese rural revitalization strategy, green finance should have great potential to help reduce carbon emissions in agriculture. Some scholars have confirmed that green finance can indeed promote carbon emission reduction. Qin and Cao established a difference-in-difference model for empirical testing and found that green finance has a significant effect in promoting carbon emission reduction, while there are
also certain levels of regional and industry heterogeneity [35]. Zaidi et al. used panel data on 17 countries from 1990 to 2016 and found that financial development reduced carbon emissions in both the long and short term [36]. Li et al. used the Beijing–Tianjin–Hebei region of China as a research region and found that green credit promoted carbon emission reduction [37]. Although these studies did not specifically investigate the promotion effect of green finance on carbon emission in the Chinese agriculture industry, they should be applicable to this industry due to the similarity in the functioning of green finance. On the one hand, financing difficulty and “expensive financing” have always been the actual problems hindering the development of China’s rural economy, and green finance can absorb social funds to invest in the rural green economy and help the rural economy achieve sustainable development. On the other hand, green finance can guide agricultural production and operations on the road to standardization and modernization, realize the scale effect of the agricultural economy, and promote agricultural carbon emission reduction. In view of this, we propose the following hypothesis:

**Hypothesis 1 (H1).** Green finance has a direct promotion effect on agricultural carbon emission reduction.

### 2.2.2. Mediating Effect and Influencing Channels

- **The Mediating Effect of Green Finance on Upgrading Agricultural Structure**

  Industrial structure is an important indicator to measure the proportion of the agricultural industry or service industry in the overall economy of a country. On the one hand, in China’s rural areas, the agricultural sector is widely distributed, with large differences in carbon emissions, although high-emitting agricultural industries account for a large proportion of these [34]. China’s agriculture mainly includes planting, animal husbandry, forestry, and fishery, and the carbon emission characteristics of different agricultural industries differ significantly. For example, the carbon emission intensity of the planting industry is much higher than that of the others. Therefore, changes in the agricultural industry structure are likely to have an impact on China’s agricultural carbon emission reduction. At the same time, China’s economy is in a critical period of development and transformation from a high-speed to a high-quality development stage. Green finance can solve the ecological and environmental problems that China is facing by limiting the expansion of high-pollution and high-emission enterprises in addition to absorbing social capital to invest in green and low-carbon industries. For example, green credit can decrease the development of non-green industries by reducing loans to high-polluting and high-emitting enterprises or lowering their credit ratings to increase their financing costs, which may in turn have an impact on the carbon reduction of China’s agriculture. In view of this, we propose the following hypothesis:

**Hypothesis 2 (H2).** Green finance can promote agricultural carbon emission reduction by upgrading the agricultural structure.

- **The Mediating Effect of Green Finance on Agricultural Technological Progress**

  The development of science and technology is a powerful driving force for economic growth, and the high-quality development of China’s economy is inseparable from this advancement. Using Chinese provincial data from 2010 to 2019, Li and Yang found that green finance can significantly promote the technological innovation of enterprises and concluded that it provides institutional guarantees for technological innovation, which can fundamentally promote sustainable economic development [38]. In recent years, with the advancement of the Chinese rural revitalization strategy, new agricultural technologies and products have been widely used in the field of agricultural production. On the one hand, when enterprises are developing and promoting new technologies and products, traditional financing methods bring limited scale and high financing costs, while green finance can reduce financing costs while widening the financing channels of enterprises, making them able to contribute more to rural areas with high capital constraints. On the
other hand, if an enterprise develops a new project with high-income uncertainty and high risk, a traditional financial fund provider will ask for a further increase in the financing cost, making it more difficult for the enterprise to obtain financing. As representative products of the emerging green finance market, green bonds, green credit, and green insurance can accurately measure the level of income and corresponding risks of new projects, and different investors can choose suitable new technologies and products to invest in according to their own risk preferences [39]. At present, Chinese agriculture is constrained by both land and labor resources. In the future, Chinese agriculture will continue to move in the direction of scale and mechanization. Green finance can help apply new technologies and products to Chinese agricultural production and guide Chinese agriculture to develop in the direction of scale and mechanization supported by green technologies, which will improve the agricultural labor output rate while helping to reduce pollution and promote carbon emission reduction. In view of this, we propose the following hypothesis:

Hypothesis 3 (H3). Green finance can promote agricultural carbon emission reduction through the advancement of agricultural technology.

