Article

The Effect of Land Right Stability on the Application of Fertilizer Reduction Technologies—Evidence from Large-Scale Farmers in China

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Abstract: This article examines the impact of the stability of the management rights of transferred land (TLMR) on the adoption of technologies aiming to reduce the use of chemical fertilizers (ARFTs) based on the survey data of large-scale grain growing households in Anhui, China. Using the IV-Probit model, the present paper defines the stability of TLMR and the results estimated by IV-Probit model shows that a one-year extension of land lease period can increase the probability of using organic fertilizer and soil-testing formula fertilizer by 3.16% and 4.92%, respectively, while contract breaching in the lease period can reduce the probability of using organic fertilizer and soil-testing formula fertilizer by 46.9% and 51.38%, respectively. However, the land-lease period and land transfer contract breaching in the lease period have no significant effect on the use of farmyard manure by large-scale grain growing households. The main conclusion is that improving the stability of TLMR is conducive to prompting large-scale grain growing households to adopt ARFTs, especially the adoption of organic fertilizer and soil-testing formula fertilizer. The government should improve the stability of TLMR by standardizing the form and content associated with land transfer contracts and setting the minimum land-lease term.

Keywords: fertilizer reduction technologies; land transfer; large-scale grain growing households; stability of land right

1. Introduction

To ensure food security, the policy of cultivated land requisition-compensation balance has been implemented to ensure the supply of cultivated land in China in recent years, whereas the decline in cultivated land quantity is still hard to prevent. The data from National Land & Resources Information shows that the cultivated area decreased by 59,900 ha from 121,775,900 ha in 2006 to 121,716,000 ha in 2008, with an average annual decrease of 0.02%; the cultivated area decreased by 384,600 ha from 121,985,000 ha in 2009 to 121,600,400 ha in 2015, with an average annual decrease of 0.05%. In the long term, market-led resource allocation can make land gradually flow from agriculture to industrial and services sectors due to a higher marginal return rate; thus, the decrease in cultivated area is unavoidable. In this case, the key to ensure food security in China is to increase the output per unit area of cultivated land by improving the quality of cultivated land. However, the quality of cultivated land in China is not optimistic at present. The proportion of cultivated land with high quality has decreased by 3% from 30% in 2009 to 27% in 2015, while the proportion of medium and cultivated land with low quality has increased by 3% from 68% in 2009 to 71% in 2015 [1].

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The evidence from West Bengal in India [2], northeast of China [3] and Johor in Malaysia [4] have shown that excessive use of chemical fertilizers is one of the main reasons for the decline in cultivated land quality, and promoting fertilization technology is an effective way to achieve chemical fertilizer reduction. The fertilizer reduction technologies refer to those technologies aiming to reduce the use of chemical fertilizers (ARFTs), mainly including farmyard manure, organic fertilizer, and formulated fertilization by soil testing [5]. Among them, farmyard manure is mainly human manure, animal manure, and kitchen waste. Organic fertilizer is a kind of fertilizer which is processed from farmyard manure and then put into the market after being processed. Both farmyard manure and organic fertilizer are characterized by persistent fertilizer efficiency and improving organic matter content in soil. Formulated fertilization by soil testing is meant to formulate a reasonable fertilizer formula based on the detection results of the content of each nutrient element in the soil, which aims to improve the efficiency of fertilizer absorption and reduce the damage of residual fertilizer to the soil.

Since the adoption of ARFTs can bring long-term benefits to farmers by improving the quality of cultivated land, it means that the benefits of adopting ARFTs need to be obtained intertemporally. Therefore, stable land rights are the key to guarantee intertemporal gains, and it is believed that stable land rights prompt farmers to choose agricultural technologies for protecting cultivated land. This was confirmed by large amount of empirical evidence from the privatized market of land property rights [6]. For example, the evidence from Brong Ahafo, Ghana has proved that enhancing the stability of land rights can encourage farmers to invest in farmland conservation [7]. Further studies found that there is a reciprocal causation between private land property right stability and protective land investment. Evidence from rural Burkina Faso showed that stronger land rights increase protective land investment, and protective land investment has positive and negative effects on stronger and weaker land rights, respectively [8,9]. The evidence from Zambia showed that widows’ land-inheritance rights and investments in land protection are highly correlated, and the results indicated that land investment by married couples is lower in the villages where widows have no rights to inherit. Although the husband is alive, the investment in land protection can be reduced by concern over prospective loss of land by the wives [10].

