Social network, environmental cognition and organic fertilizer application behavior of small farmers

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Abstract. Small farmers are the main organizational form of agricultural production and management in China, and it is very important to study their organic fertilizer application behavior to promote the development of green agriculture in China. Based on the survey data of 334 small farmers in Sichuan Province, this paper uses bivariate Probit model to analyze the influence of social network and environmental cognition on organic fertilizer application behavior. The research shows that:(1) The application of commercial organic fertilizer and farmyard manure by small farmers has a significant complementary effect.(2) Social network has a significant positive impact on organic fertilizer application behavior, and there are significant differences between kinship social network and friendship social network on organic fertilizer application behavior.(3) The level of environmental cognition has a significant positive effect on the application behavior of organic fertilizer. Therefore, it is necessary not only to make full use of and expand the social network of small farmers, but also to pay attention to improving their environmental awareness and promoting organic fertilizer application behavior.

1 Introduction

As one of the important agricultural production factors, chemical fertilizer has played a positive role in improving grain yield and ensuring national food security. However, the extensive agricultural development mode for a long time has made China one of the countries with the largest amount of chemical fertilizer in the world [1]. According to statistics, the intensity of chemical fertilizer application in 2019 is as high as 325.65kg/hm2,which is much higher than the internationally recognized safety limit of 225kg/hm2. Excessive input of chemical fertilizer has caused negative problems such as agricultural non-point source pollution and soil fertility decline, which has affected and restricted the green and sustainable development of China's agriculture [2].Under this grim situation, the No.1 Document of the Central Committee in 2021 proposed to continuously promote the reduction and efficiency increase of chemical fertilizers and pesticides and promote the development of green agriculture. Thus, how to promote farmers' input of organic fertilizer has become an important practical problem.

The existing literature mainly develops organic fertilizer application behavior from three aspects. First, personal characteristics and cognition, farmers' age and education level have significant negative effects on farmers' organic fertilizer application behavior [3]; The higher farmers' awareness of the effect of organic fertilizer application, the higher their probability of applying organic fertilizer [4]; Second, in terms of family and production characteristics, farmers' family income [5],

agricultural labor force [6], non-agricultural employment [7], land scale [8] and soil fertility [9] significantly affect farmers' organic fertilizer application behavior.The larger the land scale, the more favorable it is for farmers to apply organic fertilizer. However,with the fragmentation of land and the improvement of soil fertility, farmers' willingness to apply organic fertilizer decreases instead [9]. In addition, external factors such as whether to participate in agricultural insurance[10], stability of land property rights [11] and policy incentives [12]also affect farmers' fertilization behavior. Most previous studies analyzed farmers' organic fertilizer application behavior based on the assumption of rational economic man, but farmers' decision-making behavior is often not isolated. Under the condition of limited cognition, social relations play an important role in shaping behavior [13]. China's rural areas are a typical relational society, and farmers' economic behavior is embedded in the social network formed by interaction with others. Yang Haiyu et al. [14] found that the clan-based social network of farmers promoted the choice of direct sales channels of the company. Jiang Weijun et al. [15] pointed out that social networks further affect the willingness to adopt technology through trust and learning mechanisms.Under the condition of mastering the relevant information of organic fertilizer technology,farmers' own cognition is also very important. As a green production behavior, farmers' environmental cognition will also affect farmers' decision-making. Previous studies have shown that farmers not only maintain economic rationality but also ecological rationality in production [16]. The research by Huang Yanzhong and Luo Xiaofeng[2] shows that farmers' ecological cognition is the main power source for

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adopting organic fertilizer substitution technology, and the influence degree is greater than the influence of economic benefit cognition on organic fertilizer application.