3. Methodology and Data
3.1. Data Sources and Processing Methods

Based on the availability and completeness of data, the research data in this paper included provincial panel data on 30 provinces in China from 2011 to 2020. Among the data, those on gross agricultural output value, regional gross domestic product (GDP), the total power of agricultural machinery, rural population density, urban and total population, and railway and highway mileage were taken from the China Economic Net database. Pesticides, fertilizers, diesel fuel, agricultural film, and total crop sown area data were taken from the China Rural Statistical Yearbook. The data on the degree of economic openness to the outside world came from the Wind database. The data on fiscal support for agriculture and the relevant green finance data came from the National Bureau of Statistics, the China Environmental Statistical Yearbook, and the China Insurance Statistical Yearbook. Finally, the data on human capital levels came from the China Population and Employment Statistical Yearbook. Mean imputation was performed on the missing data for a very small number of samples, and 300 valid observations were obtained for each variable (see Table 1).

| Table 1. Descriptive statistical results. |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Variable        | Variable Definition | Symbols | N   | Mean | p50  | Std. Dev. | Min   | Max   |
| Agricultural Carbon Intensity | ine | 300 | 4.627 | 4.828 | 0.993 | 1.254 | 6.079 |
| Green Finance Index | lngf | 300 | −1.772 | −1.852 | 0.445 | −2.624 | −0.283 |
| Agricultural Industry Structure | lnindus | 300 | −0.656 | −0.677 | 0.158 | −0.994 | −0.356 |
| Advances in Agriculture Technology | Inpam | 300 | 7.494 | 7.848 | 1.800 | −0.788 | 9.440 |
| Rural Population Density | lnrd | 300 | 8.279 | 8.285 | 0.275 | 7.632 | 8.880 |
| Urbanization Rate | lnucity | 300 | −0.550 | −0.560 | 0.200 | −0.997 | −0.111 |
| The Level of Fiscal Support For Agriculture | lnfinan | 300 | −2.215 | −2.165 | 0.327 | −3.164 | −1.678 |
| Level of Human Capital | lnedu | 300 | 2.053 | 2.060 | 0.0790 | 1.822 | 2.240 |
| The Degree of Economic Opening Up To The Outside World | lnidf | 300 | −4.293 | −4.019 | 1.132 | −7.794 | −2.427 |
| Traffic Conditions | lntrans | 300 | 11.710 | 11.990 | 0.838 | 9.492 | 12.720 |
| Intensity of Agricultural Chemical Inputs | lnchem | 300 | −3.349 | −3.320 | 0.384 | −4.223 | −2.600 |
| Planting Structure | lnstru | 300 | −0.446 | −0.430 | 0.236 | −0.975 | −0.023 |

3.2. Variables
3.2.1. Dependent Variable: Agricultural Carbon Emission Intensity

Referring to the research of Li et al., this paper first calculated the total amount of agricultural carbon emissions (tc) from the six dimensions of pesticides, agricultural film,
agricultural irrigation, chemical fertilizers, diesel oil, and tillage in each province (see Table 2 [40]). It then calculated agricultural carbon emission intensity (e), which is the quotient of total agricultural carbon emissions (tc) divided by the total agricultural output value (GDP) [40]. The calculation formula is as follows:

\[ tc = \sum s_i \times a_i, \]  
\[ e = \frac{tc}{GDP}. \]

Here, \( s_i \) and \( a_i \) are the amount and calculation coefficient of the various carbon sources, respectively.

Table 2. Calculation coefficient and reference sources for agricultural carbon sources [40].

<table>
<thead>
<tr>
<th>Agricultural Carbon Sources</th>
<th>Carbon Source Calculation Coefficient</th>
<th>Reference Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticides</td>
<td>4.9341 kg·kg(^{-1})</td>
<td>Oak Ridge National Laboratory</td>
</tr>
<tr>
<td>Agricultural Film</td>
<td>5.18 kg·kg(^{-1})</td>
<td>Institute of Agricultural Resources and Ecological Environment, Nanjing Agricultural University</td>
</tr>
<tr>
<td>Agricultural Irrigation</td>
<td>25 kg·Cha(^{-1})</td>
<td>Dubey</td>
</tr>
<tr>
<td>Chemical Fertilizer</td>
<td>0.8956 kg·kg(^{-1})</td>
<td>T. O. West, Oak Ridge National Laboratory</td>
</tr>
<tr>
<td>Diesel Oil</td>
<td>0.5927 kg·kg(^{-1})</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>Plowing</td>
<td>312.6 kg·km(^{-2})</td>
<td>College of Biology and Technology, China Agricultural University</td>
</tr>
</tbody>
</table>

Note: Since indirect carbon emissions come only from thermal power generated by fossil fuel consumption, the actual agricultural irrigation coefficient is 20.48 kg·hm\(^2\), obtained by multiplying the initial value of 25 kg·cha\(^{-1}\) by the thermal power conversion coefficient of 0.82.