The particularity of China’s rural land property rights system lies in the separation of three rights, named “Three Rights Separation Policy”, that is, the division of land property rights into ownership, contracting right, and management right. Among them, ownership is owned by the rural collectives. Any rural household has the right to contract land for agricultural production from the rural collectives where they live, and then they own both the contracting right and management right, collectively referred to as the contracted management right. In recent years, a large number of studies have focused on the effects of the stability of land contracted management rights on farmers’ adoption of ARFTs [11–13]. For example, farmers could be promoted to apply farmyard manures by extending the land contracting period [11]. The adjustment in household contracted arable land would inhibit farmers from investing in improved land such as organic fertilizers [12]. Recent changes in rural land policies are conducive to increasing contracted management rights stability and providing farmers incentives to adopt ARFTs to improve land quality [13]. Over the years, the stability of contracted management rights has been strengthened after the Chinese government implemented land policies including the extension of the land contract period, certification of land rights, and the prohibition of arbitrary land reallocations [14–16].

China’s rural land system stipulates that only the management right of land can be traded, but the contracting right of land is not allowed to be traded [17]. Which means that large-scale farmers only have the management right of transferred land (TLMR) rather than contracting right, and the incompleteness of land rights increases the instability of land rights [18]. The related empirical study has proven that the probability of adopting ARFTs on farmers’ contracted land was higher than the probability of that on transferred land [19]. Although policies like the certification of land rights has made it easier for landlords to
rent their land without worrying about losing it, which is conducive to improving the stability of TLMR [20–22], whether the TLMR can be stable is still uncertain. The stability of TLMR depends on the land transfer contract signed by both parties involved in land transfer, including the land lease term, and the risk of breach of contract during the land lease term [23]. Farmers who rent their land to other farmers (landlords) and farmers who rent land from other farmers (tenants) have different objectives in land transfer; the landlords prefer a short-term contract because land ensures livelihood security and may appreciate in value in the future [20], and the large-scale farmers who are also the tenants tend to prefer a short-term contract due to the expected risk of agricultural production [24].

It is not difficult to find that self-interested motives and asymmetric information on both parties involved in land transfer always threaten the stability of TLMR; however, existing literatures lack of discussions about large-scale farmers’ adoption of ARFTs from the perspective of the stability of TLMR. With the prevalence of land transfer, agricultural scale management is developing rapidly in rural China and the number of large-scale grain growers in major grain production areas are increasing (According to data from Chinese Ministry of Agriculture, the total area of household contracted cultivated land in China increased from 4.25 million ha in 2007 to 30.67 million ha at the end of June 2016. Correspondingly, the proportion of transferred land in total household contracted cultivated land area increased from 5.2% to 35%). An unstable land transfer contract leads to uncertain future earnings of adopting ARFTs. Therefore, the instability of TLMR may limit the adoption of ARFTs by large-scale farmers.

Because more and more rural residents go to live in cities, large-scale farmers are playing an important role in China’s agricultural production. Thus, it is of great importance to focus on the application of ARFTs by large-scale farmers who farm at least 3.33 ha of land (According to the standard set by The Ministry of Agriculture and Rural Affairs, farmers who operate on at least 3.33 ha of farmland in the region of two-harvest-a-year like Anhui Province are classed as large-scale farmers), and only the application of ARFTs on transferred land is considered in this article (The production behavior of large-scale grain growing households on contracted land is often based on non-economic objectives, such as self-feeding). Therefore, based on survey data of 414 large-scale grain growing households from Anhui Province China, this paper examines the impact of land right stability on the adoption of ARFTs by large-scale grain growing households who transfer in cultivated land. Anhui Province is one of the major grain producing provinces in China, according to statistics from Chinese Ministry of Agriculture, Anhui’s grain production ranked fourth place among Chinese provinces in 2019. Meanwhile, as rural labor force export province, land transfer, and agricultural scale management develops rapidly in the rural area of Anhui Province, according to statistics from the Anhui Agricultural Commission, from 2007 to 2014, the number of large-scale grain growers over 6.67 ha increased from 7953 to 27,171, an increase of 2.4 times. It suggested that taking Anhui Province as a case study area has a practical value.

The remainder of this paper is organized as follows: Section 2 introduces the data and method; Section 3 shows the empirical results; finally, the paper is discussed and concluded in Section 4.

