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ARTICLE

Green Finance and the Transformation of Agricultural Structure in China: Empirical Evidence from Urban Panel Data (2013–2023)

Min Cao , ***Nurhafiza Abdul Kader Malim*** *

School of Management, Universiti Sains Malaysia, Penang 11800, Malaysia

ABSTRACT

Green finance (GF) offers sustainable solutions to challenges in agricultural sustainable development. This study examines the impact and mechanism of GF on the transformation of agricultural structure (AST). The problem statement highlights that although China emphasizes the establishment of a rural financial system and takes rural revitalization as a national strategy, issues related to innovative rural financial products and promoting rural economic development remain challenging. Using a dataset with 2505 observations spanning the period of 2013–2023 on China's urban population, we utilize a two-way fixed effects model to explore the relationship between GF and AST. In addition, a mediation effect model is constructed to analyze the impact of GF on AST from the perspectives of green sustainable innovation (GSI), green consumption levels (GCL), and credit allocation efficiency (CAE). To account for regional disparities, we conducted heterogeneity analyses both at the urban level and by geographic region. The results indicate that GF effectively stimulates AST by optimizing CAE, enhancing GCL, and promoting GSI. Specifically, an increase in the share of agricultural inputs supporting sustainable and green development significantly altered the structure of agricultural outputs. Additionally, the findings suggest that the influence of GF on AST shows regional heterogeneity, which is more significant in low-urbanized cities in the eastern and central regions of China. This study provides insights into how global agriculture can seize opportunities for sustainable development within the context of the GF.

Keywords: Green Finance; Transformation of Agricultural Structure; Fixed Effects Model; Mediating Effect

*CORRESPONDING AUTHOR:
Nurhafiza Abdul Kader Malim, School of Management, Universiti Sains Malaysia, Penang 11800, Malaysia; Email: fizanur@usm.my

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1. Introduction

The global consensus and agreement are to promote environmental protection and create an improved world [1]. Economic growth and environmental protection are often viewed as opposing forces. How to develop the economy while protecting the environment has become an issue. China's industrial structure underwent a dramatic shift following the reform and opening up. The government agencies recommended expediting industrial structure upgrading and actively promoting green and low-carbon sectors. As the world's foremost emitter of carbon dioxide, China has implemented several energy-saving and emission-reduction programs with notable outcomes over the past 20 years. GF seems to serve as a viable solution [2]. In the late 1980s, the London Environmental Economics Center (LEEC) introduced the concept of a Green Economy in its study, titled "Green Economy Blueprint." As awareness of environmental conservation and sustainable development grows, numerous academic studies focus on GF, with the primary subject matter being sustainable finance or environmental finance. Cowan posited that GF constitutes a novel discipline emerging from the convergence of finance and the green economy, to address the financial challenges associated with the green economy [3]. It has deepened and broadened the concept of green money by stimulating the development of research areas such as low-carbon finance, environmental finance, and sustainable finance. While some critics argue that GF has mostly focused on symbolic projects, evidence shows that GF is moving toward more substantive investments. The global green bond market has grown from $53.2 billion in 2015 to over $801.8 billion in 2024 (Climate Bonds, 2025). Dikau and Volz discussed how policy frameworks can ensure that GF leads to tangible environmental outcomes [4]. China's dual-carbon goals (reaching peak emissions by 2030 and and achieving carbon neutrality by 2060) are supported by concrete GF mechanisms, aimed at achieving ecological transition goals and strategic economic positioning, and driving measurable decarbonization. Many studies have concluded the role of GF in China's ecological goals. Despite the numerous difficulties and obstacles encountered during the energy transition journey [5], China has improved environmental quality and laid the foundation for long-term and stable economic development by gradually reducing its dependence on oil energy and substantially increasing the proportion of clean energy [6,7]. Xiao Yuan posited that GF is an important capital driver for high-quality agricultural development [8]. Previous studies often relied on simplistic metrics to evaluate GF growth, limited by data scarcity. According to Hafner and Xie, the distribution of financial institutions' investments in companies or projects is the main issue with GF; thus, green investment is often used as a singular indicator or quantified as a measurement [9,10]. However, new indicators for evaluating the development of GF have surfaced, including the diversification of green financial products and the growing market share of green bonds and green insurance.

Bair and Gereffi noted that the primary indication of industrial structure enhancement is the conversion of key industries into tertiary sectors [11]. However, the determinants affecting industrial structure are intricate. Soundarrajan and Vivek posited that, in contrast to the traditional financing model, green finance brings a range of eco-friendly financial tools that can significantly enhance environmental protection efforts [12]. The green transformation of the agricultural structure has been vigorously managed through the mobilization of funds at multiple levels and in multiple areas, as well as the strengthening of scientific and technological innovations [8]. Investigations into how eco-friendly funding affects industry configurations typically have a single indicator, such as green credit [13]. Green finance regulations not only reduce the financing constraints that businesses face, forcing them to shift to green industries [14], but also reduce energy consumption in agriculture [15]. Green technological innovation serves as the primary catalyst for industrial structural enhancement [16]. Święcki conducted an empirical analysis utilizing counterfactuals and determined that the primary driving force is attributable to various technology advancements [17]. Regarding the complementary policies necessary to promote AST, both Chen, et al. [18] and Zhang et al. [19] support the notion that increasing agricultural subsidies is beneficial for the development of green agriculture.

