**Appendix**

**Appendix1**

*Prove that  and  are linearly related*

Because  and  and  are set to specific parameters, the size of is completely dependent on . At the same time, for each householder,  as his (or her) characteristic index is also a certain parameter. Then, it can be proven that and  are linearly related.

**Appendix2**

*Control variables selection basis*

*Householder characteristics*. 1) Age. The older the householders are, the more set in their ways they are, the less inclined they are to accept new things, and the less willing they are to participate in contract farming (Bellemare, 2012). However, as householder age increases, farmers pay more attention to the sustainability of the land to meet livelihood needs for the long term, and thus, they apply organic fertilizer (Teklewold et al., 2013). This article measures a householder’s age as his or her actual age. 2) Gender. Householder gender has different impacts on contract farming participation behavior and organic fertilizer application behavior. Men’s attitudes toward participation in contract farming are more positive (Shaffril et al., 2010), while women’s attitudes toward organic fertilizer application are more positive (Nigussie et al., 2017). This article codes the gender variable such that “male” equals 1 and “female” equals 0. 3) Education. Farmers with more education are better able to master new technology and learn new things, and they are more inclined to apply organic fertilizer and participate in contract farming (Kassie et al., 2015; Mishra et al., 2018a). This article uses a householder’s number of years of education to represent the education variable.

*Production and operation characteristics.* 1) Planting scale. The larger the farmland area is, the higher the cost of applying organic fertilizer, and the less inclined the farmer is to do so (Ajewole, 2010). However, the larger the farmland area is, the stronger the farmer’s production capacity, and the more willing the farmer is to participate in contract farming to avoid unsalable agricultural products (Poku et al., 2018). This article measures the planting scale as the actual area of cultivated farmland. 2) Labor force. The greater the number of labor force participants in a household is, the greater the family consumption expenditure, the higher the liquidity constraints, and the less organic fertilizer applied (Ma et al., 2018). On the other hand, households with a larger labor force have larger social networks to obtain and exchange information, thus making such farmers more likely to participate in contract farming (Mojo et al., 2017). This article measures the labor force as the actual number of people engaged in agriculture in a household. 3) Funding status. Farmers with sufficient funds are faced with fewer liquidity constraints and stronger investment capacity in agricultural production. Thus, they are more willing to apply organic fertilizer or participate in contract farming (Belay and Bewket, 2013; Mao et al., 2018). This article measures this variable by the logarithm of the sum of the annual wage income, business income, property income and transfer payment income of rural farming households. 4) Land tenure security. The more stable the farmer’s land management rights are, the higher the expectations for future income, and the greater the likelihood of applying organic fertilizers and participating in contract farming (Xu et al., 2014; Arumugam and Arshad, 2011). In China, land tenure security is the stability of land management rights in the context of the Three Rights Separation Policy, according to which rural land ownership rights, land contract rights, and land management rights can be separated and land management rights can be freely transferred. Therefore, based on the research of Gao et al. (2019), when a farmer has transferred land and has not signed a written contract with a transfer term of three years or more, land tenure security is low and the value is 1. When a farmer has transferred land and has signed a written contract with a transfer term of three years or more, land tenure security is general and the value is 2. When the farmer has not transferred land, land tenure security is higher and the value is 3. 5) Land quality. Farmers with higher land quality pay more attention to protecting their cultivated land (Teklewold et al., 2013), and they not only are willing to apply organic fertilizer but also are better able to meet enterprises’ quality requirements (Wang et al., 2014). This article measures land quality on a 5-point Likert scale.

**Appendix3**

*Robustness tests*

In this paper, the endogenous switching regression model is used to analyze the impact of participation in contract farming on the intensity with which farmers replace chemical fertilizer with organic fertilizer. The switching equation is the same as equation (8) <1>, and the specific form of the outcome equation is as follows:

 (13)

In the formula,  is the estimated coefficient of contract farming participation behavior in the outcome equation.  represents the intensity with which farmer  replaces chemical fertilizer with organic fertilizer.  represents the characteristic variables that affect the intensity with which farmer  replaces chemical fertilizer with organic fertilizer, and  is its estimated coefficient.  is a constant term in the outcome equations, and  is a residual term. The identification variable of this equation is the same as that used in the endogenous switching probit model.