The existing literature has done a lot of research on the application behavior of organic fertilizer, but there is still room for further improvement.First,in terms of research objects, most studies treat farmers as a whole, and seldom start from the perspective of small farmers. Although the current farmers are gradually divided into different types such as traditional small farmers,large grain growers and farmers, small farmers are still the main body of agricultural production and management in the future,so it is necessary to pay attention to the fertilization behavior of small farmers. Second, from the research perspective,the existing literature pays attention to the influence of social network or farmers' cognition on organic fertilizer application behavior, but few literatures bring social network and environmental cognition into the same analysis framework to analyze their influence on technology adoption. Third, in terms of research content, most studies do not subdivide organic fertilizer and refer to organic fertilizer as a general term, ignoring the correlation between different organic fertilizer application technologies. Based on the survey data of 334 small farmers in Sichuan Province, this paper uses bivariate Probit model to analyze whether there is complementary or substitution effect between different technical choices when farmers are faced with commercial organic fertilizer and farmyard manure application choices.Is there any difference in the influence of social network and environmental cognition on different technology choices? So as to provide reference for the development of green agriculture in China.

2 Theoretical analysis and research hypothesis

2.1 Social network and organic fertilizer application behavior

Social network mainly refers to the relationship network formed by mutual communication between groups [17]. At present, China's economic construction and market are not perfect, and social network still has a far-reaching impact on rural areas with backward formal system. The mechanism of social network on farmers' organic fertilizer application behavior is at least reflected in the following aspects:First, information acquisition. Farmers are typical information vulnerable groups and lack information channels[18].Social networks play an important role in transmitting information and reducing search costs. The larger the relationship network, the more likely farmers are to know more information, and the more they can correctly contact and understand this technology, thus increasing the probability of organic fertilizer application. Second, exchange and study. Social network, as the main environment for farmers to learn from each other, is conducive to reducing the uncertainty of technology adoption and promoting the knowledge diffusion of new agricultural technologies through mutual communication and learning [15]. Third, cooperation and mutual benefit.

Agricultural technology conversion usually means higher cost input, while social network can provide farmers with financial, labor and technical support, reduce the cost pressure of technology conversion, and thus promote the application of organic fertilizer [19].

In the current Chinese rural society, farmers are mainly individuals or families, and form a social network structure of differential order pattern according to the close relationship of blood and geography. One is a social network based on "kinship" and focusing on strength, and the other is a social network based on "karma" or "geography" and focusing on universality [20]. The kinship social network plays a stronger role in information transmission, learning and communication by virtue of its emotional advantages, while the friendship social network can provide more extensive and non-repetitive information, changing the existing cognition and behavior habits of farmers. Based on this, the following assumptions are put forward:

Hypothesis 1: Social network has a positive impact on organic fertilizer application behavior, and the effects of kinship social network and friendship social network on organic fertilizer application behavior are different.

2.2 Environmental cognition and organic fertilizer application behavior

According to the theory of planned behavior, the subject's cognition will affect his willingness to participate and then affect his behavior. Environmental cognition belongs to human psychological factors. Behavioral economics believes that human beings will be affected by psychological factors in the decision-making process [21]. The higher the level of farmers' environmental awareness, the more they understand the relevant environmental knowledge and environmental protection policies, and the more they can recognize the seriousness of the current rural environmental pollution, that is, the more likely they are to apply organic fertilizer to alleviate the problem of agricultural non-point sources [22]. On the one hand, farmers, as decision makers of organic fertilizer application, may tend to choose organic fertilizer when fertilizing if they realize that organic fertilizer can improve soil fertility, improve soil structure and protect agricultural ecological environment. On the other hand,farmers,as the direct bearers of the deterioration of rural ecological environment, are more willing to change their behavior to maintain or even improve the existing environmental conditions in order to get a better environmental perception experience, thus holding a positive attitude towards the application of organic fertilizer.Based on this, the following assumptions are proposed：

Hypothesis 2: Environmental cognition has a positive impact on organic fertilizer application behavior.

