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Study on the Impact of Inclusive Finance on the Level of Green Transformation in Agriculture Based on Carbon Emission Perspective

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Abstract:

In recent years, agricultural development has been facing problems of overexploitation of resources, overlapping pollution from internal and external sources, and high carbon emission intensity in some areas. Agriculture must be transformed to a green and low-carbon model in order to achieve sustainable development. The green development of agriculture is inseparable from the allocation of sufficient financial resources, therefore, it is important to study the impact of inclusive finance on the level of agricultural green transformation to promote high-quality agricultural development. Based on the panel data of 31 Chinese provinces and cities from 2009 to 2018, this study uses the AHP-entropy method to construct the inclusive finance index; adopts the SSBM model to measure the level of agricultural green transformation, and an econometric model is constructed to investigate the impact of inclusive finance on the level of agricultural green transformation. The results show that 14 provinces and cities, such as the main grain production base in China, have high inclusive finance indices, 11 provinces and cities with mixed industrial and agricultural sectors have medium inclusive finance indices, and provinces and cities with more developed industries, such as coastal China, have low inclusive finance levels. The inclusive finance has a significant positive impact on agricultural green transformation. The level of agricultural green transformation cannot be improved without the continuous support of inclusive finance. Local governments should strengthen the concept of green ecology, continuously improve the mechanism of financial inclusion to support the development of green agriculture.

Keywords*: Inclusive finance, Level of green transformation in agriculture, SSBM model, AHP-entropy method, Econometric model.*

I. INTRODUCTION

Financial inclusion refers to the provision of effective financial services at an affordable cost to groups with financial service needs, based on the requirements of equal opportunity and the principle of commercial sustainability. Special groups such as small and micro enterprises, farmers, poor people and the elderly are the key service targets of financial inclusion in China at present.

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Agriculture is the foundation of the country and is highly relevant to financial inclusion. On the one hand, agriculture is affected by the environment and climate and has great environmental and climate externalities, so it should be one of the key areas for financial support. On the other hand, agriculture has long faced financing problems and is the key target of financial inclusion. In recent decades, China's agricultural development has effectively ensured food security, but still faces problems of overexploitation of agricultural resources, overlapping pollution from internal and external sources. Ecological Psychology is a new theoretical orientation that has emerged in recent years, emphasizing the study of human-environmental system behavior in a real environment [1], and its principle of "human-society-nature" interaction has led to the gradual application of ecological green concepts to various fields and the formation of a systematic and holistic research paradigm [2]. Based on the ecological perspective, to solve the problems faced by agricultural development, it is necessary to follow the path of green agriculture.

At present, the ways of inclusive finance to support green economic development have been gradually diversified, including credit, fund and supply chain finance, etc. Although there have been many studies on inclusive finance in supporting agriculture, it still faces many obstacles. Promoting better financial support for green agriculture in China requires synergy among all parties, and in this process, China's financial system and financial inclusion systems can complement each other. This is because indicators from an ecological perspective can reduce emissions of environmental pollutants, improve resource use efficiency, and support investment and financing activities for sustainable human development. This study can promote the protection of environmental resources and coordinated economic development through the operation of financial business, and ultimately promote the sustainable development of green agriculture.

II. LITERATURE REVIEW AT HOME AND ABROAD

2.1 Inclusive Finance

The theory of inclusive finance emerged in the 1980s, and the internationally agreed definition is that inclusive finance promotes the harmonious development of the economy through the operation of financial business. By comparing traditional finance and inclusive finance operation models, some scholars argue that inclusive finance will guide capital into rural area and thus promote sustainable economic development [3-5]; Labatt and White argue that inclusive finance can transfer environmental risks and is a financial tool to promote environmental quality [6]. Some scholars believe that inclusive finance promotes the common progress of economy, society and environment through the rational allocation of resources[7-9]; Yu Haiping believes that financial institutions can carry out finance business not only to meet the financial needs of environmental protection projects, but also to reduce their own operational risks in policy regulation and control and the financial institutions can also reduce their own operational risks and achieve their own sustainable development[10]. Chen Jiyong and Liu Weiping argue that a comprehensive "inclusive finance" credit system is needed to achieve sustainable economic development [11].

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OECD (2007) examines a country's inclusive finance level and environmental protection level as a system from a macro perspective[12]. Marcel Jeuchen takes the environmental protection attitude of the banking industry as an entry point and establishes a 5-dimensional of finance index system to measure the level of finance of 34 well-known banks around the world[13]. Zhang Lili et al. measured the development of credit and investment, etc[14]. In China based on various financial indicators of 1040 environmental protection companies. Zhou Chenying et al. constructed a finance development index system to measure the development status of different regions in China and clarified the mechanism of the role of finance on high-quality economic development [15].

