The impact of free farmland transfer on the adoption of conservation tillage technology – Empirical evidence from the plot level of China

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Abstract

At present, there are a large number of free farmland transfer without monetary or physical rents in rural China. It is relatively worthwhile to verify whether the transferees who transfer in farmland for free, the actual operators of farmland, would adopt the conservation tillage technology, which is crucial in protecting farmland quality and improving agricultural production efficiency. Based on the data of 527 plots surveyed by China Land Economic Survey (CLES) in Jiangsu Province in 2020, this paper employs Negative Binomial Regression (NBR), Poisson Regression with Endogenous Treatment Effects (ETPR) and Endogenous Switching Regression (ESR). Results show that: (1) Compared with the transferees who transfer into farmland with compensation, the free transfer is not conducive to the transferees' adoption of five CTTs such as straw mechanical returning, soil testing and formulated fertilization. Specifically, the total number of technology adoptions by transferees who transfer in farmland without compensation is decreased by 1.977. The result is still robust after replacing the dependent variable. (2) Further heterogeneity analysis results of different types of technologies show that the number of labor-saving CTTs such as straw mechanical returning adopted by the transferees of free transfer decreases by 0.231, and the number of labor-intensive tillage technologies such as soil testing and formulated fertilization decreases by 2.496. Thus, free transfer has a stronger inhibitory effect on the transferees' adoption of labor-intensive CTTs. Therefore, for the most developing countries including China, the governments should continue to improve the farmland factor market oriented by price mechanism and implement targeted conservation tillage technology according to the different degree of transfer marketization in different places.

1. Introduction

According to the general principle of market allocation of resources, farmland can theoretically flow to more efficient transferees through the price signal of rent. So the formation of rent is an important representation of the development of farmland factor market. However, there are a host of free transfer phenomena in China's farmland transfer market, which suggests that the price formation mechanism of rent is not perfect. According to the data of the rural fixed observation points of the Ministry of Agriculture and Rural Affairs from 2003 to 2013, the zero rent transfer rate of land in China exceeds 50%. The survey data of China Household Finance Survey (CHFS) in 2015 show that the proportion of free farmland transfer is about 42.5%. In addition, the investigation of farmers in three counties of Chongqing surveyed by Wang et al. (2019) also find that up to 74.0% of the plots do not charge rent when they are transferred.

Free transaction is often regarded as the lack of marketization and standardization of farmland transfer (Tang et al., 2019). In practice, the free circulation generally occurs between relatives and friends, and often replaces the written contract with oral agreement, with less agreed period, which is the concrete embodiment of relationship governance in acquaintance society on rent arrangement. Most of the existing studies have discussed the realistic causes of free transfer from the perspective of the transferors, including reducing transaction costs (Wang et al., 2015), reciprocity of human relations

(Chen, 2018; Tian et al., 2013), property security or control preference (Wang et al., 2015; Qian et al., 2018).

However, it is more important that the transferees, the actual operators of farmland, are directly related to specific agricultural production. The role of free transfer on the production behavior of the transferees is also the key to excavating the realistic impact of free transfer of farmland. Reality, the development of modern agriculture depends on the improvement of agricultural production efficiency (Sukejiro, 2000). Under the realistic background of soil acidification, hardening and fertility decline of farmland in China (Wei, 2017), the adoption of conservation tillage technologies (CTTs) such as straw mechanical returning, soil testing and formulated fertilization is of great significance to the control of agricultural pollution, the protection of farmland quality, which eventually improving agricultural production efficiency (Qiu et al., 2020). The transferees in the farmland transfer are important subjects of agricultural production. Thereby, promoting the adoption of CTTs by the transferees has always been an important policy orientation of governments at all levels, and it is also a main issue of the academic concern. The existing literatures hold that the ability of agricultural production decision makers, policy factors and property rights security have played an important role in the adoption of CTTs by transferees. For example, Zhang et al. (2019) argued that the level of specialized agricultural production affected the organic fertilizer application behavior of the transferees. The research of Kurkalova (2006) showed that the amount of subsidy was the most important factor affecting whether the operators adopt CTTs. Gao et al. (2011) found that stable property rights could encourage the transferees to make long-term investment in farmland. Xu (2018) pointed out the intertemporal attribute of straw mechanical returning technology, and analyzed in detail the impact of land tenure on the technology adoption by scale households.

