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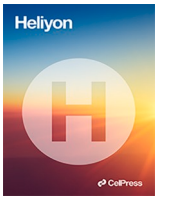

Review article

Cooperative membership and farmers' environment-friendly practices: Evidence from Fujian, China

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ABSTRACT

This study investigates the relationship between Chinese farmers' propensity to adopt environment-friendly practices and their membership in cooperatives. Based on data collected in 2021 from the Fujian China Household Survey, the Endogenous Switching Probit model (ESP) is applied to account for unobserved factors that could simultaneously affect farmers' cooperative membership and their willingness to adopt environment-friendly practices. First, the results indicate that a cooperative membership has a positive impact on the level of farmers' interest in green production practices. Second, there is evidence of some heterogeneity (based on both observable and unobservable characteristics) in the impact of cooperative membership; the higher the farmers' capital returns, the more prominent the role of cooperatives in guiding these farmers. Third, participation in cooperatives is conducive to raising farmers' interest in green production. The overall conclusion is that a cooperative membership raises the Chinese farmers' willingness to adopt environment-friendly practices.

1. Introduction

The environmental problems that agriculture generates have collective causes and require collective action. For many decades, intensified agricultural production in China has resulted in increasing environmental problems. Thus, agriculture accounts for more than 50 % of all non-point source pollution sources. Neither farmers nor consumers can be blamed. Both parties act rationally from their own, individual point of view. Consumers need large volumes of food at affordable prices, and in their legitimate strivings to satisfy consumers' demands in an economically sustainable way, agricultural producers have abandoned the production practices used by their ancestors. During the course of several decades, production practices have evolved that are harmful to the environment and the long-term interests of greater society [1]. For example, extensive tillage harms the soil, which results in a shortage of worms, microorganisms, and minerals [2], and excessive use of artificial fertilizers causes leakages of nutrients into rivers and lakes [3]. Moreover, insecticides, herbicides and fungicides threaten wildlife, vegetation and biodiversity, and these chemical substances may also contaminate food for humans.

However, there is at present a global focus on the development of environment-friendly agriculture practices, which are more compatible with sustainability [4,5]. The world successively realizes that action is needed to obtain long-term solutions to environmental problems [6]. According to the United Nations Environment Program, eco-friendly production will facilitate the effective use of

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rural resources and reduce environmental pollution.

Measures to handle environmental problems require collective action, because it is unlikely that consumers will voluntarily adopt norms, which imply that they demand exclusively environment-friendly products. As people do not protect the environment in their role as consumers, they must do so in their role as citizens, i.e., through their politicians. Hence, the problems require intervention from national governments, or even international organizations.

There is a chance that a government will succeed better with the implementation of its environmental policies if it collaborates with collective organizations, such as cooperatives. Such organizations have the task of safeguarding the collective and long-term interests of a group of individuals by uniting their individual and short-term interests. Cooperatives have proven themselves to be well suited to protect farmers' interests in many agricultural industries and countries [7–10]. Thus, cooperatives may, at least to some extent, promote farmers' adoption of environment-friendly practices [11]. Cooperatives have a potential to help farmers to get a secure sales channel for environment-friendly products, enjoy economies of scale in all phases of the value chain, receive advice and guidance from the cooperative, obtain valuable farm inputs, and otherwise gain support from their cooperative.

The topic of farmer cooperatives' environmental-friendly activities has been addressed by many researchers in both developed and developing countries. In their literature review of this topic, Ref. [10] found that cooperatives in general are not clearly oriented towards environment-friendliness. This view is supported by several other researchers, some of them presenting overview of other studies [12–14].

On the other hand, other studies argue that cooperatives promote the greening of agriculture. Many of these studies originate from developing countries, not the least China [3,5,15–18]. The divergent views among different researchers call for an inquiry about the conditions, under which cooperatives are especially likely to promote environmental-friendly farm practices. Ref. [18] state that "little is known about how membership in farmers' organizations affects members' adoption of good farm management practices, new technologies, and sustainable farming practices.".

Thus, this study is devoted to an analysis of why Chines cooperatives play an important role for the greening of agriculture. Cooperatives have a strong position in Chinese agriculture [19]. The agricultural cooperative business form (hereafter referred to as "farmer cooperatives" or "cooperatives") has expanded dramatically in China after the law on cooperatives was introduced in 2007 [20]. By the end of March 2022, there were more than two million cooperatives registered in China, with nearly half of the country's farmers as members. Because of their strong position in the Chinese agricultural sector, cooperatives may play a significant role in promoting the environment-friendly agricultural practices that the government wants to implement [21].

The aim of the study is to explore reasons why Chinese farmer cooperatives may induce their members to adopt more environment-friendly practices. The study focuses on the farmer-members' propensity to adopt less environment-harmful practices, for example, using less pesticides and mineral fertilizers without abandoning these substances completely.

The theoretical contribution of this study is that it shows how farmer cooperatives under certain circumstances have a potential to alleviate environmental problems. There are solid theoretical arguments that the cooperative business form is essential for farmers who are small and vulnerable in large markets [7,22,23]. Many studies have shown that cooperatives are valuable for their members and rural communities in economic and social terms [24–27]. This study contributes to this strand of knowledge as it investigates cooperatives' potential of supporting the members' interest in environment-friendly production.

The study has practical value for cooperative leadership, non-governmental organizations and governments, perhaps predominantly in developing countries. Based on the findings, the decision makers in these organizations could find measures regarding how to better promote the development of green agriculture.

In section 2, the core concepts of the study are subject to analyses, resulting in three hypotheses. Section 3 contains an account of the methodological issues for the empirical work, while Section 4 presents the results from the statistical analyses, followed by a discussion of the findings in Section 5. Finally, Section 6 presents conclusions, including accounts of the theoretical contributions, practical implications, limitations of the study, and suggestions for further research.

2. Conceptual framework

This section identifies factual, economic and socio-psychological conditions, under which the cooperative business form might be conducive for environmental-friendly agricultural production; a cooperative's attributes may support environmental-friendly activities; the members' economy may benefit; the mentality within the membership and the leadership may be positive.

2.1. Cooperative principles and environmental friendliness

The relationship between cooperative businesses and environment-friendly production is under debate [10,12,14]. Different studies point in different directions. One explanation to this controversy is that there are many definitions of the concepts of cooperatives and cooperative principles. According to a widely accepted scientific definition, there are three elements for a cooperative, none of which indicate any concern for environmental issues, which means that the general concept of cooperatives is neutral as concerns environmental protection [28]:

1. *The User-Owner Principle:* Those who own and finance the cooperative are those who use the cooperative
2. *The User-Control Principle:* Those who control the cooperative are those who use the cooperative
3. *The User-Benefits Principle:* The cooperative's sole purpose is to provide and distribute benefits to its users on the basis their use.

Except for the theoretically based definitions, many practitioners have stated cooperative principles, often based on the principles that were suggested in the 1840s by the pioneers behind today's large cooperative movements [7]. Thus, there are contradictory sets of principles, suitable for specific industries, time epochs, cultures, and other conditions. The most well-known set of cooperative principles is the one stated by the International Cooperative Alliance. Among these principles, there is one, saying that "Concern for Community", explained as "Cooperatives work for the sustainable development of their communities through policies approved by their members" (https://www.ica.coop/en/cooperatives/cooperative-identity). However, the last few words of this statement explain that cooperatives may take any position as concerns environmental issues.

