Coupling relationship between financial inclusion and agricultural green total factor productivity: Mechanism analysis and empirical research

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Coupling relationship between financial inclusion and agricultural green total factor productivity: Mechanism analysis and empirical research

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Abstract

Based on the panel data of 30 provinces in China from 2006 to 2019, this paper measures the coupling coordination degree of financial inclusion and agricultural green total factor productivity (AGTFP), and uses Dagum Gini coefficient and spatial feature analysis method to study the regional difference and spatial agglomeration state of coupling coordination degree. On this basis, it further discusses the impact of the improvement of the coupling co scheduling of financial inclusion and AGTFP on the urban-rural income gap. The results show that the overall level of financial inclusion and AGTFP is low, but both show a slow upward trend, and the degree of coupling and coordination between the two continues to improve, which has developed from the very low coordination stage to the primary coordination stage. The two show the characteristics of alternating changes of the relative lag of AGTFP and the relative lag of financial inclusion. At present, the main performance is the relative lag of financial inclusion. There are great regional differences in the coupling coordination degree of financial inclusion and AGTFP, but this regional difference is gradually narrowing; And its spatial pattern presents the characteristics of global positive autocorrelation and local spatial pattern evolution. Further discussion found that the improvement of the coupling and co scheduling of financial inclusion and AGTFP is conducive to narrowing the income gap between urban and rural areas. Therefore, in order to realize the sustainable development of agriculture, it is suggested to coordinate the relationship between financial inclusion and AGTFP.

Keywords Financial inclusion • Agricultural green total factor productivity • Coupling coordination • Sustainable development • Regional differences

Declaration

No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication. We declare that the work described was original research that has not been published previously, and not under consideration for publication elsewhere, in whole or in part. Our manuscript has not been submitted to a preprint server prior to submission on ESPR. All authors contributed to the completion of the manuscript. Guibo Liu (First Author) is responsible for conceptualization and writing original draft. Chenglei Liang is responsible for data curation and formal analysis. Xiaoxian Gong (Correspondence Author) is responsible for methodology and writing-review & editing. Data available on request from the authors. Our manuscript does not contain any studies with human participants or animals performed by any of the authors, so ethics approval and consent to participate section is not applicable. No funding has been received for this manuscript.

Introduction

China's agricultural economic development has made great achievements. The added value of agriculture, forestry, animal husbandry and fishery increased from RMB 102.751 billion in 1978 to RMB 7356.707 billion in 2019, with an average annual growth rate of nearly 11%. However, China's agriculture has not only achieved great achievements, but also paid a great environmental price, which is mainly reflected in the intensification of agricultural non-point source pollution, excessive consumption of resources, deteriorating ecological environment and so on. At present and for a long time to come, the goal of China's agricultural production is no longer simply to pursue the increase of output, but to pay more attention to the improvement of quality, the sustainable utilization of resources and the protection of agricultural ecological environment (Yang et al.2019). As an important engine driving economic growth other than input factors, total factor productivity has become an important basis for judging the high-quality development of agricultural economy. However, the traditional measurement of total factor productivity often only considers the input constraints of production factors such as capital and labor, and ignores the consumption of resources and environment, which makes its evaluation of social welfare changes and economic performance inaccurate, and leads to the deviation of policies formulated on this basis(Hailu & Veeman 2000). In order to measure economic growth considering the cost of resources and environment, some scholars incorporated resource and environmental factors into productivity measurement, and called the input-output efficiency considering resource consumption and pollutant emission as AGTFP (Qskam 1991; Zhiyang et al.2017;Yang et al.2019). Therefore, the key to the future development of China's agriculture lies in improving green total factor productivity and agricultural green sustainable development.

The financial system is the core and cornerstone of a national or regional economic system. How to build a highly adaptive and competitive modern financial system is the key link to promote China's sustainable economic development. However, due to special historical reasons and institutional background, the price distortion of financial products and the imbalance of factor allocation structure are common. Agriculture is facing a serious problem of financial exclusion, which inhibits agricultural scientific and technological innovation and the transformation and upgrading of industrial structure. How to reverse the deviation of resource allocation and guide more resources to gather in green development industries is not only the objective requirement of financial services for the real economy, but also the responsibility and mission of finance (Hui 2021). Financial inclusion can provide financial support for new agricultural business entities to participate in green industry projects, promote new agricultural entities to accelerate technological innovation, guide farmers to enter a new collective business model, and provide assistance for the transformation and upgrading of agricultural green development, so as to promote the sustainable development of agriculture.

In view of the relationship between financial development and total factor productivity, early scholars mainly analyzed the mechanism of financial development affecting total factor productivity from a theoretical perspective. Greenwood and Jovanovic (1990) analyzed the interaction mechanism between financial development and economic growth under the background of information asymmetry, and believed that financial intermediaries can effectively overcome adverse selection and moral hazard caused by information asymmetry by virtue of their own advantages, and allocate funds to investment projects with high profit prospects, so as to promote the growth of total factor productivity. Funte and Jose (1996) believe that the financial system promotes the flow of financial resources to high-yield and high-risk technological innovation projects through the functions of dispersing risks, reducing information costs and transaction costs, and improves the level of total factor productivity by promoting

technological progress. Tran and koker (2019) believe that the evaluation requirements of financial institutions for enterprises to obtain financing loans will become higher and higher with the development of finance, which is conducive to supervising company managers to strengthen corporate governance, so as to promote the improvement of total factor productivity by alleviating the financing constraints of technological innovation enterprises. Deonanan et al. (2020) believe that financial development can promote transactions by reducing equity transaction costs, so that investors do not need to consider too much liquidity constraints during long-term investment, but pay attention to long-term projects with high return and high efficiency, so as to promote the growth of total factor productivity. Many scholars also analyze the impact of financial development on total factor productivity from the empirical level. Arizala et al. (2013) based on the industrial data of 77 countries from 1963 to 2003, empirical analysis found that financial development has a significant positive effect on total factor productivity growth. Benhabib and Spiegel (2000) found that different financial indicators have different effects on total factor productivity. When the national fixed effect is not included, the financial deepening index and the ratio of private sector credit to GDP have a significant positive effect on total factor productivity. If the national fixed effect is included, only the ratio of private sector credit to GDP has a positive effect. Rioja and valev (2004) found that there is regional heterogeneity in the impact of financial development on total factor productivity, and financial development has a significant positive impact on the growth of total factor productivity in developed countries; In developing countries, the impact of financial development is mainly to promote capital accumulation and has no significant impact on total factor productivity.

On the whole, scholars have mainly studied the impact of financial development on the growth of total factor productivity, few scholars pay attention to the relationship between financial inclusion and AGTFP, and there is a lack of literature dedicated to the coupling and coordination relationship between financial inclusion and AGTFP. In view of this, after explaining the theoretical logic and coupling mechanism of financial inclusion and AGTFP, this paper uses the coefficient of variation method and SBM super efficiency model with unexpected output to measure financial inclusion and AGTFP in various provinces of China, and makes an empirical study on the coupling and coordination relationship between them. It further analyzes the impact of the improvement of the coupling and coordination relationship between financial inclusion and AGTFP on the urban-rural income gap, and puts forward some suggestions to promote the coordinated development of financial inclusion and AGTFP, in order to provide new ideas for agricultural sustainable development.

Theoretical analysis on the coupling and coordination of financial inclusion and agricultural green total factor productivity

The theoretical logic of financial inclusion and agricultural green total factor productivity

The theoretical logic of financial inclusion. According to the definition of the world bank, financial inclusion refers to a financial system that enables all social strata and groups to enjoy financial services widely and without obstacles (Allen et al.2016). The development of financial inclusion breaks through the financial boundary defined by the original formal financial institutions, improves the accessibility and use depth of investment and financing services for vulnerable groups, improves the efficiency of financial resource allocation, and then realizes the whole socio-economic growth and income equity(Hannig & Jansen 2015). However, financial organizations are essentially a collection of interest demands from different social strata. Although financial transactions between people can form a relationship of mutual trust, they must achieve the goal of interest compatibility and sustainable development of the financial system through intertemporal institutional arrangements and incentive

mechanism design on the basis of full information disclosure and repeated game (Soppe 2004). We cannot simply understand financial inclusion as providing low-cost financial services to vulnerable groups. In essence, financial inclusion still belongs to commercial finance. The commercial essence of financial inclusion requires that it must pursue profit maximization according to the cost-benefit principle, that is, the operation of inclusive financial institutions must give consideration to efficiency and fairness, and be able to achieve their own sustainable development while providing financial services for vulnerable groups (Zhang & Zhang 2021), which is the theoretical logic and development goal of financial inclusion.