However, the existing literature did not distinguish the behavior differences between the free and paid transfer of farmland when analyzing the adoption behavior of CTT by the transferees. Schultz (1987) pointed out in “Transforming Traditional Agriculture” that, land rents perform the necessary economic functions in the allocation of agricultural resources, and any suppression of land rents will undermine the signals and incentives for operators to use farmland effectively. As a result, effective economic rents can stimulate farmers’ investment (Zhong et al., 2009), indicating that the cost constraint and signal transmission embodied in rental arrangement may have an impact on the behavior of the transferees. Accordingly, combined with the widespread phenomenon of free transfer in China’s farmland market, it is worth thinking about whether there is a difference in the adoption behavior of CTTs between the transferees who transfer in farmland for free and those who transfer in farmland with compensation? And what is its specific mechanism? The answer to this question not only helps to deepen the understanding of the realistic influence of free circulation, but also provides some valuable suggestions for promoting farmers’ adoption of CTTs for China and other countries.

In summary, on the basis of theoretical analysis, this paper uses the data collected by CLES in Jiangsu Province in 2020 to empirically analyze the influence of free transfer on the adoption behavior of CTTs, from the perspective of farmland transferees. Our possible contributions are three-fold. Firstly, Unlike the existing literature which mainly focuses on the reasons for the formation of free circulation, this paper

focuses on the impact of free transfer on the specific production behavior of the transferees' adoption of CTTs and its microscopic mechanism. It provides a new perspective for understanding the practical impact of free transfer, and expands the understanding of farmers' adoption of CTTs. Secondly, farmers' adoption of technology on the same land is often synchronized as land is the basic unit of circulation and agricultural production. Different from the existing literature that only uses the data at the farmer level for empirical analysis, this paper matches the variables at the plot scale with those at the farmer level to eliminate the influence of the heterogeneity of plots in quality and location on the adoption of CTTs as much as possible, which helps to ensure the reliability of the empirical results. Thirdly, Poisson Regression with Endogenous Treatment Effects and Endogenous Switching Regression are used to eliminate the endogenous problems such as selective errors of free transfer in this paper, in order to ensure and improve the reliability of estimation. The remainder of this paper is organized as follows. The next section explores the mechanisms of how free transfer affect the adoption of CTTs. In Section 3 we lay out the settings for the empirical analyses in which we describe the data and the variable selections, the empirical model and estimation methods. The estimated results are presented in Section 4. And the concluding remarks and policy suggestions are put forward in the final section.

2. Theoretical Analysis

Indeed, cost-benefit analysis is the basis of decision-making for the transferees to adopt CTTs. Compared with the traditional agricultural production technology, CTTs such as straw mechanical returning generally need higher input, and its benefit from the current investment is divided into multiple periods, which indicates that the intertemporal attributes of current and future earnings need to be considered simultaneously by the transferees (Xu et al., 2018).

First of all, from the perspective of cost input of technology adoption, the transferees make the transfer decision according to the marginal cost and output of farmland input before transferring in farmland with compensation. When the marginal output of farmland input is higher than the transfer rent, the transferees will choose to transfer into farmland, and vice versa. Therefore, the sum of their own and transferred farmland area will not exceed the optimal operation scale. At this point, they have the ability and willingness to seek improvements in production technology through the realignment of capital, labor and other factors on the land transferred. However, the transferees of free circulation can obtain farmland without paying rent, and their transfer-in area is not determined by the balance of rent, which often exceeds its optimal operation scale. Therefore, it is difficult to fully match farmland with other production factors such as labor. Due to the law of diminishing marginal returns in scale expansion (Wu et al., 2011), the transferees of free circulation may still invest in production following previous experience, as measured by cost-benefits. The operation itself is extensive, which limits the transferees' ability to invest in CTT on plots. Even if the transferees who transfer farmland without compensation have certain investment capacity, they are more inclined to adopt technology on their own plots rather than on the transfer-in plots due to different guarantee effects of property rights (Wang et al., 2020).