3 Data sources, variable selection and descriptive statistics

3.1 Data source

The data comes from the field investigation of farmers in Sichuan Province in July 2019, and adopts the method of stratified sampling and equal probability random sampling. According to the research of Xu et al. [23], all districts and counties in Sichuan Province are clustered into five categories according to the per capita industrial output value from high to low, and one county sample is randomly selected from each category to obtain Jiangyou city, Zhaohua country, Guang'an city, Shehong county, Ziliujing and Yantan District. Then, the villages and towns in the sample districts and counties are divided into high and low income groups according to the ranking of per capita industrial output value. Each group randomly selects one township, each township randomly selects two villages, and each village randomly selects 20 households. A total of 400 questionnaires were obtained. According to the definition of World Bank et al.[24], small farmers are farmers whose cultivated land scale is less than 2 hectares (30 mu). After sorting out and deleting invalid questionnaires, 334 valid questionnaires for small farmers were finally obtained.

3.2 Variable selection

(1) Dependent variables. Organic fertilizer application behavior of small farmers was selected as dependent variable. Organic fertilizer includes commercial organic fertilizer and farmyard manure, which mainly refers to fertilizer made from crop straw, livestock manure and other raw materials through accumulation and fermentation.(2) Core variables. Drawing on the research of Fang Ran [25] and Yang Zhihai [26], two variables, kinship social network and friendship social network, are set up in this paper. The strength and scale of social network are characterized by the number of relatives visiting in 2018 Spring Festival and the number of fellow villagers and friends visiting in 2018 Spring Festival. Referring to the research of Kuang Foyuan et al. [27], the environmental cognition level of farmers is investigated by scoring the assigned values of 10 questions in Table 2. If the answer is correct, 1 point is counted, and if the answer is wrong or does not know, 0 point is counted. (3) Control variables. Considering the influence of farmers' individual endowment differences, gender, age and education level are selected to reflect farmers' individual characteristics; Select whether there are village cadres or party members in the family, and the proportion of family agricultural labor force and non-agricultural income reflects the characteristics of the family; Select cultivated land scale, cultivated land quality and family farming to reflect production characteristics; The regional characteristic variables are expressed by the virtual variables of the county where the farmers are located.

Table1. Farmers' environmental cognition level

Do you think air pollution has an impact on your health?1=Yes 0=No/ Don't know
Do you think pesticides pollute farmland? 1=Yes 0=No/ Don't know
Do you think discarding pesticide bottles pollutes farmland?1=Yes 0=No/ Don't know
Do you think plastic film pollutes farmland? 1=Yes 0=No/ Don't know
Do you think the application of chemical fertilizer will pollute the farmland?1=Yes 0=No/ Don't know
Do you think the application of organic fertilizer pollutes farmland? 1=No 0=Yes/Don't know
Do you think the application of farmyard manure will pollute the farmland? 1=No 0=Yes/Don't know
Do you think straw returning to the field pollutes the farmland?1=No 0=Yes/Don't know
Do you think irrigation pollutes farmland? 1=Yes 0=No/ Don't know
Do you think the direct discharge of domestic sewage pollutes the water quality?1=Yes 0=No/ Don't know

3.3 Variable descriptive statistics

The variable definitions and data descriptions involved in this paper are shown in Table 2.In terms of social network, relatives mainly visit during the Spring Festival, while friends visit less, with an average of 4.874 and 2.835 respectively. In terms of environmental awareness, farmers' environmental awareness level is not high, with an average of 5.722. For control variables, there are more men than women, accounting for 58.7%. The respondents are generally older, with an average age of 56.293 years. The education level is generally not high, and the average number of years of education per capita is 5.138 years. The average number of agricultural laborers in families is 1.787, and 22.2% of farmers have party members or village cadres in their families. Most of the household income comes from non-agricultural income, with an average value of 88.9%, which is in line with the characteristics of non-agricultural in rural areas today. The average area of cultivated land per household is 4.824 mu, and the quality of cultivated land is mostly close to the medium level, with an average value of 1.950.