Thus, it is not possible to raise any theoretical arguments for cooperatives being generally oriented towards environmental-friendly action. Because farmers belong to cooperatives for economic and social reasons, they welcome environment-friendly production only if this provides better financial results [9,29]. Farmers and their cooperatives often have financial constraints, while environmental operations require investments, and such investments are often risky [30,31]. Farmers tend to be risk averse and thus consider their membership as a shield against external impulses [17]. They generally want stability in the operations, i.e., keep to their existing production practices [10]. Moreover, farming is typically characterized by conservatism and traditions. Cooperatives' democratic governance implies inertia in the decision-making [14]. They are also stuck with their existing members, so they cannot easily shift to another agricultural industry with other products and other suppliers. The members have large transaction-specific assets in their existing production, and cooperatives exist because they protect these assets. Likewise, there are often large transaction-specific assets within the cooperative business firm [8]. All these factors mean that, in general, cooperatives are not likely to convert their existing business operations into other business operations, such as environment-friendly production [10].

Investor-owned firms, on the other hand, can easier exploit new market opportunities, for example an environment profile. They have better access to financial capital and can select farmer-suppliers with specific attributes, and they have concentrated decision-making. Thus, if the owners of an investor-owned firm expect profitable business opportunities, they can establish operations in a new industry, for example the production of green products.

Likewise, there is no empirical evidence that cooperatives in general are more oriented towards environmental issues than non-cooperative firms are [10,12,14]. In a meta study of how to evaluate the sustainability performance of farmer cooperatives, Ref. [13] write, "there is a predominance of Normativity and Descriptive approaches". This is to say that many authors write that cooperatives should work for eco-friendliness, even though they presently do not do so, and that researchers have a tendency to present positive cases. The authors also identify cooperatives that work with sustainable agriculture [32], but this research consists of many case studies of specific cooperatives [10]. These are, however, not representative of the whole population of cooperatives and thus provide only anecdotal evidence [33]. A conclusion is that it is not possible to claim that cooperatives in general are specifically oriented towards environment-friendly production.

2.2. Conditions for cooperatives' environmental friendliness

Despite the above-mentioned arguments, many empirical studies report on cooperatives and farmers working with environment-friendly products. This implies that, under certain conditions, cooperatives may be successful with such operations. The following account of such factors indicates that Chinese cooperatives have good prospects for environment-friendly operations.

Market demand. There are cases when farmers have discovered new market opportunities earlier than existing firms have [34]. When a large firm dominates a market, there is a high chance that this firm will not satisfy the consumer demand within smaller market niches, for example, a niche for environment-friendly products [35]. A group of farmers may want to fill this gap [24]. Ref. [36] present a case study about a market-dominating cooperative with conventional production. A small group of members with an environmental orientation succeeded to convince the board of this large cooperative that it should start a branch of environment-friendly products. Ref. [37] present a case, where a small group of farmers with environmental interests exited a large cooperative and established a small cooperative with only environment-friendly production, to be marketed regionally. These examples indicate the importance of short supply chains, with a proximity between the farmers and the consumers [10]. In a similar way, the Chinese market might have niches that are ripe for environment-friendly products.

Preferences for environment-friendly products. Farmers may genuinely care about environmental issues because they work with natural resources and observe how nature is changing, perhaps due to their own farming practices [2,24]. They want to take good care of their farms, because they have often inherited them and want to hand them over in the same shape to their heirs. Ref. [38] present a case of groups of farmers who established cooperatives to protect the natural environment in their neighborhood.

Decision power. The adoption of environment-friendly practices is more likely if the decision-power is centralized, i.e., if the board decides rather than the general assembly [10]. In Chinese cooperatives, a smaller group of core members own most of the shares and have more decision power than the common members who are mainly suppliers. With less education, weak connections to government and limited investments in the cooperative, the common members are likely to accept the decisions made by the core members [39]. The core members, who constitute the cooperatives' leadership, may possibly be instrumental in convincing the members to adopt environment-friendly practices, especially as they have strong networks in the agrifood sector [3]. The core members also have good contact with the banks and the government, which presently promotes green agriculture [27,40].

Social capital. It is likely that the relationships between people with strong environmental convictions are characterized by bonding social capital [15]. This is especially so if they live close to each other. There are cases when farmers consider organic farming more or less a spiritual conviction [36]. There is moreover a high probability for a similar sense of community within Chinese villages where farmers have lived all their lives.

Size of the membership. Cooperatives that work with environment-friendly practices tend to have small memberships [10]. The

likelihood that farmers want to work with environmentally sound production is larger, if the group is small enough to facilitate co-ordination and low decision-making costs. A small membership is also likely to have a small production volume, which may target a small, less price-sensitive market niche, often a local one [31]. The cooperatives in the investigated province generally have small memberships [41].

The above discussion lends itself to the following hypothesis:

Hypothesis 1. Chinese farmers who are cooperative members are more likely to adopt environment-friendly practices compared to farmers with no membership.

2.3. 3Farmers' motivation to accept environment-friendly practices

When farmers adopt environment-friendly practices, there is a variety of motivational factors behind their decisions. Motivational factors may be considered as related to different classes of capital. The classical motivational factor is economic capital, i.e., assets that have a monetary value. Economic capital is evidently a basic driver behind people's behavior. Ref. [42] added other classes of capital, which are related to how people are motivated, namely intellectual capital and social capital. Intellectual capital results from education and upbringing, whereas social capital refers to relations in social networks; it involves "trust and norms of reciprocity inherent in one's social networks" [43]. Ref. [44] proposed a similar way of distinguishing between different endowments, whereby "endowment" is understood as factors that induce people to act. Another concept is human capital, which refers to the socialization of individuals over generations. This type of capital comprises norms, values and ideas, which have an impact on individuals' behavior and their interaction patterns both within the family and in other social contexts.

Ref. [42] claimed that the different classes of capital are interrelated and can be transformed into each other. For example, good social relations and human resources not only affect farmer behavior, but also play a positive role in promoting economic capital and human capital. When it comes to the adoption of green agricultural practices, family capital endowment comprises an aggregate of all the resources of all the family members, and thus includes endowments related to human, economic and social capital. The farmers' capital endowment is thus the reflection of the overall strength of a family, and it should include all dimensions that express the family's total resources, which include material assets, education, social relations, financial lending capacity, etc.

Farmers' receptiveness towards guidance concerning environment-friendly practices varies [3,11]. If farmer-members are to adopt environment-friendly practices, this must give economic benefits. Because farmers with better financial status and higher incomes have better conditions for investing in green production, these farmers will be more likely to accept the cooperatives' guidance on environment-friendly practices. However, the other classes of capital also play a role. The members must consider the cooperatives' information and guidance trustworthy, i.e., there must be social capital. Farmers with higher education, i.e., much human capital, will more easily embrace green production knowledge, and the help cooperatives' offer to these farmers will be prominent.

The above discussion lends itself to the following hypothesis:

Hypothesis 2. The higher the farmers' capital endowment, the more prominent the role of cooperatives in guiding the farmers.

2.4. Cooperatives' promotion of environment-friendly practices through cognitive social capital

Cooperatives are typically characterized by shared values, attitudes, beliefs, opinions, views, ideals and norms. Such communality is expressed as *cognitive social capital,* while *structural social capital* concerns ties and configurations in a social network such as roles, rules, precedents, and procedures. *Relational social capital* expresses the group members' interaction in terms of trust and trustworthiness, norms and sanctions, obligations and expectations, identity and identification [45].