The relationship between GF and AST has received attention in many countries. AST has been profoundly affected by green financial policies, especially green financial support mechanisms at the national level, such as the Action Plan for the Green Development of Agriculture (2017–2025)[20]. The Chinese government has established special funds through the central government to support the development of green agriculture, covering areas such as green planting and ecological farming[21]. The United States has also enacted the Farmland Protection Program, which supports the preservation of farmland and sustainable agriculture through subsidies and loans[22]. The evolution of agricultural finance in the European Union, with an emphasis on Romania, was examined by Zaharia and Mihai between 1960 and 2016. Their findings showed a notable increase in agricultural financing-related scientific output at both national and European levels[23]. GF not only directs and fosters green industries to emerge as dominant sectors from the capital supply perspective but also significantly influences energy usage. It promotes the use of renewable energy by businesses and consumers while optimizing the energy consumption framework. Customers reduce their dependency on fossil fuels and other nonrenewable resources, transitioning to the acquisition and utilization of new renewable energy sources. So, it has directly facilitated the transformation of the energy sector[24]. Farmers play a critical role in the global food system[25]. A more loosely organized structure characterizes agriculture compared to industry. It presents one of the challenges to achieving sustainable development. Research indicates that small farmers face challenges in developing environmental awareness, caught between the conflict of environmental protection and production efficiency[26]. Guermond et al. raise concerns about GF by examining the negative effects of green microfinance on small farmers in Cambodia[27]. From a capital supply perspective, GF can assist farmers in overcoming financing and borrowing challenges by offering loan guarantees, agricultural credit, and other financial services. As the primary decision-makers and implementers of agricultural activities, farmers can ensure the sustainability of their production by accessing green funding[8].

Many studies have shown that, as a new financial paradigm, GF has a real impact on AST from the standpoints of financial supervision and policy direction[28]. Conflicts between population, resources, and the environment underscore the necessity of studying AST[8]. The study of the correlation between GF and AST has the potential to assist government departments realign their financial policies in a timely manner. It can facilitate the elucidation of the specific measures and objectives associated with AST. In addition, it can enhance the existing direction and pace of economic development[15]. This study defines AST as a shift in agricultural production towards the agricultural services output. It focuses on the growing proportion of output from agriculture-related services, such as forestry, animal husbandry, and fishery services, compared to total agricultural output. The definition highlights the importance of service-oriented activities in enhancing productivity and sustainability in agriculture[29]. Despite the increasing recognition of GF and sustainable agricultural development[15,21,28], the specific impact of GF on AST remains underexplored in the literature. Existing studies have examined the role of GF in reducing carbon[24,30] and supporting rural development[31,32]. However, few have focused on how GF facilitates AST, particularly in the context of developing economies and the broader goals of GF initiatives. The study on how GF affects AST can provide useful insights for decision-makers and policymakers to inform sustainable agricultural development.

The objective of this study is to explore the relationship between GF and AST and evaluate the effectiveness of GF in promoting sustainable agricultural development. This study also explores the mediating roles of GSI, GCL, and CAE in the relationship between GF and AST, aiming to fill a gap in understanding how financial mechanisms can support sustainable agriculture practices.

2. Literature and Hypothesis

2.1. Green Finance and Agricultural Structure Transformation (AST)

Sustained economic advancement entails ongoing and evolving change. The prompt advancement of industrial structure enhancement is essential for promoting high-quality economic development. Agriculture has

also played an important role in China. Previous studies have shown that the influx of capital can both assist established companies in their transformation and upgrade, and promote the establishment of new green enterprises, thereby optimizing industrial structure[15]. Most studies employ PSM-DID to evaluate the impact of GF on corporate green transition[28]. Due to the scarcity and non-renewability of natural resources, capital remains a key supporting factor for sustainable agricultural development[33]. Lee and Lee found that GF improves research on renewable energy production by promoting technology research and development, as well as broadening market opportunities[34]. As a financial mechanism, GF could substantially reduce greenhouse gas emissions and alleviate air pollution. GF in agriculture, sustainable construction, and other environmentally friendly efforts ought to enhance the national economy[30]. Indeed, many researchers have investigated the impact of GF on agriculture and rural finance in recent years[35,36]. Tran et al. demonstrated the role of GF in promoting sustainable agriculture in Asian countries by examining the World Bank data set from 2002 to 2020[37]. The ability of agricultural credit to increase agricultural productivity in developing countries has also been demonstrated recently[38]. In China, the source of rural agricultural financing is similar to that of enterprise financing, mainly from banks and mainstream financial institutions[31]. Simultaneously, disparities in technological advancement across various industries result in an imbalance in production efficiency and developmental pace among them. Industries exhibiting high productivity dominate the market, while those utilizing obsolete technology experience steady decline. Innovative and environmentally conscious executives progressively establish industry trends, hence facilitating the optimization and advancement of the entire sector[39]. Yang et al. further indicate that financial resources play a crucial role in the sustainable development of agriculture through the allocation of green bonds[32]. GF enhances the operational efficiency of the credit market by lowering the financing costs associated with green initiatives. GF significantly reduces financing barriers for green projects by offering preferential loan interest rates and extending repayment terms[40]. Existing research demonstrates how GF provides funds to support green development. There is still a lack of discussion about GF for AST. Thus, to close this gap, this study suggests H1.