3.2.2. Independent Variable: Green Finance Index

The Green Finance Index (gf) was calculated by referring to Fu and Peng, who followed an entropy method. Table 3 shows the four sub-indicators of the green finance composite index [18].

Table 3. Descriptions of primary indicators of green finance.

<table>
<thead>
<tr>
<th>Primary Index</th>
<th>Characterization Index</th>
<th>Indicator Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Investment</td>
<td>Proportion of investment in environmental pollution control</td>
<td>Investment in environmental pollution control/GDP</td>
</tr>
<tr>
<td>Green Credit</td>
<td>Proportion of interest expenditure of high energy-consuming industries</td>
<td>Interest expense of six high energy consuming industries/Industrial interest expense</td>
</tr>
<tr>
<td>Green Insurance</td>
<td>Depth of agricultural insurance</td>
<td>Agricultural insurance income/Gross agricultural output value</td>
</tr>
<tr>
<td>Government Support</td>
<td>Proportion of fiscal environmental protection expenditure</td>
<td>Fiscal environmental protection expenditure/General fiscal budget expenditure</td>
</tr>
</tbody>
</table>

3.2.3. Mediating Variables

- Agricultural industry structure (indus): Referring to the research method of Zhang and Wang, agricultural industry structure was expressed as the percentage of the output value of the planting industry to the total output value of the local planting, forestry, fishery, and animal husbandry industries in each region [41].
- Agricultural technological progress (pam): Referring to Deng et al., the total power of agricultural machinery was used to measure the level of agricultural technological progress in China [42].

3.2.4. Control Variables

Referring to previous literature and our own investigation, we used the following control variables in our models:
- Rural population density (pd): This paper used the number of people per unit of rural land to measure rural population density.
- Urbanization rate (city): The degree of urbanization in China was measured by the ratio of the total urban population to the total resident population.
- Level of fiscal support for agriculture (finan): The government’s support for agriculture was measured by the ratio of provincial expenditure on agriculture, forestry, and water affairs to the total fiscal expenditure of each province.
- Level of human capital (edu): Referring to Zhai’s research, the level of human capital was measured by the per capita education level of residents [43].
- Degree of economic openness to the outside world (idf): This paper used the ratio of foreign direct investment to the local gross national product (GDP) in each region to measure the degree of economic openness to the outside world.
- Traffic conditions (trans): Traffic conditions were represented by the sum of China’s total railway mileage and the total highway mileage.
- Agricultural chemical input intensity (chem): Agricultural chemical input intensity was measured by the quotient of the amount of fertilizer used in China divided by the total sown area of crops.
- Agricultural planting structure (pstru): Agricultural planting structure was represented by the percentage of the total sown area of grain in China to the total sown area of crops.

3.3. Calculation Results and Analysis of Agricultural Carbon Emissions in China’s Provinces from 2011 to 2020

According to Equations (1) and (2), the average value of the total agricultural carbon emissions and the intensity of agricultural carbon emissions were calculated for 30 provinces in China from 2011 to 2020. The results are shown in Figure 1. On the one hand, the five provinces with the largest average agricultural carbon emissions during this period were Henan, Shandong, Hebei, Anhui, and Jiangsu. The majority of these provinces are large agricultural provinces, and their average emissions exceeded 400 trillion tons. To a certain extent, this shows that China’s agricultural production needs to rely on technological development to promote the innovation of green production technology to achieve the goal of carbon emission reduction. On the other hand, the average value of agricultural carbon emission intensity in four provinces (Xinjiang, Gansu, Jilin and Heilongjiang) exceeded 250 kg/yuan. The carbon emission per unit of agricultural output value was larger here, demonstrating that these provinces had not yet rid themselves of the traditional rough agricultural production methods during this period. This also indicates that China urgently needs to increase investment in green agriculture to achieve the sustainable development goal of low-carbon agriculture.