Table2. Meaning and descriptive statistics of variables related to farmers' organic fertilizer application behavior

Variable	Definition and assignment	Mean	Standard
Dependent variable			
Whether to apply commercial organic fertilizer	1=Yes 0=No	0.156	0.363
Whether to apply farmyard manure	1=Yes 0=No	0.632	0.483
Core Variables			

Kinship social network	Number of relatives visiting your home during the Spring Festival (households)	4.874	3.590
Friendship social network	Number of friends/villagers visiting your home during the Spring Festival (households)	2.835	2.981
Environmental cognition	Knowledge score of environmental problems	5.722	2.534
Gender	Sex of head of household? 1= Male 0=Female	0.587	0.493
Age	Age of head of household (years)	56.293	11.531
Years of education	Years of education of the head of household (years)	5.138	3.970
Are there village cadres or party members at home	Are there village cadres or party members in the family? 1=Yes 0=No	0.222	0.416
Number of agricultural labor force	Number of family agricultural labor force (person)	1.787	0.820
Proportion of non-agricultural income	Proportion of non-agricultural income to total income (%)	0.889	0.202
Cultivated land scale	Area of cultivated land under operation (mu)	4.824	3.330
Cultivated land quality	The quality of cultivated land? 1 = worse than average 2 = same as average 3 = better than average	1.950	0.620
Whether or not to breed	Whether or not to breed?1=Yes 0=No	0.695	0.461
Guangan	1=Guangan 0= Other provinces	0.216	0.412
Shehong	1=Zhaohua 0= Other provinces	0.189	0.392
Jiangyou	1=Jiangyou 0= Other provinces	0.183	0.387
Zigong	1=Zigong 0= Other provinces	0.201	0.401

4 Model construction and empirical test

4.1 Model building

Whether small farmers apply commercial organic fertilizer and whether they apply farmyard manure are binomial choice variables, and some unobservable factors will affect the choice of these two behaviors at the same time. Therefore, the two decisions are not independent of each other. If y_1 and y_2 are used to represent the decision of small farmers on the application of commercial organic fertilizer and farmyard manure, and $y_1=1$ means the application of commercial organic fertilizer, while $y_1=0$ means no application of commercial organic fertilizer. $y_2=1$ means application of farmyard manure, while $y_2=0$ means no application of farmyard manure. That is, there are four results: (0, 0), (1, 0), (0, 1), (1, 1). Because the bivariate Probit model allows the correlation between the error terms of different equations, a bivariate Probit model is established to analyze the influencing factors of social network and environmental cognition on the organic fertilizer application behavior of small farmers. The specific form of model setting is:

$$y_1^* = \beta_1' x_1 + \varepsilon_1$$
$$y_2^* = \beta_2' x_2 + \varepsilon_2 \quad (1)$$

$$y_j = \begin{cases} 1, if \ y_j^* > 0 \\ 0, \ other \end{cases} \quad (2)$$

Among them, ε_1 and ε_2 meet the following assumptions:

$$\begin{cases} E(\varepsilon_1) = E(\varepsilon_2) = 0 \\ var(\varepsilon_1) = var(\varepsilon_2) = 1 \\ cov(\varepsilon_1, \ \varepsilon_2) = \rho \end{cases}$$

In (1) (2), y_1^* and y_2^* are unobservable latent variables, and y_1 and y_2 are the final result variables as explained variables. x_1 and x_2 are independent variables affecting farmers' application of commercial organic fertilizer and farmyard manure, respectively, β'_1、β'_2 are corresponding estimation coefficients. ε_1 and $\varepsilon2$ are error terms and obey two-dimensional normal distribution. ρ is the correlation coefficient of ε_1 and ε_2, when = 0, it means that ε_1 and ε_2 are not correlated; If > 0, y_1 and y_2 are complementary effects, and if < 0, y_1 and y_2 are substitution effects.