H1. *GF exerts positive influences on AST.*

2.2. The Mediating Effect of CAE

GF exerts influence on green credit through policy mechanisms. Green credit constitutes a crucial component of green financial instruments, and the total funds available to support green development are positively correlated with the allocation of green credit[41]. Green credit links savings to green investments, directs raised capital to environmentally sustainable industries, and steers the primary allocation of production factors towards environmentally competitive industries[14]. The private sector contributes significantly to green agriculture investment in addition to financial support from the state sector. It is becoming increasingly common to invest in financial solutions for agricultural technology and innovation, such as farmer crowdfunding and microcredit[42]. GF effectively directs resources to more sustainable sectors by concentrating on financial support for green, low-carbon, and environmentally sustainable initiatives. This technique enhances the efficient allocation of credit resources and directs funding towards environmentally sustainable and technologically innovative sectors, hence facilitating the optimization of industrial structure[43]. However, there is a lack of research on how GF might reshape agricultural structure by impacting credit allocation efficiency. Therefore, we propose the second hypothesis.

H2. *GF promotes AST by controlling CAE.*

2.3. The Mediating Effect of GCL

As the concept of green consumption becomes more entrenched, consumers will opt for environmentally friendly products under identical conditions. This will stimulate supply-side research, foster the growth of green industries, and facilitate the enhancement of industrial structure optimization[44]. Haiyan Sun and Fushan Chen demonstrated the role of GF on GCL in

terms of its impact on energy consumption levels [45]. The environmental values promoted by GF affected both reasons and green consumption attitudes [46]. The findings indicate that the increasing demand for green consumption has a significant impact on the supply side. It encourages firms to engage in the research and development of environmentally friendly products [47]. This study focuses on GF and emphasizes green consumption. They said this study can promote it through financial incentives and cost reductions. Jiakui et al. asserted that green financial policies can foster green technology innovation and implementation [48].

H3. *GF promotes AST by raising GCL.*

2.4. The Mediating Effect of GSI

Financial institutions can more precisely identify and fund green industries with developmental potential to enhance GSI and stimulate industrial structure advancement by implementing more efficient risk management. The emergence of GF significantly bolsters ongoing innovation within the sector. GF can reduce financial costs. Corporations can allocate more resources to research and development [39]. Conversely, GF subjects energy-intensive and polluting industries to increased financing costs, thus motivating enterprises to adopt sustainable practices and diminish pollution through continuous eco-friendly advancements [48]. GF promotes agricultural mechanization, reducing resource waste and environmental pollution through intensive agricultural production [49]. GF provides technical support for agricultural development through green and sustainable innovation. By introducing green credit funds into the agricultural sector, financial institutions will increase their understanding of agricultural development, thereby reducing information asymmetry and moral hazard [50]. It should also be proved whether there is a mediating effect of green and sustainable innovation ability.

H4. *GF promotes AST by boosting GSI.*

The study of GF and AST has advanced somewhat thanks to earlier studies. Fixed effects model [51] and two-stage least squares [52] are frequently employed in GF research. However, there are still some gaps in the existing research. Firstly, although the positive impact of GF on AST is generally recognized, the discussion on the impact mechanism and path is inadequate. Some studies have not adequately explained or supported the idea that GF influences the detrimental effects of AST. Secondly, it is also important to investigate how to encourage AST through green consumption and green innovation.

3. Materials and Methods

The objective of this study is to investigate the impact of GF on AST and propose a new perspective to assess the effectiveness of GF in promoting sustainable agricultural development. A quantitative approach was adopted in our study. This study chose Chinese cities as the research sample because financial databases will support the collection of large-scale data. The data was analyzed using Stata 16.0 to conduct descriptive statistics and regression analysis. Given the possible endogeneity problem between the error term and the independent variable, this study analyses the panel data using a fixed effects model (FEM) [53]. This study also applies two-stage least squares (2SLS) to address the endogeneity of the independent variable and residuals [51]. This approach mitigates the estimation bias inherent in empirical regression models. The 2SLS regression analysis shows that the positive impact of GF on AST remains significant, as evidenced by the use of explanatory factors with a one-period lag as instrumental variables.

3.1. Variables

Table 1 shows the main variables and measurements used in this study. Following Li et al. and Tian et al., AST was chosen as the dependent variable in this study [15,39]. According to the objectives of this study, financial support for environmental protection and sustainable development was selected as a key measurement indicator for GF [54]. AST is measured by the proportion of agricultural services in the total output value of agriculture. The larger the value is, the greater the proportion of agriculture, forestry, animal husbandry, and fishery services is, and the higher the level of service industry in agriculture [15].

Table 1. Explanation of variables.