Cognitive social capital exists in both the relationships between the members and the relationships between the members and the leadership. Thus, the leadership has the possibility to communicate to the members that green farming will bring higher revenues than the additional costs. The members' willingness to adopt environment-friendly agricultural practices rises when they learn that they may gain better economic outcomes and can reduce the negative externalities from the agricultural activities [15,16]. Norms of environmental protection may evolve in a large part of the memberships, and social interaction means that members will support each other in their work with environment-friendly practices. Information exchange within the membership and between the members and the leadership leads to more knowledge. "Cognitive factors relate to learning and reasoning about specific sustainable practices" [10]. Thus, the members will acquire a stronger cognitive social capital. As members thus join forces, the cooperatives' environmental efforts will become stronger, and the cooperatives' performance will thereby improve.

Thanks to the members' common norms, values, etc., they give assistance to each other and jointly deal with the practical and cognitive problems of environment-friendly production. They learn from each other. Moreover, members regularly and continuously receive training and advice from the leadership [46]. The more the members know about green production, the higher the probability that they will adopt them.

Hypothesis 3. The cognitive social capital within a cooperative membership will raise the likelihood that members adopt environment-friendly practices.

3. Methodology

3.1. Statistical approach

3.1.1. Benchmark model

Farmers can adopt different environment-friendly practices. We identify three types: one is green prevention and control, represented by biological and physical practices; the second is application of formula fertilization by soil testing; and the third is reducing the application of chemical fertilizers. Farmers can choose one, two or all three types. Therefore, the study employed a multivariate probit model, because it concurrently models the estimated effect of the set of explanatory variables on different environment-friendly practices while enabling the unobserved and unmeasured variables (error terms) to be orderly and freely correlated. Specifically, multivariate probit regression outspread the error terms, which have a multivariate normal distribution, each with zero mean and variance–covariance matrix, where variance and covariance allow for such correlation.

The model is written as follows:

$$Y_{io}^{*} = \beta_o X_{io} + \varepsilon_{io} \; where \; Y_{io} = \begin{cases} 1 \; if \; Y_{io}^{*} > 0 \\ 0 \; otherwise \end{cases} \tag{1}$$

$$Y_{is}^{*} = \beta_s X_{is} + \varepsilon_{is} \; where \; Y_{is} = \begin{cases} 1 \; if \; Y_{is}^{*} > 1 \\ 0 \; otherwise \end{cases} \tag{2}$$

$$YY_{im}^{*} = \beta_{im} X_{im} + \varepsilon_{im} \; where \; YY_{im} = \begin{cases} 1 \; if \; YY_{im}^{*} > 0 \\ 0 \; otherwise \end{cases} \tag{3}$$

where.

- Y_{io}^{*} and Y_{is}^{*} represent the dependent variable that farmers choose at least one or two environment-friendly production practices, respectively;
- YY_{im}^{*} is the dependent variable of one sub-item environment-friendly practice chosen by the farmers;
- Y_{io}, Y_{is} and YY_{im} are the corresponding observable variables;
- X_{io}, X_{is} and X_{im} represent explanatory variables, such as gender, age, education, proportion of household farmers and so on; and
- ε_{io}, ε_{is} and ε_{im} are the error terms.

3.1.2. ESP model

The issue concerning whether farmers adopt environment-friendly practices is not randomly assigned. Such adoptions are not only affected by observable factors but also by unobservable factors. The unobservable factors will be omitted in the error terms, leading to a correlation between it and the key explanatory variables. In addition, cooperative membership and farmers' environment-friendly practices have mutual causation because farmers who practice environment-friendly production may place greater emphasis on the importance of cooperative participation. A multivariate probit model mitigates selection bias only due to observables, not unobservable. In order to address the endogenous issue and simultaneity biases, we further employ an endogenous switching probit (ESP) model to estimate the treatment effects of cooperative participation on the choices concerning environment-friendly practices. The ESP model uses the full information maximum likelihood estimation involving one selection and two outcome equations to evaluate the effects. The ESP model uses a quasi-natural experimental method to estimate the experimental group (cooperative members) and control group (non-members) and controls the other factors that jointly affect the cooperative membership and the adoption of environment-friendly practices, accounting for verifying the impact that cooperative membership has on farmers' adoption of environment-friendly practices. Specifically, we defined the ESP model as follows: In the first stage, the probit model is used to estimate the probability of farmers' membership in a cooperative,

$$C_i^{*} = T_i\alpha + \varepsilon_i, C_i = \begin{cases} 1, if C_i^{*} > 0 \\ 0, if \; C_i^{*} \le 0 \end{cases} \tag{4}$$

where.

- C_i^{*} is a measure of farmers' cooperative membership, which is an unobservable latent variable;
- T_i is the explanatory variables that affect farmers' choice to belong to a cooperative;
- α is an estimated coefficient; and
- ε_i means a random interference term, where C_i equals 1, if a household is a member of a cooperative, and 0 otherwise.

In the second stage, we constructed the outcome equations of the impact of cooperatives on farmers' adoption of environment-friendly practices.

If $C_i = 1$:

$$Y_{1i}^{*}=\beta_{1i}X_{1i}+\epsilon_{1i}, Y_{1i}=\begin{cases}1, if\, Y_{1i}^{*}>0\\ 0, if\ Y_{1i}^{*}\leq 0\end{cases} \tag{5}$$

If $C_i = 0$:

$$Y_{0i}^{*}=\beta_{0i}X_{0i}+\epsilon_{0i}, Y_{0i}=\begin{cases}1, if\, Y_{0i}^{*}>0\\ 0, if\ Y_{0i}^{*}\leq 0\end{cases} \tag{6}$$

where.

- Y_{1i}^{*} and Y_{0i}^{*} indicate that farmers use and do not use environment-friendly production practices, respectively, which are an unobservable latent variable;
- Y_{1i} and Y_{0i} are corresponding observable variables;
- β_{1i} and β_{0i} are estimated coefficients; and
- ϵ_{1i} and ϵ_{0i} mean random interference terms.

A full information maximum likelihood method was used to simultaneously estimate the parameters of the selection and outcome equations. After computing parameters, we can calculate the average treatment effect of cooperatives on farmers' adoption of green production behavior. If taking farmers with a cooperative membership as a sample to calculate the average treatment, it represents the difference in the probability of farmers adopting environment-friendly production under the two scenarios: assuming that they belong to a cooperative and assuming that they do not. Then the average treatment effect ATT on the treated could be calculated as follows:

$$ATT=\frac{1}{n}\sum_{i=1}^{n}\{\Pr\,(Y_{1i}=1|C_i=1)-\Pr\,(Y_{0i}=1|C_i=1)\} \tag{7}$$

When taking farmers who are not a member as a sample to calculate the average treatment, the model can still estimate the probability of adopting environment-friendly practices if farmers are members. The average treatment effect ATU on the treated can be calculated as follows:

$$ATU=\frac{1}{m}\sum_{i=1}^{m}\{\Pr\,(Y_{1i}=1|C_i=0)-\Pr\,(Y_{0i}=1|C_i=0)\} \tag{8}$$

where.

- n indicates the sample size of the experimental group (farmers are cooperative members), and
- m indicates the sample size of the control group (farmers are non-members).

3.2. Data collection

This study investigates farmers in Fujian province, which is located on the coast in East China. The province became China's first ecological experimental zone in 2016.

The primary data were collected through a questionnaire survey through face-to-face interviews. A multi-stage probability and implicit stratification procedure was used to determine the sample from the county, village and household stages between June 2021 and December 2021. The survey sample was drawn from nine prefecture-level cities in Fujian province covering 720 households,[1] and 624 questionnaires were valid with an effective response rate of 86.67 %.