4.2 Empirical results and analysis

In this study, Stata16.0 software was used to test the influence of social network and environmental cognition on farmers' organic fertilizer application behavior. The results are shown in Table 3. On the whole, the model fits well, the core variables basically pass the significance test, and the coefficient symbol is basically consistent with the expected direction. Wald test shows that the coefficient is positive and significant at the level of 5%, rejecting the original hypothesis of $\rho=0$, so it is necessary to use

bivariate Probit model, and the application of commercial organic fertilizer and farmyard manure by farmers is interactive and has strong complementarity.

The results show that kinship social network has a positive effect on the application of commercial organic fertilizer and farmyard manure by small farmers, which is significant at the level of 10% and 5%, respectively, while friendship social network has no significant effect on the application of commercial organic fertilizer by small farmers, but has a positive effect on the application of farmyard manure, which is significant at the level of 10%. Hypothesis 1 is confirmed. This means that under the social background of rural acquaintances, farmers will not only make fertilization decisions according to their own agricultural production experience, but also decide their own fertilization methods with reference to other farmers around them. Furthermore, the members in the kinship social network are more closely related, the degree of mutual trust is stronger, and it is easier to realize learning imitation and risk sharing within the group, which makes farmers show "herd effect" in agricultural production. Although friendship social network can provide heterogeneous information and resources for farmers and enrich their knowledge, it is also more difficult to obtain substantial help, thus having no significant impact on the application of organic fertilizer. Environmental cognition has a significant and positive impact on the application of commercial organic fertilizer and farmyard manure by small farmers at the level of 5% and 10%, respectively. This means that farmers with higher environmental awareness are more aware of the harmfulness of current agricultural non-point source pollution and the importance of adopting organic fertilizer technology, so they are more willing to apply organic fertilizer. Hypothesis 2 is confirmed.

Among the control variables, education level has a significant positive impact on organic fertilizer application. It shows that the higher the education level, the better farmers can understand the advantages of applying organic fertilizer and improve the behavior of applying organic fertilizer; Families with village cadres or party members are more willing to apply commercial organic fertilizer than ordinary farmers. Generally speaking, families with political identity actively respond to the call of the state and are more willing to invest commercial organic fertilizer in production; The proportion of non-agricultural income has a negative impact on the application of farmyard manure; The process of farmyard manure accumulation is time-consuming and laborious; The shortage of labor caused by non-agriculturalization will not be conducive to the application of farmyard manure; The quality of cultivated land has a positive impact on the application of commercial organic fertilizer by small farmers. In order to maintain high sustainable production capacity, small farmers are more willing to apply commercial organic fertilizer to good quality land; Whether farming has a positive impact on the application of farmyard manure by small farmers, and farming can provide low-cost farmyard manure raw materials for small farmers and promote the application of farmyard manure.

Table 3. Estimation results of bivariate probit model

Variable	Commercial organic fertilizer		Farmyard manure	
	Coefficient	Z-test	Coefficient	Z-test
Core variables				
Kinship social network	0.043*	1.772	0.063**	2.484
Friendship social network	0.018	0.611	0.052*	1.879
Environmental cognition	0.081**	2.344	0.055*	1.810
Control variables				
Gender	-0.090	-0.444	0.012	0.074
Age	-0.004	-0.433	0.011	1.557
Years of education	0.067**	2.562	0.047**	2.221
Are there village cadres or party members at home	0.511**	2.442	0.199	1.051
Number of agricultural labor force	-0.024	-0.226	0.153	1.588
Proportion of non-agricultural income	-0.605	-1.239	-1.158***	-2.870
Cultivated land scale	-0.012	-0.392	0.014	0.525
Cultivated land quality	0.284**	2.004	0.155	1.262
Whether or not to breed	0.236	1.119	0.462***	2.784
Shehong	0.113	0.382	0.025	0.105
Jiangyou	0.116	0.386	0.055	0.229
Zigong	0.359	1.169	-0.240	-0.930
Guangan	0.448	1.537	0.188	0.773
_cons	-2.512***	-3.015	-1.254*	-1.758
rho	0.264**			
Log pseudolikelihood	-309.9667			
Prob＞Chi2	0.0000			
N	334			

Note: *、 **、 *** respectively indicate significant levels of 10%, 5%, and 1%.The following table is the same.