Theoretical logic of agricultural green total factor productivity. AGTFP is to bring factors such as agricultural resource consumption and pollution emission into the scope of economic growth on the basis of traditional productivity. It is the real agricultural production efficiency considering the cost of resources and environment, and can fully reflect the comprehensive competitiveness of regional agricultural economic development (Lv & Zhu 2019). AGTFP is not limited to the greening of agricultural input and output. It can lead to the greening of the whole agricultural system, including the greening before, during and after production. It has the dual objectives of agricultural production and agricultural ecological environment protection. This is highlighted in the following aspects: First, AGTFP promotes the transformation of agricultural production and farmers' lifestyle to green and environmental protection, and further promotes the adjustment of agricultural industrial structure and the transformation of agricultural development mode through the development of new business forms such as ecological agriculture, circular agriculture, biological agriculture, sightseeing and leisure agriculture and smart agriculture; Secondly, AGTFP organically connects the majority of farmers with the green development of the industry through the extension of the industrial chain, so that farmers can fully share the benefits of industrial quality and efficiency improvement; At the same time, the emergence of a series of new industries and new formats has also widened the channels for increasing farmers' income. Finally, AGTFP transforms traditional agriculture through the introduction of new factors such as technological innovation and the optimal allocation of factors, so as to inject strong power into rural economic and social development, which is also in line with the current concept of sustainable development and the requirements of agricultural supply side structural reform.

Coupling mechanism of financial inclusion and agricultural green total factor productivity

According to the viewpoint of system theory, a system is an organic whole with a certain function composed of several elements connected in a certain structural form, and coupling refers to a dynamic correlation between different systems. Benign coupling relationship is the overall evolution process of systems from simple to complex, from disorder to order, from low-level coordination and optimization to high-level coordination and symbiosis on the basis of proper cooperation and harmony. If a benign coupling relationship is formed between the two systems, the elements of the system will coordinate with each other, resulting in the overall effect of $1 + 1 > 2$, so as to promote the common development of the two systems.

In essence, financial inclusion and AGTFP represent two different systems. The main service objects and development objectives of financial inclusion and AGTFP are internally consistent. Both of them take farmers and other vulnerable groups as the main service objects and rural industrial transformation and upgrading and sustainable economic development as the main objectives. There must be a coupling relationship between the two systems. The improvement of the coupling relationship between financial inclusion and AGTFP is conducive to the virtuous cycle of credit funds, which is also conducive to the

commercial sustainability of financial inclusion, so as to realize the win-win of economic and social benefits of financial inclusion.

The development of financial inclusion can drive the improvement of AGTFP through a variety of ways. First of all, financial inclusion can provide low-cost credit funds for new agricultural operators in the early stage of entrepreneurship and lay the foundation for the entrepreneurial development of new agricultural operators (Zhang & Zhang 2021),and the endogenous technological progress caused by innovation plays an important role in improving the productivity of agricultural green elements. Secondly, financial inclusion can play a leading role. The flow of credit funds can drive the flow and aggregation of production factors such as technology, talents, capital and other social resources to the field of green agricultural development, so as to continuously promote the increase of green agricultural output scale and output efficiency. Finally, financial inclusion can not only alleviate the financing constraints of agricultural production subjects such as farmers through financing funds, but also provide strong support for the transformation and upgrading of industrial structure and the green and sustainable development of rural economy by giving full play to its resource allocation ability and risk sharing ability.

Financial inclusion is mainly committed to meeting the credit exclusion faced by vulnerable groups, but financial inclusion is not a social welfare and charity, and its business sustainability also needs to be paid enough attention. The promotion of AGTFP has brought opportunities and renewal of business philosophy to the development of financial inclusion. On the one hand, in the process of improving AGTFP, the economic opportunities faced by farmers and other agricultural production entities have been continuously improved, and the endogenous power of farmers and other agricultural production entities to use credit funds to invest in production and expand productive activities has been released, so that the effective credit demand of farmers and other agricultural production entities has increased, which plays an important role in effectively improving the efficiency and effect of inclusive financial services in agricultural production. On the other hand, the renewal of agricultural development concept and the transformation of development mode contained in AGTFP objectively promote inclusive financial institutions to continuously innovate financial products and services for their own better development. They will pay more attention to the development and hematopoiesis of credit funds, pay attention to the green development of agriculture and the transformation and upgrading of rural industries, and pay attention to the matching between credit supply and capital demand of agricultural industry chain, which is conducive to the sustainability of inclusive financial services for rural economic development.

Research design

Data sources

Because the data in Tibet are missing, the Chinese mainland is selected as the research object in the other 30 provinces except Tibet. The sample time is set from 2006 to 2019. The original data of each indicator comes from China Statistical Yearbook, China Rural Statistical Yearbook, China Financial Yearbook, as well as the statistical yearbook and regional financial operation report of each province.

Measurement of financial inclusion

At present, the academic community has not formed a generally recognized financial inclusion evaluation index system. Combined with the connotation and development concept of financial inclusion, and referring to the analysis report on China's inclusive financial indicators (2019) issued by the people's Bank of China and the research of relevant scholars(Sarma & Pais 2011;Hu et al.2021), this paper constructs an financial inclusion evaluation index system with 10 specific indicators from the three

dimensions of accessibility of financial services, usage of financial services and utility of financial services. Accessibility of financial services refers to the degree of penetration of financial services provided by a certain area among its users, that is, the extent to which residents in that area have access to or use financial services. Usage of financial services refers to the ability of residents in a certain area to obtain financial products and services. It measures the convenience of residents in obtaining corresponding financial products and services. Utility of financial services refers to the use efficiency of financial products by the economic system and financial institutions. It measures the degree of use of financial services provided by a region. The specific indicators of each dimension are shown in Table 1.

Table 1 Financial inclusion evaluation index system

Dimension	Indicator	Definition	Properties
Accessibility of financial services	Branch accessibility	Number of bank branches/Area	Positive
		Number of bank branches/Population	Positive
	Staff accessibility	Number of bank staff/Area	Positive
		Number of bank staff /Population	Positive
Usage of financial services	Savings per capita	Savings/Population	Positive
	Loans per capita	Loans/Population	Positive
	Insurance density	Insurance revenue/Population	Positive
Utility of financial services	Savings ratio	Savings/GDP	Positive
	Loans ratio	Loans/GDP	Positive
	Insurance depth	Insurance revenue /GDP	Positive

Further, this paper uses the coefficient of variation method to synthesize the above indicators into financial inclusion index. Firstly, in order to avoid the differences caused by the inconsistent dimensions of each index, each index is standardized in turn. Since the selected indicators are positive indicators, the specific formula to be standardized is shown in (1):

$$x_{ij} = \frac{A_{ij-m_{ij}}}{M_{ij-m_{ij}}} \tag{1}$$

Among them, i represents the dimension i, j represents the j-th indicator under i dimension, x_{ij} represents the indicator value after standardization, A_{ij} represents the original indicator value before standardization, and $m_{ij}$and M_{ij}represent the minimum and maximum values of the original indicators respectively.

Secondly, the weight of each indicator and each dimension are determined respectively. The basic principle of weighting is that the richer the information of an index or dimension or the greater the degree of numerical dispersion, the greater the weight value. The specific weighting formula is as follows:

$$w_i = \frac{V_i}{\sum_{i=1}^{n} V_i} \tag{2}$$

In formula (2), w_i represents the weight of the i-th index or dimension, and V_i represents the coefficient of variation of the i-th index or dimension. The calculation method of V_i is shown in formula (3):

$$V_i = \frac{S_i}{A_i} \tag{3}$$

Where, S_i represents the standard deviation of the i-th indicator or dimension, and A_i represents the average value of the i-th indicator or dimension.

Thirdly, to calculate the single dimension financial inclusion index, the principle is to calculate the European distance between the measured value of each index under each dimension and the optimal value, and integrate all distances together. The specific calculation method is shown in formula (4):

$$Ifi_i = 1 - \frac{\sqrt{w_{i1}^2(1-x_{i1})^2 + w_{i2}^2(1-x_{i2})^2 + \cdots + w_{ij}^2(1-x_{ij})^2}}{\sqrt{\left(w_{i1}^2 + w_{i2}^2 + \cdots w_{ij}^2\right)}} \quad (4)$$

Finally, after using formula (4) to calculate the single dimension financial inclusion index, further use formula (5) to calculate the composite dimension financial inclusion index. The specific calculation method is as follows:

$$Ifi = 1 - \frac{\sqrt{w_1^2(1-IFI_1)^2 + w_2^2(1-IFI_2)^2 + w_3^2(1-IFI_3)^2}}{\sqrt{w_1^2 + w_2^2 + w_3^2}} \quad (5)$$

Among them, Ifi and Ifi_1, Ifi_2 ,Ifi_3 respectively represent the financial inclusion index and the index values of the three sub dimensions of accessibility of financial services, usage of financial services and utility of financial services.