Among the respondents, 51.1 % adopted biological or physical green prevention and control; 23.7 % used the application of formula fertilization by soil testing; 69.9 % reduced the application of chemical fertilizers; 71.6 % adopted one or more of the three environment-friendly practices; and 50.2 % adopt two or more of the practices. A total of 257 respondents belonged to a cooperative, corresponding to 41.2 % of the sample.

3.3. Variables and descriptive statistics

Table 1 shows the variables, the operationalization of these variables into questions, the response alternatives, and the distribution of answers. The *dependent variables* concern whether the respondent has adopted environment-friendly practices. Three environment-friendly practices are identified, namely yy_1, yy_2 and yy_3, which represent prevention and control measures, the application of soil testing formula fertilizers, and the reduced use of chemical fertilizers, respectively. The variables Y_1 and Y_2 represent the adoption of at least one or two of the three practices.

The core *explanatory variable* is a dummy variable, namely the respondents' membership in a cooperative. As mentioned in part of

[1] Note: Informed consent was obtained from all participants for this study.

Table 1
Description of farmers' characteristics.

	Variable name (Variable symbol)	Measurement and evaluation	Mean	S. D.	Minimum	Maximum
Dependent variable-Farmers' adoption of green production practice	One or more environment-friendly production practices (Y_1)	Do you adopt one or more of the following three environment-friendly production practices (soil testing formula fertilizer, green prevention and control practice, reducing the use of chemical fertilizer and increasing the use of organic fertilizer)?Yes = 1; No = 0	0.716	0.451	0	1
	Two or more environment-friendly production practices (Y_2)	Do you adopt two or more of the following three environment-friendly production (soil testing formula fertilizer, green prevention and control practice, reducing the use of chemical fertilizer and increasing the use of organic fertilizer)?Yes = 1; No = 0	0.502	0.500	0	1
	Green prevention and control practice (yy_1)	Do you adopt biological or physical green prevention and control practice? Yes = 1; No = 0	0.511	0.500	0	1
	Soil testing formula fertilizer practice (yy_2)	Do you adopt soil testing formula fertilizer practice? Yes = 1; No = 0	0.237	0.426	0	1
	chemical fertilizers reduce (yy_3)	Do you reduce the use of chemical fertilizers and increase the use of organic fertilizers? Yes = 1; No = 0	0.699	0.459	0	1
core explanatory variable	Cooperative membership (CM)	Are you a member of a cooperative? Yes = 1; No = 0	0.412	0.493	0	1
control variables	Gender (se)	1 = male; 0 = female	0.804	0.397	0	1
	Age (ag)	continuous variable	51.753	10.891	24	82
	Square of age (ag2)	continuous variable	2796.808	1158.245	576	6724
	Education (edu)	What is your education level? 1 = No education; 2 = primary school; 3 = junior high school; 4 = senior high school or similar; 5 = college or above.	2.859	1.109	1	5
	Proportion of household farmers (fa)	How many people in your family participate in agricultural production? (Number of farmers/ total household population)	0.430	0.274	0	1
	Operating cultivated land area[a] (mu) (lad)	continuous variable	49.459	221.005	1	3200
	Income (inc)	What was your personal total income last year? Less than 10,000 yuan = 1; More than 10,000 but less than 30,000 = 2; More than 30,000 but less than 50,000 = 3; More than 50,000 but less than 100,000 = 4; More than 100,000 = 5	1.950	0.892	1	5
	Difficulty of bank loan (loa)	Do you think it is difficult to borrow money from the bank? 1 = very difficult; 2 = difficult; 3 = general '; 4 = easier; 5 = very easy	3.045	0.862	1	5
	Social relationship (sr)	Do you have any relatives or friends working in government or banks? Yes = 1; No = 0	0.127	0.347	0	3
	Cognition of green product benefits (Cog)	Do you think green products can achieve high quality and good price? Yes = 1; No = 0	0.566	0.496	0	1
Instrumental variable	Share of villagers participating in co-operatives (RPC)	What percentage of farmers in the same village participate in cooperatives? No less than 50 % = 1; Less than 50 % = 0	0.332	0.471	0	1

[a] One acre is approximately 667 square meter.

conceptual framework, whether farmer is cooperative member is the core dependent variable here.

Control variables are identified, given our interest in analyzing heterogeneity in the impact of cooperative membership on farmers' environment-friendly practices and determining how farmers' different capital endowment could affect their environment-friendly production. Thus, we need to measure the different categories of capital endowment that the farmers have. Based on previous studies [11,31,46], we supposed variables that may have influenced the farmers' adoption of environment-friendly practices. This includes the conditions of the family, farmers' material assets, and their education level, social relations, and financial lending capacity. (1) Gender. Women are often more cautious, so they are more passive towards environment-friendly practices and lack enthusiasm for participating in cooperatives. (2) Education. Education level is one of the representatives of capital endowment. According to the literature, the educational level is an important determinant in the adoption of environment-friendly practices [29]. Farmers with a higher education level may have a higher willingness to participate in cooperatives and understand the necessity of adopting their environment-friendly production. Thus, this variable was expected to influence farmer's environment-friendly practices positively. (3) Operating cultivated land area. The larger the operating cultivated land area is, the more motivated farmers are, given

the scale effect, to adopt the environment-friendly practices [17] and participate in cooperatives. (4) Social relationship. Good social relationships help reduce the information asymmetry faced by farmers in the process of cooperative participation and adoption of environment-friendly practices, enabling them to better adopt environmentally friendly practices [9].

The *instrumental variable* "share of villagers participating in cooperatives" (RPC) takes the value of 1 if the ratio is greater than 50 % and 0 otherwise. According to neighborhood effect, farmers' participating cooperative will be influenced by their neighbors. Furthermore, based on the study. [27], RPC is chosen as the instrumental variable. Before further processing the data, we estimate the relationship between the instrumental variable, the explanatory variables and the dependent variable using regression models. The instrumental variables and the dependent variable are negatively correlated at a 1 % confidence level, while in the regression analysis of the instrumental variables and the dependent variable, the result shows that the instrumental variable and the dependent variable are highly irrelevant. Hence, "share of villagers participating in cooperatives" is exogenous relative to the respondents' adoption of environment-friendly practices.

4. Results

4.1. Benchmark model results – determinants of farmers' green production

Based on the Mv-probit model, Tables 2 and 3 show the factors affecting farmers' adoption of the total environment-friendly practices and the three sub-items of green production. According to Table 2, the significant influencing factors on farmers' adoption of environment-friendly practices include cooperative membership, age and age square, income level, loan situation, and social relations. According to Table 3, the significant influencing factors on farmers' adoption of different types of green production include cooperative membership, age and age square, education, income level, loan situation, social relations and other factors. Therefore, without considering endogenous issues, cooperative membership has a significantly positive impact on the overall environment-friendly practices and the analysis of the green production behavior of YY_1 and YY_2.

4.2. Estimated results controlled the endogeneity issue

We use Stata14.0 software to jointly estimate the coefficients of the selection equation and the result equation according to the maximum information likelihood estimation method (Tables 4–7). The influencing factors of farmers' cooperative membership and their adoption of environment-friendly practices are analyzed. As shown in Table 4, the correlation coefficient between the random error term of the switching equation and the outcome equation is significantly nonzero, indicating that cooperative membership is an endogenous variable. The inspection results in Tables 5–7 also show that there is a self-selection problem between cooperative membership and the adoption of environment-friendly practices, which means that it is necessary to solve the endogenous problem and appropriate to use the endogenous switching probit model (ESP) to do so.

