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# How Does Social Embeddedness Affect Farmers' Adoption Behavior of Low-Carbon Agricultural Technology? Evidence From Jiangsu Province, China

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Agricultural carbon emissions, which are the second largest source of greenhouse gas emissions in China, not only place great pressure on emission reduction but also seriously affect food security and sustainable development of agriculture. As farmers are the direct users of cultivated land and the main adopters of agricultural technology, their adoption behavior of low-carbon agricultural technology directly determines its promotion and subsequent emissions reduction. It is of great theoretical and practical significance to analyze farmers' adoption behavior of low-carbon agricultural technology and their influencing factors. Based on social embeddedness theory and the survey data of 688 farmers in Jiangsu Province, this study applied a logistic model to analyze the impact of government support, farmers' cognition, social capital, personal characteristics, and family characteristics on farmers' adoption behavior of low-carbon agricultural technology. The results showed that (1) only 58.72% of farmers have adopted such a technology, which needs to be further improved; (2) government support and farmers' cognition had significantly positive influences on farmers' adoption behavior; (3) social capital is an important factor affecting farmers' adoption decisions, where social trust, networks, and norms play a significant role in promoting the adoption of low-carbon agricultural technology; and (4) party membership and household-contracted farmland area also had positive influences on farmers' adoption behavior of low-carbon technology. Therefore, to continue developing low-carbon agriculture, it is recommended to further strengthen government support, raise the price of low-carbon agricultural products, strengthen environmental supervision, and build a social embedded environment according to local conditions, and further improve farmers' social trust, enrich social networks, improve social norms, and give full play to the guiding and exemplary role of social capital. Additionally, it is also recommended to reinforce education and training to raise farmers' awareness regarding low-carbon agricultural technology, thereby guiding them to actively adopt these technologies.

**Keywords: sustainable agriculture, social embeddedness theory, social capital, factor analysis, logistic model**

## 1 INTRODUCTION

Climate change has brought upon adverse effects on human production and life, becoming a global concern for the international community (IPCC, 2014; Rees et al., 2016). Agriculture, an important factor in climate change, has become the second largest source of greenhouse gas emissions (Shang and Yang, 2021). At the United Nations Climate Change Conference in Paris, China promised to peak its carbon emissions around 2030 and reduce its carbon dioxide emissions per unit of GDP by 60–65 percent compared to that of 2005 (Hou and Hou, 2019; Zhao and Zhou, 2021). China's high-input and output agricultural production mode inevitably produces several greenhouse gases, which contributes to the continuous growth of agricultural carbon emissions and seriously affects China's food security and sustainable development of agriculture (Liu et al., 2019; Shang and Yang, 2021). Low-carbon agricultural technologies, which can improve the agricultural ecology and reduce carbon emissions, have begun to attract the attention of the government. Developed regions such as Europe and the United States have proposed these technologies, including precision agriculture and conservation tillage, and reduced the use of chemical fertilizers to minimize emissions (Hutchinson et al., 2007; Todd et al., 2009). China has also issued a series of incentives and policies to vigorously promote low-carbon agricultural technology. These policies involve agricultural waste treatment, resource recycling, or reducing the input of chemical fertilizers and pesticides. As farmers are the direct users of cultivated land and the main adopters of agricultural technology, their adoption behavior of low-carbon agricultural technology directly determines the degree to which the technology is promoted, as well as the effects of agricultural carbon emissions reduction (Hou and Hou, 2019; Zhao and Zhou, 2021). Therefore, it is key to promote low-carbon agricultural technologies, reduce agricultural carbon emissions, and realize sustainable agricultural development to guide farmers away from the high-input and output production mode and toward low-carbon agricultural technology.

Research on low-carbon agricultural technologies has mainly focused on the importance of low-carbon agricultural technologies (Freibauer et al., 2004; Kroodsma and Field, 2006; Norse, 2012; Vinholis et al., 2021), adoption of low-carbon agricultural technologies by farmers (Yang and Dong, 2019; Shang and Yang, 2021; Zhao and Zhou, 2021), the corresponding adoption effects (Todd et al., 2009; Norse, 2012; Fan and Wei, 2016; He et al., 2021), and the development paths of these technologies (Arima et al., 2014; Rees et al., 2016; Piwowar, 2019; Xiong et al., 2021). Some studies have used logistic models, Heckman sample models, structural equation models, and other methods on survey data to analyze the influencing factors on farmers' adoption behaviors toward low-carbon agricultural technology (Hou and Hou, 2019; Liu et al., 2019; Li et al., 2021; Shang and Yang, 2021; Zhao and Zhou, 2021). Their studies have shown that the behavior influencing factors predominantly included the farmers' individual characteristics, family characteristics, arable land resource endowment, and cognition (Hou and Hou, 2019; Yang and Dong, 2019; Shang and Yang, 2021; Zhao and Zhou, 2021).