2.2 Financial Inclusion and Agricultural Development

In 2005, the United Nations proposed Financial Inclusion as a new development opportunity for the rural financial market. Burgess and Pande argue that financial inclusion significantly reduces the income gap between rural and urban residents by reducing the cost of financial services and making banking services available to rural residents [16]. Dupas and Robinson argue that financial inclusion can promote rural households' savings, production equipment innovation and living standard improvement [17]. Guo Feng et al. argue that financial inclusion makes financial services commonplace by means of innovating more financial products with low market threshold access conditions [18]. Chen Baozhen and Ren Jinzheng argue that finance can help farming families achieve income growth by improving farmers' financial knowledge and loan knowledge to achieve information effects[19]. Ren Biyun and Li Liuying argue that the use of payment services and lending services has a direct contribution to inclusive rural growth [20]. Tian Juanjuan and Ma Xiaolin argue that the development of financial inclusion can have a positive impact on modern agricultural economic development and agricultural industry restructuring [21].

2.3 Literature Evaluation

By combing through the relevant literature, it is found that, firstly, there are fewer studies examining inclusive finance's impact on the level of agricultural green transformation; secondly, most of the studies stay at the overall macro level, with less in-depth; Finally, less analysis is conducted within the provincial areas. Based on this, this study innovatively constructs an inclusive finance index from the perspective of green finance; based on the panel data of 31 provinces and cities in China from 2009-2018, using the AHP-entropy method to measure the index, and using the SSBM model to measure the level of agricultural green transformation; on the basis of the evolution analysis of the index, an econometric model is constructed to examine the impact of inclusive finance on the level of agricultural green transformation.

III. RESEARCH METHODS

3.1 Analytic Hierarchy Process (AHP)

In this paper, the hierarchical analysis method is used to determine the index system of inclusive finance. Model construction is divided into the following four steps [22]:

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3.1.1 Establishment of hierarchical structure model

Firstly, a hierarchical structure model is established. Use hierarchical analysis to judge the relevant objectives for decision making and divide them accordingly from the highest level to the lowest level, as shown in Fig 1:

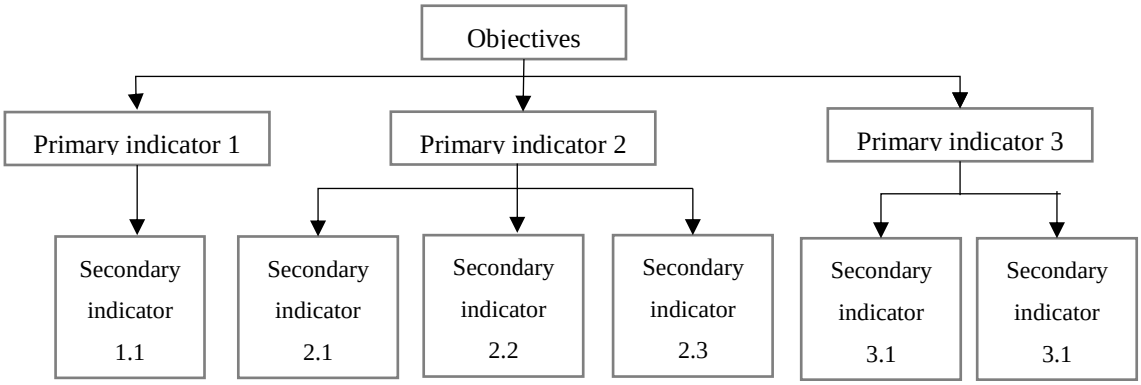

Fig 1 Hierarchical Model Diagram.

3.1.2 Construction of judgment matrix and processing of indicator weights

The degree of importance of the two indicators is scored according to the unified Saaty scale, and a pairwise orthogonal judgment matrix is obtained for n(n-1)/2 comparisons, which takes the following form[23]:

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{pmatrix} \quad (1)$$

$$p_{ij} = \frac{p_{ij}}{\sum_{j=1}^{n} p_{kj}}$$

Where the element of P satisfies: (2)

The matrix P can be obtained to satisfy: $\overline{P} = \left|\overline{p_{ij}}\right|$ (3)

The algorithm for averaging the elements of P satisfies: $\overline{P} = \frac{1}{n}\sum_{j=1}^{n}\overline{p_{ij}}$ (4)

Then the vector $y=\begin{pmatrix} y_1 & y_2 & \cdots & y_n \end{pmatrix}^T$ is the required weight vector.