4.2.1. Factors affecting farmers' participation in cooperatives

According to the estimation results of Model 1 and 2 in Table 4, all the variables have significant effects, except for the proportion of family members working with agriculture as well as whether relatives and friends are village cadres. This result is consistent with the research results of some scholars, for example, as concerns personal characteristics.

Table 2
Multivariate-Probit regression estimate for Y_1 and Y_2.

	Equation 1		Equation 2	
	Y_1		Y_2	
	Coef.	S.E.	Coef.	S.E.
Cooperative membership (CM)	0.276**	0.137	0.299***	0.114
Gender(se)	−0.0742	0.148	−0.051	0.128
Age (ag)	0.120***	0.0379	0.0764**	0.0363
Square of age (ag2)	−0.00112***	0.000352	−0.000833**	0.000341
Education (edu)	−0.0127	0.0664	−0.0248	0.0573
Proportion of household farmers (fa)	0.0398	0.211	0.0358	0.191
Operating cultivated land area (mu) (lad)	−0.000499*	0.000266	−0.0000656	0.000283
Income (inc)	0.143*	0.074	0.134**	0.064
Difficulty of bank loan (loa)	0.354***	0.0736	0.168***	0.059
Social relationship (sr)	0.361**	0.179	0.467***	0.148
Cognition of green product benefits (Cog)	0.0272	0.116	−0.0219	0.102
Constant	−3.875***	1.04	−2.490**	0.99
Cross-correlation of two equation's error terms				
	Coef.	S.E.		
ρ_{21}	1.259***	0.113		
Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(1) = 199.658, Prob > chi2 = 0.0000				
Log likelihood = −629.17792; Wald chi2(22) = 101.87				

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 3
Multivariate-Probit regression estimate for yy_1-yy_3.

	Equation 1		Equation 2		Equation 3	
	yy_1 — Green prevention and control practice		yy_2 — Soil testing formula fertilizer practice		yy3 –- chemical fertilizers reduce	
	Coef.	**S.E.**	**Coef.**	**S.E.**	**Coef.**	**S.E.**
Cooperative membership (CM)	0.343***	0.121	0.435***	0.134	0.0868	0.133
Gender (se)	−0.00403	0.134	−0.135	0.155	−0.0175	0.149
Age (ag)	0.0558	0.0364	0.0497	0.0443	0.125***	0.039
Square of age (ag2)	−0.000602*	0.000341	−0.000582	0.00043	−0.00126***	0.000362
Education (edu)	0.0179	0.0592	0.181***	0.0667	0.056	0.0653
Proportion of household farmers (fa)	0.00517	0.198	0.580**	0.232	−0.267	0.21
Operating cultivated land area (mu) (lad)	−0.00005	0.000265	−0.0000718	0.000282	−0.000304	0.000308
Income (inc)	0.121*	0.0671	0.0848	0.0748	0.247***	0.0767
Difficulty of bank loan (loa)	0.148**	0.0642	−0.0321	0.0738	0.470***	0.0743
Social relationship (sr)	0.204	0.155	0.561***	0.152	0.187	0.172
Cognition of green product benefits (Cog)	−0.0151	0.107	0.0833	0.122	−0.0446	0.118
Constant	−2.080**	0.987	−2.803**	1.167	−4.319***	1.069
Cross-correlation of three equation's error terms						
	Coef.	S.E.		Coef.	S.E.	
ρ_{21}	0.346***	0.067				
ρ_{31}	0.576***	0.052	ρ_{32}	0.4456***	0.0667	
Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 124.705 Prob > chi2 = 0.0000						
Log likelihood = −952.90789; Wald chi2(33) = 196.81						

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 4
Estimates of the ESP model for Y1 and Y2.

Variable	Cooperative membership (CM)	Y1 = 1	Y1 = 0	Cooperative membership (CM)	Y2 = 1	Y2 = 0
	Coef.(S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)	Coef. (S.E.)
Gender(se)	0.451***(0.159)	−0.294(0.336)	−0.0897(0.173)	0.440***(0.16)	0.211(0.251)	−0.0446(0.166)
Age (ag)	0.05 (0.0424)	0.124*(0.0713)	0.100**(0.0509)	0.0497(0.0424)	0.0646(0.06)	0.0903*(0.0526)
Square of age (ag2)	−0.000516* (0.000403)	−0.00097 (0.000711)	−0.000942** (0.000463)	−0.000509 (0.000403)	−0.000615 (0.000588)	−0.000950* (0.000492)
Education (edu)	0.333***(0.0669)	0.155(0.129)	−0.121(0.1)	0.348***(0.0668)	0.118(0.106)	0.0048(0.102)
Proportion of household farmers(fa)	0.0946(.)	0.281(0.372)	−0.139(0.275)	0.135(0.227)	0.574*(0.304)	−0.148(0.274)
Operating cultivated land area (mu)(lad)	0.00212*** (0.000761)	−0.000206 (0.000311)	0.0126(0.0137)	0.00223*** (0.000794)	0.00027 (0.000311)	0.000146 (0.00249)
Income (inc)	0.0791(0.081)	−0.112(0.116)	0.417***(0.121)	0.0779(0.0812)	0.0386(0.0981)	0.286***(0.102)
Difficulty of bank loan (loa)	0.108(0.0768)	0.0623(0.139)	0.518***(0.102)	0.101(0.0771)	−0.0875(0.116)	0.304*** (0.0845)
Social relationship (sr)	−0.0645(0.171)	0.615**(0.286)	−0.0814(0.235)	−0.0216(0.169)	0.774*** (0.226)	−0.105(0.227)
Cognition of green product benefits (cog)	0.233*(0.121)	0.264(0.197)	−0.135(0.148)	0.251**(0.12)	0.143(0.165)	−0.155(0.141)
Share of villagers in co-operatives (RPC)	0.936***(0.134)			0.894***(0.136)		
Constant	−3.744***(0.134)	−3.498* (2.121)	−4.119***(1.513)	−3.783***(1.137)	−2.639(1.777)	−3.579**(1.485)
$\rho_{\mu 1}$	0.243	0.333		0.628*		
$\rho_{\mu 2}$	−0.632**	0.316		−0.371		
LR test of indep. eqns. (rho1 = rho0 = 0):chi2(2) = 4.23; Prob > chi2 = 0.1206				LR test of indep. eqns. (rho1 = rho0 = 0):chi2(2) = 5.18; Prob > chi2 = 0.0751		
Log likelihood = −606.74342; Wald chi2(11) = 178.48				Log likelihood = −685.9897; Wald chi2 (11) = 178.83		

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

4.2.2. *Factors affecting farmers' environment-friendly practices*

Tables 4–7 show factors that influence cooperative members and non-members to adopt environment-friendly production. Here personal characteristics, family characteristics, social relationships and other factors have a significant impact, to varying degrees.

Among the cooperative members, social relationships have a significant influence on the adoption of environment-friendly practices. The respondents' social relations with relatives and friends who are village cadres have a strong positive correlation with

Table 5
Estimates of the ESP model for yy1.