Nature of the Variable	Variable Names	Variable Symbols	Measurement
Dependent variable	Agricultural structure transformation	AST	The proportion of agricultural services in the total output value of agriculture (%)
Independent variable	Green Finance	GF	Financial support for environmental protection and sustainable development
Mediating variables	Credit allocation efficiency	CAE	Green project loan balance as a percentage of total green loans (%)
	Green consumption levels	GCL	Green product sales as a proportion of total product sales (%)
	Green sustainable innovation capacity	GSI	Number of green patent applications
Control variables	Gross regional product	GDP	Gross Domestic Product ($bn)
	Openness to the outside world	OPEN	Total exports and imports/GDP (%)
	Foreign direct investment	FDI	Foreign direct investment (million yuan) / 10,000 / Gross regional product (billion yuan)
	Human capitalisation	HC	Number of students enrolled in higher education (10,000)/total population
	Financial development level	FDL	Sum of deposits and loans/GDP (%)
	Scientific and technological level	STL	Science and technology expenditure/local public budget expenditure (%)
	Urbanisation level (of a city or town)	UL	Resident urban population/resident population (%)

In further research, we propose the mediating role of CAE [55], GCL [43], and GSI [39,56] in the influence of GF on agricultural development.

Referring to Rao et al., Zhao et al., and Demertzis and Wolff [55], total exports and imports/GDP [30], foreign direct investment [43], sum of deposits and loans/GDP [57], science and technology expenditure, and resident urban population [54] are regarded as control variables.

3.2. Data Description

This study examines 240 cities in China between 2013 and 2023. The observational samples include 2505 annual panel data from the China City Statistical Yearbook (CCSY). CCSY is a comprehensive database that encompasses economic, social, and environmental indicators. Variables including GDP, FDI, OPEN, and GCL were selected from CCSY. The data provided by the CCSY is systematically collected and published by the National Bureau of Statistics of China, ensuring a high level of accuracy and credibility. Based on the research of Little and Rubin, missing values need to be handled in statistical analysis in different ways [58]. Given our large sample size and the relatively few random missing values, we chose to remove the missing values during data processing directly. The data underwent a cleansing process, considering the reasonableness, availability, and comparability of empirical data, and addressing missing values and outliers. In this study, data from Tibet, Hong Kong, Macau, and Taiwan were omitted, as they account for the unique geographical and socio-economic conditions in these areas. In order to reduce the extreme value effect, this study restricts continuous variables to the 1% upper and lower quartiles. Despite the established authority of CCSY in providing statistical information, potential statistical biases may still emerge due to inconsistencies in statistical rigor and delays in data updating.

3.3. Empirical Model

The fixed effects model is employed in this study to enable a more logical analysis of how green funding affects AST. The following model is developed based on current literature [Equation (1)]:

$$AST_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_4 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (1)$$

In the Equation (1), i represents individual, t represents year, AST as a dependent variable, GF as an independent variable, control variables including GDP, human capital level (HC), foreign direct investment (FDI), openness to other countries (OPEN), financial development level (FDL), science and technology level (STL), urbanization level (UL). α_0 is the constant term; ρ_t represents an individual fixed effect [57]. ε_{it} represents time effect, as a random disturbance term.

This section utilizes the mediating effect model to examine the transmission mechanism of GF on AST, emphasizing GCL, CAE, and GSI as mediating variables (M), and constructs the model as Equation (2).

$$M_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_4 control_{it} + \delta_i + \rho_t + \varepsilon_{it} \quad (2)$$

Equation (2) assesses the transmission linkage through the main predictor, the mediator variable, and the dependent variable, specifically determining whether the mediator variable serves as a substantial conduit of influence. The initial equation for each mediating effect mirrors the fixed effects outlined in the previous section. This study focuses on GF as the research aim and AST as the research subject. This study theoretically clarifies how GF and control variables affect the AST through empirical analysis and research. Equation (2) for each mediating effect analyses the mediating variables of GCL, CAE, and GSI to evaluate the degree of influence that explanatory variables have on these mediating variables, thus addressing the scientific question of whether this influence is statistically significant. Ultimately, the two-step methodology was employed to clarify the connection between those mediating variables and explanatory variables.

3.4. Descriptive Statistics

Table 2 details preliminary data characteristics via descriptive statistics. The mean of AST is 0.040, the median is 0.031, and the standard deviation is 0.029, implying a higher concentration and less variability in the degree of AST within the sample. The smallest value is 0.002, and the maximum value is 0.238, signifying that the degree of AST fluctuates within a specific range. The mean value of GF is 0.345, the median is 0.369, and the standard deviation of GF is 0.10, suggesting a more uniform distribution of GF within the sample. The minimum value is 0.080, and the most significant value is 0.532, indicating the disparities in GF among various cities.

Table 2. Descriptive statistics.

