Assessing the Role of Green Finance in Enhancing Rural Economic Resilience and Environmental Sustainability

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Abstract

Green finance plays a key role in enhancing the resilience of rural economies and environmental sustainability. Rural economies have traditionally relied on natural resources, which makes them particularly vulnerable to climate change and environmental degradation. By providing the necessary financial support, green finance can help rural areas invest in sustainable agricultural practices, upgrade aging infrastructure, implement resource conservation projects, and adopt clean energy and energy-efficient technologies. Green finance can facilitate shifts in agricultural practices, such as supporting organic farming, precision farming and conservation tillage. These practices help to increase land productivity, reduce the use of chemical fertilizers and pesticides, and conserve biodiversity, while increasing the resilience of agricultural systems to climate change. Green finance supports the sustainable transformation of rural infrastructure, such as the efficiency improvement of irrigation systems, the recycling of agricultural waste and the green transformation of rural energy, which helps to reduce environmental pollution and improve resource efficiency. The development of green finance also requires the support of relevant policies, including the establishment of a sound green financial system, the improvement of financial institutions' awareness and assessment capacity of green projects, policy tools to incentivize green investment and credit, and the enhancement of rural communities' awareness and acceptance of green finance.

Keywords: green finance, rural economy, environmental sustainability, climate change, agricultural practices

1. Introduction

With the rapid development of information technology, digital finance, as an emerging service model, is expanding rapidly worldwide, especially in the area of financial inclusion. Digital inclusive finance utilizes modern information technology such as the Internet, big data, cloud computing and other modern information technologies to reduce the transaction cost and risk control cost of financial services, providing more convenient and efficient financial services for the vast rural areas. In China, agriculture, as an important foundation of the national economy, the improvement of its productivity is of great significance in guaranteeing national food security, promoting farmers' income and realizing rural revitalization. By improving the rural financial environment, digital inclusive finance helps to solve the problems of difficult and expensive financing for farmers, and may have an important impact on enhancing agricultural productivity.

With the orderly implementation of the Plan for Promoting the Development of Inclusive Finance (2016-2020), China has basically realized an inclusive financial service system in 2020 that is compatible with the construction of a moderately prosperous society in all aspects, creating good conditions for promoting common prosperity. On this basis, during the 2020-2021 period, the continuous progress and empowerment of digital technology has led to a smoother digital inclusive financial service chain, continued improvement of infrastructure, and more solid institutional protection. A variety of new services, products and models have flourished in rural revitalization, green finance, small and microenterprise financing, and people's livelihoods. Unlike the traditional inclusive

financial system, digital inclusive finance has added new players — technology enterprises — while the traditional system is mainly composed of financial institutions and users. The current development of digital inclusive finance in China has initially formed an ecosystem involving banks, non-bank financial institutions, internet giants and fintech enterprises. Banking financial institutions are actively building an industrial internet ecosystem through digital transformation; non-banking institutions are broadening their customer base through cooperation with different industries and technologies; internet companies are promoting technology development and focusing on data security; and fintech companies are focusing on privacy computing and data circulation.

The services provided by these institutions cover areas such as supply chain finance, consumer finance, insurance technology and digital banking, and target rural revitalization, small and microenterprise financing, green finance and people's livelihoods, relying on infrastructures such as payments, credit and capital markets, while being institutionally safeguarded by policies and legal systems. Digital inclusive finance provides diversified financial products and services such as payment, savings, credit and insurance, with transactions realized through digital or electronic technologies, such as e-money, payment cards or e-accounts. Business forms include online payment, online insurance, online lending and Internet wealth management. Financial institutions and technology enterprises utilize digital technology to provide universal financial services for disadvantaged groups, "three rural" users and small and micro-enterprises by focusing on their typical businesses. Exploring the relationship between digital inclusive finance and agricultural productivity not only helps to understand the actual effect of digital financial development on agricultural production, but also provides a theoretical basis and empirical support for the formulation and improvement of financial policies to support agriculture. In addition, the research results are of great practical significance for promoting agricultural modernization, advancing rural economic development, and achieving sustainable socio-economic development.