Secondly, from the perspective of current income, in the paid circulation, the transferees need to bear the transfer rent and face the possible fluctuation of the rent, and thereby transferees have the motivation to seek production improvement through technological progress to cover the rent cost and ensure the current income. However, in the free circulation, the transferees can easily be assured of their current earnings and expected profits by virtue of the depressed rental cost, so they may lack the willingness to improve production. More importantly, since the current income is easier to be obtained, the real price of farmland is underestimated for the transferees who obtain farmland for free, resulting in that the relative price of farmland and other factors such as labor cannot reflect its scarcity (Wei et al., 2021). The theory of induced technological change holds that the relative price among factors is an important signal to reflect the resource endowment and then guide the technological progress and choice (Sukejiro, 2000). In other words, the absence of rent in free circulation weakens the price signal function of rent, thereby reducing the willingness of the transferees to choose CTT for production improvement.

Finally, from the perspective of expected earnings, property rights theory demonstrates that property rights determine the distribution of future multi-period income of land (Zhong et al., 2009). Stable property rights contribute to the formation of long-term expectations, thereby promoting farmers' soil conservation investment (Besley, 1995; Lovo et al., 2016). Due to the intertemporal nature of CTT, whether the transferees can obtain all future benefits will directly affect their willingness to adopt technology. It can be seen that clearer rights boundary and longer transfer period can effectively encourage the transferees to adopt CTT (Lu et al., 2019). A large number of literatures believe that the purpose of the transferors not charging rent in the free circulation is to reduce the risk that the farmland cannot be recovered (Qian et al., 2018; Macours, 2014; Wang et al., 2015), or to achieve more flexible control of farmland afterwards (Qian et al., 2018). That is to say, the free transfer can be regarded as the game between the two transferring parties on the terms, control rights and rents. In most cases, no written contract or specific period will be signed in the free circulation (Chen et al., 2019; Wang et al., 2015), and the transferors may request to recover farmland at any time. This will directly cause the transferees unconvinced of obtaining the future income. Meanwhile, the difference of discount rate of different transferees will also lead to different expected profits (Liebenehm et al., 2014), which reflects the difference of adoption behavior of CTT. Compared with the paid transfer, the discount rate of the transferees in the free circulation is higher due to the uncertainty of future income caused by the unstable management right. The transferees who transfer for free have a low present value of discounting the future income of adopting CTT to the current period because of the high discount rate. And the net present value is lower after deducting the investment cost of potential technology adoption, so the willingness to adopt technology is impeded.

Accordingly, **hypothesis 1 is proposed: Compared with the transferees in the paid transfer, the transferees in the free transfer is less willing to adopt the CTTs after comprehensively considering the cost input, current and expected benefit of technology adoption.**

Further, among the many types of CTTs available, farmers will make choices in order to maximize the benefits of adopting decisions based on their own factor endowment constraints (Popkin, 1979). CTTs

can be divided into labor-saving and labor-intensive technologies in light of the difference of labor input (Cao et al., 2019). For example, farmers who adopt straw mechanical returning technology only need to invest in the purchase of corresponding services without additional labor time. However, if farmers adopt soil testing and formulated fertilization technology, they need to increase the number of fertilization and invest additional labor time. According to the theory of factor-induced technological innovation, the scarcity of land, labor, capital and other resources available to farmers is the driving force for their cognitive demand for agricultural technology (Hayami and Ruttan, 1985), according to which they will choose technologies with different labor attributes.

Generally speaking, the transferees in the free circulation prefer to adopt labor-saving technology rather than labor-intensive technology. The possible reasons are that, on one hand, the transfer-in area of the transferees in the free circulation is not regulated by rent, so it may exceed its optimal operating scale, which will lead to a decrease in the allocation of family labor force on the farmland per unit area. The shortage of labor force makes the transferees only maintain the basic labor time of agricultural production (Yang et al., 2015). On the other hand, free transfer is generally accompanied by labor exchange. It is often necessary for the transferees to provide care for the transferors in daily life after obtaining farmland for free (Chen et al., 2019), which indicates that the free transfer will actually disperse part of the transferees' working time in the form of human exchange and further lead to the tension of the working time of the transferees' family. At the same time, considering that the current agricultural opportunity cost increases year by year, the labor factor of the transferees in the free circulation is relatively scarce. Therefore, the transferees who transfer in farmland for free are more reluctant to adopt labor-intensive technologies.