Variable	N	Mean	p50	Sd	Min	Max
AST	2505	0.0400	0.0310	0.0290	0.00200	0.238
GF	2505	0.345	0.369	0.100	0.0800	0.532
GCL	2505	0.115	0.112	0.0330	0	0.249
CAE	2505	0.984	0.840	0.526	0.132	5.305
GSI	2505	5.152	5.050	1.573	0.693	10.15
GDP	2505	7.534	7.442	0.828	5.611	9.694
HC	2505	0.0200	0.0110	0.0240	0.00100	0.119
FDI	2505	0.0170	0.0120	0.0160	0	0.0700
OPEN	2505	0.172	0.0800	0.256	0.00200	1.568
FDL	2505	2.499	2.252	1.029	1.026	6.555
STL	2505	0.0180	0.0130	0.0170	0.00100	0.0880
UL	2505	0.577	0.555	0.138	0.296	0.952

3.5. Correlation Analysis

A larger absolute value of the correlation coefficient denotes a more robust association between the two variables, indicating a stronger correlation. The correlation coefficients of the variables are distant from -1 or 1, signifying their independence and a minimal probability of adversely affecting the subsequent regression analysis. This suggests that the data used in this study are largely dependable, thereby alleviating the problem of covariance in the regression equations to some extent.

A fundamental correlation analysis of the variables is carried out in this investigation. The correlation coefficient between AST and GF is 0.249, as indicated in **Table 3**. At 1%, it has statistical significance. This finding is also supported by Zhao and Han [54]. The correlation coefficients between GF and AST are between -1 and 1, which have less impact on the subsequent regression analyses.

Table 3. Correlation analysis of variables.

Variable	AST	GF	GCL	CAE	GSI	GDP
AST	1					
GF	0.249***	1				
GCL	0.053***	0.240***	1			
CAE	0.128***	0.184***	0.313***	1		
GSI	0.409***	0.351***	0.274***	0.474***	1	
GDP	0.363***	0.300***	0.162***	0.306***	0.860***	1
HC	0.186***	0.102***	0.138***	0.623***	0.507***	0.456***
FDI	0.177***	-0.034*	-0.041**	0.149***	0.308***	0.261***
OPEN	0.115***	0.252***	-0.061***	0.233***	0.385***	0.354***
STL	0.102***	0.186***	0.378***	0.932***	0.410***	0.216***
UL	0.324***	0.150***	0.00800	0.314***	0.629***	0.560***
	HC	**FDI**	**OPEN**	**FDL**	**STL**	**UL**
HC	1					
FDI	0.325***	1				
OPEN	0.279***	0.224***	1			
FDL	0.573***	0.093***	0.202***	1		
STL	0.438***	0.418***	0.476***	0.228***	1	
UL	0.548***	0.255***	0.415***	0.461***	0.521***	1

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

4. Results

The hypotheses on the relationship between GF and AST have been answered and verified in the quantitative study. These findings align with previous studies [54,57]. The results and comments, including baseline regression, mediating analysis, evaluation of the FE and 2SLS models, hypothesis testing, discussion, and implications, are presented in this part.

4.1. Baseline Regression

Table 4 presents the findings from the panel data analysis. This study uses GF as a baseline and adds other control variables to stabilize the regression results. The estimation findings in the table demonstrate that the first column uses GF as the exclusive explanatory variable. The regression results indicate that GF achieves the 1% significance level, with a coefficient of 0.20338. In the second column, the findings indicate that GF has a positive effect on AST at a 1% significance level. The regression coefficient shows that a 1% increase in GF is associated with a 6.146% increase in AST. Moreover, the regression results for the control variables GDP, FDL, and STL are significant at the 1% level, achieving coefficients 0.01843, 0.00619, and 0.2304, respectively. Other control variables are observed at a comparatively lower level.

Table 4. Baseline regression results.

	(1) AST	(2) AST
GF	0.20338***	0.06146***
	(25.22)	(5.20)
GDP		0.01834***
		(9.85)
HC		0.09294
		(1.54)
FDI		0.08406**
		(2.25)
OPEN		0.00700
		(1.56)
FDL		0.00619***
		(8.15)
STL		0.23040***
		(5.79)
UL		0.01101
		(1.45)

Table 4. *Cont.*

	(1) AST	(2) AST
_cons	−0.03054***	−0.15031***
	(−10.92)	(−13.67)
N	2505	2505
R^2	0.219	0.313
Year	Yes	Yes
FE	Yes	Yes

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

4.2. Endogeneity Test

This study advocates for the application of 2SLS instrumental variable regression to reevaluate the impact of GF on AST. Therefore, mitigating the estimation bias is inherent in the empirical regression model. According to Bhuller and Sigstad, the selection of explanatory factors with a one-period lag as instrumental variables indicates that the beneficial effect of GF on AST remains substantial in the 2SLS regression analysis [52]. The conclusions in **Table 5** show that the regression results are similar to those in **Table 4**. A 1% increase in GF is associated with a 6.205% increase in AST. The regression results for the control variables—GDP, FDI, OPEN, and STL—are significant at the 1% level.

Table 5. Endogeneity test.