2. Theoretical Foundations and Literature Review

2.1 Productivity Theory

The concept of production efficiency began in the field of physics, referring to the ratio of effective power to overall driving power. In economics, the concept of efficiency was extended to the field of resource utilization, referring to the level of output that can be achieved given the input factors at a given level of technology. Historically, economists have defined efficiency in multiple ways: Marx: he believed that efficiency is reflected in the creation of more fruits of labor in a short period of time. Samuelson: proposed that efficiency is the process of reducing the waste of resources and bringing out their potential maximum output capacity. Pareto: His theory suggests that Pareto optimality is achieved through optimal allocation of resources, i.e., the welfare of someone cannot be improved through reallocation without harming anyone's interests, and such a state maximizes efficiency. Reibenstein: proposes the theory of X-efficiency, which argues that efficiency does not always exist within a firm, and that non-allocative efficiency exists objectively and has some value. Combining the above views, this study defines agricultural production efficiency as the ratio between the output obtained by using the same agricultural production factors (capital, labor, and land) and the maximum output that may be achieved in an ideal state under the premise of a fixed level of agricultural technology. On the basis of the theory of production efficiency, the impact of resource allocation efficiency on output has been fully reflected in the classical economic theory of Adam Smith, the neoclassical economic theory of Marshall, and Keynesian and other economic theories. Effective resource allocation and market regulation can ensure that all types of resource inputs are maximized to achieve producer equilibrium. Resource allocation efficiency is the basic law of resource allocation under the condition of resource scarcity, the premise is the stability of factor prices, on the basis of which the minimization of production costs or the maximization of production efficiency is achieved within a certain period of time.

This study explores the impact of digital inclusive finance on agricultural production efficiency on the basis of this theory, especially from the perspective of resource allocation, and analyzes how digital inclusive finance can improve agricultural production efficiency by improving the allocation of capital and labor. By calculating the allocation index of agricultural factor investment in each province and city and adopting the mediation effect model, the path of digital inclusive finance on agricultural production efficiency is empirically tested, aiming to provide more comprehensive and scientific empirical evidence.

2.2 Information Asymmetry Theory

The information asymmetry theory mainly refers to the inequality in information possession among the participants in the market. In this theory, there are usually an information superior and an information inferior party. The information superior party may gain additional benefits in market transactions because it has more information, while the information inferior party may make unfavorable decisions due to lack of information. In the financial market, especially in the field of agricultural finance, information asymmetry manifests itself in the inability of financial institutions (banks, etc.) to fully grasp the real situation of the lenders (farmers), such as the growth of crops, market sales, etc., which increases the credit risk of banks. As a result of this information asymmetry, financial institutions may be excluded from agricultural production in the provision of their services, due to the

tendency of financial institutions to reduce or not provide loans when they cannot accurately assess the risks in order to avoid potential losses. In addition, information asymmetry can lead to undesirable outcomes and adverse selection. Adverse selection refers to the phenomenon of risky subjects being selected for a transaction that occurs due to information asymmetry prior to the transaction. For example, if banks are unable to distinguish between higher and lower risk farmers, they may tend to offer the same interest rate to all farmers applying for a loan, which will attract higher risk farmers to apply for a loan, leading to an increase in overall risk. One of the solutions to the information asymmetry theory is through the provision of more information and improved transmission of information. In the context of digital financial inclusion, financial institutions can utilize big data technology to mitigate information asymmetry. Big data technology enables financial institutions to more conveniently and comprehensively collect and analyze farmers' credit information, including but not limited to farmers' production and sales data, as well as their personal credit history. This helps financial institutions to more accurately assess the credit risk of farm households, so that they can provide loans in a more targeted manner and reduce the negative impact of information asymmetry.