The existing research results have important value and enlightenment for this study, but most studies mainly start from the internal factors of farmers or families and ignore the premise that the current application of low-carbon agricultural technology is mainly promoted by the government. Under the current background of China's grass-roots governance system and agricultural green and low-carbon development, local governments are still the main promoters of the application of low-carbon agricultural technology. It is necessary to include external factors such as government support into the analysis of farmers' adoption behavior of low-carbon agricultural technology. Most of the existing studies analyze farmers' adoption behavior of low-carbon agricultural technology from the perspective of economics and psychology, ignoring the impact of social capital on farmers' adoption behavior of low-carbon agricultural technology. Some studies involve the social motivation of farmers' adoption behavior, but the selection of indicators is not systematic and the dimension of indicators is single, and a set of multi-dimensional social embeddedness index system suitable for the reality of rural society in China has not been formed. In view of the above shortcomings, this study attempts to make the following improvements: Relying on the social embeddedness theory of new economic sociology, starting from the role of farmers' "economic and social people", this paper constructs a multi-dimensional framework of influencing factors of farmers' adoption behavior of low-carbon agricultural technology and systematically analyzes all kinds of factors (government support, social capital, farmers' cognition, personal characteristics, and family characteristics) under a unified framework.

Jiangsu is a major agricultural province in China, with various ecological types and unique agricultural production conditions. It is known as "the south of the Yangtze River with mountains and rivers and the land of fish and rice." Jiangsu is a major grain producing province in China, the largest japonica rice producing province in southern China, and also an advantageous area for the production of high-quality weak gluten wheat in China. Corn, peanut, rape, a variety of miscellaneous grains, miscellaneous beans, and other characteristic grain crops are all over the province. Jiangsu is not only a large agricultural province but also an economic province located in the east coast of China. Strong economic strength provides solid support for agricultural production. The construction of agricultural infrastructure is relatively perfect, the level of agricultural science and technology is high, and the contribution rate of agricultural science and technology is much higher than the national average level, which makes Jiangsu have a strong comprehensive agricultural production capacity. Jiangsu is one of the earliest provinces in China to explore low-carbon agriculture, and the construction of low-carbon agriculture has always been in the forefront of the country. In recent years, Jiangsu has continuously improved the legal and policy support system for low-carbon agriculture and carried out rich forms of low-carbon agricultural practice, such as vigorously developing organic agriculture, promoting the comprehensive utilization of straw and the substitution of agricultural chemicals, and promoting low-carbon agricultural technology so as to continuously improve the level of green and low-carbon development of agriculture. Therefore, the study of farmers' adoption behavior and its influencing factors of low-carbon agricultural technology in Jiangsu has an important reference value.

Based on the social embeddedness theory and the survey data of 688 farmers in Jiangsu Province, this study uses logistic model to analyze the influencing factors of farmers' adoption behavior of low-carbon agricultural technology, with the aim of providing a reference basis for the formulation and implementation of the government's low-carbon agricultural technology promotion policies.

## 2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESES

### 2.1 Theoretical Analysis Framework

In 1944, Polanyi proposed the concept of "social embeddedness of economy", which marked the initial formation of social embeddedness theory (Polanyi, 1944). In 1985, Granovetter further developed the theory and put forward the view that "economic behavior is embedded in social structure", arguing that human economic activities are always embedded in social structure, that they are not completely isolated and atomized, and that rational economic behavior is always subject to the influence of surrounding social relations (Granovetter, 1985). By integrating the zero-embedded position of economics and the strongly embedded position of sociology, social embeddedness theory has a higher explanatory power for human economic activities and provides a scientific method for studying economic behavior and social phenomena around the world.

The social embeddedness theory provides a new theoretical perspective for the research on farmers' adoption behavior of low-carbon agricultural technology. The farmers' adoption behaviors are embedded in the rural social structure and are affected by "autonomous factors" such as individual characteristics and farmers' family characteristics. These factors will in turn affect the autonomy of adoption behavior and determine to a large extent the initial adopting intent. The "embedded factors" such as government support, social capital, and farmers' cognition restrict or promote the farmers' adoption behavior of low-carbon agricultural technology, and can even change their initial behavior intentions, which has an important impact on the final adoption behavior of farmers. Based on this theoretical analysis and social embeddedness theory, our study analyzed the influence of autonomous and embedded factors on farmers' adoption behavior of low-carbon agricultural technology from five dimensions: personal characteristics, family characteristics, government support, social capital, and farmers' cognition.

### 2.2 Decomposition of Autonomous Factors and Embedded Factors

#### 2.2.1 Decomposition of Autonomous Factors

The household contract system is the basic system of agricultural production in China. Agricultural production and management decisions are usually made on a household basis, and decision behaviors are influenced by both individual and household characteristics (Kong et al., 2004; Korir et al., 2015; Long et al., 2016). Therefore, this study divided the autonomy factors into these two categories.

Farmers of different ages and identities have different social experiences, physiological, psychological, and participation abilities and have different expectations in adopting low-carbon agricultural technologies, reflected by their adoption behavior choices. Therefore, in this study, the age and party membership of farmers were chosen to characterize the farmers' individual characteristics.

Household characteristics mainly include the contracted farming area and economic status of the household, with different household characteristics leading to different motivations for adoption behavior and thus different choices. Farmers with a high proportion of farm income have more capital to invest in agricultural production and are more likely to adopt low-carbon agricultural technologies. Farmers with larger contracted farming areas are more dependent on agricultural production and are more likely to adopt low-carbon agricultural technologies when the government is vigorously promoting them. Therefore, we selected the area of contracted farmland and the proportion of farm income to characterize farmers' household characteristics.