After the form of the judgment matrix is clarified and the corresponding orthogonal case is determined, the specific values of the eigenvectors of the judgment matrix are normalized.

3.1.3 Test the consistency of the judgment matrix

In order to ensure the consistency of the logic in the research process, the consistency test of the judgment matrix is needed. Firstly, the specific value of CI is obtained according to the formula, and then the specific value of RI is obtained according to the formula. RI is the average random consistency

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indicator of the same order, and when the order of the judgment matrix is 2 and CI is 0 or the order of the judgment matrix is greater than 2 and the value of CR is less than 0.1, the consistency check of the judgment matrix is considered to be passed and it has consistency.

3.1.4 Hierarchical ranking and consistency testing

The overall ranking of the relevant factors relative to the important procedures of the research objectives is carried out, and the weights are quantified. Let all factors in the previous level be P_i (i = 1, 2 - - -) and their weights be m_i (i = 1, 2 - - -) respectively; all factors in this level be Q_j (j = 1, 2 - - -) and their weights be n_j (j = 1, 2 - - -) respectively, then the relevant weights of the ranking process in this level should satisfy:

$$CR = \frac{\sum_{j=1}^{m} Q_j CI_j}{\sum_{j=1}^{m} B_j RI_j} \quad (5)$$

Based on the results of the above equation, it is possible to perform the corresponding hierarchical ranking based on the specific values of the CR values at each principle level and to judge the results.

3.2 Entropy Evaluation Method

The entropy evaluation method theory holds that for the observed value of a certain evaluation index, the greater the difference between data and data, the more obvious the objective effect of the index on the whole system, i.e., the greater the entropy value of the system-related information contained in the index, which needs to be given a relatively high weight. The specific operation steps are as follows [24]:

$$e_i = -\frac{1}{\ln n}\sum_{i=1}^{n} f_{ij}\ln(f_{ij}), \quad e > 0 \quad (6)$$

$$f_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (7)$$

where f_{ij} is the value of the feature weight of the j^{th} indicator at the i^{th} level, x_{ij} characterizes the observed value obtained for the j^{th} indicator in the i^{th} level, and $\sum_{i=1}^{n} x_{ij}$ characterizes the sum of the observed values obtained for the j^{th} indicator in all the n levels.

The a_j in the following equation is expressed as the objective entropy value of the j^{th} evaluation index. According to the theory of entropy method, its calculation formula is obtained:

$$w_j = \frac{1-e_j}{n-\sum_{i=1}^{n} e_i} \quad (8)$$

Before carrying out the entropy method calculation, the data need to be dimensionless processed,

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and the logarithmic type efficacy function method was selected to process the data operationally with reference to the study of Guo Feng[25].

3.3 SSBM Model

Agricultural operations will produce the agricultural products we need, but also accompanied by undesired outputs such as surface source pollution and carbon dioxide, this paper draws on the research of Hou Mengyang [26], incorporates the concept of super efficiency (Super) on the basis of SBM model and constructs SSBM model.

$$\text{Minp} = \frac{\frac{1}{m}\sum_{i=1}^{m}(\bar{x}/x_{ik})}{\frac{1}{s_1+s_2}\left(\frac{\sum_{s=1}^{s_1}\bar{y}^g}{y_{sk}^g}+\frac{\sum_{s=1}^{s_1}\bar{y}^{-b}}{y_{qk}^b}\right)} \tag{9}$$

$$\begin{cases} \bar{x} \geq \sum_{j=1,\neq k}^{n} x_{ij}\lambda_j; \bar{y}^g \leq \sum_{j=1,\neq k}^{n} y_{sj}^g\lambda_j; \bar{y}^g \leq \sum_{j=1,\neq k}^{n} y_{sj}^g\lambda_j; \\ \bar{x} \geq 0, i = 1,2,\dots,m; j = 1,2,\dots,n; \\ j \neq 0; s = 1,2,\dots s_1; q = 1,2,\dots,s_2 \end{cases} \tag{10}$$

Where p is the efficiency evaluation indicator; x, y^g, y^b represent input indicators, desired output indicators and non-desired output indicators, respectively; n denotes the number of desired output indicators; s_2 represents the number of non-desired output indicators.