3.4. Models

According to the previous theoretical analysis of the direct impact of green finance on China’s agricultural carbon emissions and the indirect impact of green finance on China’s agricultural carbon emissions through agricultural structure and agricultural industrial technological progress, this paper set the following empirical research framework:

\[
\ln e_{it} = \alpha_0 + \alpha_1 \ln g_{f_{it}} + \alpha_2 c_{it} + u_i + \mu_{it}, \quad (3)
\]

\[
\ln m_{it} = \beta_0 + \beta_1 \ln g_{f_{it}} + \beta_2 C_{it} + u_i + \xi_{it}, \quad (4)
\]

\[
\ln e_{it} = \gamma_0 + \gamma_1 \ln g_{f_{it}} + \gamma_2 m_{it} + \gamma_3 C_{it} + u_i + \eta_{it}. \quad (5)
\]

Equation (3) is the benchmark model, and Equations (4) and (5) are mediating effect models constructed with reference to the research of Wen and Ye [44]. Among them, \(e_{it}\) represents the agricultural carbon emission intensity of province i in year t; \(g_{f_{it}}\) represents the green finance index of province i in year t; \(m_{it}\) represents the intermediary variable of province i in year t, including the agricultural industrial structure (indus) and agricultural
technological progress (pam); and $C_{it}$ denotes other control variables of province $i$ in year $t$, including the rural population density (pd), urbanization rate (city), level of financial support for agriculture (finan), level of human capital (edu), degree of economic opening to the outside world (idf), traffic conditions (trans), agrochemical input intensity (chem), and planting structure (pstru). Additionally, $u_i$ is the province fixed effect; and $\mu_{it}$, $\xi_{it}$, and $\eta_{it}$ are the random error terms of Equations (3)–(5), respectively. The specific variables and their statistical descriptions are given in Table 1.

![Figure 1](image1.png)

**Figure 1.** Trends in agricultural carbon emissions by province (city) in China from 2011 to 2020.

**4. Empirical Results and Analysis**

**4.1. Preliminary Investigation**

Figure 2 reports China’s average development level of agricultural carbon emission intensity and green finance from 2011–2018. It can be seen that, while green finance was increasing year by year, the intensity of agricultural carbon emissions was decreasing, and the two crossed each other while moving in opposite directions.

![Figure 2](image2.png)

**Figure 2.** The relationship between agricultural carbon intensity and green finance.
Figure 3 shows a full-sample scatterplot of green finance and agricultural carbon intensity. It can be seen that there is a negative correlation between the two, indicating that the development of green finance is conducive to the realization of the agricultural sustainable development goal of reducing agricultural carbon emissions.

Figure 3. The scatter plot relationship between agricultural carbon intensity and green finance.

4.2. Benchmark Regression Model

4.2.1. The Choice of Econometric Model

To select the appropriate model among the mixed-effects model, the random-effects model, and the fixed-effects model, a Hausman test with the original hypothesis of the random-effects model and another test with the original hypothesis of the mixed-effects model were conducted respectively. The results of these two tests showed that the models’ p-values were 0, meaning two original hypothesis were rejected, and the fixed-effects model was selected for our empirical study.

4.2.2. Regression Results for Direct Effects

The regression results regarding the direct effect of green finance on agricultural carbon emission reduction are shown in Table 4. Model (1) shows the regression results without the control variables, while models (2)–(4) show the regression results after gradually adding the control variables. It can be seen from Table 4 that no matter whether the control variables were added, the lngf coefficients were significantly negative at the 1% level, meaning the direct inhibitory effect of green finance on agricultural carbon emission reduction was significant. This indicates that green finance does indeed have a direct promotion effect on agricultural carbon emission reduction, verifying Hypothesis 1. Green finance introduces additional idle social funds into the rural economy and helps the rural economy move towards low-carbon and sustainable development. When farmers have sufficient funds, they will invest more in improving green agricultural production conditions, such as by expanding the scale of green agricultural production to obtain agricultural scale effects and gradually phasing out high-pollution and high-emission agricultural production models.
Table 4. Regression results for direct effects.