#### 2.2.2 Decomposition of Embedded Factors

Government support. China has successively introduced a series of low-carbon agriculture policies and incentives to vigorously promote low-carbon agricultural technologies. The general requirements of laws, regulations, policies, and measures at the national level are consistent (Tian et al., 2015; Tan et al., 2021). In the specific implementation processes, the local governments' policies and measures are somewhat emphasized, which will have varying degrees of impact on the farmers' adoption behavior of low-carbon agricultural technology. The local governments' support for the promotion of low-carbon agricultural technology is shown in the form of paying attention to low-carbon agricultural technology, raising the price of low-carbon agricultural products, and strengthening environmental supervision, which will affect farmers' adoption of low-carbon agricultural technology. Therefore, this study chooses the government's attention to low-carbon agricultural technology, the price guarantee of low-carbon agricultural products, and the strength of village environmental supervision to represent the government support in the "embedded factors."

Farmers' cognition. Farmers' cognitive level is an important factor influencing their production behavior decisions. Farmers' technology adoption behavior is constrained and influenced by their behavioral habits, perceptions, and their own experiences (Gao et al., 2020; Tan et al., 2021). In agricultural production, the higher the farmers' awareness of environmental protection or the role of low-carbon agricultural technologies, the higher the adoption rate of suggestions and measures that protect the agricultural environment, and the more they positively promote low-carbon agricultural technologies. It has been found that farmers with high awareness of low-carbon agricultural technologies are more likely to adopt them (Li et al., 2021). This study therefore focused on low-carbon agricultural technology understanding as a cognitive embedded factor and analyzed its effect on farmers' adoption behavior of low-carbon agricultural technology.

Social capital. This includes social trust, norms, and relationship networks, which can improve social efficiency through cooperative behavior (Bourdieu, 1986; Coleman, 1990; Putnam et al., 1994; Ostrom, 2000). Social capital is a whole entity consisting of three mutually influencing and closely linked factors, including social networks, social trust, and social norms, which can affect farmers' adoption behavior of low-carbon agricultural technology (Michelini, 2013; Zhang et al., 2015). Social trust, which can reduce the cost of social communication, boosts the efficiency of social operations and promotes the realization of collective action. It is the core discourse of the social capital theory (Zhang et al., 2020). Good social trust can generate or encourage a tacit understanding of cooperation and the sharing of agricultural environmental information among the participants to promote low-carbon agricultural technology. It also advances the usage of the agricultural information to formulate and implement targeted low-carbon agricultural technology promotion measures. As an important channel for social capital to play its role, social norms are the code of conduct for people to participate in social life and an important support for realizing mutual assistance and cooperation (Lyon, 2000; Ostrom, 2000). Social norms form a reciprocal or binding mechanism through the reciprocity and integrity between the participants of an agricultural environment, which reduces the cost and difficulty and improves the level of agricultural environmental governance. Social norms help to form the constraint function of low-carbon agricultural technology promotion, to externally or internally restrict farmers' agricultural environmental behavior, and to encourage farmers to adopt low-carbon agricultural technology. Social networks promote close relationships through constant interactions and reinforce a sense of social responsibility and resource sharing awareness among participants during interactions within the network, which enhances participants' sense of identity and belonging to the social community (Tsang, 1998; Bandiera and Rasul, 2006). The participants in low-carbon agricultural technology promotion have a strong sense of trust and belonging in the social network, which can realize the sharing of agricultural knowledge and information, promote the smooth and orderly expression of environmental demands and coordination interests of the participants, and form a "bottom-up" decision-making mechanism for promoting low-carbon technology. Social networks help to shape the communication function of low-carbon agricultural technology promotion and to incite farmers' adoption of low-carbon agricultural technology.

### 2.2.3 Research Hypothesis

Based on the aforementioned analysis of autonomous factors, it is assumed that both individual and family characteristics of farmers will impact the farmers' adoption behavior of low-carbon agricultural technology, hence the corresponding research hypotheses: Individual characteristics of farmers significantly affect the farmers' adoption behavior of low-carbon agricultural technology, and family characteristics of farmers have a significant positive impact on the farmers' adoption behavior of low-carbon agricultural technology.

Based on this analysis of the embedded factors, this study assumed that government support, farmers' cognition, and social capital all have an impact on the farmers' adoption behavior of low-carbon agricultural technology, thus lending to the corresponding research hypotheses: Government support has a positive impact on the farmers' adoption behavior of low-carbon agricultural technology, farmers' cognition has a significant positive impact, social trust has a positive impact on the farmers' adoption behavior of low-carbon agricultural technology, social norms have a significant positive impact on the farmers' adoption behavior of low-carbon agricultural technology, and social networks have a positive impact on the farmers' adoption behavior of low-carbon agricultural technology.