Variable	Cooperative membership		yy1 = 1		yy1 = 0	
	Coef.	Std. Err	**Coef.**	Std. Err	**Coef.**	Std. Err
Gender (se)	0.451***	0.159	−0.294	0.336	−0.0897	0.173
Age (ag)	0.05	0.0424	0.124*	0.0713	0.100**	0.0509
Square of age (ag2)	−0.000516	0.000403	−0.00097	0.000711	−0.000942**	0.000463
Education (edu)	0.333***	0.0669	0.155	0.129	−0.121	0.1
Proportion of household farmers (fa)	0.0946	0.227	0.281	0.372	−0.139	0.275
Operating cultivated land area (mu) (lad)	0.00212***	0.000761	−0.000206	0.000311	0.0126	0.0137
Income (inc)	0.0791	0.081	−0.112	0.116	0.417***	0.121
Difficulty of bank loan (loa)	0.108	0.0768	0.0623	0.139	0.518***	0.102
social relationship (sr)	−0.0645	0.171	0.615**	0.286	−0.0814	0.235
Cognition of green product benefits (cog)	0.233*	0.121				
Share of villagers in co-operatives (RPC)	0.936***	0.134			−0.135	0.148
Constant			−3.498*	2.121	−4.119***	1.513

LR test of indep. eqns. (rho1 = rho0 = 0):chi2(2) = 1.25 Prob > chi2 = 0.5358 Log likelihood = −699.05277 Wald chi2(11) = 176.72
Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 6
Estimates of the ESP model for yy2.

Variable	Cooperative membership (CM)		Soil testing formula fertilizer practice (yy2 = 1)		Soil testing formula fertilizer practice (yy2 = 0)	
	Coef.	Std. Err	**Coef.**	Std. Err	**Coef.**	Std. Err
Gender (se)	0.491***	0.16	−0.184	0.265	−0.243	0.193
Age (ag)	0.0477	0.0425	0.0213	0.0671	0.0333	0.0609
Square of age (ag2)	−0.000494	0.000403	−0.000237	0.000665	−0.000445	0.000591
Education (edu)	0.320***	0.0666	0.044	0.11	0.210*	0.118
Proportion of household farmers (fa)	0.142	0.228	0.564*	0.336	0.368	0.341
Operating cultivated land area (mu) (lad)	0.00200***	0.000702	−0.0000284	0.000282	−0.00115	0.00125
Income (inc)	0.101	0.0802	−0.0372	0.0992	0.162	0.122
Difficulty of bank loan (loa)	0.106	0.0767	−0.153	0.115	−0.0726	0.099
social relationship (sr)	−0.0799	0.173	0.595***	0.204	0.311	0.233
Cognition of green product benefits (cog)	0.230*	0.12	0.131	0.179	−0.0557	0.171
Share of villagers in co-operatives (RPC)	0.945***	0.135				
Constant	−3.737***	1.14	−0.398	2.041	−2.388	1.644
LR test of indep. eqns. (rho1 = rho0 = 0):chi2(2) = 6.35 Prob > chi2 = 0.0418						
Wald chi2(11) = 181.42						
Log likelihood = −586.47067						

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 7
Estimates of the ESP model for yy3.

Variable	Cooperative membership (CM)		chemical fertilizers reduce (yy3 = 1)		chemical fertilizers reduce (yy3 = 0)	
	Coef.	Std. Err	**Coef.**	Std. Err	**Coef.**	Std. Err
Gender (se)	0.456***	0.159	−0.146	0.325	−0.0181	0.178
Age (ag)	0.0498	0.0426	0.0798	0.069	0.157***	0.0557
Square of age(ag2)	−0.000511	0.000404	−0.000786	0.000668	−0.00149***	0.000511
Education (edu)	0.336***	0.0668	0.341***	0.111	−0.161	0.1
Proportion of household farmers (fa)	0.0982	0.228	0.141	0.351	−0.348	0.276
Operating cultivated land area (mu) (lad)	0.00224***	0.000724	0.000147	0.000417	−0.000623	0.00305
Income (inc)	0.0658	0.0814	0.0973	0.119	0.426***	0.12
Difficulty of bank loan (loa)	0.103	0.0766	0.155	0.127	0.637***	0.106
social relationship (sr)	−0.0525	0.17	0.594**	0.276	−0.0133	0.238
Cognition of green product benefits (cog)	0.234*	0.12	−0.312	0.216	0.00176	0.151
Share of villagers in co-operatives (RPC)	0.938***	0.136				
Constant	−3.726***	1.146	−3.19	2.024	−5.802***	1.642
LR test of indep. eqns. (rho1 = rho0 = 0):chi2(2) = 6.00 Prob > chi2 = 0.0497						
Wald chi2(11) = 179.78						
Log likelihood = −601.50566						

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

the adoption of environment-friendly production at the level of 1 %. Social capital is considered important for farmers' adoption of farm practices. Education level also has a positive impact on the adoption of farmers' use of chemical fertilizer, and passed the significance test at the level of 1 % (Table 7). Generally, the higher the level of education, the higher the ability to learn about green production, which is conducive to the acceptance of these practices. In addition, the higher the proportion of household members working in agriculture, the more likely the farmers will adopt environment-friendly practices of Y_2 (Table 4) and yy_2 (Table 6). Age also showed a positive relationship with the adoption of yy_1.

Among non-cooperative farmers, the significant influencing factors of farmers' adoption of green production are different from members. First, the age of farmers and the square of their age have a positive and negative correlation with the adoption of all types of environment-friendly production except for group yy_2. This indicates that the influence of farmers' age on their adoption of green production is like an "inverted U", i.e., the older the farmers, the more likely they are to adopt environment-friendly production practices, but when they reach a certain age, their likelihood of adopting green production declines. This may be related to resistance towards innovation. Second, income level and loans show a positive correlation with the other four types of green production, except for the yy_2 at the 1 % significance level. That is, farmers with higher income and better loans opportunities are more likely to adopt environment-friendly production. This is different from cooperative members. The reason may be it is easier for cooperative members to receive financial assistance from cooperatives, so the impact of financial constraints on their adoption of green production is not so significant. Third, education has a significant positive correlation with the adoption of environment-friendly production in terms of use of soil testing for fertilizing at the level of 10 %.

4.2.3. Average treatment effect from ESP model estimation results

Table 8 shows the average treatment effect on the treated (ATT) and Untreated (ATU) for farmers' participation in cooperatives with respect to their adoption of environment-friendly production.

For total environment-friendly production (Y_1 and Y_2), the results show that ATT is 0.209 and 0.227. Thus, for cooperative members, the probability of adopting at least one or two environment-friendly production practices is 20.9 % and 22.7 % higher compared to not participating in a cooperative, respectively. Table 8 also shows that ATU is 0.518 and 0.429, that is, for non-members; the probability of adopting at least one or two environment-friendly practices is 51.8 % and 42.9 % lower compared to participating in a cooperative.

For the sub-items of environment-friendly production – prevention and control measures, the application of soil testing before

Table 8
Average treatment effect of cooperative membership on farmers 'adoption of green production techniques.

Type of farmers		cooperative memberships(n = 257)	non-cooperative memberships(n = 367)
Probability of adopting green production practice (Y1)	Farmers are cooperative members	0.816	0.828
	Farmers are not members	0.607	0.31
	ATT	0 .209	
	ATU		0.518
	T-value	10.544***	37.358***
Probability of adopting green production practice (Y2)	Farmers are cooperative members	0.618	0.642
	Farmers are not members	0.391	0.212
	ATT	0.227	
	ATU		0.429
	T-value	14.048***	40.108**
Probability of adopting green production practice (yy1)	Farmers are cooperative members	0.618	0.629
	Farmers are not members	0.424	0.28
	ATT	0.214	
	ATU		0.349
	T-value	18.653***	41.039***
Probability of adopting green production practice (yy2)	Farmers are cooperative members	0.372	0.241
	Farmers are not members	0.087	0.022
	ATT	0.285	
	ATU		0.218
	T-value	39.96***	42.004***
Probability of adopting green production practice (yy3)	Farmers are cooperative members	0.805	0.761
	Farmers are not members	0.533	0.339
	ATT	0.271	
	ATU		0.422
	T-value	17.771***	33.739***

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

fertilization, and the reduced use of chemical fertilizers – the result shows that ATT is 0.214, 0.285 and 0.271, respectively; that is, for cooperative members, the probability of adopting these three sub-items is 21.4 %, 28.5 and 27.1 % higher compared to not participating in a cooperative, respectively. Table 8 also shows that ATU is 0.349, 0.218 and 0.422, respectively, that is, for non-cooperative farmers, the probability of adopting one or two environment-friendly practices is 34.9 %, 21.8 % and 42.2 % lower than if they were participating a cooperative, respectively.