Measurement of agricultural green total factor productivity

Index selection. The indicators needed to measure AGTFP include input indicators, expected output indicators and unexpected output indicators. (1) Land input. It is expressed by crop sowing area (2) Mechanical input. It is expressed by the total power of agricultural machinery (3) Fertilizer input. It is expressed by the net amount of agricultural chemical fertilizer application (4) Labor input. It is expressed by agricultural employment. The proportion of the total agricultural output value in the total output value of agriculture, forestry, animal husbandry and fishery is multiplied by the number of employment in the primary industry to obtain the number of agricultural employment.The increase of agriculture is the expected output index, which is expressed by the total agricultural output value. The total agricultural carbon emission is an unexpected output index. The total amount of agricultural carbon emission is estimated by multiplying the amount of six carbon emission sources of agricultural chemical fertilizer application, pesticide use, agricultural plastic film use, agricultural diesel use, crop sowing area and agricultural effective irrigation area by their respective carbon emission coefficients. The carbon emission coefficient of each carbon emission source is shown in Table 2.

Table 2 Agricultural carbon emission sources, coefficients and reference sources

Carbon emission source	Carbon emission coefficient	Reference source
Chemical fertilizer	0.8956 $kg \cdot kg^{-1}$	West and Marland[20], Oak Ridge National Laboratory
Pesticides	4.9341 $kg \cdot kg^{-1}$	Oak Ridge National Laboratory[21]
Agricultural film	5.18 $kg \cdot kg^{-1}$	Institute of agricultural resources and ecological environment, Nanjing Agricultural University
Diesel oil	0.5927 $kg \cdot kg^{-1}$	IPCC United Nations Intergovernmental Committee of experts on climate change
Agricultural sowing	312.6 $kg \cdot km^{-2}$	College of biology and technology, China Agricultural University[22]
Agricultural irrigation	25 $kg \cdot cha^{-1}$	Dubey and Lal[23]

Measure method. Referring to the research of Tone (2002), this paper uses the SBM super efficiency model incorporating unexpected output to calculate the AGTFP. Suppose that the k-th decision unit (j=

1,2, ⋯n) has input vector $x \in R^M$, expected output vector $y^g \in R^{S1}$, and unexpected output vector $y^b \in R^{S2}$ respectively. At the same time, define matrices $X=[x_1, x_2, \cdots x_n] \in R^m \times n$, $Y^g=[y_1^g, \cdots, y_n^g] \in R^{S1} \times n$, and $Y^b=[y_1^b, \cdots, y_n^b] \in R^{S2} \times n$. For the decision-making unit K to be measured, as shown in formula (6):

$$min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}}{1-\frac{1}{s_1+s_2}(\sum_{r=1}^{s_1}s_r^g/y_{rk}^g+\sum_{t=1}^{s_2}s_t^b/y_{tk}^b} \tag{6}$$

$$s.t. \begin{cases} \sum_{j=1,j\neq k}^{n} x_{ij}\,\lambda_j - s_i^- \leq x_{ik} \\ \sum_{j=1,j\neq k}^{n} y_{rj}\,\lambda_j + s_r^g \geq y_{rk}^g \\ \sum_{j=1,j\neq k}^{n} y_{tj}\,\lambda_j - s_b^t \leq y_{tk}^b \\ \lambda \geq 0,\ s^g \geq 0,\ s^b \geq 0,\ s^- \geq 0 \end{cases}$$

Where λ is the weight vector, S_i^-, S_r^g and S_t^b are relaxation variables. $\frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{ik}}$ represents the average invalidity degree of input and $\frac{1}{s_1+s_2}(\sum_{r=1}^{s_1}s_r^g/y_{rk}^g+\sum_{t=1}^{s_2}s_t^b/y_{tk}^b$ represents the average invalidity degree of output. ρ is the efficiency value of decision-making units and can be greater than 1, so effective decision-making units can be distinguished.

Because total factor productivity needs to be calculated with index method, but the traditional ML index does not have transitivity, this paper selects GML index to represent the change of AGTFP. Referring to the study of Oh (2010) , GML index can be expressed by formula (7):

$$GML^{t,t+1}(x^{t+1},y^{t+1},b^{t+1},x^t,y^t,b^t) = \frac{1+D_G^T(x^t,y^t,b^t)}{1+D_G^T(x^{t+1},y^{t+1},b^{t+1})} \tag{7}$$

If $GML^{t,t+1} > 1$, it indicates that the expected output increases, the unexpected output decreases, and the AGTFP is higher than that of the previous period; On the contrary, it shows that the AGTFP decreases.

Considering that the AGTFP calculated by GML index is a month on month index, that is, the change of AGTFP in this year compared with the previous year. Therefore, this paper transforms AGTFP into fixed base index to reflect the cumulative change trend of AGTFP. That is, AGTFP in 2006 is 1, and the actual value of AGTFP in 2007 is the product of AGTFP in the current year and AGTFP in 2006, and so on. Since the coupling relationship between financial inclusion and AGTFP needs to be analyzed later, we also standardize the AGTFP after fixed base transformation.

Coupling coordination model

The coupling degree mainly measures the linkage degree between the two systems, and the coupling coordination degree mainly measures the level of mutual promotion and benign interaction between the two systems. Firstly, the coupling degree model of financial inclusion and AGTFP is constructed, as shown in formula (8):

$$C = 2[(R_1 \times R_2)/(R_1 + R_2)^2]^{1/2} \tag{8}$$

Where R_1 and R_2 represent the measurement indexes of financial inclusion and AGTFP respectively. Although the coupling degree C measures the interaction between the two systems, it does not reflect the overall efficacy and coordination effect of the interaction between financial inclusion and AGTFP. This is because the coupling between the two systems with higher development level may be very low.

Therefore, it is necessary to further introduce the coupling coordination degree model to measure the overall synergy, as shown in formula (9):

$$D = \sqrt{C \times T} \tag{9}$$

Among them, D is the coupling co scheduling, T is the comprehensive coordination index of financial inclusion and AGTFP, which reflects the contribution of the overall development level of the two systems to the coupling coordination degree, $T=\alpha R_1+\beta R_2$, $\alpha$and β respectively represent the system weight of financial inclusion and AGTFP, which is assigned as $\alpha=\beta=0.5$.

In order to better understand the coordination level between financial inclusion and AGTFP, referring to the research of Zhu et al. (2019), the coupling coordination degree is divided into six stages according to the value range of coupling co scheduling. The specific division results are shown in Table 3:

Table 3 Hierarchy of coupling coordination degree

Serial number	Value of coupling coordination degree	Coordination phase
1	$0 < D < 0.3$	Very low degree of coordination
2	$0.3 \le D < 0.4$	Low degree of coordination
3	$0.4 \le D < 0.5$	Primary level coordination
4	$0.5 \le D < 0.6$	Moderate level coordination
5	$0.6 \le D < 0.7$	High degree of coordination
6	$0.7 \le D < 1$	Very high degree of coordination

Analysis of empirical results

Analysis on the measurement results of financial inclusion and agricultural green total factor productivity

Table 4 reports the average level of financial inclusion and AGTFP in 30 provinces of China in different time intervals. The overall development level of financial inclusion in China is low, and there are obvious inter provincial differences and two-level differentiation. Specifically, the overall average value of financial inclusion in most provinces is between 0.05 and 0.20. The development level of financial inclusion in some provinces such as Shanghai, Beijing and Tianjin is much higher than that in other provinces. Among them, the development level of financial inclusion in Shanghai is the highest, with an overall average of 0.5997; The overall average value of financial inclusion in Guangxi is only 0.0458, and the overall average value of financial inclusion in Shanghai is 13 times that in Guangxi. From the perspective of development trend, during the sample period, the development level of financial inclusion in various provinces in China showed a gradual upward trend, which shows that China's financial inclusion development strategy has achieved certain results. Specifically, the average value of financial inclusion in all provinces is the smallest from 2006 to 2009, the middle from 2010 to 2014 and the highest from 2015 to 2019.