Accordingly, **hypothesis 2 is proposed: Compared with labor-saving CTT, the transferees in the free transfer are less willing to adopt labor-intensive CTT.**

3. Materials And Methods

3.1 Data and Variables

The data sources used for analysis are the China Land Economic Survey (CLES) conducted by the Department of Humanities and Social Sciences of Nanjing Agricultural University and Jin Shanbao Institute of Modern Agricultural in Jiangsu Province in 2020. The survey covers land market, agricultural production and other aspects. The sampling method of Probability Proportional to Size (PPS) was adopted in the survey. Twenty-six counties were selected from thirteen prefecture-level cities of Jiangsu Province. Two sample townships were chosen from each county, and one administrative village was selected from each township. Finally, the researchers randomly selected fifty households in every village. The database contained 52 villages and 2628 households.

In the survey at the plot level, the plot information collected by the survey includes the basic information such as plot area, plot fertility, plot slope, the distance between the plot and the hardened road, and the

transfer information such as transfer rent, transfer period and transfer way, as well as the specific cost input and the adoption of production technology in each plot, which exactly meet the needs of this study. Matching each plot with variables at other levels of the surveyed families, 527 valid samples were retained after excluding missing and abnormal samples. Based on whether the transfer rent (including the physical rent converted into cash) of the plot in 2019 is zero or not, there are 95 samples of free transfer, accounting for about 18.03% of the total samples. In view of the purpose of this paper, our empirical estimations require measures of the adoption of CTT, free transfer and other explanatory variables.

3.1.1 Adoption of CTT

In a broad sense, CTT refers to all tillage technologies aiming at protecting the ecological environment of farmland and improving the long-term productivity of farmland. Most of the existing literatures measure CTT by single technology such as straw mechanical returning or all possible technologies (Li et al., 2021; Mao et al., 2020). However, according to the policy requirements of “Key Technical Points of Conservation Tillage” and “National Plan for Agricultural Sustainable Development (2015–2030)” issued by the Ministry of Agriculture and Rural Affairs and other departments, as well as the characteristics of different regions such as the ridge farming area in northeast China, the farming-pastoral ecotone along the Great Wall, the loess plateau area in northwest China and the middle and lower reaches of the Yangtze River, the combination of targeted CTTs should be adopted in different places. Therefore, combined with the regional characteristics of Jiangsu Province, this paper defines the adoption of CTT as the number of five technologies used in the agricultural production process by the transferees, including straw mechanical returning, application of high-efficiency, low-toxicity and low-residue pesticides, pesticide packaging recovery, application of organic fertilizer and application of soil testing formula fertilizer, in order to obtain a set of counting variables.

3.2 Free Transfer

In this paper, whether the transferees transfer into farmland for free is taken as the proxy variable of “free transfer”. If the transferees do not pay the rent (including the physical rent converted into cash) when transferring into farmland, a value of 1 is assigned; but if the transferees actually pay the rent during the transfer, the value equals 0.

3.3 Control Variables

Referring to the existing literature, this paper also introduces the control variables including the characteristics of family management decision-makers, family-level characteristics, the characteristics of plots transferred, policy support, village-level fixed effects to reduce estimation bias (Qiu et al., 2020; Qian et al., 2021). The characteristics of family decision-making managers include demographic characteristics such as education level and age. In general, young adults with higher education level have a better understanding of the role of CTT. Moreover, the young labor force has a longer time to benefit from technology under the same learning cost (Yang, 2018), so it’s expected that young people are

relatively more willing to adopt CTT. In the characteristics of family level, the higher the family agricultural population and agricultural machinery value, the greater the family's dependence on agriculture, which increases the possibility of adopting conservation tillage techniques to improve agricultural income. The characteristics of plots are the important control variables introduced in this paper. The use change and technology adoption of the same plot are often synchronized. The area, quality and traffic convenience of plots may have affect CTT, but the direction of the impact is uncertain. Government promotion is an important driving force for farmers to adopt CTT (Mao et al., 2020). Agricultural technology training is conducive to increasing farmers' understanding and recognition of CTT and improving farmers' technical application ability. Therefore, it is expected that the more times the transferees participate in agricultural technology training, the more likely they are to adopt CTT. In addition, the fixed effect at the village level is controlled in all models in order to avoid the interference of village heterogeneity on the estimation results. These are further summarized and reported in Table 1.