Therefore, hypothesis 1 is supported; Chinese farmers who are cooperative members are more likely to adopt environment-friendly practices compared to farmers with no membership.

4.3. Heterogeneity in the impact of farmers' green production on cooperative membership

Farmers with different capital endowments may to a varying extent gain support from cooperatives as concerns their adoption of environment-friendly practices. According to Table 9, cooperatives play a greater role in guiding farmers who are young, have better incomes, have better access to loans, and have a better education. Thus, hypothesis 2 gains support: The higher the capital endowment of farmers, the more prominent the role of cooperatives in guiding such farmers.

4.4. Results of balance test

In order to obtain more reliable stability results, the propensity score matching (PSM) methods are used to test the stability of the above conclusions. PSM is a quasi-natural experimental method, widely used to solve the problem of sample selectivity bias. The sample matching between the experimental group and the control group is realized by using the PSM model through caliper matching. According to Table 10, ATT is 0.168, 0.196, 0.216, 0.214 and 0.178, which indicates that farmers' participation in cooperatives is conducive to the adoption of total and sub-item environment-friendly practices.

Table 9
Heterogeneity in the green production adoption(Y_2) of cooperative membership.

Order number	Type of farmers		cooperative memberships(n = 257)	non-cooperative memberships(n = 367)
1	Group A (age >49) (N = 352)	Farmers are cooperative members	0.643	0.729
		Farmers are not members	0.17	0.122
		ATT/ATU	0.472	0.606
		T-value	27.389***	46.863***
	Group B(age≤49) (N = 272)	Farmers are cooperative members	0.715	0.816
		Farmers are not members	0.227	0.084
		ATT/ATU	0.488	0.731
		T-value	21.18***	45.287***
2	Group A (edu1<3) (N = 268)	Farmers are cooperative members	0.684	0.727
		Farmers are not members	0.181	0.118
		ATT/ATU	0.503	0.609
		T-value	30.138***	47.506***
	Group B (edu1≥3)(N = 356)	Farmers are cooperative members	0.616	0.643
		Farmers are not members	0.111	0.032
		ATT/ATU	0.504	0.611
		T-value	41.92***	77.918***
3	Group A (inc2 = 1) (N = 192)	Farmers are cooperative members	0.639	0.665
		Farmers are not members	574	0.200
		ATT/ATU	0.065	0.465
		T-value	2.2212	26.418
	Group B (inc2 = 2) (N = 334)	Farmers are cooperative membersa	0.559	0.559
		Farmers are not cooperative members	0.28	0.279
		ATT/ATU	0.279	0.280
		T-value	14.697***	14.698***
	Group C (inc2>2) (N = 268)	Farmers are cooperative members	0.828	0.909
		Farmers are not members	0.142	0.039
		ATT/ATU	0.685	0.870
		T-value	32.114***	71.870***
4	Group A (loan2>3) (N = 159)	Farmers are cooperative members	0.644	0.695
		Farmers are not members	0.114	0.022
		ATT/ATU	0.529	0.672
		T-value	25.249***	58.907***
	Group B (loan2≤3) (N = 465)	Farmers are cooperative members	0.661	0.699
		Farmers are not members	0.422	0.241
		ATT/ATU	0.238	0.458
		T-value	13.788***	34.409***

Notes: ***, **, and * represent significance at the 1 %, 5 %, and 10 % levels, respectively.

Table 10
Balance test result from PSM model.

Variable		Treated	Controls	Difference	S.E.	T-stat
Y1	ATT	0.817	0.649	0.168	0.035	4.820
Y2	ATT	0.619	0.423	0.196	0.040	4.920
yy1	ATT	0.638	0.422	0.216	0.040	5.420
yy2	ATT	0.638	0.424	0.214	0.040	5.390
yy3	ATT	0.805	0.628	0.178	0.035	5.020

NOTE:*** Use method of radius caliper.

4.5. Test on the mechanism of cooperatives' influence on farmers' adoption of environment-friendly production

Taking farmers' cooperative membership as the core independent variable, we use the Iv-probit model to test how cooperative participation affects farmers' adoption of environment-friendly production from the perspective of cognitive social capital. The estimated results are shown in Table 11. Farmers who have followed the cooperatives' training programs are more likely to accept green production, and have a stronger awareness and better understanding, and so they are more likely to adopt green production. The results in Table 11 show that cooperative members have a higher awareness, specifically of the government's standards for pesticide residues (f_1) and the relevant policies of agricultural product safety standards (f_2). The cognitive social capital is also higher, thus promoting farmers to adopt green production. Thus, hypothesis 3 gains support: *The cognitive social capital within a cooperative membership will raise the likelihood that members adopt environment-friendly practices.*

5. Discussion

This section is structured in accordance with the three hypotheses, which were deducted from the aim of the study – "to explore reasons why Chinese farmer cooperatives may induce their members to adopt more environment-friendly practices".

5.1. Cooperative membership and farmers' adoption of environment-friendly practices

The findings indicate that Chinese cooperatives provide training, education and information programs to their members who thereby become more aware of environmental production practices. Comparisons between cooperative members and non-members indicate that a cooperative membership stimulates farmers' willingness to adopt environment-friendly practices. The higher the income and education, the more likely male farmers of the right age will belong to cooperatives and adopt environment-friendly practices. Ref. [47] suggest that standardized organizational norms, organizational learning and organizational support in cooperatives will promote farmers in adopting environment-friendly production practices.

The observation made in this study corroborates the findings of many other studies concerning the value that cooperatives have for their members and their rural districts [24–27]. At least under the conditions that prevail in China, farmer cooperatives may have a positive role to play for the members' adoption of greener production practices.

5.2. The guiding effect of cooperatives on farmers with different capital endowments

The heterogeneity analysis indicates that the guiding effect of cooperatives on farmers with different capital endowments is different. Farmers are more likely to adopt eco-friendly practices when they have higher capital endowments. This result is consistent with the results of Ref. [47] who studied the impact of capital endowment and ecological cognition on farmers' adoption of environment-friendly practices. This is mainly because their decisions are often constrained by poor capital endowments. The objective factors that limit farmers' eco-friendly production include family status, age, education, social capital, and borrowing difficulty. When farmers have better capital endowments, they are willing to accept the risks of innovation.

Younger and better-educated farmers are more willing to adopt new practices. The cooperative membership has the effect of

Table 11
The impact of cooperatives on farmers' awareness of environment-friendly production.