## 3 DATA SOURCES AND RESEARCH METHODS

### 3.1 Data Sources

Jiangsu Province is located in the scenic and fertile Yangtze River Delta, which is a vast plain with superior natural conditions and a good economic foundation. The province boasts of an area of 107,200 $km^2$, which accounts for 1.1% of China's landmass. In this province, there are 13 cities and 96 counties, and the resident population is 84.7726 million. Additionally, in this province, the overall GDP, the per capita GDP, and the per capita disposable income of residents are 10271.898 billion, 121231, and 43390 yuan, respectively (Jiangsu Provincial Bureau of statistics and Jiangsu survey team of National Bureau of Statistics, 2021). This province has unceasingly improved on its management and control systems for agricultural resources and environment. It has promoted green, low-carbon, and recycling-based modes of production and has accelerated the development of low-carbon agriculture. Jiangsu Province is at the forefront of modern agricultural construction in China. In 2020, the province built 240000 ha of high-standard farmland. The mechanization rate of crop cultivation and harvest reached 80%, and the contribution rate of agricultural scientific and technological progress reached 70%. Moreover, this province has progressed in the development of the agricultural ecological environment, priority has been given to the prevention and control of agricultural non-point source pollution, and the "zero-growth" action plan to reduce the use of chemical fertilizers and pesticides has been implemented. There has therefore been a decline in the total use of chemical fertilizers and pesticides in the whole province. With the steady promotion of utilizing agricultural waste, the recovery rate of waste agricultural film has reached 87%, the comprehensive utilization rate of crop straw has reached 95%, and the comprehensive utilization rate of livestock and poultry manure has reached 97%.

In this study, we used both stratified and random sampling and administered a questionnaire survey to farmers. The survey

**TABLE 1 |** Meaning and assignments of variables.

| Category | Name | Meaning and assignments |
|---|---|---|
| Dependent variable | farmers' adoption behavior | adoption or not: Yes = 1; No = 0 |
| Embedded factors | Degree of attention | Not paying attention = 1, generally = 2, paying great attention = 3 |
| | Strength of environmental supervision | Lower = 1, generally = 2, higher = 3 |
| | Price guarantee degree | Lower = 1, generally = 2, higher = 3 |
| | Farmers' Cognition | Don't know = 1, know = 2 |
| | Social trust | Factor analysis score |
| | Social norms | Factor analysis score |
| | Social networks | Factor analysis score |
| Autonomous factors | Age | Continuous variable |
| | Party membership | party members = 1, not party members = 0 |
| | Proportion of agricultural income | Continuous variable |
| | Household-contracted farmland area | Continuous variable |

was conducted between July of 2016 and April of 2017 in Xuyi County, Guanyun County, Xinghua City, Jingjiang City, Lishui District, and Jiangning District. The questionnaires were administered to 714 farmers, and after verification, 688 questionnaires were found to be valid. The average age of the farmers was 53 years, and the average area of contracted farmland cultivated by each household was 0.36 $hm^2$. The proportions of respondents who have had a primary or secondary school education were approximately 14.68 and 32.27%, respectively. In regards to the annual household income of the respondents, the minimum and maximum were 6,500, and 1.9 million, respectively, and the average agricultural income proportion of the farmers was approximately 22.38%.

## 3.2 Variable Selection

### 3.2.1 Dependent Variable

Low carbon agricultural technology refers to various methods and means adopted by agricultural producers in the process of agricultural production and management to reduce energy consumption, emissions, and pollution so as to minimize carbon emissions in the process of agricultural production and reduce its impact on society, mainly including soil testing and formula fertilization technology, pest control technology, biological pesticide use technology, straw returning technology, less tillage and no tillage technology, soil subsoiling technology, food safety production technology, and so on.

The dependent variable was "farmers' adoption behavior of low-carbon agricultural technology," which was reflected by the question, "Do you adopt low-carbon agricultural technology?" (Answer: Yes/No). "Yes" meant that the farmer was willing to adopt low-carbon agricultural technology and was assigned a value of 1, otherwise a value of 0 was assigned. The results obtained showed that in the survey sample, 58.72% of farmers have adopted low-carbon agricultural technology, indicating that the adoption level of low-carbon agricultural technology needs to be further improved.

### 3.2.2 Independent Variable

Among the farmers' individual characteristics, age and party membership were selected as independent variables, and among the farmers' household characteristics, the proportion of agricultural income and the area of household contracted cultivated land were selected as independent variables (**Table 1**). In regard to government support, the government's attention to low-carbon agricultural technology, strength of village environmental supervision, and price guarantee degree of low-carbon agricultural products were selected as independent variables (**Table 1**). For the farmers' cognition, the low-carbon agricultural technology understanding was selected as the independent variable (**Table 1**).

The independent variable social capital was measured from three dimensions: social network, social norms, and social trust (Michelini, 2013; Zhang et al., 2015; Zhang et al., 2020). The indicators for social trust were "degree of trust in the township government," "degree of trust in village cadres," "degree of trust in neighbors," and "degree of trust in highly respected villagers." The indicators for social norms were "whether one will be punished or queried for not participating in collective activities" and "ease of borrowing money based on the establishment of good interpersonal relationships with surrounding people." The indicators for social networks were "frequency of contact with relatives" and "frequency of contact with acquaintances" (**Table 1**).

## 3.3 Model Building

### 3.3.1 Factor Analysis Method

Factor analysis is a multivariate statistical analysis method that extracts a few factors that could reveal vital information from many original variables while ensuring the minimization of information loss (Dong et al., 2020; Zaleski and Michalski, 2021). Its basic idea is to group variables based on correlation such that the correlation is higher between variables in the same group and lower for variables in different groups. Each group of variables represents a basic structure called a common factor. An indicator system was formed for social capital measurement and used for factor analysis to measure that of farmers, based on its three aspects: social trust, social norms, and social networks.