2.3 Theories of Rural Financial Exclusion

The theory of financial exclusion, originally proposed by Leigh in 1993, focuses on the phenomenon of some groups within the financial services sector failing to access appropriate financial services. In the context of rural financial exclusion theory, financial exclusion does not only refer to the inability to approach financial services, but also includes the various barriers encountered in the process of accessing financial services, which result in high costs of accessing financial services. Kempson and Whyley developed the concept of financial exclusion in depth, proposing six dimensions of exclusion that affect not only urban areas but it is also prominent in rural areas, especially in agricultural production. Geographical location plays a decisive role in access to financial services. In remote rural areas, financial institutions have fewer service points, which directly leads to higher time and transportation costs for farmers to access financial services. Farmers in remote areas are often unable to enjoy the same financial services as in urban areas because of these additional costs. Loan conditions set by financial institutions may be too harsh for farm households, such as high collateral requirements or guarantee conditions, which are often difficult for farmers to meet, thus preventing them from obtaining the necessary financial support. The cost of financial services, including interest rates, fees and other related charges, may be too high for farmers to bear. Such high costs make financial services uneconomical for farmers, who then abandon their use. The marketing strategies and financial product designs of financial institutions may not be suitable for the actual needs of the rural market. For example, the promotion methods and application processes of financial products may not be in line with the habits and perceptions of rural residents, making it difficult to popularize financial products in rural areas. Farmers may avoid using financial services because of their own personality, cultural and knowledge levels, or cognitive reasons. For example, some farmers may lack trust in financial products or believe that they do not meet the eligibility criteria, and are unwilling to take the initiative to obtain financial services.

2.4 Results of Previous Research

In 2020, the average value of China's Digital Financial Inclusion Index reached 341.22, with the median value of provinces at 334.82, significantly higher than the level in 2011, showing the rapid momentum of development in the field. Looking back to 2011, the median value of the digital financial inclusion index for each province was only 33.58, while just five years later in 2016, the figure had surged to 225.41, realizing a nearly six-fold increase. By 2020, the median value has even soared to 344.31, an increase of nearly ten times compared to 2011, with an average annual growth rate of 29.1%, fully demonstrating the booming development of China's digital inclusive finance industry. Despite the continuous progress of digital technology and the maturity of the digital financial market, the growth rate of China's digital inclusive finance is gradually slowing down, which indicates that the industry is moving from a period of high-speed growth to a period of normalized growth. In 2020, despite the impact of the epidemic on China's economy, which led to a decline in the annual economic growth rate, the growth trend of digital inclusive finance remained positive, albeit at a slower rate. Particularly noteworthy is that in Wuhan City and Hubei Province, which were severely hit by the epidemic, the digital inclusive finance index still maintained positive growth after ten days, reflecting the unique advantages and strong adaptive capacity that digital finance has demonstrated during the epidemic. By analyzing the data for the period 2011-2015, we found that among the sub-indices, digitization grew the fastest, followed by coverage, while the depth of use grew the slowest. However, with further analysis of the 2016-2018 period, the picture changes, as depth of use of digital finance begins to grow faster than reach. the 2020 data corroborates this trend even more, with the provincial median of the depth of use index growing by 7.31% compared to 2019, a rate of growth that outpaces both the breadth of reach index's 7.15% and digitization extent index's — 0.08%. In four of the last five years, the growth rate of the depth of use of digital finance has exceeded the breadth of coverage. This suggests that depth of use has become a key driver of growth in the development of digital financial inclusion. The integration of digital technology and financial inclusion not only promotes risk reduction, but also brings opportunities for development. For example, in terms of credit risk, digital inclusive finance effectively reduces the frequency of credit fraud and improves the