Table 1
The definitions and descriptive statistics of variables

Variable	Definition	Mean	SD	Min	Max
Adoption of CTT	Number of technologies actually adopted	1.169	1.296	0	5
Free transfer	Yes = 1; No = 0	0.148	0.355	0	1
Age of family decision maker	Actual age	56.069	9.111	24	75
Education level of family decision maker	Years of schooling	7.308	3.497	0	17
Household's agricultural population	Number of households engaged in agricultural work	1.932	0.873	1	7
Value of household agricultural machinery	Value of agricultural machinery family owned (10,000 yuan)	4.935	17.309	0	260
Household non-agricultural income	Annual household nonfarm income (10,000 yuan)	8.513	4.753	0	13.494
Plot area	The actual area of the plot transferred in (mu)	16.495	23.564	0.3	140
Distance from plot to hardened road	Distance from the plot to the nearest hardened cement road (mile)	0.625	1.426	0	20
Is the plot near the expressway?	There is an expressway within 1000 meters = 1; otherwise = 0	0.088	0.283	0	1
Can the plot be irrigated?	Yes = 1; No = 0	0.040	0.196	0	1
Plot fertility	Poor = 1; Medium = 2; Good = 3	2.329	0.621	1	3
Was the plot hit?	The plot was hit in 2019 = 1; otherwise = 0	0.161	0.368	0	1
Is there an agreed period for transfer?	Yes = 1; No = 0	0.631	0.483	0	1
Policy support	Number of family members with agricultural skills or training	0.349	0.687	0	4

3.2 Model Specification

3.2.1 Poisson Regression and Negative Binomial Regression

Actually, the adoption quantity of CTT belongs to the counting data. If the traditional linear regression model is adopted, it will lead to biased estimation. Considering that the five CTT adoptions concerned in

this paper have strong independence and no inevitable connection with each other, this paper employs the counting model. The commonly used counting models include Poisson Regression (PR) and Negative Binomial Regression (NBR). The difference between the two is to assume whether the expectation and variance of the sample distribution are equal, that is, equal dispersion or over dispersion. If they are equal, PR should be adopted. The model is set as follows:

$$P\left(y_i|Price_i, Z_i\right) = \frac{e^{-\lambda_i}{\lambda_i}^{y_i}}{y_i!}(y_i = 0,1,2,\cdots)$$

1

where whether the CTT is adopted on the plot is denoted by y_i, whether the plot is transferred for free is denoted by $Price_i$, and control variables that affect the adoption of CTT is denoted by Z_i. The Poisson arrival rate is represented by λ_i, which refers to the number of events determined by each explanatory variable.

If the variance is greater than the expectation, it is excessive dispersion, and the NBR should be used at this time. Specifically, ϵ_i is added to model 1 to control the unobservable varaibles and individual heterogeneity, which is set as follows:

$$P\left(y_i|Price_i, Z_i, \epsilon_i\right) = \frac{e^{-\lambda_i}{\lambda_i}^{y_i}}{y_i!}(y_i = 0,1,2,\cdots)$$

2

As for the choice of the two models, it can be judged by the LR test after the NBR, the original assumption of which is “there is no excessive dispersion, so the PR should be used”. If the original assumption is passed, the PR should be used; otherwise, the NBR should be employed.

3.2.2 Poisson Regression with Endogenous Treatment Effects (ETPR)

Compared with the panel data, the cross-sectional data is faced with a serious problem of missing variables. In this paper, there may also be the problem of sample self-selection, which means that whether the transferees can transfer the plot for free is not entirely determined by the transferees themselves, and it may also be selected by the transferors for reasons such as property rights protection or human exchange (Wang et al., 2015; Chen et al., 2019). The instrumental variable method is a good solution to this problem. Since the traditional IV-Poisson method is only applicable to the case where the endogenous variable is a continuous variable, and the endogenous variable in this paper is a binary variable, the ETPR is introduced to solve this problem. The ETPR model includes two-stage equations, and the specific settings of the equations are as follows:

$$Price_i^* = \phi C_i + \mu_i, Price = \begin{cases} 1, if Price_i^* > 0 \\ 0, otherwise \end{cases}$$