### 3.3.2 Logistic Model

The dependent variable is a binary variable comprising "adopt low-carbon agricultural technology" and "not adopt low-carbon

**TABLE 2 |** Factor loading matrix after rotation.

| Original variable | F1 | F2 | F3 |
|---|---|---|---|
| Degree of trust in the township government | 0.825 | –0.006 | 0.096 |
| Degree of trust in village cadres | 0.892 | 0.041 | 0.101 |
| Degree of trust in neighbours | 0.791 | 0.099 | 0.016 |
| Degree of trust in highly respected villagers | 0.794 | 0.095 | 0.067 |
| Whether one will be punished or queried for not participating in collective activities | –0.004 | –0.037 | 0.876 |
| Ease of borrowing money based on the establishment of good interpersonal relationships with surrounding people | 0.131 | 0.137 | 0.535 |
| Frequency of contact with relatives | 0.011 | 0.876 | 0.065 |
| Frequency of contact with acquaintances | 0.128 | 0.866 | 0.073 |

agricultural technology." Thus, to analyze influencing factors of farmers' adoption behavior of low-carbon agricultural technology, a logistic regression analysis was performed (Zhang et al., 2020),

$$In\left(\frac{p_i}{1-p_i}\right) = \alpha_0 + \sum \beta_i x_i + \varepsilon. \quad (1)$$

In **Eq. 1**, $\frac{p_i}{1-p_i}$ represents the ratio of the probability of adoption of low-carbon agricultural technology to the probability of farmers' non-adoption of low-carbon agricultural technology ($i = 1, 2, \ldots, n$). Additionally, $p_i$ denotes the probability of the $i$th farmer adoption of low-carbon agricultural technology, whereas $1 - p_i$ denotes the probability of the $i$th farmer non-adoption of low-carbon agricultural technology. $\alpha_0$ represents a constant term, while $x_i$, $\beta_i$, and $\varepsilon$ represent the independent variables (divided into embedded factors and autonomous factors), the partial regression coefficient, and the stochastic disturbance term, respectively.

**TABLE 3 |** Estimated results on factors that influence farmers' adoption behavior of low-carbon agricultural technology.

| Variable | M1 | M2 |
|---|---|---|
| Age | –0.021 (0.006) | –0.010 (0.007) |
| Party membership | 1.075 (0.164)*** | 0.797 (0.178)*** |
| Household-contracted farmland area | 0.075 (0.027)*** | 0.074 (0.028)*** |
| Proportion of agricultural income | 0.001 (0.003) | 0.002 (0.003) |
| Degree of attention | | 0.732 (0.134)*** |
| Strength of environmental supervision | | 0.271 (0.128)** |
| Price guarantee degree | | 0.245 (0.124)** |
| Farmers' cognition | | 0.584 (0.184)*** |
| Social trust | | 0.224 (0.098)** |
| Social networks | | 0.215 (0.114)* |
| Social norms | | 0.206 (0.091)** |
| Constant term | 0.510 (0.367) | –5.522 (0.862)*** |
| -2Log Likelihood | 863.330 | 775.653 |
| Cox & Snell $R^2$ | 0.096 | 0.204 |
| Nagelkerke $R^2$ | 0.129 | 0.275 |

*Notes: *, **, and *** passing the significance test at statistical significance levels of 10,5, and 1%, respectively; the values in parentheses are standard errors.*

# 4 RESULTS AND ANALYSES

## 4.1 Social Capital of Farmers

To determine whether the questionnaire data were suitable for factor analysis, the validity of the social capital questionnaire was first tested. The test results showed that the KMO value reached 0.725 and that Bartlett's test statistics reached 1622.886, which passed the significance test at $p < 0.01$, indicating that the data were suitable for factor analysis (Liu and Zheng, 2021; Zaleski and Michalski, 2021). Thus, factor analysis was performed, and common factors were extracted. In accordance with the principle that the eigenvalue should be greater than 1, the common factors were examined, and eventually, three common factors were obtained. The total variance contribution rate of the three common factors was 67.658%, which implied that the common factors could replace the overall data on farmers' social capital and indicated that the results of the factor analysis were effective. To better dissect the common factors, the factor analysis model was subjected to orthogonal rotation so as to bring their load coefficients closer to 1 or 0. After four iterations, the orthogonal rotation of the factor analysis converged to generate the factor loading matrix (**Table 2**).

**Table 2** shows that the load coefficients of Factor 1 were higher in "degree of trust in the township government," "degree of trust in village cadres," "degree of trust in neighbors," and "degree of trust in highly respected villagers," which reflected social trust. The load coefficients of Factor 2 were higher in "frequency of contact with relatives" and "frequency of contact with acquaintances," which reflected social networks, and the load coefficients of Factor 3 were higher in "whether one will be punished or queried for not participating in collective activities" and "ease of borrowing money based on the establishment of good interpersonal relationships with surrounding people," which reflected social norms. The load coefficients of the three common factors to the original variables were all above 0.5, there was no cross loading of the original variables on the common factors, and the original variable displayed good discriminant validity and convergent validity (Zhang et al., 2020). Therefore, according to the factor coefficient matrix, the three common factors F1, F2, and F3 were measured to score social trust, social networks, and social norms, respectively.