The overall level of AGTFP of China is low, and the difference between provinces is relatively small. Specifically, only Qinghai, Guizhou, Jiangsu and Shaanxi provinces have the overall average value of AGTFP above 0.20, accounting for only 13.3% of all provinces. The overall average value of AGTFP in other provinces is mostly about 0.15. The overall average value of AGTFP is 0.2814 in Qinghai and 0.0732 in Jilin. From the perspective of development trend, similar to financial inclusion, AGTFP in various provinces of China also shows a gradual upward trend. Specifically, the average value of AGTFP

in most provinces is the smallest from 2006 to 2009, the middle from 2010 to 2014 and the highest from 2015 to 2019; However, the average value of AGTFP in some provinces such as Shanghai and Jilin from 2015 to 2019 is less than that from 2010 to 2014, which indicates that there are some differences in the growth trend of AGTFP in different provinces. However, compared with financial inclusion, the growth trend of AGTFP is relatively fast. Taking Jiangxi as an example, the average AGTFP was only 0.0258 from 2006 to 2009, while it reached 0.2548 from 2015 to 2019, an increase of nearly 10 times.

Table 4 Financial inclusion and agricultural green total factor productivity

Province	Financial inclusion				AGTFP			
	2006-2009	2010-2014	2015-2019	2006-2019	2006-2009	2010-2014	2015-2019	2006-2019
Beijing	0.3236	0.4088	0.5137	0.4219	0.0372	0.1232	0.1926	0.1234
Tianjin	0.1929	0.2510	0.3313	0.2631	0.0291	0.1240	0.2200	0.1312
Hebei	0.0532	0.0733	0.1138	0.0820	0.0440	0.1682	0.2151	0.1495
Liaoning	0.0738	0.0988	0.1483	0.1093	0.0427	0.1402	0.2065	0.1360
Shanghai	0.4302	0.5888	0.7464	0.5997	0.0425	0.1324	0.1269	0.1047
Jiangsu	0.0955	0.1375	0.2001	0.1479	0.0438	0.1787	0.4093	0.2225
Zhejiang	0.1168	0.1664	0.2199	0.1713	0.0352	0.1418	0.2963	0.1665
Fujian	0.0580	0.0882	0.1267	0.0933	0.0407	0.1503	0.3046	0.1741
Shandong	0.0653	0.0909	0.1284	0.0970	0.0462	0.1372	0.2178	0.1400
Guangdong	0.0941	0.1276	0.1832	0.1379	0.0333	0.1045	0.2364	0.1313
Hainan	0.0491	0.0748	0.1164	0.0823	0.0306	0.1128	0.2651	0.1437
Shanxi	0.0635	0.0857	0.1195	0.0914	0.0439	0.2016	0.2980	0.1910
Jilin	0.0449	0.0587	0.1007	0.0697	0.0346	0.0942	0.0831	0.0732
Heilongjiang	0.0330	0.0500	0.0846	0.0575	0.0357	0.1659	0.3579	0.1973
Anhui	0.0474	0.0661	0.1001	0.0729	0.0430	0.1337	0.2083	0.1344
Jiangxi	0.0365	0.0537	0.0891	0.0614	0.0258	0.0977	0.2548	0.1332
Henan	0.0506	0.0701	0.1054	0.0771	0.0382	0.1196	0.1812	0.1184
Hubei	0.0455	0.0628	0.0968	0.0700	0.0321	0.1322	0.2408	0.1424
Hunan	0.0370	0.0487	0.0790	0.0562	0.0473	0.1732	0.2324	0.1583
Inner Mongolia	0.0251	0.0461	0.0860	0.0544	0.0301	0.1059	0.1392	0.0961
Guangxi	0.0239	0.0424	0.0668	0.0458	0.0463	0.1252	0.2541	0.1487
Chongqing	0.0644	0.0931	0.1236	0.0958	0.0229	0.1226	0.2733	0.1479
Sichuan	0.0436	0.0714	0.1020	0.0744	0.0434	0.1556	0.3408	0.1897
Guizhou	0.0299	0.0476	0.0805	0.0543	0.0214	0.1378	0.6140	0.2746
Yunnan	0.0330	0.0497	0.0690	0.0518	0.0310	0.1014	0.2351	0.1291
Shaanxi	0.0494	0.0687	0.1043	0.0759	0.0498	0.1928	0.3492	0.2078
Gansu	0.0319	0.0540	0.0901	0.0606	0.0386	0.1415	0.2292	0.1434
Qinghai	0.0300	0.0573	0.0928	0.0622	0.0487	0.2355	0.5135	0.2814
Ningxia	0.0512	0.0724	0.1094	0.0795	0.0571	0.1818	0.3273	0.1981
Xinjiang	0.0326	0.0556	0.0866	0.0601	0.0209	0.1041	0.1470	0.0957

Analysis on the measurement results of the coupling and coordination between financial inclusion and agricultural green total factor productivity

The measurement results of the coupling coordination degree between financial inclusion and AGTFP

are shown in Table 5. From the overall average value, the coupling coordination degree of financial inclusion and AGTFP in China's provinces is low, and the coupling coordination relationship of most provinces is in a very low coordination stage and a low coordination stage, indicating that the coupling coordination degree of financial inclusion and AGTFP in China still has a large room for improvement. Specifically, Shanghai ranks the highest in the coupling coordination degree, with an average value of 0.4852, while Inner Mongolia ranks the lowest, with an average value of only 0.2585, indicating that there are great regional differences in the coupling coordination degree between China's financial inclusion and AGTFP. Beijing, Shanghai, Tianjin and Jiangsu have an overall average value of more than 0.4 for the coupling coordination between financial inclusion and AGTFP. The coupling coordination relationship of these four provinces is in the primary coordination stage, accounting for 13.3% of all provinces. There are 17 provinces such as Hebei, Liaoning and Zhejiang with an overall average value of more than 0.3 in the coupling and coordination of financial inclusion and AGTFP. The coupling and coordination relationship of these provinces is in the low coordination stage, accounting for 56.7% of all provinces. There are nine provinces such as Jilin, Jiangxi and Henan with an overall average value of more than 0.2. The coupling coordination relationship between financial inclusion and AGTFP is in a very low coordination stage, accounting for 30% of all provinces. From the perspective of development trend, the coupling coordination degree of financial inclusion and AGTFP in all provinces showed a slow upward trend from 2006 to 2019. Specifically, from 2006 to 2009, the average coupling coordination degree of financial inclusion and AGTFP in most provinces was below 0.3, and the coupling coordination relationship was in a very low coordination stage. Only the average coupling coordination degree of Beijing and Shanghai exceeded 0.3, 0.3252 and 0.3594 respectively, and the coupling coordination relationship was in a low coordination stage. From 2010 to 2014, the average value of the coupling coordination between financial inclusion and AGTFP in most provinces exceeded 0.3, and the coupling coordination relationship rose to the low coordination stage. Only nine provinces such as Jilin, Heilongjiang and Jiangxi have the average value of coupling coordination degree lower than 0.3, accounting for 30% of all provinces. The average value of coupling coordination degree in a few regions such as Beijing, Tianjin and Shanghai even exceed 0.4. The coupling coordination relationship has reached the primary coordination stage and the medium-level coordination stage respectively. From 2015 to 2019, the average value of the co scheduling of financial inclusion and AGTFP in more provinces exceeded 0.4, accounting for 60% of all provinces; Among them, the average value of coupling coordination degree exceeds 0.5 in five provinces, namely Beijing, Tianjin, Shanghai, Jiangsu and Zhejiang, and the coupling coordination relationship is in the moderate coordination stage.

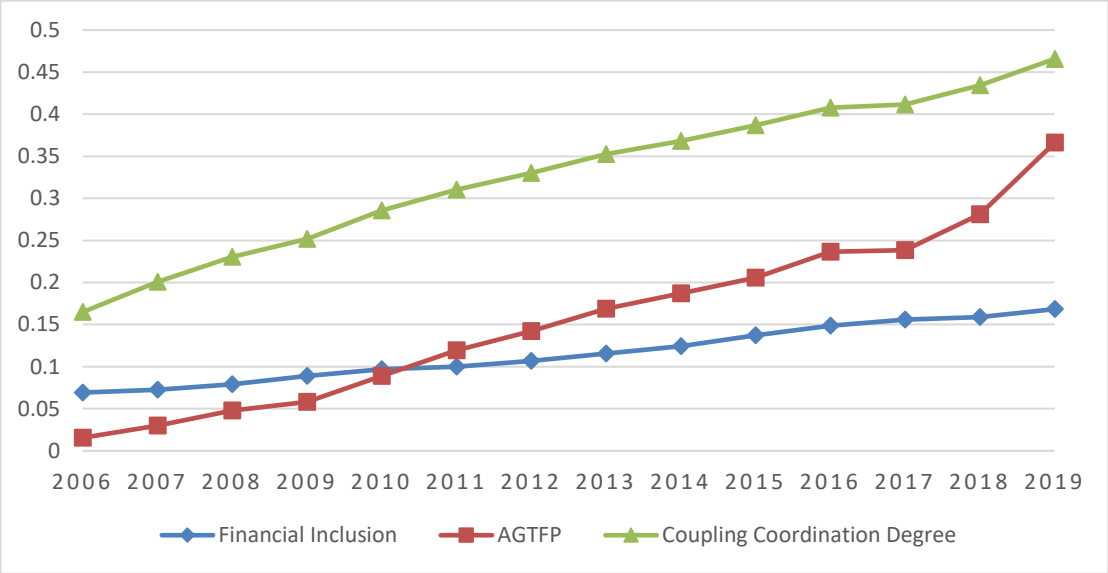
Table 5 Coupling and Co scheduling of financial inclusion and agricultural green total factor productivity

