Influencing Factors of Grain Farmers' Application Behavior to Adopt Organic Fertilizer from the Perspective of Heterogeneity——Based on The Empirical Study of 512 Farmers in Sichuan Province

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Abstract. Based on the survey data of 512 households in Sichuan Province, this paper uses the binary logistic model to analyze the influencing factors of organic fertilizer application behavior of grain farmers in the perspective of heterogeneity. The study shows that the organic fertilizer application behavior of grain farmers is a complex decision-making behavior under the interaction of various heterogeneous factors. In terms of human capital, grain farmers who are young, highly educated and have a large family labor force are more likely to apply organic fertilizers; in terms of economic capital, grain farmers with high household income and high proportion of agricultural income are more likely to apply organic fertilizer; in terms of social capital, grain farmers who joined farmers’ specialized cooperatives and received training on organic fertilizer and had some family members who have served as village cadres prefer to apply organic fertilizer. In terms of natural capital, the large scale of cultivated land and the low degree of fragmentation of cultivated land are conducive to promoting the application of organic fertilizers to grain farmers.

1. Introduction
At present, China's agricultural pollution problem is very serious. The Ministry of Agriculture and Rural Affairs of People’s Republic of China pointed out that China's agricultural resource environment suffer from the dual pressure of exogenous pollution and endogenous pollution, so the green transformation of traditional high-pollution agriculture is imperative. Among them, excessive and unreasonable use of fertilizer is one of the main sources of agricultural pollution. The raw material of organic fertilizer mainly comes from organic waste and belongs to the category of renewable energy, which is different from the chemical fertilizer whose raw material depends on fossil energy. In 2015, the Ministry of Agriculture and Rural Affairs of People’s Republic of China proposed to improve the way of fertilization, improve the utilization rate of fertilizer, focus on promoting the use of organic fertilizer resources, and promote the sustainable development of agriculture. As the main agricultural production body, the application of organic fertilizer by farmers can effectively alleviate agricultural non-point source pollution. Therefore, it is of great significance to further explore the influencing factors of the organic fertilizer application behavior of farmers to improve the agricultural production environment and ensure food security.
The application behavior of organic fertilizer is affected by many factors, including their own factors and external environment. At present, there are many research results on the influencing factors of farmers' organic fertilizer application behavior, mainly in the following aspects. First, from the individual level of farmers, the effects of farmers' age \[3\], education level, agricultural income, awareness of organic fertilizers, and awareness of the environment \[4\] on their organic fertilizer application behavior were mainly investigated. Among them, Geng Biao found that the age of farmers has a negative correlation with the application of organic fertilizer \[3\], while the education level, the understanding of organic fertilizer, the understanding of environment and other aspects have a positive impact on the application behavior of farmers' organic fertilizer \[4\]. The second is to study the effect of family endowment on the application behavior of organic fertilizer. It mainly involves factors such as the number of family labor force, the average family education level and the family annual income. Zhao Qing showed that the income level of farmers has an important impact on the willingness of farmers to apply organic fertilizer, and the lack of economic capacity is the main factor limiting the willingness of farmers to apply organic fertilizer \[5\]. The third are other aspects. Scholars also explored the impact of land management scale \[6\], information channel \[7\], sales contract \[8\], organic fertilizer price \[5\], government guidance and training \[10\] and other factors on the application of organic fertilizer.

To sum up, the academic community has made relatively rich research results on the factors affecting farmers' organic fertilizer application behavior, which also provides certain reference for the author's research. But at the same time, there is still room for improvement. First, most of the existing studies examine farmers' organic fertilizer application behavior from a single dimension, and the heterogeneity perspective of production decision makers is relatively single. Second, there are few large sample surveys on the organic fertilizer application behavior of grain farmers, which leads to the lack of research breadth. Based on the survey data of 512 grain farmers' samples in Sichuan Province, this paper systematically investigated the influencing factors of agricultural organic fertilizer application from the perspective of heterogeneity, in order to provide certain basis and reference for promoting the green development of agriculture and the formulation of relevant policies.