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<th>(4)</th>
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<tr>
<td></td>
<td>lne</td>
<td>lne</td>
<td>lne</td>
<td>lne</td>
</tr>
<tr>
<td>lngf</td>
<td>−0.98 ***</td>
<td>−0.93 ***</td>
<td>−0.96 ***</td>
<td>−0.97 ***</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(0.15)</td>
<td>(0.15)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>lnpd</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>lncity</td>
<td>0.20</td>
<td>0.31</td>
<td>0.46 **</td>
<td></td>
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<td></td>
<td>(0.21)</td>
<td>(0.21)</td>
<td>(0.21)</td>
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<tr>
<td>lnfinan</td>
<td>0.12</td>
<td>0.12 *</td>
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<td></td>
<td>(0.07)</td>
<td>(0.07)</td>
<td>(0.08)</td>
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<tr>
<td>lnedu</td>
<td></td>
<td></td>
<td></td>
<td>−1.04 ***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.34)</td>
</tr>
<tr>
<td>lnidf</td>
<td>−0.01</td>
<td>−0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lntrans</td>
<td>−0.24</td>
<td>−0.28 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnchem</td>
<td></td>
<td>0.30 **</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lnpstru</td>
<td></td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>1.40 ***</td>
<td>1.10 *</td>
<td>5.79 ***</td>
<td>7.19 ***</td>
</tr>
<tr>
<td></td>
<td>(0.12)</td>
<td>(0.59)</td>
<td>(1.70)</td>
<td>(1.79)</td>
</tr>
</tbody>
</table>

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.2.3. Endogeneity Issues and Robustness Tests

Although this paper controlled for many variables that could affect agricultural carbon emission reduction, there is no absolute guarantee that problems such as missing variables or reverse causality were avoided. To mitigate the possibility of issues arising from endogeneity in the econometric model, we selected the first- and second-order lagged terms of green finance as instrumental variables of the model. From the robustness test results in Table 5, it can be seen that the coefficients of lngf were significantly negative, meaning that, after re-regressing the first- and second-order lag terms of green finance as instrumental variables, green finance was still found to significantly promote carbon emission reduction in agriculture. This result strengthens the verification of Hypothesis 1.

Table 5. Endogeneity and robustness test results.

<table>
<thead>
<tr>
<th>Variables</th>
<th>L.lngf</th>
<th>L2.lngf</th>
</tr>
</thead>
<tbody>
<tr>
<td>lngf</td>
<td>−1.02 ***</td>
<td>−0.94 ***</td>
</tr>
<tr>
<td></td>
<td>(0.15)</td>
<td>(0.15)</td>
</tr>
<tr>
<td>Constant</td>
<td>7.17 ***</td>
<td>7.40 ***</td>
</tr>
<tr>
<td></td>
<td>(1.89)</td>
<td>(1.95)</td>
</tr>
<tr>
<td>Control variable</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Provincial fixed effect</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cluster to province</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>R2</td>
<td>0.989</td>
<td>0.990</td>
</tr>
<tr>
<td>N</td>
<td>300</td>
<td>240</td>
</tr>
</tbody>
</table>

Note: *** indicate significance at the 1% levels.

4.3. Mediation Effect Model

To improve the test accuracy, bootstrapping was used (using Stata16 software to set 1000 iterations at a 95% confidence interval) to test the mediation effect as a means of
overcoming the shortcomings of the traditional regression method [45]. The test results are shown in Table 6.

Table 6. Test results on the mediating effects of agricultural industrial structure and agricultural technological progress.

<table>
<thead>
<tr>
<th>Mediating Variable</th>
<th>Effect Type</th>
<th>Value</th>
<th>Standard Error of Deviation Correction</th>
<th>95% Confidence Interval of Parameter Percentile Bootstrap Method</th>
<th>95% Confidence Interval of Deviation Correction Percentile Bootstrap Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural industrial structure</td>
<td>Indirect effect</td>
<td>-0.2637</td>
<td>0.0139</td>
<td>-0.0552</td>
<td>-0.0024</td>
</tr>
<tr>
<td></td>
<td>Direct effect</td>
<td>-1.2228</td>
<td>0.0953</td>
<td>-1.3924</td>
<td>-1.0114</td>
</tr>
<tr>
<td>Agricultural technology progress</td>
<td>Indirect effect</td>
<td>-0.3055</td>
<td>0.0804</td>
<td>-0.4599</td>
<td>-0.1426</td>
</tr>
<tr>
<td></td>
<td>Direct effect</td>
<td>-0.9437</td>
<td>0.0681</td>
<td>-1.0761</td>
<td>-0.7993</td>
</tr>
</tbody>
</table>

4.3.1. The Mediating Effect of Green Finance on Agricultural Industrial Structure

The results of the agricultural industry structure test in Table 6 indicate that the 95% confidence interval of neither the parameter percentile nor the deviation percentile contained 0. Therefore, the mediating effect of green finance on agricultural industrial structure was significant, meaning green finance can help to achieve agricultural carbon emission reduction by promoting upgrades of the agricultural industry structure. Accordingly, Hypothesis 2 was confirmed. As a representative of traditional Chinese agriculture, the planting industry has a prominent carbon sink effect and is one of the important sources of agricultural carbon emissions. Therefore, it is of great significance to appropriately reduce the share of the planting industry within agriculture and optimize the structure of the agricultural industry to promote carbon emission reduction in China [46]. In addition, industries in rural areas are widely distributed, and their carbon emissions vary widely. In these areas, green finance can optimize the agricultural industrial structure and promote agricultural carbon emission reduction by guiding the flow of funds.