Province	2006-2009	2010-2014	2015-2019	2006-2019
Beijing	0.3252	0.4705	0.5608	0.4612
Tianjin	0.2694	0.4170	0.5180	0.4109
Hebei	0.2166	0.3317	0.3948	0.3214
Liaoning	0.2341	0.3410	0.4174	0.3377
Shanghai	0.3594	0.5252	0.5460	0.4852
Jiangsu	0.2488	0.3932	0.5329	0.4018
Zhejiang	0.2496	0.3900	0.5016	0.3898
Fujian	0.2173	0.3369	0.4416	0.3401
Shandong	0.2284	0.3327	0.4083	0.3299

Guangdong	0.2353	0.3375	0.4521	0.3493
Hainan	0.1946	0.3006	0.4173	0.3120
Shanxi	0.2165	0.3614	0.4340	0.3459
Jilin	0.1962	0.2709	0.2979	0.2592
Heilongjiang	0.1796	0.2962	0.4117	0.3041
Anhui	0.2083	0.3054	0.3796	0.3042
Jiangxi	0.1724	0.2650	0.3869	0.2821
Henan	0.2063	0.3019	0.3708	0.2992
Hubei	0.1912	0.3001	0.3896	0.3010
Hunan	0.1988	0.3021	0.3667	0.2957
Inner Mongolia	0.1638	0.2627	0.3300	0.2585
Guangxi	0.1798	0.2687	0.3592	0.2756
Chongqing	0.1567	0.3243	0.4267	0.3130
Sichuan	0.2002	0.3229	0.4299	0.3261
Guizhou	0.1527	0.2779	0.4690	0.3104
Yunnan	0.1770	0.2626	0.3525	0.2702
Shaanxi	0.2184	0.3374	0.4356	0.3385
Gansu	0.1840	0.2943	0.3784	0.2928
Qinghai	0.1892	0.3386	0.4591	0.3389
Ningxia	0.2272	0.3375	0.4343	0.3406
Xinjiang	0.1590	0.2752	0.3347	0.2633

Figure1 depicts the trend of the coupling coordination degree of financial inclusion and AGTFP over time. From 2006 to 2019, the average value of China's financial inclusion and AGTFP coupling co scheduling increased from 0.1649 to 0.4657, from the very low coordination stage to the primary coordination stage, and the coordinated development level between the two continued to improve. The degree of coupling coordination is affected by the overall development degree of the system and the development gap between systems. The increase of the development gap between systems will have a negative impact on the degree of coupling coordination. According to the development level of financial inclusion and the level of AGTFP, the coordinated development relationship between the two systems is divided into two types: Financial inclusion is relatively lagging and AGTFP is relatively lagging. From 2006 to 2010, the development level of financial inclusion in China was higher than that of AGTFP, which belongs to the relatively backward coordinated development relationship of AGTFP; From 2010 to 2019, China's AGTFP exceeded the development level of financial inclusion, which belongs to a relatively lagging coordinated development relationship of financial inclusion. From the time trend chart, it can be found that the level of financial inclusion and AGTFP in China showed an upward trend during the sample period, which made a certain contribution to the increase of coupling coordination degree; However, it should be noted that the gap between financial inclusion and AGTFP is increasing, which will have a potential adverse impact on the continuous improvement of coupling coordination. In the context of national implementation of agricultural sustainable development, to effectively promote the coordinated development of financial inclusion and AGTFP, the primary task is to change the development strategy of financial inclusion. financial inclusion should not only meet the credit availability of agricultural production subjects, but also guide and support agricultural green transformation and upgrading and take the road of sustainable development.

Figure 1 Time trend of financial inclusion and agricultural green total factor productivity



Regional difference of coupling coordination degree

Regional difference analysis method. In this paper, Dagum (1997) Gini coefficient and its decomposition method are used to calculate the intra regional differences, inter regional differences and their sources of the coupling co scheduling of financial inclusion and AGTFP. This method effectively solves the source problem of spatial differentiation and the problem of cross overlap between sub samples. The basic definition of Gini coefficient is shown in equation (10), $y_{ji}(y_{hr})$ is the coupling co scheduling of financial inclusion and AGTFP in a province in j(h), $\bar{y}$ represents the average value of the coupling coordination degree of each province, n represents the number of provinces, k is the number of regions, and $n_j(n_k)$ is the number of provinces in j(h). During Gini coefficient decomposition, regions need to be sorted according to the average value of coupling co scheduling, as shown in equation (11):

$$G = \sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_k}|y_{ji} - y_{hr}|/2n^2\ \bar{y} \tag{10}$$

$$\bar{Y}_h \le \cdots \bar{Y}_j \le \cdots \bar{Y}_k \tag{11}$$

Equation (12) and equation (13) represent Gini coefficient G_{jj} and intra regional difference G_w of j region respectively; Equations (14) and (15) represent the inter regional Gini coefficient G_{jh} and inter regional net value difference G_{nb} of regions j and h respectively; Formula (16) represents the super density G_t, and the relationship between them satisfies $G=G_w+G_{nb}+G_t$.

$$G_{jj} = \frac{1}{2\ \bar{Y}_j}\sum_{i=1}^{n_j}\sum_{r=1}^{n_j}|y_{ji} - y_{jr}|/n_j^2 \tag{12}$$

$$G_w = \sum_{j=1}^{k} G_{jj}\, p_j s_j \tag{13}$$

$$G_{jh} = \sum_{i=1}^{n_j}\sum_{r=1}^{n_h}|y_{ji} - y_{hr}|/n_j n_h(\ \bar{Y}_j + Y\ \bar{Y}_h) \tag{14}$$

$$G_{nb} = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}\,(p_j s_h + p_h s_j) D_{jh} \tag{15}$$

$$G_t = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}\,(p_j s_h + p_h s_j) 1 - (D_{jh}) \tag{16}$$

Among them,$p_j = n_j/\ \bar{Y}$, $s_j = n_j\ \bar{Y}_j/n\ \bar{Y}$(j=1,⋯,k). In this paper, D_{jh} is defined as the relative influence of coupling co scheduling between j and h regions, as shown in equations (17), (18) and (19), where $F_j(F_h)$ is the cumulative density distribution function of j and h regions respectively, and d_{jh} is the difference of coupling co scheduling between regions, which can be interpreted as the mathematical expectation of the sum of all $y_{jr} - y_{ji} > 0$sample values in j and h regions; p_{jh} is the supervariant

first-order distance, which can be interpreted as the mathematical expectation of the sum of all $y_{hr} - y_{ji} > 0$ sample values in j and h regions.

$$D_{jh} = \frac{d_{jh} - p_{jh}}{d_{jh} + p_{jh}} \tag{17}$$

$$d_{jh} = \int_0^{\infty} dF_j(y) \int_0^{y} (y - x) dF_h(x) \tag{18}$$

$$p_{jh} = \int_0^{\infty} d\,F_h(y) \int_0^{y} (y - x) dF_j(y) \tag{19}$$

Analysis of regional difference results. The Gini coefficient and regional analysis results are reported in Table 6. As can be seen from table 6, there are great regional differences in the coupling coordination degree between China's inter provincial financial inclusion and AGTFP, but this difference shows a fluctuating downward trend. Specifically, Dagum Gini coefficient was on the high side from 2006 to 2011, above 0.1 for a long time; After 2012, Dagum Gini coefficient dropped below 0.1 and reached the minimum value of 0.0813 in 2016. Although it rebounded in the later stage, Dagum Gini coefficient was always lower than 0.1. From the perspective of regional differences, the Dagum Gini coefficient in the East, middle and West is less than the overall Gini coefficient, which shows that the regional difference of the coupling co scheduling of financial inclusion and AGTFP is less than the overall difference of the whole country; And the Dagum Gini coefficient from large to small is the East, the West and the middle, which shows that the regional difference of financial inclusion and AGTFP coupling co scheduling is greater in the east than in the West and the middle. From the perspective of interregional differences, the differences between the East and the West are the largest, but on the whole, they show a downward trend year by year, although they have rebounded slightly in the past two years; The second is the difference between the eastern and central regions, and shows a fluctuating downward trend during the sample period; The difference between the central and western regions is relatively small, and shows a downward trend of fluctuation during the sample period, but the fluctuation range is slightly smaller than that between the eastern and central regions. From the contribution rate of relative difference, the contribution rate of interregional difference is the largest and the contribution rate of over variable density is the smallest, which shows that interregional difference is the main source of regional difference in the coupling and co scheduling of financial inclusion and AGTFP. How to reduce interregional difference is the focus of future work.