2. Concept definition and research hypothesis

2.1. Concept definition

2.1.1. Heterogeneity of farmers. Heterogeneity refers to the differences in the components, resources, quality and dimensions of substances or organisms \[9\]. The heterogeneity of farmers refers to the differences in resource endowment, production willingness and decision-making among farmers engaged in agricultural production \[10\]. Among them, the difference in resource endowment is the direct cause of the heterogeneity of farmers \[11\], which leads to the different factors input and participation purpose of farmers. Therefore, this study will define the heterogeneity of farmers from the perspective of resource endowment.

2.1.2. Organic fertilizer. The definition of organic fertilizer can be divided into narrow sense and broad sense. The broad sense organic fertilizer is commonly known as farm manure, including various animal and plant residues or metabolites, such as human and animal manure, straw, animal residues, slaughterhouse waste, etc. In a narrow sense, organic fertilizer refers to a kind of fertilizer formed by processing various animal wastes and plant residues, such as commercial organic fertilizer. The organic fertilizer in this study includes commercial organic fertilizer and farm manure.

2.2. Research hypothesis

The heterogeneity of farmers is essentially the difference of resource endowment of farmers, and the judgment of organic fertilizer application behavior needs the support of behavioral economic theory. According to the behavior theory of farmers of the rational peasant theory, as a rational economic man who pursues the maximization of personal benefits, the purpose of farmers engaging in the economic
activities of agricultural production is to realize the maximization of profits, and there are few cases of low efficiency in their production distribution\cite{14}. In other words, farmers can reasonably allocate and use the resources they have, including human capital and economic capital, to maximize the benefits of agricultural production and operation activities. At this time, production factors in the hands of farmers can maximize their benefits.

According to the types of production factors, the resource endowments of farmers can be divided into natural capital resources \cite{15}, labor resources \cite{16}, technical resources \cite{17}, human capital \cite{18}, financial capital \cite{19}, social capital \cite{20}, etc. According to the above definition of heterogeneity of farmers, this study will measure the resource endowment of grain farmers from four aspects: human capital, economic capital, social capital and natural capital, so as to measure the heterogeneity of farmers.

Human capital is a combination of knowledge, skills, experience and health, mainly including physical strength and intelligence \cite{21}. Among them, physical strength mainly includes age, the quantity of labor force and so on, intelligence mainly includes education level and so on. Compared with the young labor force, the elderly labor force has a lower ability to learn and apply new technologies, and a weaker motivation to learn new technologies \cite{22}. Farmers with higher education level are more advanced in thinking, have a more comprehensive understanding of the ecological benefits of organic fertilizers, and may be more willing to apply organic fertilizers \cite{23}. Compared with fertilizers, the application of organic fertilizer requires extra labor, and the shortage of labor force will reduce farmers' willingness to apply organic fertilizer \cite{2}. Based on this, this paper proposes hypothesis 1: the farmers with more human capital are more likely to apply organic fertilizers.

Economic capital reflects the income level and economic status of rural labor force \cite{24}. The existing researches mainly measure the family economic capital by the family economic level, such as the total income of the family, the total income of agriculture, the proportion of the agricultural income to the total income of the family, etc. Compared with chemical fertilizer, the application of commercial organic fertilizer requires more investment. Generally, farmers with high total household income have more capital to invest in agriculture, and the more likely they are to apply organic fertilizer \cite{2}. As agricultural income accounts for a high proportion of the total household income, and the farmers tend to prefer agricultural production. These farmers also pay more attention to agricultural techniques such as organic fertilizer \cite{25}. Based on this, this paper proposes hypothesis 2: the farmers with more economic capital are more likely to apply organic fertilizers.

Social capital mainly exists in interpersonal relationships and social structures, and facilitates individual actions within the structure \cite{26}, and can be divided into community social capital and family social capital \cite{27}. Referring to the relevant research results, the social capital of the community in this study is mainly measured by whether to join the cooperative, whether to receive the guidance and training in production, and the social capital of the family is mainly measured by the number of village cadres in the family. As an important market subject of agricultural technology supply, cooperatives have certain advantages in promoting new agricultural technology \cite{28}. Joining cooperatives can provide a good platform for farmers and improve their preference for applying organic fertilizer. Receiving relevant training and guidance can enable farmers to obtain relevant cost and benefit information, so as to improve the possibility of applying organic fertilizer to farmers \cite{29}. Compared with ordinary farmers, those who have served or served as cadres in the family have a wider network of interpersonal relationships and more information resources \cite{24}, making it easier to learn about organic fertilizer. Based on this, this paper proposes hypothesis 3: the farmers with more social capital are more likely to apply organic fertilizers.