	(1) AST	(2) AST
GF	0.07993***	0.06205***
	(13.46)	(11.12)
GDP		0.00795***
		(8.25)
HC		−0.01933
		(−0.53)
FDI		0.14991***
		(3.78)
OPEN		−0.01574***
		(−5.49)
FDL		−0.00063
		(−0.94)
STL		0.31218***
		(5.38)
UL		0.00897
		(1.61)
_cons	0.01270***	−0.05008***
	(6.49)	(−7.24)
N	2240	2240
R^2	0.061	0.191
Year	Yes	Yes
FE	Yes	Yes

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

4.3. Robustness Test

In **Table 6**, column (1) shows that the metric that substitutes the dependent variable for AST is agricultural structure rationalization (ASR) [59]. ASR is a more thorough and nuanced evaluative metric that considers not only the proportionality among industries but also the coordination and efficiency of their internal structures. The introduction of this indicator allows for a more precise assessment of the substance and impact of agricultural structure restructuring, hence offering a more empirical foundation for policy formation and corporate advancement. As a substitute for the dependent variable, ASR was tested in the robustness analysis. The conclusions in **Table 6**, column (1) show that a 1% increase in GF is associated with a 5.403% increase in AST. The control variables, GDP, FDI, OPEN, and STL, are significant at the 1% level.

Column (2) shows the result of removing the effects of the COVID-19 pandemic [1]. The COVID-19 pan-

demic[1] has a substantial influence on the global economy, affecting operations, market demand, supply chain integrity, and various other aspects. To mitigate the influence of the COVID-19 pandemic, the variable is omitted from the model to reduce its effect on the outcomes. The test findings indicate that the significance and the positive and negative correlations of the core explanatory variables remained mostly unchanged, hence demonstrating the reasonableness of the previously developed model and the stability of the regression results. The significance and correlations of the other control variables remained mostly unchanged, suggesting that the previously created model is sound and the regression results are stable and dependable. The conclusions in **Table 6**, column (2), show that a 1% increase in GF is associated with a 5.539% increase in AST. The control variables GDP, FDL, and STL are significant at the 1% level.

Table 6. Robustness test.

	(1) ASR	(2) AST
GF	0.05403***	0.05539***
	(9.33)	(4.50)
GDP	0.00769***	0.01868***
	(9.12)	(9.67)
HC	−0.03091	0.10897*
	(−0.97)	(1.76)
FDI	0.12866***	0.09467**
	(3.46)	(2.44)
OPEN	−0.01476***	0.00714
	(−6.02)	(1.56)
FDL	−0.00045	0.00628***
	(−0.68)	(7.92)
STL	0.32733***	0.23830***
	(7.50)	(5.80)
UL	0.01234**	0.00865
	(2.36)	(1.09)
_cons	−0.04803***	−0.15059***
	(−7.83)	(−13.28)
N	2505	2274
R^2	0.191	0.325
Year	No	Yes
FE	No	Yes

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

4.4. Heterogeneity Analysis

Table 7 shows that GF has a stronger impact on AST in eastern and central regions. A 1% increase in GF is associated with a 5.99% increase in AST in the eastern region and an 8.923% increase in AST in the central region. A 1% increase in GF is associated with a 4.176% increase in AST in the western region. The findings suggest that the economic development and comprehensive financial system of the eastern and central regions enhance the efficacy of GF policies. Enterprises in the eastern region exhibit greater capital accumulation and enhanced technological research and development capabilities, enabling them to utilize GF more effectively for technological innovation and to advance industry towards high-value-added and low-pollution outcomes.

Table 7. Sub-regional analysis.

	(1) Eastern	(2) Central	(3) Western
GF	0.05990***	0.08923***	0.04176**
	(3.58)	(3.47)	(2.32)
GDP	0.01412***	0.02634***	0.01721***
	(4.79)	(6.07)	(6.82)
HC	0.20937***	−0.10126	0.03491
	(2.60)	(−0.66)	(0.39)
FDI	0.04237	0.05631	0.28682***
	(1.00)	(0.55)	(3.17)

Table 7. *Cont.*

	(1) Eastern	(2) Central	(3) Western
OPEN	0.00738	0.01039	−0.01422*
	(1.52)	(0.44)	(−1.73)
FDL	0.00451***	0.00795***	0.00884***
	(4.81)	(3.65)	(5.89)
STL	0.21502***	0.13998*	0.23278***
	(3.73)	(1.69)	(3.28)
UL	0.03461***	−0.00773	−0.00948
	(3.31)	(−0.40)	(−0.91)
_cons	−0.13804***	−0.19830***	−0.12515***
	(−7.31)	(−8.26)	(−8.72)
N	1037	835	633
R^2	0.315	0.329	0.351
Year	Yes	Yes	Yes
FE	Yes	Yes	Yes

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

As **Table 8** shows, GF has a stronger impact on AST in non-first-tier cities. A 1% increase in GF is associated with a 7.112% increase in AST. In contrast, the regression result demonstrates that the relationship between GF and AST in first-tier cities did not reach significance. This conclusion is attributed to a higher level of urbanization and a smaller share of agricultural percentage in first-tier cities.

Table 8. The heterogeneity analysis of urban levels.