Table 6 Gini coefficient and regional analysis results

Year	Gini coefficient (G)	Intra regional differences (Gw)			Interregional differences (Gnb)			Hypervariable density contribution (Gt)	Contribution rate (%)		
		Eastern	Central	Western	Eastern-Central	Eastern-Western	Central-Western		Gw	Gnb	Gt
2006	0.1499	0.0919	0.0540	0.1587	0.1427	0.2284	0.1216	0.0059	23.98	72.09	3.93
2007	0.1059	0.0937	0.0359	0.0637	0.1385	0.1549	0.0549	0.0090	23.44	68.05	8.51
2008	0.1048	0.0983	0.0279	0.0784	0.1236	0.1499	0.0644	0.0095	25.41	65.51	9.07
2009	0.1083	0.1040	0.0627	0.0697	0.1278	0.1468	0.0722	0.0121	26.57	62.30	11.13
2010	0.1031	0.0992	0.0682	0.0646	0.1320	0.1316	0.0681	0.0151	26.92	58.42	14.66
2011	0.1059	0.1078	0.0556	0.0661	0.1353	0.1370	0.0667	0.0144	26.94	59.46	13.60
2012	0.0927	0.0913	0.0470	0.0544	0.1235	0.1208	0.0585	0.0128	25.73	60.48	13.79
2013	0.0889	0.0871	0.0427	0.0555	0.1180	0.1170	0.0540	0.0125	25.90	60.02	14.08
2014	0.0843	0.0780	0.0394	0.0570	0.1128	0.1095	0.0540	0.0112	25.60	61.11	13.29
2015	0.0818	0.0711	0.0317	0.0628	0.1080	0.1048	0.0577	0.0114	25.35	60.74	13.91

2016	0.0813	0.0632	0.0389	0.0674	0.1088	0.0981	0.0653	0.0118	25.34	60.14	14.52
2017	0.0848	0.0716	0.0650	0.0694	0.1082	0.0921	0.0773	0.0153	28.08	53.87	18.05
2018	0.0890	0.0799	0.0598	0.0658	0.1202	0.0979	0.0758	0.0130	27.31	58.08	14.60
2019	0.0910	0.0749	0.0669	0.0761	0.1189	0.0997	0.0797	0.0167	27.83	53.77	18.40

Spatial characteristic analysis of coupling coordination degree

Spatial feature analysis method. Spatial feature analysis usually includes global spatial autocorrelation analysis and local spatial autocorrelation analysis. Global spatial autocorrelation is used to explore the distribution state of the coupling coordination degree of financial inclusion and AGTFP in the overall space. It is usually measured by global Moran's I. The calculation method is shown in formula (20):

$$I = \frac{N}{S_0} \cdot \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_{j=1}^{N}(X_i - \bar{X})^2} \tag{20}$$

Among them, i≠j and N are the number of study areas, X_i is the observation data, $\bar{X}$ is the average value of X_i, W_{ij} is the spatial weight matrix of areas i and j, the spatial adjacent value is 1, and the spatial non adjacent value is 0. Moran's I value is between [- 1,1], and the value is positive, indicating that there is a positive spatial autocorrelation, indicating that the regions with high (or low) coupling coordination degree between financial inclusion and AGTFP tend to cluster in space; If the value is negative, it shows negative spatial autocorrelation, indicating that there is a significant spatial difference in the coupling coordination degree of financial inclusion and AGTFP between adjacent regions; A value of 0 indicates that there is no correlation and the spatial distribution is random.

Local spatial autocorrelation is used to measure the spatial correlation and difference degree of the coupling co scheduling of financial inclusion and AGTFP in adjacent provinces. In this paper, local Moran's I is used to measure the local spatial autocorrelation of region i and region j. the calculation method is shown in formula (21):

$$I_i = Z_i \sum_{i=1}^{N} W_{ij Z_j} \tag{21}$$

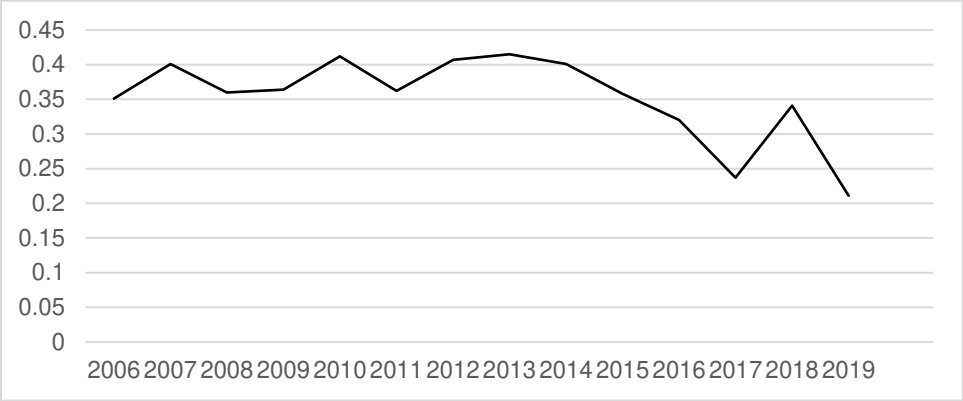
Where Z_i and Z_j are the standardization of observation data of region i and region j, and W_{ij} represents spatial weight. If the value of I_i is positive, it means that the region i and the adjacent region belong to high values and are surrounded by high values or low values and are surrounded by low values. The value of I_i is negative, indicating that the region i and adjacent regions belong to low values and are surrounded by high values or high values are surrounded by low values.

Global spatial autocorrelation analysis. Using Geoda and Stata software, the global spatial autocorrelation analysis is carried out on the coupling coordination value of financial inclusion and AGTFP in 30 provinces of China, and the global Moran's I index of the coupling coordination degree of the two in each year is obtained, as shown in Figure 2:

During the sample period, the Moran's I index of each year passed the significance test, and the values are greater than 0, indicating that the coupling coordination degree of financial inclusion and AGTFP presents the characteristics of spatial positive autocorrelation. Overall, Moran's I index showed a downward trend of fluctuation from 2006 to 2019, and the spatial agglomeration decreased, but it showed different characteristics in different stages. From 2006 to 2012, Moran's I index showed a slight fluctuation trend and was at a high level, indicating that during this period, the change trend of China's financial inclusion and AGTFP coupling co scheduling was small and showed strong spatial agglomeration distribution characteristics. From 2012 to 2017, Moran's I index showed a slow downward trend, indicating that during this period, the spatial agglomeration of the coupling coordination degree of financial inclusion and AGTFP in China gradually decreased. From 2017 to 2019, Moran's I index

showed a strong fluctuation trend, indicating that the spatial characteristics of China's financial inclusion and AGTFP coupling co scheduling have changed dramatically in a short time. Global spatial autocorrelation only shows the overall comprehensive characteristics of the coupling coordination degree of financial inclusion and AGTFP, and can not reveal the local spatial correlation with adjacent provinces. Therefore, it needs to be further analyzed in combination with local spatial autocorrelation.

Figure 2 Global Moran's I Index of the coupling Co scheduling of financial inclusion and agricultural green total factor productivity in 2006 and 2009



Local spatial autocorrelation analysis. The mean value of the coupling coordination degree of financial inclusion and AGTFP in 2006-2009, 2010-2014 and 2015-2019 is selected as the cross-sectional data, and the local spatial autocorrelation analysis is used to measure the distribution and evolution characteristics of the coupling coordination between financial inclusion and AGTFP in each province. The spatial agglomeration type of the coupling coordination degree of each province is divided into four quadrants, in which the first quadrant (HH) represents the coupling coordination degree of financial inclusion and AGTFP in the province and surrounding provinces, both of which belong to high-value areas; The second quadrant (LH) represents that the coupling coordination between provincial financial inclusion and AGTFP is low, while the surrounding provinces are high; The third quadrant (LL) represents that the coupling coordination degree of financial inclusion and AGTFP in provinces and surrounding provinces belongs to low value area; The fourth quadrant (HL) represents that the coupling coordination between provincial financial inclusion and AGTFP is high, while the surrounding provinces are low.