IV. IIDEX MEASUREMENT

4.1 Inclusive Finance Index Measurement

4.1.1 Indicator Selection

In terms of indicator selection, drawing on Yin Zhichao's study[27], inclusive finance is divided into demand and supply levels, with the demand level referring to the depth of inclusive finance use by farmers and agriculture-related enterprises, mainly including three indicators of per capita agriculture-related finance, loan balance per 10000 people, and the ratio of agriculture-related expenditure amount; the supply level refers to the protection of inclusive finance, with the main indicators set from the loan special statistical system, covering the indicators of China's commercial banks on forestry development, forestry investment, ecological construction and protection, as well as the efficiency of loans. Specifically, it includes forestry support and guarantee investment, forestry development project loans and ecological construction and protection completion investment. As shown in Table I.

TABLE I. Inclusive Finance Indicator System

Primary indicators	Secondary indicators	Indicator definition	Data source
Demand level	Per capita agriculture-related finance[28]	Agriculture-related expenditure finance/total number of provincial farmers	Source: People's Bank of China, China Finance Society, China Banking

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The depth of use of inclusive finance	Rural loan balance per 10000 people[29]	Number of financial institutions of various types in the province/total number of farmers (10000)	Regulatory Commission, China Securities Regulatory Commission, China Insurance Regulatory Commission, State Administration of Foreign Exchange
	Proportion of agricultural expenditure[30]	Amount of agricultural expenditure/total financial expenditure	
Supply level	Forestry support and guarantee investment	Loan for green agriculture development project/total amount of forestry support and guarantee for the current year in provincial region	Source: Ministry of Agriculture of China, State Forestry Administration, National Bureau of Statistics of China
The protection of inclusive finance.	Loans for forestry development projects	Provincial forestry investment completed in the current year	
	Investment in ecological construction and protection	Total investment in provincial ecological construction and protection	
Degree of finance support for de-carbonization	Regional environmental protection tax strength	Regional sewage charges (environmental tax)	Source: China Environmental Protection Administration

Considering that this study is to achieve agricultural productivity improvement and energy saving and emission reduction through the development of inclusive finance, the indicator of the degree of financial support for agricultural de-carbonization, i.e., the environmental taxation strength of the region, is added to the indicator system, which is expressed by using the emission fee in the region.

4.1.2 AHP-Entropy Method Measurement

After dimensionless processing of the indicators, the "AHP-Entropy Method" was used for the comprehensive measurement of the inclusive finance index.

The results of relevant index weights calculation are shown in Table II.

TABLE II. Weight Calculation Results of Inclusive Finance Indicators

Primary indicators	Primary weight	Secondary index	Information entropy value
Depth of use of inclusive finance	0.3129	Per capita agriculture-related finance	0.9764
		Rural loan balance per 10,000 people	0.9855
		Proportion of agricultural expenditure	0.9630

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Inclusive Financial Protection efforts	0.3832	Forestry support and guarantee investment	0.9944
		Loans for forestry development projects	0.9910
		Investment in ecological construction and protection	0.9788
		Green finance loans efficient	0.9438
Degree of inclusive finance support for de carbonization	0.3039	Regional environmental protection tax strength	0.9790

4.1.3 Analysis of Inclusive Finance Index from Provincial Perspective

Based on the panel data of 31 Chinese provinces and cities in 2009-2018, the AHP-entropy method is used to measure the inclusive finance index, and the trends of inclusive finance are shown in Table III.

TABLE III. Distribution of Inclusive Finance Index in 31 Provinces and Cities of China in 2009 To 2018

Province	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Beijing	18.7742	15.4238	17.9822	22.6382	24.4513	26.9040	23.4152	25.3728	24.1208	42.0529
Tianjin	9.4589	10.6744	12.8097	13.9970	12.3612	13.9013	13.4286	13.4869	10.8012	21.9885
Hebei	30.8188	29.5506	33.4726	36.6368	35.0907	37.8878	39.8197	40.7287	45.4327	44.3849
Shanxi	31.8580	33.0625	33.6824	35.8668	36.6195	38.5260	38.1006	37.3781	35.3643	48.6867
Inner Mongolia	43.5845	38.1104	43.6415	48.4639	47.3703	46.7764	49.7224	54.5951	53.2483	63.1275
Liaoning	30.7012	29.1713	33.6826	39.5804	38.3032	36.9809	37.4964	35.2619	33.7651	39.8879
Jilin	40.4869	42.2144	44.3328	43.9588	41.0936	43.1728	42.4199	44.0065	42.6543	55.7972
Heilongjiang	43.0714	42.0158	52.4893	52.9526	52.8183	53.4828	56.6684	62.5320	67.3706	62.3299
Shanghai	17.0214	15.2478	18.7805	21.0102	20.9366	20.8048	20.8015	21.7932	36.3840	45.0651
Jiangsu	29.1014	28.1101	31.2063	34.3538	35.0516	38.2485	36.6561	35.1506	31.6428	38.2609
Zhejiang	21.4465	24.0029	24.5234	28.0532	28.2310	30.4857	31.5718	33.0200	29.2742	40.8930
Anhui	34.9094	34.8653	36.3490	38.6953	39.4817	40.8545	40.6013	39.6947	38.3542	46.7300
Fujian	28.6783	26.8038	32.4347	32.3623	30.9206	32.8747	36.6164	35.5677	29.0938	35.4604
Jiangxi	35.7794	32.3279	34.6140	36.2542	34.8637	36.9758	37.1849	37.8212	39.3740	38.9398