## 4.2 Regression Analysis Results

To explore the influencing factors of farmers' adoption behavior of low-carbon agricultural technology, an analysis method that allowed model comparison was employed. First, the autonomous factors (farmers' individual and family characteristics) were fed into the logistic regression model to obtain the benchmark model, namely, Model 1. Based on Model 1, embedded factors including government support, farmers' cognition, and social capital were included. This model was referred to as Model 2 (**Table 3**). The chi-square test values obtained from Models 1 and 2 both reached the 1% significance level, indicating that the regression model is generally applicable. The estimated results from the logistic regression models shown in **Table 3** reveal that including the core independent variables of social capital in Model 2 resulted in a considerable increase in Cox & Snell $R^2$ and Nagelkerke $R^2$, while the explanatory power became stronger. Therefore, subsequent analyses were based on the estimated results of Model 2.

### 4.2.1 Influence of Embedded Factors on Farmers' Adoption Behavior

Model 2 showed that government support, farmers' cognition, and social capital are major factors that influenced farmers' adoption of low-carbon agricultural technology, and that they affected the adoption behavior to varying degrees.

1) The impact of government support on the farmers' adoption behavior of low-carbon agricultural technology.

Government support had a significant positive impact on the farmers' adoption behavior of low-carbon agricultural technology (**Table 3**). The degree of attention had an impact on the farmers' adoption behavior of low-carbon agricultural technology at the significance level of 1%, the impact of village environmental supervision on the farmers' adoption of low-carbon agricultural-technology can pass the 5% significance test, and the price guarantee degree of low-carbon agricultural products can affect farmers' adoption of low-carbon agricultural-technology at the 5% significance level, therefore supporting the research hypothesis.

The government, especially the local government, plays a prominent guiding role in the process of agricultural production by farmers. Therefore, government support also had a great impact on the farmers' adoption behavior of low-carbon agricultural technology. The policies and measures formulated by the government enabled farmers to form a basic understanding of these issues and actively drove them to participate in modern agricultural production. Farmers were encouraged by a series of government low-carbon agricultural technology measures and were thus more willing to adopt this technology. The government effectively increased the price of low-carbon agricultural products and increased the price guarantee of low-carbon agricultural products, which can improve the vitality of low-carbon agricultural products, enable farmers to produce low-carbon agricultural products with good income guarantee, stimulate farmers' enthusiasm for changing agricultural production methods, and strengthen farmers' spontaneous low-carbon agricultural production behavior, thereby promoting farmers to adopt low-carbon agricultural technologies. The government strengthens the environmental supervision of villages and strengthens the supervision of low-carbon agricultural development, which can restrain farmers' agricultural production behavior, drive farmers to change agricultural production methods, and significantly increase farmers' adoption of low-carbon agricultural technologies, thereby increasing the probability of farmers to adopt low-carbon agriculture technology.

2) The influence of farmers' cognition on the adoption behavior of low-carbon agricultural technologies.

Farmers' cognition had a significant positive effect on low-carbon agricultural technology adoption behavior and passed the significance test at the 1% level, which once again supports the research hypothesis (**Table 3**). This suggests that farmers with high awareness of low-carbon agricultural technologies are more likely to adopt them. One possible explanation is that as farmers' awareness increases, they begin to pay attention to the agroecological environment and care about promoting low-carbon agricultural technologies. This in turn further motivates farmers to adopt such technologies and makes them more willing to actively improve the agroecological environment. It is also possible that the increase in farmers' awareness level will be further internalized in the farmers' own rational choices to the same benefit to adoption behavior.

3) Influence of social trust on farmers' adoption behavior of low-carbon agricultural technology.

Social trust positively influenced the farmers' adoption behavior of low-carbon agricultural technology at a significance level of 5%, supporting the first research hypothesis (**Table 3**). When other conditions remained constant, the probability that farmers will exhibit adoption behavior of low-carbon agricultural technology increased by 25.11% per each raised level of social trust, indicating that farmers with high level of social trust were more likely to adopt low-carbon agricultural technology compared with those with low level of social trust. In rural communities, the level of social trust is an important factor in the promotion of cooperation. Low-carbon agriculture is a systematic project that requires substantial manpower and financial input, as well as coordination and cooperation among participants. To a certain extent, the level of trust provides a good guarantee for cooperation, stimulates farmers to adopt spontaneous participation behavior and carry out mutually beneficial cooperation, and lowers transaction costs, thereby encouraging farmers to adopt low-carbon agricultural technology.

4) Influence of social networks on farmers' adoption behavior of low-carbon agricultural technology.

Social networks positively influenced the farmers' adoption behavior of low-carbon agricultural technology at the significance level of 10%, thus supporting the second research hypothesis (**Table 3**). When other variables remained constant, the probability that the farmers' adoption behavior skewed in favor of low-carbon agricultural technology increased by 23.99% per each raised level of social network, indicating that farmers with stronger social networks were more likely to adopt low-carbon agricultural technology compared with those with lower weaker social networks. In rural communities, farmers with higher levels of social networks found it easier to obtain and share information resources on low-carbon agricultural technology, and this enhanced their willingness to participate in rural collective actions. Furthermore, farmers with high levels of social networks had more stable social resources; and as carriers of agricultural environmental information, they contributed to agricultural environmental information spillover and knowledge dissemination. This further encourages them to participate in low-carbon agriculture. Farmers with higher contact frequencies with relatives and acquaintances generally possess more social resources, which helps them to exercise their strong communication and social mobilization skills, thereby promoting the adoption of low-carbon agricultural technology.