selection of loans and investment projects through Internet credit collection, big data analysis and scenario-based transaction strategies. In terms of operational risk, the aggregated nature of Internet platforms has helped to create a national market scale, thereby reducing risk. Even in terms of liquidity, despite the limitations of creating pools of funds through online platforms, liquidity risk can be effectively controlled as the scale of supply and demand for funds grows. However, the growth of digital financial inclusion has also amplified certain risks. Different types of Internet financial products exhibit different risk patterns. For example, credit risk is likely to increase with the expansion of digital financial inclusion services, as more people in financial need who were previously excluded from traditional financial services are now being served. In a competitive market, inappropriate credit collection and false advertising could lead to unhealthy competition, which could increase credit risk. While digital technology can reduce operational risk to some extent, it may also create new personal information security and system security issues. In addition, with the rapid global development of digital financial inclusion, systemic risk has increased, which poses a challenge to traditional financial regulatory policies and requires corresponding adjustments and controls on monetary and credit policies. Social regulatory issues, such as "down payment loans" and "naked notes", have also brought new problems to regulation. In summary, although the growth of China's digital inclusive finance industry has faced challenges such as the epidemic, it has maintained strong growth overall and has shown a certain degree of resilience in risk management. In the future, maintaining continued growth in the depth of usage while effectively regulating emerging risks will be key to the continued healthy development of the digital inclusive finance industry.

3. Research Methodology and Data Sources

3.1 Source: Provincial and Municipal Panel Data 2011-2023

The data source for this paper is provincial and municipal level panel data from 2011 to 2023. The dataset covers 270 sample data points from 30 provinces and municipalities in China, detailing relevant financial and agricultural production information for each province and municipality within these years.

In this study, the literature research method was first utilized to review and integrate the existing research literature in depth. By combing the research results of domestic and foreign scholars on digital financial inclusion and agricultural productivity, this paper not only summarizes the research experience of previous researchers, but more importantly, identifies the gaps and shortcomings in existing research. This process helps us to clarify the research direction, lay a theoretical foundation for constructing an analytical framework, and propose innovative points on this basis, which provides a solid theoretical support for further empirical and comparative analyses.

In this paper, panel data of 30 provinces and municipalities from 2011 to 2019 are selected as research samples, and the relationship between digital financial inclusion and agricultural production efficiency is deeply explored using empirical analysis. First, the overall effect of digital inclusive finance is analyzed using the fixed effect model, and further explored how it improves agricultural production efficiency by affecting capital mismatch and labor mismatch, which is verified by calculating the mismatch index and applying the mediation effect model. To ensure the robustness of the findings, this paper also conducts a threshold effect analysis to test the extent of the impact of the digital financial inclusion index on agricultural productivity and the threshold of its effect.

In order to further understand the specific effects of digital financial inclusion in promoting agricultural production efficiency in different regions, this study utilizes comparative analysis to make a side-by-side comparison of data from different provinces and cities. Through this comparison, this paper reveals the differentiated effects of digital inclusive finance on agricultural production efficiency in different regions and analyzes the path choices and effectiveness in promoting the transformation and upgrading of modern agriculture. This approach not only enriches the research content, but also provides targeted recommendations for policymakers to help them more effectively promote the application of digital inclusive financial services in agricultural development.

3.2 Stochastic Frontier Modeling (SFA) to Measure Agricultural Productivity

The stochastic frontier model (SFA), as a parametric approach to frontier analysis, is able to accurately quantify production efficiency and take into account random fluctuations in the production process. The introduction of this model greatly enhances the level of detail and practical applicability of analyzing agricultural production efficiency. In agricultural production, there are numerous unpredictable factors, such as unstable climatic conditions, outbreaks of pests and diseases, etc., which affect output but do not directly reflect the efficiency of the production process. The SFA model is able to distinguish these external, stochastic influences from the production efficiency of farmers by introducing a random error term. This treatment ensures the accuracy of the efficiency assessment, makes the analysis results more in line with the actual production situation, and provides a reliable basis for precise policymaking. The SFA model usually adopts the transcendental logarithmic production function, which has a high degree of flexibility, and can be well adapted to different production technologies and changing input-output relationships. The beyond logarithmic function not only does not make strict assumptions about the elasticity of substitution and returns to scale among factors, but also can accurately describe the complex relationship among

various factors of production (e.g., labor, land, and capital). Therefore, the SFA model can more realistically reflect the technical state of agricultural production and provide a solid foundation for further analysis. After estimating the production efficiency, the traditional "two-step method" often needs to separately analyze the factors affecting the efficiency, which may lead to biased results. The advantage of the SFA model is that it can estimate the production efficiency and the factors affecting the efficiency in one step at the same time. This integrated estimation method not only saves analysis time and reduces the accumulation of errors in the calculation process, but also provides a more accurate and comprehensive analysis of efficiency and its influencing factors, which in turn provides more effective decision support for policymaking.