Natural capital refers to the storage and flow of natural resources that people depend on for their livelihood, including biodiversity, directly available resources and ecological services (UK International Development Agency, 1999). Cultivated land is the most important natural capital for Chinese farmers \cite{30}. Large-scale cultivated land operation is easy to form economies of scale, and the demand for technology is likely to be stronger \cite{31}. However, the high degree of cultivated land fragmentation will increase the cost of applying organic fertilizers, and the less likely the farmers will
use organic fertilizers \[2\]. Based on this, this paper proposes hypothesis 4: the farmers with more natural capital are more likely to apply organic fertilizers.

3. Research design

3.1. Data sources and basic characteristics of the sample

The data used in this research comes from a sample survey conducted by the research group on grain farmers in Chengdu and Meishan in Sichuan Province in January and July 2019. The surveyed areas are all located in the Chengdu Plain Economic Zone. The Chengdu Plain has flat terrain, fertile land, mild climate and abundant rainfall. It is a well-known commodity grain and oil base in the country and has a good representation. The survey uses stratified and random sampling and random sampling methods, randomly selecting 2 counties in each city, randomly selecting 1-2 towns in each county, randomly selecting 3 villages in each town, and finally randomly in each village Select 20-30 grain farmers. The sample used in this study is 512 households, including 244 households in Chengdu and 268 households in Meishan City. The distribution of sample households is shown in Table 1.

| Table 1. Distribution of sample farmers. |
|-----------------------------------------|
| City          | District (County) | Town (Township) | Sample farmers (households) |
|--------------|------------------|----------------|-----------------------------|
| Chengdu      | Pengzhou, Jintang| Aoping, Sanjie, Yunhe | 244 |
| Meishan      | Pengshan, Renshou| Gongyi, Yihe, Dahua, Caojia | 268 |

The basic characteristics of sample farmers are shown in Table 2. Among the surveyed farmers, men accounted for 69.34% and women accounted for 30.66%; from the perspective of age, they were mainly middle-aged, aged 40 and below accounted for 25.39%, aged 40-60 accounted for 50.20%, and aged 60 and above accounted for 24.41%; From the perspective of education level, most farmers have received junior high school and below education, accounting for 84.57%, and only 15.43% have received senior high school (technical secondary school) and above education; the scale of operation is generally not large, and most of them are under 10 mu. It accounts for 94.53%; the labor force is mostly 3 or less, accounting for 63.87%.

| Table 2. Basic characteristics of sample farmers. |
|-----------------------------------------------|
| Options                                      | Frequency number | Frequency   |
| Gender                                       |                  |             |
| Male                                         | 355              | 69.34%      |
| Female                                       | 157              | 30.66%      |
| Age                                          |                  |             |
| 40 years old and below                       | 130              | 25.39%      |
| 40-60 years old                              | 257              | 50.20%      |
| 60 years old and above                       | 125              | 24.41%      |
| Education level                              |                  |             |
| Uneducated                                   | 49               | 9.57%       |
| primary school                               | 156              | 30.47%      |
| junior high school                           | 228              | 44.53%      |
| Senior high school / technical secondary school | 73              | 14.26%      |
| College and above                            | 6                | 1.17%       |
| Scale of operation                           |                  |             |
| 3 mu and below                               | 224              | 43.75%      |
| 3-10 mu                                      | 260              | 50.78%      |
| 10 mu and above                              | 28               | 5.47%       |
| Quantity of labor force                      |                  |             |
| 3 people and less                            | 327              | 63.87%      |
| 4 to 6 people                                | 181              | 35.35%      |
| 7 people and above                           | 4                | 0.78%       |

3.2. Variable setting and descriptive statistical analysis
3.2.1. Dependent variable. The dependent variable $Y$ in this study is "the behavior of organic fertilizer application by grain farmers", and the corresponding question in the questionnaire is: "Whether the following green agricultural production technology is adopted in your family's agricultural production (multiple choices)", set options for "not adopted"; "application of commercial organic fertilizer or farm manure". According to the answers of farmers, they are assigned 0 and 1, respectively.