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Shandong	44.0578	41.4642	44.9261	53.1545	51.5070	50.8530	51.4728	51.4778	43.7671	59.9615
Henan	35.2471	34.1149	36.7090	39.7897	37.7226	38.7714	39.0579	38.7495	40.0954	37.3466
Hubei	36.0445	34.1100	37.0893	39.2735	37.3133	37.5165	37.9137	37.8484	38.9950	42.2632
Hunan	45.6195	44.8808	47.2037	50.5657	47.8355	50.1463	51.7956	50.4074	45.6677	63.6458
Guangdong	21.2016	22.0564	24.8970	27.6824	27.9349	28.3017	30.9238	29.5242	26.9703	36.8651
Guangxi	45.3307	45.8320	48.1437	49.7725	48.3215	47.8917	49.3556	54.2678	55.1645	50.3470
Hainan	51.3276	49.1625	49.2413	48.7719	46.7410	47.0739	47.7485	45.6119	48.6728	39.9013
Chongqing	17.2647	20.7885	20.3726	20.2331	19.6845	21.6130	22.4725	22.6854	24.4362	22.6510
Sichuan	44.9088	42.4084	44.2083	48.1592	48.1220	50.6657	51.3851	52.8266	50.1337	59.6486
Guizhou	39.5822	39.3096	42.7533	42.1772	42.0138	45.0453	45.7004	47.7900	52.1317	48.9736
Yunnan	33.8270	37.3004	38.2913	40.3795	40.1883	39.8627	41.2210	42.8081	49.6948	35.0342
Tibet	41.3068	37.0696	36.6993	39.6137	34.8886	35.0056	34.2983	35.2598	33.1810	39.5887
Shaanxi	34.3298	33.8171	34.8404	37.7311	37.1330	38.4470	38.3314	39.4764	38.4463	44.2083
Gansu	32.9918	30.5692	34.0014	37.2385	36.5669	38.8367	38.9323	39.8117	43.7723	39.2193
Qinghai	35.2216	32.6320	31.7933	36.7846	35.6019	37.4466	38.1999	38.6794	37.2989	47.9602
Ningxia	38.3212	34.0451	39.2233	40.4221	37.7372	38.1779	37.5807	35.7389	34.0029	45.9407
Xinjiang	41.8202	36.7838	38.2520	40.3627	39.5137	39.5475	42.5980	42.1884	49.3392	34.0915

Table III show the results of the inclusive finance index distribution of 31 provinces and cities in China from 2009 to 2018, respectively. From the distribution, it can be found that 14 provinces in China, including Xinjiang, Shandong and Hainan, have higher inclusive finance indices. In contrast, 11 provinces, including Qinghai, Shanxi and Yunnan, have a medium financial inclusion index. The financial inclusion index of Beijing, Chongqing and Shanghai is low. The reason for this is that the provinces with high indices are the major food or other crop production bases in China, and the financial inclusion support for local agricultural production is generally good, compared to the 11 provinces in the middle of the range, which are the major inland provinces in China with a mixed industrial structure of agriculture and industry, and not major food and crop producing regions. In contrast, Beijing and Shanghai are major open areas in coastal and inland China, as well as major industrial areas, and these areas show a high trend of

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urbanization, and the lack of market space leads to the poor performance of the local inclusive finance index.

Further, during the time series change from 2009 to 2018, the biggest gap between the before and after comparison is in Central China, firstly, the performance of the inclusive finance index in Hubei and Jiangxi provinces changes from high to low, which indicates that the local economic development is gradually shifting from agricultural areas to mixed industrial and agricultural development areas. In contrast, the inclusion index performance in Henan and Anhui provinces has changed from low to high during the development process of this decade, which indicates that the local inclusion financial support for agriculture is in a rising trend year by year. In the coastal areas of East China and South China, these areas have undergone long-term urbanization development and industrialization, and the performance of the financial index is lower, and the key direction of local inclusive financial inclusion is not agriculture.