In this study, the specific application steps of the SFA model are:

$$Y_{it} = f(L_{it}, A_{it}, M_{it}) + v_{it} - u_{it}$$

The production function is set as follows: the production function is set as Y_{it}, where denotes the GDP of the primary industry of the ith province or city in year t, and L_{it}, A_{it}, M_{it} denote the inputs of labor, land and capital, respectively, v_{it} is the random error term, and u_{it} is a non-negative efficiency term.

Measurement of production efficiency: Substitute the data of agricultural input and output into the set production function, and use software such as Frontier 4.1 to estimate and get the value of agricultural production efficiency in each province and city.

Analyzing the current status of efficiency: Analyze the obtained efficiency values in depth to explore the current status and development trend of agricultural production efficiency in each province and city.

3.3 Hierarchical Regression Modeling to Analyze Impact Mechanisms

In this study, hierarchical regression modeling was used to analyze the internal mechanism of the impact of digital financial inclusion on agricultural productivity. Through the hierarchical regression model, the study is able to reveal how digital financial inclusion can affect agricultural production efficiency through the improvement of agricultural resource mismatch. Based on the literature review and theoretical analysis, the study first establishes a basic econometric model to examine the impact of digital financial inclusion on agricultural production efficiency. The model not only includes the impact effect of digital inclusive finance, but also controls for other factors that may affect agricultural production efficiency.

The model is set up as follows:

$$EFF_{it} = \alpha_0 + \beta_0 DFI_{it} + \sum_{k=1}^{K} \lambda_{k0} CONTROL_{kit} + \mu_{0i} + \grave{\mathrm{o}}_{0it}$$

where EFF_{it} denotes the agricultural production efficiency of the ith province and city in year t, DFI_{it} stands for Digital Financial Inclusion Indicator, $CONTROL_{kit}$ is the control variable, μ_{0i} is the province and city-specific effect, and $\grave{\mathrm{o}}_{0it}$ is the error term. The study further constructs a mediation effect model to identify and validate the mediating role of digital inclusive finance in improving agricultural resource mismatch and thus agricultural production efficiency. Specifically, by introducing the agricultural capital mismatch index and the labor mismatch index as mediating variables, the effects of digital inclusive finance on these two mismatch indices and the effects of the mismatch indices on agricultural productivity are examined, respectively. The empirical results show that digital inclusive finance can improve the efficiency of agricultural production directly while also indirectly by improving the mismatch of capital and labor over the examined time period. Specifically, the development of digital financial inclusion significantly reduces the mismatch of agricultural resources, thereby increasing the efficiency of resource use and agricultural output.

4. Results of Empirical Analysis

4.1 Digital Financial Inclusion and Agricultural Productivity

According to the study, digital financial inclusion significantly enhances agricultural productivity. Among the multiple dimensions of digital financial inclusion, breadth of coverage and depth of use have a significant positive impact on improving agricultural production efficiency. In particular, breadth of coverage, as a measure of the population covered by digital inclusive financial services, will increase agricultural production efficiency by 0.0211 units on average for every unit of improvement. The breadth of coverage of digital financial inclusion refers to the extent to which financial services cover a wide range of people. In agriculture, an increase in breadth