3

$$f(y_i) = \frac{exp\{-exp(\beta Price_i + \gamma Z_i + \epsilon_i)\}\{exp(\beta Price_i + \gamma Z_i + \epsilon_i)\}^{y_i}}{y_i!}$$

4

where Eq. (3) and Eq. (4) are the first-stage and the second-stage regression of the ETPR model, respectively. The latent variable for the adoption of CTT is denoted by $Price_i^*$. When $Price_i^*$ > 0, $Price_i$ = 1, otherwise $Price_i$ = 0. The control variables affecting the free transfer and affecting the adoption of CTT are separately represented by C_i and Z_i. It should be noted that there may be overlapping variables in C_i and Z_i, but at least one variable in C_i is not in Z_i, in order to play the role of an instrumental variable. ϕ, β and γ are parameters to be estimated, μ_i and ϵ_i are random interference terms.

In addition, the ETPR model can also measure whether there are endogenous problems such as selective bias caused by unobservable factors and mutual causality by calculating ATT. Specifically, the y_{1i} of the treatment group (the adoption level of CTT by the transferees in free transfer) is shown in Eq. (5), and the y_{0i} of the control group (the adoption level of CTT of the transferees in paid transfer) is shown in Eq. (6):

$$E(y_{1i}|Price_i = 1) = exp(\beta_1 Price_i + \gamma_1 Z_i + \epsilon_{1i})$$

5

$$E(y_{0i}|Price_i = 0) = exp(\beta_0 Price_i + \gamma_0 Z_i + \epsilon_{0i})$$

6

Furthermore, the ATT of ETPR model can be expressed as:

$$E(y_{1i} - y_{0i}|Price_i = 1) = E\begin{bmatrix} \{exp(\beta_1 Price_i + y_1 Z_i + \epsilon_{1i}) - exp(\beta_0 price_i + y_0 Z_i + \epsilon_{0i})\} \\ exp\left(\frac{\sigma^2}{2}\right)\frac{\Phi(\sigma\rho + \phi C_i)}{\Phi(\phi C_i)}|price_i = 1 \end{bmatrix}$$

7

In order to ensure that the ETPR model can be identified, it is necessary to find an effective instrumental variable, which should not only correlate with endogenous variables, but also meet the exogenous conditions. In the research on micro-individual level of farmers, it is a common method to use the data at the county level and village level as instrumental variables (Qiu et al., 2019). This paper takes the “average human expenditure at the village level” as the instrumental variable of free transfer. Its rationality lies in that, on the one hand, the higher average value of human expenditure at the village level

indicates that the village environment is closer to the acquaintance society under the traditional “gap pattern”, and the rural land transfer is more likely to appear the relational characteristics in the form of rent-free. So the correlation requirement of the instrumental variable is satisfied. On the other hand, the average human expenditure at the village level does not directly affect the transferees’ adoption of CTT, thus the exogenous requirement of instrumental variable is also met.

4. Results

4.1 Benchmark Regression

Table 2 presents the estimation results of the PR and NBR respectively. Since the regression coefficients of the counting model are not directly comparable, Table 2 also shows the results of the average marginal effect. The regression results show that whether the PR or NBR is employed, the free farmland transfer significantly reduces the adoption level of transferees’ CTT, which preliminarily verifies Hypothesis 1. Further, in terms of the selection of the model, the result of NBR reports that the 95% confidence interval of alpha is (0.02, 0.52). Corresponding to PR, whose result presents the null hypothesis of “alpha = 0” can be rejected at 5% level, the results of NBR are relatively more reliable. From the perspective of the marginal effect reported by the NBR, compared with the paid farmland transfer, the free transfer reduces the number of 2.65 CTT adoptions of the transferees when selecting the number of technology adoptions to measure the adoption level of CTT. Thus Hypothesis 1 is preliminarily tested.