4.3.2. The Mediating Effect of Agricultural Technology Progress in Green Finance

The results of the agricultural technology progress test in Table 6 show that, once again, 0 was not within the 95% confidence interval of either the parameter or deviation percentile, meaning agricultural technology progress had a significant mediating effect on green finance. Thus, green finance can promote carbon emission reduction through the mediating effect of agricultural technology progress, confirming Hypothesis 3. In particular, green finance can provide continuous financial support for the development of new agricultural technologies, products, and agricultural production methods. It can also effectively promote the transformation of agriculture from traditional high-emission and high-pollution technologies to low-carbon and environmentally friendly technologies, aiding in agricultural carbon emission reduction.

5. Research Conclusions and Policy Recommendations

Whether or how green finance can promote carbon emission reduction in agriculture is an important issue in achieving sustainable agricultural development. Our empirical research results based on Chinese data demonstrated both a direct and indirect effect of green finance in promoting agricultural carbon emission reduction. First, green finance has a direct impact on agricultural carbon emissions, i.e., the development of green finance can directly reduce agricultural carbon emissions. At the same time, green finance can influence agricultural carbon emission reduction through the intermediary effect of upgrading the agricultural industrial structure and accelerating agricultural technological progress. After robustness tests of instrumental variables, the above conclusions still hold. Our research provides a theoretical basis and empirical support for agricultural sustainable development and has strong guiding significance for the development of green finance, for the dual
carbon goals, and for the specific realization of rural revitalization goals. Based on the above empirical results, we propose three policy suggestions as follows.

Firstly, green finance should be actively developed. China’s commercial banks are widely distributed, strong, and well-served. With commercial banks as the fundamental pillar, corresponding policies and regulations should be issued to popularize the concept of green finance in rural areas, green financial products should be launched, and the green financial market should be expanded. While vigorously developing green finance, the relevant authorities should also strengthen supervision and prevent possible systemic financial risks. At the same time, China should increase government transfer payments and give relevant green industries and agricultural micro-entities (agricultural enterprises and farmers) corresponding subsidies to increase the enthusiasm of participants and ensure that green finance can achieve positive healthy development.

Secondly, the structure of the agricultural industry should be optimized. Rural areas show a wide distribution of industries, large differences in carbon emissions, and a large proportion of high-emission industries [34]. Therefore, it is particularly important to guide the flow of funds to low-carbon and green industries through green finance and to limit the expansion of high-pollution and high-emission enterprises. While ensuring the normal development of the planting industry, the continuous optimization of the carbon emission structure of other agricultural industries is an important means to promote the green development of rural areas.

Finally, the advancement of agricultural technology should be promoted. Advances in agricultural technology play an important role in the development of low-carbon agriculture. They not only help to reduce agricultural carbon emissions but also provide an important guarantee for the development of low-carbon agriculture. For a long time, backward agricultural production technology has limited the sustainable development of China’s agricultural production, causing China to lag behind developed countries in terms of the quality, efficiency, and effectiveness of agricultural production. The Chinese government should continue to increase support for agricultural technology research and development and application, such as setting up additional special funds for agricultural technology patents and green agricultural technology transformation, encouraging the innovation and upgrading of agricultural technology, strengthening skills training for agricultural production personnel, and promoting the application of green agricultural technology to help Chinese agriculture achieve carbon emission reduction and sustainable development.

However, there are two main limitations in our study. First, since the scope of data employed in this article is the panel data of 30 provinces in China, the conclusion that green finance can promote carbon emission reduction in agriculture should be limited to China. Second, the construction of green finance indicators in this article mainly covered four dimensions: green investment, green credit, green insurance, and government support. Nevertheless, the true connotation of green finance may not be limited to this. Future studies may use the panel data in other countries (including developed and developing countries, agricultural and non-agricultural countries) and a better composite green finance development system to validate our findings.

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