of coverage means that more farmers have access to digital financial services, such as mobile payments and online loans. This wide coverage not only provides farmers with convenient ways of financial transactions and reduces transaction costs, but also helps farmers obtain timely access to production materials and market information, accelerating the efficiency of agricultural production decisions. The study shows that for every percentage point increase in the breadth of coverage of digital financial inclusion, there is a significant increase in agricultural production efficiency. This suggests that there is a positive correlation between the spread of financial services and increased agricultural production efficiency. Depth of use, on the other hand, measures the frequency and extent of farmers' use of digital inclusive financial services. Higher depth of use maps farmers' high-frequency usage habits in terms of access to financial resources, payments, and loans, which not only improves the efficiency of capital flows, but may also help farmers manage price volatility and production risks through financial innovation products such as insurance, futures, and other tools. Deeper usage means that farmers are able to dispatch funds more precisely according to production needs and optimize the allocation of capital and labor. Empirical analysis shows that when the depth of use of digital inclusive finance increases by one unit, regional agricultural production efficiency can be improved by 0.0085 units on average, reflecting the positive driving effect of depth of use on agricultural production efficiency. It is found that digital inclusive finance improves agricultural production efficiency by significantly reducing the degree of mismatch between agricultural capital and labor. This indicates that the development of digital inclusive financial services plays an important role in optimizing the allocation of agricultural resources. Among them, the improvement effect on agricultural capital mismatch is stronger than that on labor mismatch, which may be due to the fact that digital financial services are able to improve the access to and use of agricultural capital more efficiently, such as providing funds for agricultural investment through convenient loan services and reducing production risks through agricultural insurance services.

4.2 Regional Variability Analysis

The western region has a lower penetration of e-financial services compared to the eastern and central regions due to its unique geographic location and development history. However, in the area of digital financial inclusion, the western region shows greater growth potential and effectiveness. According to the study, the degree of development of digital financial inclusion has the most significant effect on the improvement of agricultural productivity in the western region. Specifically, a one-unit increase in digital financial inclusion can increase agricultural productivity in the western region by 0.0249 units. This may be due to the relatively weak foundation of financial services in the western region, and the introduction of digital inclusive finance can significantly improve the availability of financial services to farmers, which in turn effectively promotes the flow of capital and the rational allocation of labor. Regions with a high level of urbanization usually have better infrastructure, a higher level of economic development and more favorable geographical conditions, which together constitute favorable conditions for the marketization of agricultural products. In these regions, digital financial inclusion can better connect farmers and markets, reduce transaction costs and improve transaction efficiency. Farmers are able to access market information more effectively through digital means, optimize production decisions, and increase the marketing channels and scope of agricultural products. Therefore, provinces and cities with a high level of urbanization can more obviously feel the effect of digital inclusive finance on the improvement of agricultural production efficiency. Specifically, digital inclusive finance is more widely applied in these regions, and financial products and services are more diversified, meeting the diversified financial needs of agricultural production.

There are significant regional differences in the impact of digital inclusive finance on agricultural production efficiency in different regions. Due to their special geographic and economic conditions, western regions and regions with a high level of urbanization are able to make more effective use of digital inclusive finance to enhance the efficiency of agricultural production. Therefore, relevant policies should be designed with full consideration of regional characteristics in order to maximize the promotional effect of digital inclusive finance.

4.3 Analysis of Differences in Stages of Development

The rise of digital financial inclusion has brought about a sea change in agricultural production. During the period from 2011 to 2015, we witnessed the first signs of digital finance making an initial positive impact on agricultural productivity. According to statistics, every bit of growth in digital financial inclusion during this period led to a 0.0143 unit increase in agricultural output efficiency. This shows that, although in its infancy, digital financial inclusion has begun to have a positive effect on the agricultural sector by increasing access to financial services and reducing information asymmetry. Subsequently, from 2016 to 2019, digital inclusive finance entered a period of rapid development, and the effect of promoting agricultural productivity became more and more prominent. There was a significant increase in the amount of agricultural productivity gains per unit of growth in digital financial inclusion compared to the previous period. The data from this period reveal an important trend: with the continuous deepening of financial services and the advancement of financial product innovation, the application of digital inclusive finance in the agricultural sector has become more widespread, and the effect of resource

allocation optimization has become more obvious. Thus, during the rapid development period, digital inclusive finance not only expanded the penetration of financial services quantitatively, but also greatly improved the efficiency of financial services qualitatively. Technological and product innovations during this period, in particular, have played a key role in how to promote agricultural productivity more effectively. As digital inclusive financial services continue to deepen, there is reason to believe that it will have an even more profound impact on agricultural production in the future.

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