Variable	Dependent variable(f1)		Dependent variable(f2)		Dependent variable(f3)	
	Coef.	Std. Err	**Coef.**	Std. Err	**Coef.**	Std. Err
Cooperative membership (CM)	2.875***	0.603	3.235***	0.586	3.283***	0.595
controlled variables	–	–	–	–	–	–
Wald chi2(11)	92.410		137.900		116.890	
Prob > chi2	0.000		0.000		0.000	
Wald test of exogeneity chi2(1)	38.110		15.350		15.870	

Notes: f1: Do you know the sign of green food? Yes = 1,No = 0.
f2: Do you know the pesticide limit standards for agricultural products published by the government? Yes = 1,No = 0.
f3: Do you understand the food safety and quality policy in your field? Yes = 1,No = 0.

increasing farmers' green awareness, and the farmers' green awareness and their membership of a cooperative has an intermediary effect on their adoption of green production. Ref. [48] also suggest that effective use of land capital and educational capital promote the greening of agriculture. Ref. [49] proposed that income and assets influence farmers' environment-friendly behavior, and the adoption of new practices requires both income and assets, which is consistent with the conclusion of this paper. In addition, social capital is important for farmers' behavior. Farmers with higher social capital tend to increase their resources by using their social networks to obtain loans.

5.3. Farmers gain green awareness thorough their cooperative membership

This study supports the notion that farmers' knowledge of green production is important for their acceptance of environment-friendly practices, and a cooperative membership can enhance farmers' green awareness. When starting to apply environment-friendly practices, farmers have difficulties due to a lack of understanding. Regular pedagogical explanations and technical training within cooperatives raise farmers' information and promote green awareness. The members accept the environment-friendly practices when they learn that they may acquire better economic outcomes.

According to the theory of planned behavior, the greater the subjective norms perceived by individuals, the more their behavioral intentions will be transformed into corresponding behavior, and the perpetrators of this normative pressure are farmers' professional cooperatives. The cognitive social capital within the cooperative will promote members to gain value identification from others members should not only consider their own interests, but also social interests, including environmental protection. Cooperative members are conducive to the transformation of green awareness into environment-friendly practices behavior. However, there are significant differences between members and non-members in their green awareness and adoption of the environment-friendly practices. Non-members are often unable to improve their green awareness and do not see the importance of green production for increasing production and protecting the environment.

6. Conclusions

6.1. Empirical findings

This study presents empirical evidence for the importance that a cooperative membership has for Chinese farmers' adoption of environment-friendly farming practices. All the three hypotheses gain support from the data.

1. *Chinese farmers who are cooperative members are more likely to adopt environment-friendly practices compared to farmers with no membership.* For cooperative members, the probability of adopting one or two of the three investigated co-friendly production practices is 20.9 % and 22.7 % higher than that of non-members, respectively. If non-members were to become members, the probability of adopting one or two green production practices would increase by 51.8 % and 42.9 %, respectively. For the three sub-items of eco-friendly production – prevention and control measures, application of soil testing before fertilization, and reduced use of chemical fertilizers – the members' probability of adopting these practice is 21.4 %, 28.5 % and 27.1 % higher than for those who do not belong to a cooperative, respectively.
2. *The higher the farmers' capital endowment, the more prominent the role of cooperatives in guiding the farmers.* Their decisions are often constrained by poor capital endowments. The objective factors that limit farmers' eco-friendly production include family status, age, education, social capital, and borrowing difficulty. When farmers have better capital endowments, they are willing to accept the risks of innovation. In terms of human capital, younger and higher-educated farmers are more willing to adopt new practices. The cooperative membership has the effect of increasing farmers' green awareness. The farmers' green awareness and their membership of a cooperative has an intermediary effect on their adoption of green production. In addition, social capital is an important factor affecting farmers' behavior. Farmers with higher social capital tend to increase their resources by using their social networks to obtain loans.
3. *The cognitive social capital within a cooperative membership will raise the likelihood that members adopt environment-friendly practices.* This study supports the notion that farmers' knowledge of green production is important for their acceptance of the green production practices, and a cooperative membership can enhance farmers' green awareness. When starting to apply green production practices, farmers have difficulties due to a lack of understanding.

6.2. Theoretical findings

The findings of this study are in line with those of other studies on Chinese cooperatives. The study explains why many Chinese researchers claim that cooperatives are conductive for environmental-friendly farming even though such a view is at odds with empirical observations in many other countries as well as the general theoretical concept of cooperatives. There is a growing interest in environment-friendly production within Chinese agriculture. However, the findings are at odds with the empirical evidence that Western researchers report about cooperatives' involvement in environment-friendly production, and likewise, they are not in line with the mainstream theory of the functions that cooperatives offer to their members.

There is a chance for a *market demand* for environment-friendly products, even though such products are somewhat more expensive. Some consumers might have listened to the government's decision in 2022 that green agricultural production should be promoted. Both among consumers and farmers, there may be people who have *preferences for environment-friendly products*. Likewise,

the farmer cooperatives' leadership might want to adhere to the government's desire for more environment-friendly production. Many factors support such a supposition. These leaders belong to the group of core members who have not only large financial investments in the cooperative, but also the dominant *decision-power* regarding the cooperatives' strategies. It is likely that the leading figures can convince the common members, who are primarily suppliers to the cooperative. The common members will listen to messages about environment-friendly practices, which are *easy to convert* to, especially as they promise a better economic result. Because the leading figures enjoy *social capital* in the community, they have good relationships with financial institutions and the village cadres, and therefore they could help the farmer-members' acquire bank loans with good conditions.

These factors are largely related to the specific characteristics of Chinese cooperatives. According to Ref. [20], the Chinese government is highly involved in farmer cooperatives. Thus, the cooperatives probably adhere to the government's quest for more environment-friendly farming. Ref. [20] state that Chinese "cooperatives received intensive governmental intervention", further noting that no less than 46 % of the cooperatives are government-involved cooperatives. They can provide technology or information services to their members by fully using their social capital." [20].

6.3. Limitations and suggestions for further research

This study is the first one to provide empirical evidence and theoretical explanations about the importance that a membership in Chinese farmer cooperatives has for the farmers' adoption of environment-friendly farming. Given the scrutiny of the research, a high response rate, representativeness among the farmer population of Fujian Province, and statistically significant findings, the study provides valuable insights. Nevertheless, the study suffers from some limitations, which means that further research is needed, before the findings of this study could serve as the basis for strategic decision by cooperative leaderships and government. Thus, the present study has a value as a stepping-stone for many other research projects:

- This study investigates what the farmers say while there is a need for research about their actual behavior and how the farmers' actually respond to the cooperatives' signals. Self-reported data may be problematic as opportunistic respondents may give incorrect information.
- There is a need for research about how the three investigated farming practices alleviate the environmental problems, especially so, because these practices are admittedly only vaguely stated in terms of "less use of fertilizers and insecticides".
- Researchers should focus on the potential environmental effects of other environment-friendly farm practices, except for the ones that are included in the present study.
- There is a need for research about how the new farming practices affect the farmers' workload, different types of costs, prices and revenues as well as the household welfare.
- Researchers should investigate whether the characteristics of the Chinese cooperative model make the farmer-members more involved in environmental issues, compared to cooperatives in most other countries.

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Data availability statement

The author cannot share the raw data described in the manuscript for legal and confidential reasons. However, we will include a statement that readers could contact the corresponding author for investigating to which extent data can be shared.

Ethics declarations

All participants/patients (or their proxies/legal guardians) provided informed consent to participate in the study.

All participants/patients (or their proxies/legal guardians) provided informed consent for the publication of their anonymised case details and images.

Review and/or approval by an ethics committee was not needed for this study because the respondents are completely voluntary, and data analysis does not reflect specific personal sensitive information.

Informed consent was not required for this study because data analysis does not reflect specific personal sensitive information.

CRediT authorship contribution statement

Liyan Yu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Jerker Nilsson:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Yongyan Li:** Writing – original draft, Writing – review & editing. **Minghao Guo:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Liyan Yu reports financial support was provided by National Natural Science Foundation of China. Liyan Yu reports a relationship with Natural Science Foundation of China that includes: funding grants.

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