4.3 Robustness test

Considering that social environment plays an important role in shaping individual cognition, social network, as a special form of social environment, may also have an impact on farmers' environmental cognition. The more communication between farmers and people with strong environmental awareness, the deeper understanding of the harm of excessive application of chemical fertilizer and the benefits of applying organic fertilizer, thus affecting farmers' fertilization behavior. In order to avoid the influence of multicollinearity between social network and environmental cognition, social network and environmental cognition are added to the model for regression. The results show that social network and

environmental cognition have no change in the direction and significance of organic fertilizer application, so the research results of this paper are relatively stable.

Table4. Robustness test

Variable	Bivariate Probit model I		Bivariate Probit model II	
	Commercial organic fertilizer	Farmyard manure	Commercial organic fertilizer	Farmyard manure
Core Variables				
Kinship social network	0.050** （2.053）	0.070*** （2.705）		
Friendship social network	0.013 （0.421）	0.047* （1.734）		
Environmental cognition			0.085** (2.572)	0.063** （2.201）
Control variables	Controlled	Controlled	Controlled	Controlled
Rho	0.283		0.301	
Log Like-lihod	-313.6931		-317.4392	
Prob>Chi2	0.0000		0.0000	
Sample size	334		334	

5 Summary and suggestions

5.1 Summary

(1)The behavior of small farmers applying commercial organic fertilizer and farmyard manure has complementary effects.(2)Social network has a positive effect on organic fertilizer application behavior, and the influence of kinship social network and friend social network on organic fertilizer application behavior is different. Genetic social network has a positive impact on farmers' application of commercial organic fertilizer and farmyard manure, while friendly social network has a significant positive impact on farmers' application of farmyard manure, but has no significant impact on the application of commercial organic fertilizer.(3)The environmental cognition of small farmers can significantly promote the application behavior of organic fertilizer. That is, farmers' environmental cognition is also one of the most intuitive factors affecting farmers' organic fertilizer application behavior.

5.2 Suggestions

According to the above conclusions, the following enlightenment is obtained：

(1) Pay attention to the cultivation and promotion of social networks. Farmers are encouraged to use the relationship resources of relatives and friends to strengthen their network ties, and to create a community cultural atmosphere of mutual benefit and mutual assistance by organizing rural cultural activities and production mutual assistance activities. Combined with

the characteristics of social networks, through the establishment of "village-level demonstration households" and "demonstration sites" and other forms, the strong trust characteristics of kinship social networks are brought into play to create convenient conditions for farmers to realize "learning by watching" and "learning by doing". With the help of modern means such as Internet media, we should build a communication platform between small farmers and agricultural technicians, broaden the circle of friends of farmers, and give full play to the positive role of social networks of friends.

(2)Enhance farmers' environmental awareness level. In the process of formulating policies, the government considers small farmers' environmental awareness as an important policy reference, carries out publicity and education activities on ecological environment-related knowledge, promotes farmers' learning and understanding of legal provisions related to ecological environment protection, and improves their environmental awareness level. At the same time, it also strengthens the publicity of organic fertilizer knowledge, improves farmers' understanding of the application of organic fertilizer, cultivates farmers' positive attitude, and promotes the promotion of organic fertilizer.

(3)Establish a cooperation mechanism for close communication between growers and farmers. On the one hand, it can meet the demand of growers for farmyard manure, on the other hand, it can also solve the pollution problem of livestock manure of farmers, promote the integration of planting and breeding cycle, and promote the development of green agriculture.

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