2. Data and Method

2.1. Data

The study was conducted in Anhui Province, China in the year of 2017. For obtaining the data we need in this article, we conducted a questionnaire survey on the large-scale grain growers whose transfer-in cultivated land is over 3.33 ha, and the number of original samples obtained from the survey is 414 in total. Figure 1 displays the locations of Anhui Province.
A multistage cluster random sampling method was used to derive the original sample, and the related information was collected by questionnaire survey on the individual and household levels. Specifically, two sample townships were randomly selected in each sample county, and two sample villages were randomly selected in each township. Then, 8–10 large-scale grain-growing households who transfer in cultivated land over 3.33 ha were randomly selected. Finally, 414 effective samples were obtained.

We select 11 counties whose grain output ranks in the forefront of Anhui Province, China as the sample counties. The 11 major grain-producing counties are Funan, Linquan and Taihe in Fuyang City, Guzhen and Wuhe in Bengbu City, Lixin and Mengcheng in Bozhou City, Yongqiao and Lingbi in Suzhou City, Mingguang and Dingyuan in Chuzhou City. Figure 2 displays the locations of these counties.

2.2. Definition of Variables

2.2.1. Assessment of ARFTs

ARFTs includes application of farmyard manure, organic fertilizer, and formulated fertilization by soil testing. Three variables are thus selected as dependent variables of the empirical model: whether to apply farmyard manure (FM), whether to use organic fertilizer (COF), and whether to use soil-testing formula fertilizer (SFF).

2.2.2. Measurement of Stability of Land Right

The stability of land right, measured as cultivated land lease term (RET), is chosen as the key independent variable [25]. Moreover, for the robustness test, we also choose whether the land transfer contract is breached in the lease term (DES) as an alternative variable of a cultivated land lease term.
2.2.3. Controlled Variables

The individual and family characteristics are also included in the model to control the heterogeneity in large-scale grain-growing households [26]. In addition to some basic individual characteristics of the head of a household such as age (AGE), educated years (EDU), times of technical training attended by the household head (TRA), it is also necessary to consider the impact of risk preference, experience, and reputation demands of large-scale grain-growing households on adoption of ARFTs. Farmers with an appetite for risk are more innovative and more willing to break tradition and adopt new technologies [27]; thus, we use risk preference degree of self-evaluation (RIS) to describe risk preference of large-scale grain-growing households. Experience is an important human capital accumulated by farmers through “learning by doing”, which can significantly promote the use of new technology [28]. Years of large-scale grain-growing households engaged in grain production (EXP) is used to express experience for grain plantation of large grain-growing households.

Some variables are selected to control household characteristics. Farmers who care more about their personal reputation tend to adopt environmentally friendly technologies in rural acquaintance society [29], and this paper uses the variable named “whether household members of large-scale grain-growing households are village cadres” (VOF) to describe personal appeal for reputation. The variable of per capita household income (INF), the number of family members engaged in grain production (FAR), and the area of transferred land (SIZ) (We only counted the transferred land that had been cultivated) were selected to control the family capital endowment, labor endowment, and farmland endowment, respectively. Moreover, the impact of off-farm employment and household burden on farmers’ adoption of technology are considered. The proportion of off-farm income to total household income (UNF) and the proportion of family members over 65 years old and
under 16 years old to total household population (BUR) are selected to measure non-farm employment and household burden, respectively.

2.3. Descriptive Statistics of Variables

The statistical characteristics of all the variables in this paper are listed in the Table 1, and we make the following comments on the results reported in Table 1.

Table 1. Descriptive statistics of variables.

| Variable Name                                     | Variable Code | Variable Definition | Mean  | Var   | Max  | Min  |
|--------------------------------------------------|---------------|---------------------|-------|-------|------|------|
| Whether to apply farmyard manure                 | FM            | 0 = no, 1 = yes     | 0.27  | 0.44  | 1    | 0    |
| Whether to apply organic fertilizer              | COF           | 0 = no, 1 = yes     | 0.32  | 0.47  | 1    | 0    |
| Whether to use soil-testing formula fertilizer   | SFF           | 0 = no, 1 = yes     | 0.51  | 0.5   | 1    | 0    |
| Cultivated land lease term                       | REN           | —                   | 6.77  | 4.16  | 50   | 1    |
| Whether the land transfer contract is breached in the lease term | DES          | 0 = no, 1 = yes     | 0.34  | 0.47  | 1    | 0    |
| Age of householder                               | AGE           | 2016-birth year     | 46.92 | 6.87  | 65   | 29   |
| Educated years of householder                    | EDU           | computation from primary school | 9.59 | 2.64  | 15   | 0    |
| Times of technical training attended by the household head | TRA          | number of times in 2016 | 3.01 | 2.85  | 20   | 0    |
| Risk preference degree of self-evaluation        | RIS           | 0 = risk aversion, 1= risk neutrality, 2= risk preference | 1.55  | 0.69  | 2    | 0    |
| Years of large grain-growing households engaged in grain production | EXP          | —                   | 19.32 | 11.11 | 45   | 2    |
| Whether family members are village cadres        | VOF           | 0 = no, 1 = yes     | 0.25  | 0.43  | 1    | 0    |
| Per capita household income                       | INC           | unit: 10,000 yuan per person | 5.27 | 5.17  | 37   | 0.27 |
| The number of family members who are engaged in grain production | FAR          | —                   | 2.45  | 1.1   | 7    | 1    |
| The area of transferred land                      | SIZ           | unit: ha            | 30.56 | 46.27 | 366.17 | 0.67 |
| The proportion of non-farm income to total household income | UNF          | —                   | 0.37  | 0.31  | 0.99 | 0    |
| The proportion of family members over 65 years old and under 16 years old | BUR          | —                   | 0.4   | 0.2   | 0.86 | 0    |