	(1) First-Tier Cities	(2) Non-First Tier Cities
GF	0.02729	0.07112***
	(1.14)	(5.31)
GDP	0.02757***	0.01788***
	(6.88)	(8.51)
HC	0.26282***	−0.04032
	(3.36)	(−0.50)
FDI	0.24538***	0.02780
	(4.14)	(0.60)
OPEN	0.02017***	0.00080
	(2.73)	(0.14)
FDL	0.00605***	0.00587***
	(3.92)	(6.74)
STL	0.13456**	0.27365***
	(2.45)	(5.23)
UL	0.02957*	0.00623
	(1.94)	(0.72)
_cons	−0.27112***	−0.13821***
	(−9.54)	(−11.57)
N	461	2044
R^2	0.505	0.286
Year	Yes	Yes
FE	Yes	Yes

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

4.5. Mediating Effects

This study infers causal relationships through a two-step method proposed by Jiang Ting[60]. Based on regression results that demonstrated the impact of GF on AST, this paper initially examines the influence of GF on CAE, GCL, and GSI. Subsequently, it references the research findings of Rao, S.[43], Sethi, L.[38], Mollick, E, and Xiong[49] on the effects of CAE, GCL, and GSI, though the effect of mediating variables on AST is not directly discussed. As **Table 9** shows, following the mediation effect test, the results in column (1) align with the baseline regression results. In column (2), the regression coefficients suggest that a 1% increase in GF is associated with a 0.2136 increase in CAE, while its influence is more minor but still statistically significant.

This is mainly due to the policy effects of GF and the effective mobilization of financial resources in microfinance regulation. In column (3), the regression coefficient for GF about GSI ability is 2.08905. It suggests that the progression of GF can significantly improve the potential for GSI. This can be attributed to the provision of crucial financial support for green technology research and development, allowing firms to enhance their R&D expenditure in this area, thereby enhancing their innovative capabilities. In column (4), the regression coefficient of GF on GCL is 0.5616. The results are significant at the 1% level, suggesting that the advancement of GF markedly enhances GCL. This improvement might be the result of financial institutions focusing more on identifying and evaluating environmental hazards as well as businesses' sustainability capabilities, which makes it easier to allocate credit resources more efficiently.

Table 9. Mediating effects.

	(1) AST	(2) CAE	(3) GSI	(4) GCL
GF	0.06146***	0.21360**	2.08905***	0.05616***
	(5.20)	(2.01)	(5.13)	(3.88)
GDP	0.01834***	0.22238***	1.71051***	0.01097***
	(9.85)	(13.31)	(26.65)	(4.82)
HC	0.09294	2.25979***	1.83154	−0.02607
	(1.54)	(4.18)	(0.88)	(−0.35)
FDI	0.08406**	−0.14352	−0.51723	−0.10584**
	(2.25)	(−0.43)	(−0.40)	(−2.31)
OPEN	0.00700	−0.01337	−0.14124	0.01604***
	(1.56)	(−0.33)	(−0.91)	(2.92)
FDL	0.00619***	0.37810***	0.54367***	0.01456***
	(8.15)	(55.49)	(20.76)	(15.68)
STL	0.23040***	0.22766	1.90568	−0.02163
	(5.79)	(0.64)	(1.39)	(−0.44)
UL	0.01101	0.19346***	0.14472	−0.01957**
	(1.45)	(2.84)	(0.55)	(−2.10)
_cons	−0.15031***	−1.86579***	−9.93590***	−0.01228
	(−13.67)	(−18.90)	(−26.20)	(−0.91)
N	2505	2505	2505	2505
R^2	0.313	0.771	0.646	0.240
Year	Yes	Yes	Yes	Yes
FE	Yes	Yes	Yes	Yes

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

5. Discussion

This study discusses the impact of GF on AST from the perspective of agricultural service outputs, and investigates the mediating roles of CAE, GCL, and GSI. The regression results show that GF has a positive impact on promoting AST. The result is maintained in the robustness test and heterogeneity test. For every 1% increase in financial support for the protection of the environment, the share of agricultural services in total agricultural output increased by 6.146%. This indicates that GF can affect AST in terms of policy guidance and financial orientation. Environmental protection and governance responsibilities turn into explicit capital costs affecting agricultural investment. The results of the quantitative analysis support the hypothesis that GF influences AST. This aligns with the findings of Xiao Yuan et al. [8] and Shi and Yang [61], who also observed that GF significantly contributes to high-quality agricultural development. Firstly, this study expands on their conclusions by refining the sample. Xiao Yuan et al. chose provincial panel data from 2007 to 2021, and Shi and Yang investigated data from 2000 to 2020 in East Asian. At the same time, we constrained our sample to city data from 2013 to 2023 in Chinese. This sample both avoids discussion of data from the period of the World Financial Crisis and expands the sample size from the much smaller city-based data. Secondly, this study extends the definition of high-quality agricultural development [8] by using the increase in agricultural services output as an explanation for AST. Thirdly, in the study of mediating analysis, Xiao Yuan et al. emphasize the mediating role of sci-

ence and technology innovation, which we add in terms of CAE and GCL. Shi and Yang also observed that carbon dioxide emissions, GDP, and the consumer price index have a negative impact on agricultural sustainability, emphasizing the importance of achieving balanced economic and environmental growth [61]. There are some opposing views between this study and the findings of Guermond et al., who raise critical concerns regarding the effectiveness of GF and green bonds in contexts characterized by high levels of over-indebtedness in agriculture [27]. Their concern mainly stems from the difficulties farmers may encounter with microcredit. This divergence may result from differences in factors including economic conditions, regulatory backgrounds, and financial policies. Our study suggests that when GF is effectively integrated into supportive institutional frameworks, it can enhance AST and make a positive contribution to agricultural development.