3.2.2. Independent variables and control variables. In terms of the selection of independent variables, human capital, economic capital, social capital and natural capital are selected as the key factors that affect the application of organic fertilizer in grain and agriculture. Human capital is measured by age, education level, and the number of family labor force; economic capital is measured by total household income and the proportion of agricultural income; social capital is measured by whether to join a farmer cooperative, whether to receive training or guidance on organic fertilizer, and the number of family village cadres; natural capital is measured by the scale of operation and the degree of fragmentation of cultivated land.

In terms of the introduction of control variables, according to the theory of planned behavior [32], this paper studies it from two aspects: the attitude towards the behavior and subjective norms. Because the attitude towards the behavior and subjective norms of farmers applying organic fertilizer cannot be observed directly, this study uses the existing research results for reference and combines with the actual investigation situation to design observation variables to measure them. The survey of farmers' attitude towards the application of organic fertilizer is as follows: "the application of organic fertilizer can make their own agricultural products sell at a good price". The survey of farmers' subjective norms on the application of organic fertilizer is as follows: "the application of organic fertilizer is conducive to environmental protection". Using the Likert scale, set 5 options: "Strongly Disagree", "Comparatively Disagree", "General", "Comparatively Agree" and "Strongly Agree", and assign 1-5 points respectively. In addition, previous studies have shown that farmers' gender and risk preference have an impact on their adoption behavior of agricultural technologies such as organic fertilizer [23][33]. Therefore, the gender and risk preference of respondents are selected as control variables. The definition of variables and the results of descriptive statistical analysis are shown in Table 3.

| Table 3. Variable definition and descriptive statistical analysis results. |
|---------------------------------------------------------------|
| **Variable name** | **Variable meaning** | **Mean** | **Standard deviation** |
|-------------------|----------------------|----------|-----------------------|
| **Explained variable** | | | |
| Organic fertilizer application behavior | 1 = with application behavior; 0 = without application behavior | 0.71 | 0.45 |
| **Explanatory variables** | Human capital | | |
| Age | Respondents' age (years old) | 49.68 | 11.72 |
| Education level | Respondents' years of education (years) | 6.98 | 3.40 |
| Quantity of labor force | Number of family labor force | 3.22 | 1.13 |
| Economic capital | Total household income | Total household income in 2018 (ten thousand yuan) | 8.37 | 10.51 |
| Proportion of agricultural income | Proportion of agricultural income to total household income | 0.23 | 0.16 |
| Social capital | Farmers’ cooperative | 1 = is a farmer cooperative member; 0 = is not a farmer cooperative member | 0.93 | 0.26 |
| Organic fertilizer related training or guidance | 1 = have received guidance or training on organic fertilizer in recent 3 years; 0 = have not received guidance or training on organic fertilizer in recent 3 years | 0.86 | 0.33 |
| Number of family | Number of family members who have served or served as | 0.52 | 0.61 |
3.3. Model selection

According to the theoretical analysis and research hypothesis, the explained variables in this paper select the application behavior of agricultural organic fertilizer, only "application" and "no application" two kinds, each grain farmer will make a choice after comprehensive evaluation of various influencing factors, which is a typical binary decision problem. Since the explained variable belongs to binary discrete variable, it is an ideal estimation method to use probability model when analyzing discrete selection problem. Therefore, this study constructs binary logistic regression model, and the proposed model adopts the following function form:

\[
\text{Logit}(P_j = 1) = \Phi(\alpha_i H_i + \beta_i E_i + \gamma_i S_i + \delta_i N_i)
\]

\(P_j\) is the 0-1 variable of the organic fertilizer application behavior of grain farmers If the farmer has the application behavior, \(P_j = 1\), otherwise \(P_j = 0\). \(i\) is the \(i\)-th grain farmers surveyed, \(H_i, E_i, S_i, N_i\) represent the explanatory variables of farmer 's human capital, economic capital, social capital, and natural capital, and \(\alpha_i, \beta_i, \gamma_i, \delta_i\) represent the parameters of each explanatory variable to be estimated.