4.2 Measurement of the Level of Green Transformation in Agriculture

4.2.1 Selection of Indicators

In agricultural production input indicators, there are labor, land, machinery allocation and resource consumption, which are measured by proxy variables such as provincial rural population, provincial arable land area, and provincial agricultural machinery quantity, respectively; the desired output indicator is agricultural value added, and the annual value added of agricultural production in the provincial area is selected for measurement; in non-desired output indicators, combined with ecological psychology and "carbon neutral", the carbon emission indicators of agriculture are chosen, and the total carbon emission of the province is measured in the current year (Table IV).

TABLE IV. Indicator Description

Indicators	Refined indicators	Indicator definition
Agricultural production input index	Labor	Provincial rural population
	Land area	Provincial arable land area
	Mechanical allocation and resource consumption	Number of provincial agricultural machinery
Output indicators	Agricultural Value Added	N-year agricultural output value-N-1 annual agricultural output value
Unexpected output	Agricultural carbon emissions	Provincial total annual carbon emissions

4.2.2 Measurement Results of Agricultural Green Transformation Level Based on SSBM Model

Based on the relevant data of 31 provinces and cities in China, the super-efficient SSBM model was used to measure the level of green transformation in agriculture.

The measures of the level of green transformation in agriculture are divided into three types: comprehensive index, pure index and scale index, and the three indices can be divided into Malmquist

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index, technical efficiency index and technical progress index, respectively. The table of agricultural green transformation level indices at the national level is shown in Table V. From the time series, the integrated Malmquist index and pure Malmquist index are greater than 1 in all years except 2017, and the scale Malmquist index is below 1 in 5 years and greater than 1 in 4 years, showing an irregular trend. The integrated Malmquist index shows a decreasing trend from 2011 to 2015, after which it increases. The cross-sectional comparison of the mean values of different indices shows that the composite technical progress index is the highest and the scale technical efficiency index is the lowest.

TABLE V. Results of National Agricultural Green Transformation Level Index

Year	Composite Malmquist index	Comprehensive Technical Efficiency Index	Comprehensive Technical Progress Index	Pure Malmquist index	Pure technical efficiency index	Pure technological progress index	Scale Malmquist index	Scale technical efficiency index	Scale technology progress index
2010	1.1500	1.0181	1.1300	1.1475	1.0032	1.1438	1.0027	1.0149	0.9880
2011	1.1710	0.9639	1.2148	1.1727	1.0044	1.1675	0.9986	0.9597	1.0405
2012	1.0870	0.9935	1.0940	1.0739	1.0021	1.0716	1.0122	0.9914	1.0209
2013	1.0810	0.8380	1.2897	1.1212	0.9987	1.1226	0.9639	0.8390	1.1488
2014	1.0440	0.9804	1.0651	1.0540	1.0002	1.0538	0.9906	0.9802	1.0107
2015	1.0450	0.9744	1.0720	1.0443	1.0007	1.0436	1.0002	0.9738	1.0272
2016	1.0650	0.8945	1.1910	1.2105	1.0055	1.2038	0.8801	0.8896	0.9894
2017	0.9870	1.0980	0.8984	0.8635	0.9996	0.8639	1.1424	1.0984	1.0400
2018	1.1140	0.9938	1.1207	1.2365	1.0008	1.2355	0.9008	0.9930	0.9071
Mean	1.0827	0.9727	1.1195	1.1027	1.0017	1.1007	0.9879	0.9711	1.0192

V. Regression Analysis

5.1 Variable Settings

In this paper, the explanatory variables, core explanatory variables and control variables are selected as follows, and the constructed indicator system is shown in Table VI. The level of green transformation in agriculture is the explanatory variable, the inclusive finance index is the core explanatory variable, and the proportion of grain sown area to crop sown area, the proportion of value added of secondary industry to value added of GDP and total import and export are the control variables.

TABLE VI. Variable Setting

Variable attribute	Variable name and code	Variable definition
Explained variable	Green Transformation Level in Agriculture (GAC)	Comprehensive technical efficiency index values in the level of green transformation of agriculture constructed based on SSBM model
Explanatory variables	Inclusive finance index (IF)	The value of the inclusive finance index based on the AHP-entropy method.
Control variable	Grain sown area/crop sown area (K1)	Provincial annual grain sown area/provincial annual crop sown area

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1159-1176
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

	The value added of the secondary industry as a proportion of GDP value added (K2)	Provincial annual secondary industry value added/provincial annual GDP value
	Total Import and Export (K3)	Provincial annual normalized total import and export

5.2 Data Sources

The sample data covers 31 provincial and municipal administrative regions in China from 2009-2018. The data used for measuring the level of green transformation in agriculture are obtained from the China Statistical Yearbook and the China Rural Statistical Yearbook, and the inclusive finance index is obtained from the annual statistics of the People's Bank of China, the China Finance Society, the State Administration of Foreign Exchange, the Ministry of Agriculture of China, the State Forestry Administration, the National Bureau of Statistics, the Ministry of Water Resources, the China Meteorological Administration and the China Customs. In order to ensure the comparability of statistical data, the year of 2009 was used as the base period, and all relevant variables involving monetary measures were deflated.