5) Influence of social norms on the farmers' adoption behavior of low-carbon agricultural technology.

Social norms positively influenced the farmers' adoption behavior of low-carbon agricultural technology at a significance level of 5%, which supports the first research hypothesis (**Table 3**). When other conditions remained constant, the probability that farmers exhibited positive adoption behavior of low-carbon agricultural technology increased by 22.88% with each raised level of social norms, indicating that farmers with high level of social norms were more likely to adopt low-carbon agricultural technology compared with those with low level of social norms. The rural social norms can play a binding role and have a significant positive affect on farmers' adoption of low-carbon agricultural technology. Norms stipulate what is permitted and what is not, and informal norms such as village rules, folk conventions, and folk customs can greatly encourage collective cooperation. With the acceleration of urbanization, some moral rules in rural cultures have been deconstructed, but they continue to play a role in regulating the behavior of villagers. In rural society, if members do not participate in collective activities which are necessary, they will be talked about by other villagers. Hence, when making behavior choices, other members need to take into consideration the pressure of public opinion in the village. There is no doubt that such moral pressure is an intangible constraint on the villagers; therefore, farmers' participation in collective affairs will increase significantly because of the guidance of norms. In addition, a good relationship with the community will help when the farmer needs to borrow money. Farmers become willing to interact with the community and to establish good relationships so that they can benefit from such relationships and obtain needed resources in the future.

#### 4.2.2 Influence of Autonomous Factors on Farmers' Adoption Behavior

Model 2 showed that, among the autonomous factors, party membership and household-contracted farmland area passed the significance test (**Table 3**). Party membership had a significant and positive influence on farmers' adoption of low-carbon agricultural technology and passed the significance test at a 1% level, and the study hypothesis was tested. It indicated that farmers with the status of Communist Party of China were more willing to adopt low-carbon agricultural technology. A possible explanation is that compared with farmers who are not party members, farmers with the status of party members participate in more public affairs in the village, have more open vision, and are more receptive to new practices. They have a relatively better understanding of the critical role of low-carbon agricultural technology in agricultural sustainable development. Thus, they show more enthusiasm in their willingness to adopt low-carbon agricultural technology.

Household-contracted farmland area had a significant and positive influence on farmers' adoption behavior of low-carbon agricultural technology and passed the significance test at a 1% level, indicating that farmers with a larger household contracted farmland area were more willing to adopt low-carbon agricultural technology. A possible explanation is that, compared with farmers with smaller farmland areas, those with larger household-contracted farmland areas are more dependent on agricultural production and are more concerned about low-carbon agriculture when the government promotes its development. Consequently, they possibly possess a greater understanding of the nature and future expectations of low-carbon agricultural technology, and this causes them to show more interest in such a technology.

## 5 CONCLUSIONS AND POLICY IMPLICATIONS

### 5.1 Conclusions

Government support had a significant positive impact on the farmers' adoption behavior of low-carbon agricultural technology, while the degree of attention impacted it at the significance level of 1%. The impact of village environmental supervision on the farmers' adoption of low-carbon agriculture-technology can pass the 5% significance test, and the price guarantee degree of low-carbon agricultural products at the 5% significance level has an impact on the farmers' adoption of low-carbon agriculture-technology agricultural. Farmers' cognition had a significant positive impact on farmers' adoption behavior of low-carbon agricultural technology (significance level of 1%).

The social capital is a major factor that affected farmers' adoption behavior of low-carbon agricultural technology. Social trust, social networks, and social norms positively influenced the farmers' adoption behavior of low-carbon agricultural technology at 5, 10, and 5% significance levels, respectively, indicating that social trust, social networks, and social norms play a significant role in the enhancement of farmers' adoption of low-carbon agricultural technology.

Party membership showed a significantly positive influence on the farmers' adoption behavior of low-carbon agricultural technology. Farmers with the status of party members of Communist Party of China displayed greater willingness to adopt low-carbon agricultural technologies. Additionally, the household-contracted farmland area also had a significantly positive effect on the farmers' adoption behavior of low-carbon agricultural technology (significance level of 1%).

Overall, this study made some interesting findings. The government support, social capital, and farmers' cognition significantly enhanced farmers' adoption levels of low-carbon agricultural technology in China. We can strengthen government support, build a social embedded environment conducive to the application of low-carbon agricultural technology according to local conditions, improve the level of social capital, give full play to the guiding and exemplary role of social capital in the application of low-carbon agricultural technology, reinforce the education and training, and improve the farmers' awareness and responsibility to lead them to actively adopt in low-carbon agricultural technology. Furthermore, this conclusion could also be applied to rural areas in other countries.