In this study, we used the two-stage least squares (2SLS) method for testing endogeneity. This improved method enhances the reliability of the results. In the robustness test, the results were further tested by replacing the causal variables with ASR and controlling for the impact of the COVID-19 pandemic. In the heterogeneity analysis, the discussion mainly focuses on subregions and city levels. There are significant differences in the impact of GF on AST under different location conditions and city development levels. The policy effect is more pronounced in regions and cities with a better level of economic development. Regions with a lower level of economic development need more macroeconomic control from the government and targeted measures to strengthen the implementation of green finance policies and emphasize environmental awareness. The results of the mediation analysis indicate a significant mediation effect from CAE and GSI. GF promotes the allocation of credit resources towards sustainable agricultural development projects by enhancing CAE. The inclusion of green funds not only creates conditions for sustainable agricultural development but also provides financial support for technological innovation in the agricultural sector. The results of the mediation analysis emphasize the importance of researching the dynamic relationship between GF and AST.

5.1. Limitations

One limitation of this study is that it only examines China's urban data from 2013 to 2023 as the sample. This will lead to bias and limit the application of results in other countries or regions. Moreover, there is a more complex relationship between GF and AST. This complex relationship may not be perfectly solved by quantitative research alone. Qualitative research should perhaps also be more widely applied to the study of the relationship between GF and AST.

5.2. Future Research Directions

To expand research on the impact of GF on the sustainable development of the agricultural sector, individual countries could share practical examples of how GF promotes sustainable agricultural development. Future research could explore the impact of GF on the agricultural sector from a broader international perspective and attempt to make cross-country comparisons. It could also explore the need for government departments to provide categorized guidance to enterprises in the implementation of GF policies.

6. Conclusions

This study uses a double fixed-effects model with panel data. The regression results show a positive effect of GF on AST. For each 1% rise in financial support for environmental protection, the proportion of agricultural services in total agricultural output grows by 6.146%. This finding supports and complements the mainstream theory of GF in support of sustainable development. The study also discusses the mediating role of GAE, GCL, and GSI in the process of GF's effect on AST. Among these, the mediating effects of GAE, GCL, and GSI are significant. GF shows a positive impact, particularly in GSI (2.08905***) and GCL (0.05616***). The effect on CAE is 0.2136**, but it is still statistically significant (at the significance level of 0.05). The study also points out the heterogeneity of the effect of GF on AST, which is greater in underdeveloped cities in the eastern (0.05990***) and central regions (0.08923***) with better locational conditions. This result may stem from the fact that first-

tier cities have a lower share of the agricultural sector in their industrial structure. Based on these findings, we provide new ideas and recommendations for policymakers. When developing and implementing GF policies, governments should give due consideration to the impact these policies will have on the agricultural sector. Regional conditions have a more significant effect on the implementation of policies. The implementation of GF policies in developed countries and regions should consider targeting policies towards regions with a high agricultural sector. Regions with a lower share of the agricultural sector may be better suited to developing GF policies that specifically serve the industrial sector. GF targeted at the agricultural sector can be more effective in supporting sustainable agricultural development in developing countries or developing regions that are relatively less well-located. Government departments should provide more financial support to promote the innovation of green financial products and raise awareness about green practices in regions where the agricultural sector is the main industry. Governments should increase their support and investment in green technology innovation, including financial support for research and development, technology transfer, and intellectual property protection. Green technology innovation can promote the development of agricultural enterprises and improve the development chain of the agricultural industry.

The main contribution of this study is to expand the scope of the definition of structural adjustment in agriculture. The output of agricultural services as a percentage of total agricultural output is used as a factor to measure AST. The changes of agricultural structure under green financial policies are discussed separately from the perspective of industrial structure optimization, which is conducive to the sustainable development of world agriculture. In terms of research conclusions, the shortcomings of the impact of GF on the sustainable development of agriculture in less developed regions are discussed through heterogeneity analysis, and corresponding policy recommendations are provided.

Author Contributions

Conceptualization, M.C. and N.A.K.M.; methodology, M.C. and N.A.K.M.; validation, M.C. and N.A.K.M.; formal analysis, M.C.; investigation, M.C.; resources, M.C.; data curation, M.C.; writing—original draft preparation, M.C.; writing—review and editing, N.A.K.M.; visualization, M.C.; supervision, N.A.K.M.; project administration, N.A.K.M. All authors have read and agreed to the published version of the manuscript.

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The observational samples and annual panel data from the China City Statistical Yearbook (CCSY). CCSY is a open access database in China. The data provided by the CCSY is systematically collected and published by the National Bureau of Statistics of China, ensuring a high level of accuracy and credibility. The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

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