5.3 Empirical Analysis

5.3.1 Composite Index Regression Results

TABLE VII Composite Index Regression Results

	Composite Malmquist index	**Composite technical efficiency index**	**Composite technical progress index**
IF	0.016**	0.004*	0.012*
	(2.821)	(2.157)	(2.056)
K1	0.000	0.000**	0.001**
	(26.256)	(-9.559)	(25.505)
K2	0.010**	0.005**	0.004
	(2.868)	(3.032)	(1.040)
K3	-0.464*	-0.145	-0.192
	(-2.844)	(-1.080)	(-0.637)
Cons	0.082	0.637*	0.480
	(0.228)	(5.203)	(1.207)
R^2(w)	0.117	0.019	0.062
F Test	(4,253)=3151.310 p=0.000	(4,252)=2641.813, p=0.000	(4,252)=6741.666, p=0.000

Note:*p<0.05, **p<0.01, t-value in parentheses.

From Table VII, it can be seen that the effects of inclusive finance on both the composite Malmquist index, composite technical efficiency index, and composite technological progress index show different levels of significance, indicating that inclusive finance can have a significant positive effect on the level of

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1159-1176
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

green transformation in agriculture. From the regression results of the composite Malmquist index, the area of grain sown/crop sown shows a significance at 0.01 level (t=26.256, p=0.000), indicating that the area of grain sown/crop sown will have a significant positive influence relationship on the level of green transformation in agriculture. For the value added of secondary industry as a percentage of GDP, it shows a significant level of 0.01 (t=2.868, p=0.0040), which indicates that the value added of secondary industry as a percentage of GDP has a significant positive influence on the level of green transformation in agriculture. For total imports and exports, it shows a significant level of 0.01 (t=-2.844, p=0.005<0.01) and the regression coefficient value is -0.464< 0, which indicates that it has a significant negative effect on the level of green transformation in agriculture.

5.3.3 Pure Index Regression Results

TABLE VIII. Pure Index Regression Results

	Pure Malmquist index	Pure technical efficiency index	Pure technological progress index
IF	0.021**	0.004*	0.014*
	(3.921)	(3.421)	(2.440)
K1	0.000**	0.000**	0.001**
	(22.275)	(-8.879)	(23.512)
K2	0.017**	0.005**	0.010*
	(4.323)	(3.134)	(2.244)
K3	-0.231	-0.047	-0.130
	(-1.010)	(-0.683)	(-0.495)
Cons	-0.441	0.588**	0.134
	(-1.244)	(4.842)	(0.339)
R^2(w)	0.191	0.034	0.088
F Test	(4,253)=4093.127 p=0.000	(4,252)=2682.842, p=0.000	(4,252)=14787.628, p=0.000

Note:*p<0.05, **p<0.01, t-value in parentheses.

From the Table VIII, it can be seen that the effects of inclusive finance on both pure Malmquist index, pure technical efficiency index, and pure technological progress index show different degrees of significance, indicating that the inclusive finance index will have a significant positive influence relationship on the level of green transformation in agriculture. From the regression results of the pure Malmquist index, the area of grain sown/crop sown and the share of value added of secondary industry in GDP all have a significant positive influence relationship on the level of green transformation in agriculture.

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1159-1176
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

5.4.4 Scale Index Regression Results

TABLE IX Scale Index Regression Results

	Scale Malmquist index	Scale technical efficiency index	Scale technology progress index
IF	-0.003	-0.002	-0.002
	(-1.747)	(-1.210)	(-1.351)
K1	-0.000*	0.000	-0.000
	(-2.093)	(-1.425)	(-1.626)
K2	-0.006	-0.001	-0.006
	(-1.932)	(-0.672)	(-1.733)
K3	-0.131	-0.082	-0.020
	(-0.787)	(-0.671)	(-0.139)
Cons	1.421**	1.103**	1.356**
	(7.708)	(12.329)	(7.555)
R^2(w)	0.117	0.004	0.020
F Test	(4,253)=3151.310	(4,252)=19.443,	(4,252)=0.972,
	p=0.000	p=0.000	p=0.423

Note:*p<0.05, **p<0.01, t-value in parentheses.