Note: Since farmers have not yet started farming on the newly transferred land, their technology adoption behavior cannot be counted. Therefore, these newly transferred land is not counted into the variable “SIZ”, which makes the minimum value of “SIZ” lower than 3.33 ha.

The overall adoption rate of ARFTs is low among the samples. The adoption rate of formula fertilizer by soil testing is the highest reaching 51%, followed by organic fertilizers. Only 27% of the total sample adopts farmyard manure, which is the lowest.

The average cultivated land lease term of the total sample is relatively long, but the individual differences are obvious. The longest land lease period is 30 years covering the whole second contract period, while 52 samples’ land lease periods are only one year, accounting for 12.56% of the total sample. Moreover, the rate of land transfer contract breached in the lease term is high, reaching 34%. The reason for the breach is usually because the farmers who transferred out of the land require rent increases, and there is a herd effect. The destruction of a household will lead other farmers to breach the contract together, making it difficult for the transferees to parry.

Among the respondents, they are mainly middle-aged and young people, and only 12 rural households aged 60 and over, accounting for 2.9% of the sample. They generally have a relatively high education level. The average years of education of the sample is 9.59 years, which significantly exceeds the average education years of the rural population in 2016 of 8.33 years (It is calculated according to the data of China Rural Statistical Yearbook 2017). Moreover, large-scale grain growers generally have long been engaged in grain
production and show risk preference. There are 274 farmers with risk preferences, far more than 46 with risk aversion, indicating that the production behavior of large-scale grain growers is no longer the pursuit of livelihood security like traditional small farmers. In addition, the average family per capita annual income of the sample is 7936.63 dollars (The arithmetic average value of the 12-month exchange rate for 2016 shows that one dollar is worth 6.6401 RMB, according to the data from China Foreign Exchange Trade Center), which is much higher than the per capita disposable annual income of rural residents in China in 2016 of 1867.44 dollars (The data is from China Statistical Yearbook 2017). It is found that most of the samples are engaged in the operation of multiple related industries such as planting, processing, sales of agricultural materials, and farmhouses, which has a significant effect on increasing revenue.

2.4. Empirical Model

Since the dependent variables in this paper are binary selection variables, the Probit model is used for estimation. The form of the model is as follows:

\[ P(NJF_i/YJF_i/CTP_i = 1) = \Phi(\alpha + \beta_1 REN_i/DES_i + \beta_2 Z_i + \epsilon_i) \]  \hspace{1cm} (1)

The left side of Equation (1) indicates the probability of applying farmyard manure, commercial organic manure, and soil-testing formula fertilizer by the large-scale grain-growing households. The key independent variable on the right side is the stability of TLMR, measured by “REN” and “DES”. Because of the high correlation between the two variables, they are separately put into the Probit model respectively. \( Z_i \) represents the controlled variables. \( \alpha, \beta_1, \) and \( \beta_2 \) are parameters to be estimated, and \( \epsilon_i \) are random perturbation terms.

However, there may be an endogenous correlation between the adoption of ARFTs and the stability of TLMR. For example, landlords may be willing to extend the lease period because of the protective fertilization by farmers who transfer in cultivated land. Therefore, it is doubtful that the land-lease period and whether the contract has been breached are endogenous variables. In order to eliminate the endogenous issues, this paper uses an IV-Probit model based on instrumental variables. We select whether the village committee provides land transfer service (INT) and the distance between the village and town (DIS) as instrumental variables for “REN” and “DES”.