4. Empirical results and analysis

4.1. Estimated results

In this study, Stata 13.0 software was used to conduct an empirical study on grain farmers' organic fertilizer application behavior. In order to avoid multicollinearity between variables, it is necessary to conduct multicollinearity test on explanatory variables first, and the test results are shown in Table 4. In the test results, the VIF values of all variables are less than 5 and the VIF mean is 1.40, indicating that there is no serious multicollinearity problem among variables.
Binary logistic regression is applied to the sample data, and the estimated results are shown in Table 5. The chi-square test statistic is 112.94, and the likelihood ratio test has passed the significant test at the level of 1%. The overall effect of the model estimation is better, and it has better explanatory power.

Table 5. Model estimation results of influencing factors of organic fertilizer application behavior of grain farmers.

| Variable name                               | Coefficient | Standard error | Z    | P      |
|---------------------------------------------|-------------|----------------|------|--------|
| Age                                         | -0.038**    | 0.015          | -2.38| 0.017  |
| Education level                             | 0.090***    | 0.017          | 3.76 | 0.000  |
| Quantity of labor force                     | 0.133**     | 0.067          | 2.11 | 0.030  |
| Total household income                      | 0.028*      | 0.016          | 1.75 | 0.081  |
| Proportion of agricultural income           | 0.837*      | 0.501          | 1.67 | 0.094  |
| Farmers’ cooperative                        | 0.978*      | 0.564          | 1.73 | 0.083  |
| Organic fertilizer related training or guidance | 1.361***    | 0.546          | 2.49 | 0.013  |
| Number of family village cadres             | 0.307**     | 0.148          | 2.08 | 0.038  |
| Scale of operation                          | 0.027*      | 0.016          | 1.67 | 0.094  |
| Degree of cultivated land fragmentation     | -0.075*     | 0.044          | -1.71| 0.076  |
| Gender                                      | -0.487*     | 0.275          | -1.77| 0.076  |
| Risk preference                             | -0.096*     | 0.057          | -1.68| 0.093  |
| Attitude towards the behavior               | 0.118***    | 0.066          | 2.76 | 0.006  |
| Subjective norms                            | 0.185***    | 0.064          | 2.88 | 0.004  |

LR chi2(11) = 112.94*** (Prob > chi2 = 0.0000)  
Log likelihood = -250.49479
Pseudo R2 = 0.1840

* **, *** are significant at the levels of 1%, 5%, and 10%, respectively.

4.2. Analysis of estimation results

Through the regression of binary logistic model, the author found that the variables of age, education level, quantity of labor force, total household income, proportion of agricultural income, farmers’ cooperative, organic fertilizer related training or guidance, number of family village cadres, scale of operation, degree of cultivated land fragmentation had passed the significant test, shows that the above 10 factors are the important factors influencing grain farmers applying organic fertilizer.

4.2.1. The impact of human capital. The variable coefficient of age is -0.038, which passed the significance test at the 5% level and was in line with expectations. Generally speaking, young people are more likely to receive new information and are willing to try new agricultural technologies.

The variable coefficient of education level is 0.090, which passed the significance test at the 1% level and is an important factor that positively affects the application behavior of organic fertilizers of grain farmers, which was in line with expectations. On the one hand, the highly educated grain farmers have a broader vision, are aware of the economic and ecological benefits of organic fertilizers, and are more willing to apply organic fertilizers. On the other hand, low-educated grain farmers are more likely to fall into path dependence and stick to traditional fertilizer application.

The variable coefficient of the quantity of labor force is 0.133, which passed the significance test at the 5% level and is in line with expectations. On the one hand, the application of organic fertilizer requires additional labor, and the shortage of labor will reduce the preference of grain farmers to apply organic fertilizer. On the other hand, increasing labor input can reduce dependence on other factors of
production (such as cultivated land, money, etc.), and sufficient labor will make grain farmers prefer organic fertilizers.

4.2.2. The impact of economic capital. The variable coefficient of total household income is 0.028, which passed the significance test at the 10% level. The increase in total household income can increase the capital of grain farmers to adopt new technologies, thereby effectively improving the initiative of grain farmers to apply organic fertilizers.