From Table IX, it can be seen that the effect of inclusive finance on either the scale Malmquist index, the scale technical efficiency index, or the scale technological progress index does not show significance, indicating that at the scale efficiency level, the inclusive finance index does not have an impact relationship on the level of green transformation in agriculture. None of the coefficients of the control variables are significant, indicating that none of the control variables will have a significant effect on the level of green transformation in agriculture at the scale efficiency level.

5.3.5 Resolution of Endogenous Problems

In order to avoid endogeneity problems due to omission of some variables, this paper further includes one period lags of the core explanatory variables as instrumental variables and performs complementary regression tests using two-stage least squares. The correlation results are shown in Table X.

TABLE X. Fixed Effect (FE) Model And Two-Stage Least Squares(2SLS) Regression Results.

Variables	FE	2SLS
IF	0.004**	0.525*
	(3.046)	(3.833)
K1	0.000	-0.002
	(-1.751)	(-1.852)
K2	0.006**	0.005**
	(4.084)	(4.235)
K3	-0.136	-0.141
	(-0.884)	(-0.962)

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1159-1176
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

cons	0.571**	0.453**
	(6.415)	(3.833)
R^2	0.717	0.543
First stage F value		79.36**
Wald value		$\chi^2(1)=3.865, p=0.049$
N	288	288

* p<0.05 ** p<0.01

The results of the endogeneity problem analysis of the 2SLS show that the first stage has a large F-value, indicating that there is no if instrumental variable problem. The regression results of the second stage show that the effect of inclusive finance on the level of green transformation in agriculture remains significantly positive and above the 5% significance level, indicating that the conclusion that inclusive finance has a catalytic effect on the level of green transformation in agriculture is robust.

VI. Conclusions and Recommendations

6.1 Research Conclusion

In this study, the financial inclusion index was firstly constructed by using the AHP-entropy weight method. From the perspective of the analysis results, among all the secondary indicators, the largest influence on the inclusive finance index is the indicator of the proportion of agriculture-related expenditures, whose weight coefficient reaches 0.1541, while in contrast, the lowest proportion of forestry support and related safeguard investment is 0.0232.

Second, the super-efficient SSBM model is used to measure the level of agricultural green transformation in 31 Chinese provinces and cities. From 2011 to 2016, the pure technical efficiency value of agricultural green transformation level in China was low, but from 2017 onward, the level of agricultural green transformation changed from a decreasing to an increasing trend.

Finally, the regression results through the fixed-effects model show that the effect of the core explanatory variable inclusive finance on the level of green transformation in agriculture is always significantly positive at the combined efficiency and pure efficiency levels, indicating that the development of inclusive finance can have a significant contribution to the total factor productivity of green agriculture. Regarding the solution of the endogeneity problem, with the assistance of the 2SLS model, inclusive finance has a 54.30% degree of explanation on the level of green transformation in agriculture, which basically excludes the possibility of endogeneity problem.

6.2 Research Recommendations

Promoting the development of green industry requires efforts from the perspective of the whole industrial chain. There are many elements related to the inclusive finance index, and relevant departments in provinces and cities can formulate a series of policies and measures to promote the development of green industries according to the national unified planning combined with ecological concepts, and adopt

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
March-April 2022 Page No. 1159-1176
Article History: Received: 08 February 2022, Revised: 10 March 2022, Accepted: 02 April 2022, Publication: 30 April 2022

positive incentive mechanisms. In addition, the government can also consider replacing the current financial subsidy path for green industries and granting financial subsidies directly to green agriculture in the form of credit subsidies, so as to enhance the utilization rate and fairness and universality of government funds by market means. Only then will agriculture have a sense of urgency and drive to protect the environment and reduce pollution, and promote the green transformation of agriculture.

The level of green transformation in agriculture cannot be improved without the continuous support of inclusive finance for agricultural production. Local governments should make full use of the current financial market to continuously improve the mechanism of financial inclusion to support the development of green agriculture and lower the threshold for agriculture to receive financial inclusion support. At the same time, there are obvious geographical differences in the performance of the inclusive financial index in each region, for which each local government should implement differentiated inclusive financial support policies in light of the actual local situation, and the investment of relevant resources should be focused on agricultural production areas to effectively bring into play the inclusive attributes and positive spillover effects of inclusive finance.

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Forest Chemicals Review
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