The variables of village level as instrumental variables can ensure instrumental variables and random perturbation terms are uncorrelated [30]. On the one hand, land transfer services provided by village committees help resolve the information asymmetry in cultivated land transfer and reducing friction in negotiations. Moreover, village committees dominate the allocation of village public resources, and thus land transfers involving village committees can more effectively prevent a series of opportunistic actions such as breach of contract [31]. On the other hand, the closer the village to the town, the tighter the agricultural land resources, the greater the possibility of occupation of agricultural land, and thus the increase in uncertain factors in land transfer makes it difficult to reach a long-term stable land-transfer contract [32]. It is obvious that the two instrumental variables and the endogenous variables have a strong correlation. Therefore, “INT” and “DIS” are suitable as instrumental variables for “REN” and “DES”.

3. Empirical Results

3.1. Estimated Results of Probit Model

The results estimated by Probit model are presented in the Table 2. The key explanatory variable in column (1) to (3) is “REN”, while it is “DES” in column (4) to (6). All the models pass the chi-square test at 1% significance level, which indicates the model fits well.
Table 2. Estimated results of Probit model.

| Variables | (1) FM | (2) COF | (3) SFF | (4) FM | (5) COF | (6) SFF |
|-----------|-------|--------|--------|-------|--------|--------|
| REN       | 0.0154 *** | 0.0169 *** | 0.0253 *** | -0.0997 ** | -0.1123 ** | -0.1355 *** |
|          | (0.0055) | (0.0056) | (0.0064) | (0.0455) | (0.0461) | (0.0476) |
| DES       | 0.0014 | 0.0023 | 0.0054 | 0.0014 | 0.0024 | 0.0052 |
|          | (0.0037) | (0.0037) | (0.004) | (0.0037) | (0.0037) | (0.004) |
| AGE       | -0.011 | 0.0184 ** | 0.0248 *** | -0.0094 | 0.0203 ** | 0.0264 *** |
|          | (0.0083) | (0.0087) | (0.0089) | (0.0083) | (0.0087) | (0.009) |
| EDU       | 0.0187 *** | 0.013 * | 0.0229 *** | 0.0189 *** | 0.0133 * | 0.0229 *** |
|          | (0.0069) | (0.0075) | (0.0083) | (0.0069) | (0.0076) | (0.0083) |
| RIS       | -0.0039 | -0.0436 | -0.009 | -0.0078 | -0.0408 | -0.0058 |
|          | (0.0307) | (0.0319) | (0.0336) | (0.0308) | (0.0321) | (0.0342) |
| EXP       | 0.008 ** | -0.0042 * | 0.0011 | 0.0113 *** | -0.0405 ** | 0.0007 |
|          | (0.004) | (0.0022) | (0.0024) | (0.0039) | (0.0022) | (0.0024) |
| VOF       | 0.1441 *** | 0.1038 ** | 0.0514 | 0.1372 *** | 0.111 ** | 0.0509 |
|          | (0.0491) | (0.0525) | (0.0557) | (0.0494) | (0.0531) | (0.0562) |
| INC       | -0.0025 | 0.0094 ** | 0.0166 *** | -0.0027 | 0.0133 *** | 0.0112 ** |
|          | (0.0022) | (0.0041) | (0.0047) | (0.0022) | (0.0038) | (0.0046) |
| FAR       | -0.0107 | -0.0154 | -0.0482 ** | -0.0157 | -0.0195 | -0.0536 ** |
|          | (0.0198) | (0.0202) | (0.0212) | (0.0201) | (0.0203) | (0.021) |
| SIZ       | -0.0001 | 0.0007 | 0.0006 | 0.0002 | 0.001 ** | 0.0011 ** |
|          | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0004) | (0.0005) |
| LINF      | -0.006 | 0.1342 ** | 0.1415 * | -0.0154 | 0.1263 * | 0.1302 * |
|          | (0.0685) | (0.0677) | (0.0743) | (0.0695) | (0.0681) | (0.0751) |
| BUR       | -0.2148 ** | -0.2219 ** | -0.0116 | -0.2061 * | -0.2322 ** | -0.0085 |
|          | (0.1083) | (0.1098) | (0.1205) | (0.1087) | (0.1107) | (0.1213) |
| Log       | -221.34 | -228.636 | -256.35 | -222.902 | -230.186 | -260.105 |
| LR chi²   | 36.68 *** | 64.04 *** | 60.98 *** | 33.55 *** | 60.94 *** | 53.47 *** |
| Prob > chi² | 0.0003 | 0.0000 | 0.0000 | 0.0008 | 0.0000 | 0.0000 |
| Pseudo R² | 0.0765 | 0.1228 | 0.1063 | 0.07 | 0.1169 | 0.0932 |
| Observations | 414 | 414 | 414 | 414 | 414 | 414 |

Note: Table 2 reports the average marginal effect, and the standard errors are shown in parentheses. The *, ** and *** represent the significant levels of 10%, 5% and 1%, respectively.