## 5.2 Policy Recommendations

### 5.2.1 Strengthen Government Support

Further strengthening government support, improving policies and regulations, and optimizing incentive measures are ways to promote low-carbon agricultural technology. It is recommended to increase the government's attention to low-carbon agricultural technologies for establishing and improving the supervision mechanism and the reward and punishment mechanism. This will increase the promotion of low-carbon agricultural technologies and promote the construction of low-carbon agricultural technology demonstration zones. Through on-site demonstrations and the introduction of typical experiences, "personal statement" of people around them can be collected to enhance the effect of technology demonstration, and farmers can be helped with the idea of "seeing is believing," thereby encouraging them to actively adopt low-carbon agricultural technology, increase the publicity of the ecological, social, and economic value of low-carbon agricultural technology, further improve farmers' awareness of the utility of low-carbon agricultural technology, and create a good atmosphere for the adoption of low-carbon agricultural technology; and further improve the price of low-carbon agricultural products, improve the price guarantee degree of low-carbon agricultural products, and build farmers' good expectations for the benefits of adopting low-carbon agricultural technologies; and further strengthen environmental supervision, strengthen the supervision of low-carbon agricultural technology adoption, effectively restrict farmers' agricultural technology adoption behavior, and then improve the probability of farmers' adoption of low-carbon agricultural technology.

### 5.2.2 Enhance Social Trust

Social trust helps to eliminate information asymmetry between participants in low-carbon agricultural technology extension, reduce transaction costs, and strengthen governance performance. Therefore, to enhance social trust, it is recommended to promote the leading role of village cadres, improve the deliberative democracy system of villages, and implement social supervision over village affairs. Additionally, it is also recommended to enhance sufficient publicity in advance, conduct strict deliberations over matters so as to arrive at fair conclusions, and establish a system in which village cadres serve farmers. This enhances farmers' trust in the village cadres and in turn also increases their trust in low-carbon agriculture policies. It also reduces the transaction costs associated with the implementation of low-carbon agriculture.

It is also recommended to promote social trends of mutual trust, facilitate win-win cooperation, and enhance communication and interactions between farmers and heterogeneous groups through collective activities, as these can facilitate the establishment of trust among farmers, create positive expectations of the others, and increase the probability of farmers adopting low-carbon agricultural technology.

### 5.2.3 Broaden Social Networks

Social networks suggest making use of relationship networks that involve a wider participation to build interactive platforms for participants in low-carbon agricultural technology promotions, improve the mechanism of participation in agricultural environmental governance, and promote benign interactions among participants, thereby heightening the development level of low-carbon agriculture. To broaden social networks, it is recommended to reinforce the construction of village cooperative organizations, support the development of cross-village cooperative organizations, and enhance the degree of familiarity among farmers. It is also recommended to reinforce the training of rural elites and enhance the exemplarity of their leading roles. Additionally, the establishment of multi-level communication avenues and agricultural environmental information channels using the internet, television, and radio to improve communication and interaction among farmers as well as heterogeneous groups through collective activities, such as training and mobilization, is also recommended. To expand farmers' relationship networks and encourage them to use relationship network channels to acquire resources, it is also recommended to guide the farmers to participate in various types of cooperative organizations, including "cooperatives + farmers" and "enterprises + farmers." This will further enhance the probability of farmers adopting low-carbon agricultural technology.

### 5.2.4 Develop Social Norms

By utilizing the reciprocity principle, binding norms, and informal systems, social norms can influence the behavior of participants in low-carbon agricultural technology extension. Therefore, to develop social norms, it is recommended to reinforce the cultivation of team spirit and social virtues among the participants in low-carbon agricultural technology promotion. This will make them fully aware of the relationship between their own interests and collective interests and will also enhance their sense of collective belonging and identity. It is also recommended to allow farmers to establish correct values, promote their awareness regarding mutually beneficial cooperation, and reduce the difficulty associated with agricultural environmental behavior. Based on customs, village rules, and regulations, it is recommended to devise a reward and penalty system surrounding low-carbon agricultural technology adoption to reward and offer publicity to farmers with good participation. This will build up their trust in low-carbon agriculture policies. Additionally, it is essential to prioritize the main role farmers play in low-carbon agricultural technology adoption, perform a careful analysis of their psychological characteristics in the agricultural environment, and encourage them to take the initiative to cooperate.

### 5.2.5 Reinforce Education and Training

The effective implementation of education and training can increase the probability of farmers adopting low-carbon agricultural technology. Cultural education, science and technology training, and inviting farmers to participate in learning activities can enhance their education level and decision-making abilities in production and management. This can facilitate their participation in low-carbon agriculture. Conducting training and enhancing publicity with respect to policies on low-carbon agricultural technology will enable farmers to be fully aware of the importance of low-carbon agricultural technology. Through education and training, the main role of farmers in low-carbon agricultural technology adoption can be reinforced, their sense of agricultural environmental responsibility can be enhanced, and their confidence in low-carbon agricultural technology adoption extension can be developed and bolstered. This will reshape their ideas, raise their awareness on participation, and guide them to adopt low-carbon agricultural technologies.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## AUTHOR CONTRIBUTIONS

HZ: Conceptualization, data analysis, data description, explanation of results, and writing. JM: Data analysis and writing. ZY: Conceptualization, methodology, explanation of results, reviewing, and editing. FH: Conceptualization, explanation of results, reviewing, and editing.

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