HH cluster: as can be seen from table 7, the number of provinces of this type in the three stages is 8, accounting for 26.6% of all provinces. In terms of spatial distribution, the regional scope of this type is gradually expanding, showing a development trend from relative concentration to regional dispersion. From 2006 to 2014, it was mainly distributed in 8 eastern provinces such as Beijing, Shanghai and Jiangsu. The span between provinces was not obvious, and the spatial distribution was concentrated. From 2015 to 2019, in addition to being mainly distributed in the eastern provinces, western provinces such as Sichuan and Chongqing have also become new members of this type. The spatial distribution state gradually tends to be widely dispersed from the eastern agglomeration to the western region.

LH cluster: the number of provinces of this type has gradually increased from 5 to 9, and the proportion has increased from 16.7% to 30%. In terms of spatial distribution, the regional scope of this type is gradually expanding, showing a development trend from relatively concentrated in the middle and west to scattered in the East, middle and West. From 2006 to 2014, it was mainly distributed in three central provinces such as Anhui, Jiangxi and Henan, as well as Hainan and Inner Mongolia, with

relatively concentrated spatial distribution. From 2015 to 2019, it is mainly distributed in three eastern provinces such as Hainan, Shandong and Hebei, three central provinces such as Anhui, Jiangxi and Hunan, and three western provinces such as Xinjiang, Yunnan and Jiangxi. The spatial distribution spans the East, middle and West, showing a decentralized development trend.

LL cluster area: the number of provinces of this type has changed relatively greatly, showing a gradual downward trend, and the proportion has decreased from 40% to 23.4%, indicating that the coupling and coordination level of China's financial inclusion and AGTFP is increasing. In terms of spatial distribution, the regional scope of this type is gradually reduced, and the spatial pattern is basically concentrated in the central and western regions. From 2006 to 2009, it was mainly distributed in 12 central and western provinces such as Chongqing, Xinjiang and Heilongjiang, and the spatial distribution tends to be concentrated as a whole. From 2010 to 2014, it was mainly distributed in 11 central and western provinces such as Chongqing, Xinjiang and Heilongjiang, and the spatial distribution status was basically the same as that from 2006 to 2009. Only Qinghai province changed from this type of cluster area to HL cluster area. From 2015 to 2019, it is mainly distributed in 7 provinces such as Inner Mongolia, Henan and Heilongjiang. The spatial distribution tends to be widely dispersed from the central and western regions and extends to the eastern region, indicating that the gap between the eastern and central and western regions is gradually narrowing.

HL cluster area: the number of provinces and regions of this type fluctuates slightly, but remains stable as a whole. There is no obvious change in the spatial scope, but the spatial pattern presents a decentralized development trend in the East, middle and West. From 2006 to 2009, it was mainly distributed in five provinces: Shanxi, Shaanxi, Ningxia, Liaoning and Guangdong. The spatial distribution spans three regions: East, middle and West. Among them, Liaoning and Guangdong have a large spatial span, while the other three provinces are relatively concentrated. From 2010 to 2014, it was mainly distributed in six provinces such as Shanxi, Shaanxi and Liaoning, and the spatial distribution status was basically the same as that from 2006 to 2009. The spatial distribution of the newly added Qinghai and four provinces such as Shanxi, Shaanxi and Ningxia was relatively concentrated. From 2015 to 2019, it is mainly distributed in six provinces such as Shanxi, Ningxia and Guizhou. The spatial distribution shows a trend of decentralized development from the East, middle and west to the central and western regions.

Table 7 Spatial correlation between financial inclusion and agricultural green total factor productivity in China

Year	HH		LH		LL		HL	
	Province	%	Province	%	Province	%	Province	%
2006-2009	Fujian, Shandong Hebei, Zhejiang Jiangsu, Tianjin Beijing, Shanghai	26.6	Anhui, Jiangxi Hainan, Henan Inner Mongolia	16.7	Chongqing, Xinjiang Guizhou, Heilongjiang Yunnan, Qinghai Hunan, Sichuan Guangxi, Gansu Hubei, Jilin	40	Shanxi, Shaanxi Liaoning, Guangdong Ningxia	16.7
2010-2014	Fujian, Shandong Hebei, Zhejiang Jiangsu, Tianjin Beijing, Shanghai	26.6	Inner Mongolia, Jiangxi Hainan, Henan Anhui	16.7	Chongqing, Xinjiang Guizhou, Jilin Yunnan, Hunan Sichuan, Guangxi Gansu, Hubei Heilongjiang	36.7	Shanxi, Shaanxi Liaoning, Guangdong Qinghai, Ningxia	20
2015-2019	Sichuan, Chongqing Fujian, Zhejiang Tianjin, Jiangsu Beijing, Shanghai	26.6	Hainan, Shandong Anhui, Hebei Jiangxi, Xinjiang Yunnan, Hunan Guangxi	30	Inner Mongolia, Henan Gansu, Hubei Jilin, Liaoning Heilongjiang	23.4	Shaanxi, Shanxi Ningxia, Guangdong Guizhou, Qinghai	20

Further discussion

Model setting

In order to further explore the impact of the coupling and coordination of financial inclusion and AGTFP on the urban-rural income gap, this paper further sets the econometric model as follows:

$$Iga_{it} = \alpha_0 + \alpha_1 Cor_{it} + \gamma Control_{it} + Id_i + Year_t + \varepsilon_{it} \quad (22)$$

Among them, Iga_{it} is the urban-rural income gap, this paper uses the ratio of urban residents' per capita income to farmers' per capita income as its characterization index; Cor_{it} is the coupling and co scheduling of financial inclusion and AGTFP; $Control_{it}$ is the control variable. Studies have shown that the income gap between urban and rural areas is closely related to employment(Emp_{it}), educational level(Edu_{it}), economic development level(Eom_{it}), local government behavior(Gov_{it}), degree of opening to the outside world(Ope_{it}), industrial structure(Ids_{it}), etc. This paper uses the unemployment rate, the proportion of financial education expenditure in total financial expenditure, per capita GDP, the proportion of local government financial expenditure in GDP, the proportion of total import and export in GDP, and the proportion of added value of secondary and tertiary industries in GDP to measure the control variables; Id_i is the regional fixed effect (province); $Year_t$ is the time fixed effect; ε_{it} is random error term; Subscripts i and t indicate provinces and years, respectively.

Analysis of benchmark regression results

In this paper, the panel fixed effect is used to estimate. In order to minimize the interference of unobservable factors on the estimation results, all regression estimates control the time fixed effect and individual fixed effect. Table 8 reports the regression results without and after adding control variables. It can be found that the regression coefficient of Cor is significantly negative and passes the significance level test of 1%, which shows that the increase of the coupling coordination level of financial inclusion and AGTFP can significantly reduce the income gap between urban and rural areas. Among the control variables, the unemployment rate has a significant positive impact on the urban-rural income gap, and has passed the significance level test of 5%. This may be because the rise of unemployment rate is more caused by the unemployment of those who do not have high skills, unstable jobs and transfer from rural to urban employment, resulting in the decline of per capita disposable income of rural residents, thus widening the income gap between urban and rural areas. The degree of opening to the outside world has a significant negative impact on the urban-rural income gap, and has passed the significance level test of 1%. This may be because with the deepening of opening to the outside world, the opening level of rural areas has been greatly improved, more and more "going global" labor forces, the extension of agricultural industrial chain and the rapid development of export-oriented agriculture, which will be conducive to the improvement of the income level of rural residents. The industrial structure has a significant negative impact on the urban-rural income gap, and has passed the significance level test of 1%. This may be because China is still at the peak of labor transfer at this stage. The optimization and upgrading of industrial structure is conducive to attracting a large number of rural surplus labor from the agricultural sector to the non-agricultural sector, thus narrowing the income gap between urban and rural areas.

Table 8 Benchmark regression results

Variable	Iga	
Cor	-0.9476*** (0.3281)	-1.7254*** (0.3046)
Emp		0.0574**

		(0.0276)
Edu		0.6232 (0.7430)
Eom		0.0215 (0.0139)
Gov		0.2295 (0.3415)
Ope		-0.6610*** (0.0922)
Ids		-1.3867** (0.6073)
Cons	3.2827*** (0.0617)	4.4904*** (0.5825)
Id	Yes	Yes
Year	Yes	Yes
Obs	420	420
R^2	0.7086	0.8018

Note: * * *, * * and * respectively represent the significance levels of 1%, 5% and 10%. The robust standard error is in brackets, the same as the following table.