According to the mean marginal effects reported in the Table 2, a year increase in land lease period from its mean can increase the probability of using farmyard manure, organic fertilizer, and soil-testing formula fertilizer by 1.54%, 1.69% and 2.53%, respectively, which are all statistically significant at the 1% level. In addition, breaching contract in lease period reduces the probability of using farmyard manure, organic fertilizer, and soil-testing formula fertilizer by 9.97%, 11.23% and 13.55%, respectively, which pass the test at the significance level of at least 5%.

Therefore, it can be concluded that stable land right can effectively increase the probability of applying ARFTs by large-scale grain growing households. On the contrary, the instability of TLMR significantly reduces the probability of using ARFTs by large-scale grain growing households. We also find that the effect of TLMR stability on the adoption of farmyard manure is weakest, but that on the adoption of soil-testing formula fertilizer is strongest.

3.2. Estimated Results of the IV-Probit Model

In order to account for the potential endogeneity of the cultivated land-lease period and contract breaching, we used a wald test. The results for the above six estimations all reject the null hypothesis that the land-lease period and contract breaching in the lease period are exogenous variables. Hence, there do exist endogenous problems, and the IV-Probit model is necessary.

The estimated results of the IV-Probit models are reported in the Table 3. Although the Pseudo R² are low in all the 6 IV-Probit models, Pseudo R² is not a suitable index
testing the goodness of fit for LM estimation. The percent of correctly predicted value in all the 6 IV-Probit models are over 70%, which indicates that the independent variables chosen here are acceptable in terms of predicting. The regression results of the IV-Probit model illustrate that extending the land-lease term has a positive effect on the application of organic fertilizer and soil-testing formula fertilizer, whereas land transfer contract breaching during the lease period has a negative impact. The estimated results of marginal effect show that a one-year extension of the land lease period from its mean can increase the probability of using organic fertilizer and soil-testing formula fertilizer by 3.16% and 4.92%, respectively, while land transfer contract breaching in the lease period can decrease the probability of using organic fertilizer and soil-testing formula fertilizer by 46.9% and 51.38%, respectively. Compared to the benchmark from the Probit model, the marginal effects of the land-lease period on organic fertilizer and soil-testing formula fertilizer usage increased by 86.98% and 94.47%, respectively; moreover, the marginal effect of land transfer contract breaching during the lease period on organic fertilizer and soil-testing formula fertilizer usage increased by 317.63% and 279.19%, respectively. It indicates that if the exogeneity is not considered, the impact of the stability of land right on the use probability of organic fertilizers and soil testing formula fertilization will be greatly underestimated.

Table 3. Estimated results of IV-Probit model.

| Variables | FM   | COF  | SFF   | FM   | COF  | SFF   |
|-----------|------|------|-------|------|------|-------|
| REN       | 0.0088 | 0.0316*** | 0.0492*** | (0.0119) | (0.0102) | (0.0087) |
| DES       | 0.0113 | 0.022 | 0.051 | 0.014 | 0.019 | 0.027 |
| AGE       | (0.0037) | (0.0036) | (0.0036) | (0.0037) | (0.0032) | (0.0027) |
| EDU       | −0.0102 | 0.0155* | 0.0188* | −0.0103 | 0.0105* | 0.0079* |
| (0.0084) | (0.0086) | (0.0087) | (0.0083) | (0.0058) | (0.0032) |
| TRA       | 0.0193*** | 0.0113** | 0.0185** | 0.0175** | 0.0057 | 0.0296* |
| (0.007) | (0.0053) | (0.0078) | (0.0077) | (0.0073) | (0.0158) |
| RIS       | −0.0045 | −0.0447 | −0.014 | −0.0093 | −0.025 | −0.0025 |
| (0.031) | (0.0309) | (0.0309) | (0.0305) | (0.0286) | (0.0224) |
| EXP       | 0.0094*** | −0.0035* | 0.0016 | 0.0112*** | −0.0027* | 0.0009 |
| (0.0045) | (0.002) | (0.0022) | (0.0039) | (0.0015) | (0.0016) |
| VOF       | 0.1463*** | 0.1004** | 0.0436 | 0.1287** | 0.1014** | 0.0008 |
| (0.0495) | (0.051) | (0.0513) | (0.0532) | (0.047) | (0.0382) |
| INC       | −0.0027 | 0.0057** | 0.0206*** | −0.0025 | 0.0105*** | 0.0047* |
| (0.0022) | (0.0027) | (0.0044) | (0.0022) | (0.0004) | (0.0025) |
| FAR       | −0.0117 | −0.0111 | −0.0359* | −0.0167 | −0.0182 | −0.0164** |
| (0.02) | (0.0196) | (0.0204) | (0.0198) | (0.0173) | (0.0065) |
| SIZ       | 3.25 × 10⁻⁵ | 0.0003 | −0.0001 | 0.0001 | 0.0005 | −0.0002 |
| (0.0006) | (0.0005) | (0.0005) | (0.0005) | (0.0005) | (0.0004) |
| UNF       | −0.0062 | 0.125* | 0.1196* | −0.0283 | 0.0389 | 0.0001 |
| (0.069) | (0.0656) | (0.0691) | (0.0734) | (0.0693) | (0.0547) |
| BUR       | −0.219* | −0.2075* | 0.0008 | −0.1976* | −0.1539* | 0.0151 |
| (0.1092) | (0.1069) | (0.1115) | (0.1094) | (0.0849) | (0.0801) |
| Pseudo R² | 0.1364 | 0.1443 | 0.1268 | 0.1491 | 0.1865 | 0.1947 |