Furthermore, the treatment effect of the intensity with which a farmer replaces chemical fertilizer with organic fertilizer when that farmer is participating in contract farming is as follows:

 (14)

In the formula,  represents the expected value of the intensity with which the farmer replaces chemical fertilizer with organic fertilizer for farmers participating in contract agriculture, and  represents the expected value of the intensity with which the farmer replaces chemical fertilizer with organic fertilizer for farmers participating in contract farming if they had not participated.

Similarly, the treatment effect of the intensity with which the farmer replaces chemical fertilizer with organic fertilizer by farmers not participating in contract farming is as follows:

 (15)

In the formula,  represents the expected value of the intensity with which the farmer replaces chemical fertilizer with organic fertilizer by contract farming for those farmers not participating if they had chosen to participate, and  represents the expected value of the intensity with which the farmer replaces chemical fertilizer with organic fertilizer for farmers not participating in contract agriculture.

According to Table A1, the ATT of participation in contract farming on the intensity with which vegetable farmers replace chemical fertilizer with organic fertilizer has a significant positive impact at the 1% level. Taking into account the counterfactual hypothesis, when vegetable farmers participating in contract farming do not implement the corresponding contract farming participation behavior, the intensity with which they replace chemical fertilizer with organic fertilizer is reduced by 0.09, a decrease of 13.25%. In contrast, when vegetable farmers not participating in contract farming participate in contract farming, the intensity with which they replace chemical fertilizer with organic fertilizer increases by 0.10, an increase of 19.71%. This finding shows that participation in contract farming can significantly increase the intensity with which farmers replace chemical fertilizer with organic fertilizer and can lead to a continuous increase in organic fertilizer application.

**Table A1** Average treatment effect of participation in contract farming on the intensity with which vegetable farmers replace chemical fertilizer with organic fertilizer.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Outcome variable | Farmer types | Decision type | ATT | ATU |
| Applied | Not applied |
| The intensity with which farmers replace chemical fertilizer with organic fertilizer | Farmers participating in contract farming | 0.66\*\*\*(0.15) | 0.58\*\*\*(0.08) | 0.09\*\*\*(0.02) | — |
| Farmers not participating in contract farming | 0.58\*\*\*(0.11) | 0.49\*\*\*(0.08) | — | 0.10\*\*\*(0.02) |

The estimated results of the RBPM are shown in Table A2. The direction and significance of the coefficients of the variable of farmers’ contract farming participation behavior and the control variables are generally consistent with the estimated results in Table A2, which indicates that the aforementioned results are relatively robust.

**Table A2** Estimation results of the recursive bivariate probit model.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable type | Variable | Switching equation(Contract farming participation behavior) | Outcome equation(Organic fertilizer application behavior) |
| Main independent variable | Contract farming participation behavior | — | 1.09\*\*\* (0.26) |
| Control variable | Age | -0.05\*\*\*(0.01) | 0.08\*\*(0.04) |
| Gender | 0.02 (0.15) | -0.04 (0.08) |
| Education | 0.10\*\* (0.05) | 0.09\*(0.05) |
| Planting scale | 0.37\*(0.22) | -0.97\*(0.55) |
| Labor force | 0.04(0.09) | 0.03(0.07) |
| Funding status | -0.06(0.13) | 0.03\*\*(0.01) |
| Land tenure security | 0.14\*\*\*(0.02) | 0.05\*\*\*(0.02) |
| Land quality | 0.16\*\*(0.08) | 0.14\*(0.08) |
| Identification variable | The proportion of farmers participating in contract farming from other villages in the same township | -0.63\*\*\*(0.15) | — |
| Correlation coefficient |  |  | -0.74\*\*\*(0.13) |
|  | Constant | -3.01\*\*\*(1.02) | -5.12\*\*\*(1.33) |
|  | Observations | 473 |

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