Regional heterogeneity analysis

In order to further analyze whether there are regional differences in the improvement effect of the coupling and coordination of financial inclusion and AGTFP on the urban-rural income gap, we further divide the research samples into eastern region, central region and western region according to the regional location of each province[1]. The regression results in Table 9 show that the improvement of the coupling co scheduling of financial inclusion and AGTFP will significantly reduce the urban-rural income gap between the eastern and western regions, and the impact on the western region is greater than that on the eastern region; There is no significant impact on the urban-rural income gap in the central region. According to the above regression results, there are certain regional differences in the improvement effect of the coupling and coordination of China's financial inclusion and AGTFP on the urban-rural income gap. In the future policy-making process, we need to pay due attention to the coordinated relationship between financial inclusion and AGTFP in the central region, so as to better play its role in reducing the income gap between urban and rural areas.

Table 9 Regional heterogeneity regression results

Variable	Iga		
	Eastern	Central	Western
Cor	-1.3628*** (0.4663)	0.0116 (0.4361)	-1.9051*** (0.4779)
Control	Yes	Yes	Yes
Id	Yes	Yes	Yes

[1]The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan (11 provinces), and the central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan (8 Provinces), the western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang (11 provinces).

Year	Yes	Yes	Yes
Obs	154	112	154
R^2	0.6656	0.9338	0.9079

Conclusions and recommendations

Using the panel data of 30 provinces in China from 2006 to 2019, we empirically analyze the coupling and coordination relationship between financial inclusion and AGTFP, and further discuss the impact of the improvement of the coupling and coordination relationship on the urban-rural income gap. We found that: (1) The overall level of financial inclusion and AGTFP is low, but both show a slow upward trend. (2) The coupling and co scheduling of financial inclusion and AGTFP has been continuously improved, which has developed from the very low coordination stage to the primary coordination stage, and presents the characteristics of alternating changes of the relative lag of AGTFP and the relative lag of financial inclusion. (3) There are great regional differences in the coupling coordination degree of financial inclusion and AGTFP, but this regional difference is gradually narrowing; The spatial pattern of their coupling coordination degree presents the characteristics of global positive autocorrelation and local spatial pattern evolution. (4) The promotion of financial inclusion and AGTFP coupling co scheduling is conducive to narrowing the urban-rural income gap, and this impact effect has regional heterogeneity.

Our empirical results have the following implications for policy-makers and financial service providers. First, technological innovation plays an important role in improving agricultural output(Schultz 1964). Financial inclusion should increase the financial support for the R & D, application and promotion of agricultural green science and technology, so that the majority of agricultural producers can obtain more preferential credit loans, so as to increase the R & D investment in agricultural green technology, and then promote the improvement of AGTFP through the progress of agricultural green technology. Secondly, accelerate the innovation of inclusive financial tools and green financial products suitable for the improvement of AGTFP, improve the development level and service quality of financial inclusion, and guide farmers and other agricultural production subjects to optimize the resource allocation of land, labor and other production factors and improve the efficiency of agricultural production and operation through relevant green credit projects. Third, establish a coordination and management mechanism for the improvement of AGTFP and the development of financial inclusion. Financial institutions should strengthen the coordination and cooperation with relevant agricultural enterprises, support relevant agricultural enterprises to develop green agricultural brands by relying on the advantages of resource endowment, and encourage them to drive the production and operation of farmers. Finally, we should take a more rational view of economic development and productivity improvement, and should not blindly follow the old road of extensive economic development at the expense of the environment. Especially when evaluating economic growth, if environmental factors are not considered, the role of financial development in productivity improvement may be partially exaggerated, so as to make some policies with general or even negative effects (Zhang 2017).

References

Allen F, Demirguc-kunt A, Klapper L,.Peria MSM(2016) The foundations of financial inclusion: Understanding ownership and use of formal accounts. Journal of Financial Intermediation 27:1-30. https://doi.org/10.1016/j.jfi.2015.12.003

Arizala F, Cavallo EA, Galindo A(2013) Financial development and TFP growth: Cross country and industry level evidence. Applied Financial Economics 23(6):433-448. https://doi.org/10.1080/09603107.2012.725931

Benhabib J, Spiegel MM (2000) The role of financial development in growth and investment. Journal of Economic

Growth 5(4):341-360. https://doi.org/10.1023/A:1026599402490
Dagum C (1997). A new approach to the decomposition of the Gini income inequality ratio. Empirical Economics 22(4):515-531.https://doi.org/10.1007/BF01205777
Deonanan R, Ramkissoon B, Ramkissoon D, Hosein R (2020) Disentangling the relationship between remittances and financial development: Evidence from Jamaica. International Review of Applied Economics 34(2):193-216.
Dubey A, Lal R (2009) Carbon footprint and sustainability of agricultural production systems in Punjab, India, and Ohio, USA. Journal of Crop Improvement.
Funte DL, Jose AA(1996) Innovation, banking monitoring and endogenous financial development. Journal of Monetary Economics 38(2):269-301. https://doi.org/10.1016/S0304-3932(96)01277-9
Greenwood J, Jovanovic B(1990) Financial development, growth and the distribution of income. Journal of Political Economy 98(5):1076-1107.
Hailu A, Veeman TS(2000) Environmentally sensitive productivity analysis of the Canadian pulp and paper industry,1959-1994: An input distance function approach. Journal of Environmental Economics and Management 40:251-274.
Hannig A, Jansen S(2015) Financial inclusion and financial stability: Current policy issues. Social Science Electronic Publishing.
Hu Y, Liu C, Peng JG (2021) Financial inclusion and agricultural total factor productivity growth in China. Economic Modelling 96:68-82. https://doi.org/10.1016/j.econmod.2020.12.021
Hui XB (2021) Digital inclusive finance and urban green total factor productivity: Internal mechanism and empirical evidence. South China Finance 5:20-32.
Lv N, Zhu LZ (2019) Study on China's agricultural environmental technical efficiency and green total factor productivity growth. Journal of Agrotechnical Economics 4:95-103.
Oh DA (2010) Global Malmquist-Luenberger productivity index. Journal of Productivity Analysis 34(3):183-197. https://doi.org/10.1007/s11123-010-0178-y
Qskam A (1991) Productivity measurement, incorporating environmental effects of agricultural production. Development in Agricultural Economics 7(2):186-204.https://doi.org/10.1016/B978-0-444-88974-4.50023-1
Rioja F, Valev N (2004) Finance and the sources of growth at various stages of economic development. Economic Inquiry 42(1):127-140. https://doi.org/10.1093/ei/cbh049
Sarma M, Pais J (2011). Financial inclusion and development. Journal of International Development 23(5): 613-628.
Schultz TW (1964) Transforming Traditional Agriculture. New Haven: Yale University Press.
Soppe A (2004).Sustainable corporate finance. Journal of Business Ethics 53:213-224.https://doi.org/10.2307/25123294
Tone K (2002) A slacks-based measure of efficiency in data envelopment analysis. European Journal of Operational Research 130(3):498-509. https://doi.org/10.1016/S0377-2217(99)00407-5
Tran TT, De Koker L(2019) Aligning financial inclusion and financial integrity: Regulating and supervising microfinance in Vietnam. Journal of Money Laundering Control 22(4): 595-613.https://doi.org/10.1108/JMLC-01-2019-0004
West TO, Marland G (2002) A synthesis of carbon sequestration, Carbone missions, and net carbon flux in agriculture: Comparing tillage practices in the United States. Agriculture Ecosystems and Environment 91:217-232. https://doi.org/10.1016/s0167-8809(01)00233-x
Wu FL, Li L Zhang HL, Chen F (2007) Effects of conservation tillage on net carbon flux from farmland ecosystems. Chinese Journal of Ecology 12:2035-2039.
Yang Q, Wang, J Li C, Liu XP (2019) The spatial differentiation of agricultural green total factor productivity and its driving factor recognition in China. The Journal of Quantitative & Technical Economics 36(10): 21-37.

Zhang F (2017) Theoretical and empirical research on the effect of financial development on green total factor productivity. China Soft Science 9:154-167.

Zhang L, Zhang WQ (2021) Study on the coupling cooperative relationship and its dynamic evolution of inclusive finance and integrated development of rural industries. The Theory and Practice of Finance and Economics 42(2): 2-11.

Zhi J, Gao JX(2009) Analysis of carbon emission caused by food consumption in urban and rural inhabitants in China. Progress in Geography 28(3):429-434.

Zhiyang S, Jean P, Bousement HL (2017) Aggregate green productivity growth in OECD's countries. International Journal of Production Economics 189:30-39. https://doi.org/10.1016/j.ijpe.2017.04.007

Zhu JH, Wang HJ, Zheng P (2019) Coupling and coordinated development of circular economy and green finance in Guizhou. Economic Geography 12:119-128.