Correctly classified Wald test of exogeneity

74.40% 74.40% 72.32% 74.88% 77.83% 77.97%

4.95** 8.28*** 7.01*** 4.77** 5.03** 12.67***

Note: Table 3 reports the average marginal effect, and the standard errors are shown in parentheses. The *, ** and *** represent the significant levels of 10%, 5% and 1%, respectively.

However, the results show that the land-lease period and land transfer contract breaching in the lease period (DES) have no significant effect on the use of farmyard manure by large-scale grain growing households. It indicates that the impact of the stability of land
right on the probability of using farmyard manure will be overestimated without taking
endogeneity issues into account. The possible reason is that although farmyard manure
is easy to obtain on-site, it is difficult to apply to large-scale agricultural production due
to limited availability. Moreover, the efficiency of farmyard manure is too slow and the
use of farmyard manure can bring discomfort to the producers. In addition, farmyard
manure is not conducive to labor saving. Therefore, the adoption rate of farmyard manure
in agricultural scale management is low. It is easier for farmers to obtain formula fertil-
izer than organic fertilizer, since fertilizer stations are set up in many Chinese villages to
provide formula fertilizer to local farmers, and this is the reason why the incentive effect
of TLMR stability on soil-testing formula fertilizer application is stronger than that on
organic fertilizer.

The results for most control variables are in line with expectations. For instance,
education level of householder (EDU) significantly increases the probability of using
organic fertilizers and soil testing formula fertilization, but there was no significant impact
on the use of farmyard manure. The possible reason is that farmyard manure is a traditional
technology, while organic fertilizer and soil-testing formula fertilizer belong to modern
fertilization technology, which are more acceptable for farmers with high educational level.
Times of technical training (TRA) has a positive effect on application of ARFTs. Also, village
cadre in the family members (VOF) significantly increase the probability of using farmyard
manure and organic fertilizer, and village cadres may pay more attention to personal
reputation and usually play an exemplary role in the construction of ecological agriculture.
Therefore, village cadres tend to more actively adopt environmentally friendly technologies.
In addition, per capita household income (INC) significantly increases the probability of
using organic fertilizer and soil-testing formula fertilizer are higher than farmyard manure. The latter is often easy to obtain
locally, so the use of farmyard manure is not always restricted by income constraint.
The proportion of non-agricultural income to total household income (UNF) significantly
increases the probability of using organic fertilizer and soil-testing formula fertilizer, but
the result is not robust, since it is only true when ”REN” is the independent variable. On
the one hand, the income effect of non-agricultural employment helps resolve income
constraints, which enables large-scale grain-growing households to adopt relatively high-
cost fertilization technology. On the other hand, the time effect of off-farm employment
makes labor resources more scarce, and farmers are more willing to increase fertilization
instead of labor.

Furthermore, the two instrumental variables are tested, and the results are listed in
Table 4. The results pass the underidentification test at the significance level of 1% and 10%,
indicating that the instrumental variables can effectively identify endogenous variables.
The value of Cragg-Donald Wald F is always greater than the critical values at 10% maximal
IV size, which is 19.93, which indicates that both of the two instrumental variables are not
weak instrumental variables. Furthermore, the Sargen test is not significant, which implies
the selected instrumental variables are not correlated with the error terms.