The variable coefficient of agricultural income proportion is 0.837, which passed the significance test at the 10% level and is in line with expectations. Grain farmers with a high proportion of agricultural income rely heavily on the income of agricultural products, so they are more willing to try applying organic fertilizer to increase income. In contrast, farmers with a high proportion of non-agricultural income have a high opportunity cost of farming, so they tend to engage in non-agricultural industries, and then have a small preference for the application of organic fertilizer.

4.2.3. The impact of social capital. The variable coefficient of the farmer cooperative is 0.978, which passed the significance test at the 10% level and is in line with expectations. Farmers' cooperatives, as the main body of green production promotion, can provide farmers with more quantity and higher quality agricultural services, so that grain farmers have a better understanding of organic fertilizers, and then promote the organic fertilizer application behavior of grain farmers.

The variable coefficient of organic fertilizer related training or guidance is 1.361, which passed the significance test at the 5% level and is in line with expectations. Organic fertilizer related training or guidance can enable grain farmers to change their production concepts, enhance safety awareness, and gain a better understanding of the benefits of using organic fertilizers, thereby promoting the use of organic fertilizers for grain farmers.

The variable coefficient of the number of family village cadres is 0.307, which passed the significance test at the 5% level and is in line with expectations. On the one hand, grain farmers who have served or served as village cadres have more channels for obtaining policy information, and have a better understanding of the relevant policy objectives such as "one control, two reductions and three basics". On the other hand, the “leading demonstration” effect of family member cadres will prompt such grain farmers to lead by example and actively apply organic fertilizer.

4.2.4. The impact of natural capital. The variable coefficient of scale of operation is 0.027, which passed the significance test at the 10% level and is in line with expectations. Grain farmers with larger planting scale generally use agricultural production as their main source of income. Compared with others, grain farmers with larger planting scale have a greater preference for organic fertilizers that can improve soil fertility.

The variable coefficient of cultivated land fragmentation degree is -0.075, which passed the significance test at the 10% level and is in line with expectations. The high degree of cultivated land fragmentation means that the cultivated land is very scattered, which is not conducive to the large-scale implementation of agricultural technology, and to a certain extent restricts the application of organic fertilizers to grain farmers.

5. Conclusions and policy implications

5.1. Conclusion
Based on the survey data of 512 households in Sichuan Province, this paper uses the binary logistic model to analyze the influencing factors of organic fertilizer application behavior of grain farmers in the perspective of heterogeneity. The study shows that the organic fertilizer application behavior of grain farmers is a complex decision-making behavior under the interaction of various heterogeneous factors. Specifically, in terms of human capital, grain farmers who are young, highly educated and have a large family labor force are more likely to apply organic fertilizers; in terms of economic
capital, grain farmers with high household income and high proportion of agricultural income are more likely to apply organic fertilizer; in terms of social capital, grain farmers who joined farmers’ specialized cooperatives and received training on organic fertilizer and had some family members who have served as village cadres prefer to apply organic fertilizer. In terms of natural capital, the large scale of cultivated land and the low degree of fragmentation of cultivated land are conducive to promoting the application of organic fertilizers to grain farmers.

5.2. Policy implications
Based on this, the author proposes the following policy implications: First, it is necessary to strengthen the vocational education and training of grain farmers and raise grain farmers’ awareness of the environmental and economic value of organic fertilizers. The government should enhance the influence of organic fertilizer, so as to improve the utilization rate of organic fertilizer, and create an agricultural production atmosphere that understands knowledge, technology and green production. The second is to attach great importance to the impact of economic capital on grain farmers’ application of organic fertilizers, vigorously develop the rural economy, increase farmers’ incomes, especially agricultural income, and raise their economic capital. The third is to pay attention to the organization's regulations and the role of radiation. In particular, give play to the leading role of farmers’ professional cooperatives, strengthen the guidance and support for cooperatives, and support the standardized development of cooperatives. It is necessary to encourage grain farmers to participate in professional farmer cooperatives, and also to encourage national public officials and village cadres to maintain close contact with grain farmers and give full play to their exemplary role in the promotion and implementation of organic fertilizers. The fourth is to continue to promote the improvement of land circulation policies, promote the development of moderately large-scale land operation, and encourage grain farmers to adopt organic fertilizers according to local conditions.

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