Table 4. Tests of the instrumental variables.

| Tests                  | IV-Probit (1) | IV-Probit (2) | IV-Probit (3) | IV-Probit (4) | IV-Probit (5) | IV-Probit (6) |
|------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Underidentification test | 25.013        | 25.013        | 25.013        | 5.86          | 5.86          | 5.86          |
| p value of underidentification test | 0.0000        | 0.0000        | 0.0000        | 0.0534        | 0.0534        | 0.0534        |
| Weak identification test | 22.861        | 22.861        | 22.861        | 22.872        | 22.872        | 22.872        |
| Overidentification test | 0.761         | 1.614         | 0.001         | 0.001         | 0.001         | 0.035         |
| p value of overidentification test | 0.383         | 0.2039        | 0.9759        | 0.3829        | 0.9818        | 0.8525        |
| Dependent variable     | FM            | COF           | SFF           | FM            | COF           | SFF           |
| Endogenous variables   | REN           | REN           | DES           | REN           | DES           | DES           |

Note: Anderson canon. corr. LM statistic is used for underidentification test; Cragg-Donald Wald F statistic is
used for weak identification test; Sargan statistic is used for overidentification test.
4. Conclusions and Discussion

With the decline in cultivated land quality and the prevalence of land transfer in China, the present study aims to analyze the effect of land-right stability on the adoption of ARFTs by large-scale grain growing households who are the tenants in land transfer. The main conclusion is that improving the stability of land right is conducive to prompting large-scale grain growing household to adopt ARFTs. Specifically, a one-year extension of the land-lease period can increase the probability of using organic fertilizer and soil-testing formula fertilizer by 3.16% and 4.92%, respectively, while contract breaching in the lease period can reduce the probability of using the two types of fertilizer by 46.9% and 51.38%, respectively. However, both land lease period and contract breaching in lease period have no significant impact on farmyard manure use.

The results of this paper indicate that stable land property can always prompt farmers to adopt ARFTs. Under the land property rights system of “Three Rights Separation” in rural China, land management right plays the role of resource allocation and create value in the element market. Large-scale grain growing households are more sensitive to the future earnings, because of magnitude effect and sufficient capital endowments [33]. However, large-scale grain growing households only have TLMR, which is easily destabilized by self-interest motives of both parties involved in land transfer, making the future earnings of adopting ARFTs become uncertain. Therefore, the instability of TLMR restricts large-scale grain growing households from adopting protective fertilization.

As a traditional type of ARFTs, the application of farmyard manure has played a very important role for the protection of cultivated land, but with the progress of science and technology, farmyard manure is not suitable for being used in agricultural scale management; therefore, it needs to increase the application of organic manure and soil-testing formula fertilizer to meet the large-scale farmers’ demand of protecting cultivated land. However, the high price of organic fertilizers has become an important factor restricting the use of organic fertilizers, and the imprecise collection of soil samples often leads to the poor effect of using soil-testing formula fertilizer.

Based on the present study’s findings, the following suggestions associated with improving the stability of TLMR and increase the adoption of ARFTs by large-scale farmers are put forward: (1) Improve the land transfer contract mechanism by standardizing the form and content associated with land-transfer contracts, and written contracts should be promoted widely. (2) The government needs to set the minimum land-lease term by legislation and relevant laws should be improved to increase the binding force of the land transfer contract. Set up village courts to deal with disputes about land transfer contracts such as prohibited behavior. (3) The village committees shall intervene in land circulation as an intermediary, by which they can play the function of credit guarantee, prevent landlords as well as tenants from opportunistic behavior, thus improving the stability of land transfer contract. (4) Innovative land-transfer mode are needed, such as land transfer through taking the land as shares should be promoted widely, in which the landlords get a dividend from the profits his tenants make from cultivating the transferred land. Finally, a system of sharing risk and benefit can be formed between the landlords and tenants, which is conductive to improving the stability of TLMR. (5) Ensure that farmers with sufficient human capital, such as young and highly educated farmers, can engage in non-agricultural industries rather than relying on farming land for their livelihoods. Therefore, it is necessary to continue to vigorously develop non-agricultural industries so that cities and towns can continue to provide non-agricultural employment opportunities; meanwhile, the government should improve policies of social security to encourage farmers working in cities to settle in cities. (6) Subsidies should be raised to encourage large-scale farmers to use more organic fertilizer, and the government should give more technical support to the collection of soil samples for the soil-testing formula fertilization. (7) Agricultural technology training should be used to popularize ARFTs.
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