Table 2
Benchmark regression results

	(1) PR		(2) NBR	
	Estimation coefficient	marginal effect	Estimation coefficient	marginal effect
Free transfer	-2.340***	-2.633***	-2.348***	-2.650***
	(0.518)	(0.589)	(0.516)	(0.586)
Age of family decision maker	0.006	0.007	0.006	0.007
	(0.005)	(0.006)	(0.005)	(0.006)
Education level of family decision maker	-0.005	-0.005	-0.005	-0.005
	(0.014)	(0.016)	(0.015)	(0.017)
Household's agricultural population	0.078*	0.088*	0.082*	0.093*
	(0.041)	(0.046)	(0.042)	(0.048)
Value of household agricultural machinery	0.005**	0.005**	0.005*	0.006*
	(0.002)	(0.002)	(0.003)	(0.003)
Household non-agricultural income	-0.005	-0.005	-0.004	-0.005
	(0.009)	(0.010)	(0.009)	(0.010)
Plot area	-0.000	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Distance from plot to hardened road	-0.011	-0.013	-0.010	-0.011
	(0.033)	(0.038)	(0.034)	(0.038)
Is the plot near the expressway?	0.230	0.259	0.245	0.277
	(0.148)	(0.168)	(0.150)	(0.170)
Can the plot be irrigated?	0.634***	0.713***	0.631***	0.712***
	(0.187)	(0.209)	(0.187)	(0.210)
Plot fertility	0.036	0.041	0.036	0.041
	(0.073)	(0.082)	(0.074)	(0.084)
Was the plot hit?	0.707***	0.795***	0.722***	0.815***
	(0.079)	(0.081)	(0.084)	(0.086)

	(1) PR		(2) NBR	
Is there an agreed period for transfer?	0.128	0.144	0.110	0.125
	(0.114)	(0.127)	(0.118)	(0.133)
Policy support	0.104*	0.117*	0.109*	0.123*
	(0.061)	(0.069)	(0.062)	(0.071)
Village fixed effect	Yes	Yes	Yes	Yes
Wald chi^2	165.77***		160.43***	
Pseudo R^2	0.16		0.13	
N	527	527	527	527

As for the control variables, the number of farmers in the transferee's family promotes the adoption of CTT, which is in line with the general common sense judgment. The more agricultural population in the transferee's family indicates that agricultural production plays an important role in family management. So family members can better recognize the role and benefits of CTT in future production, and the transferee's family will have more labor force to invest in learning and adopting CTT. The value of household agricultural machinery also significantly promotes the adoption of CTT by the transferees, which also aligns with the theoretical expectation. The higher the value of household agricultural machinery, the stronger the agricultural production capacity of the transferees, the stronger the risk resistance function of technology adoption. Accordingly, the transferees have stronger willingness and ability of technology adoption. In terms of plot characteristics, the ability of plot irrigation has a significant positive impact on the adoption of CTT. The possible explanation is that the transferees have higher expected returns on plots with better quality, stimulating the stronger willingness to adopt new technology. It should be noted that if the plot has suffered natural disasters in the year before the survey, the transferee is more willing to adopt CTT on the plot, which is not consistent with the general understanding. This is probably because that the transferees tend to invest more in the plots in order to make up for the past losses, since the transferees' income is affected by the disaster. Policy support significantly promotes the adoption of CTT of the transferees. The more times the transferees receive technical training, the more comprehensive their understanding of technology and the stronger their ability and willingness to adopt new technologies, which is also consistent with the conclusions of Mao et al. (2020).

4.2 Endogenous Discussion

Generally speaking, it is difficult to control individual effect and endogenous problems in the model with cross-sectional data. Taking the above benchmark regression as a reference, Table 3 shows the regression results of the ETPR model. In order to facilitate comparison, the regression results assuming that the dependent variable is a continuous variable are also presented in Table 3. The Eregress under the

framework of the extended regression model (ERM) is employed to estimate. This model and ETPR model can simultaneously solve the endogenous problem and the selective bias caused by unobservable factors.

Table 3
Regression results considering endogeneity

	Eregress		**Etpoisson**	
	Free transfer	Adoption of CTT	Free transfer	Adoption of CTT
	Stage	Stage	Stage	Stage
Average human expenditure at the village level	0.724***		0.816***	
	(0.209)		(0.201)	
Free transfer		-3.091***		-1.591***
		(0.639)		(0.335)
Control variables	Yes	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes	Yes
ATT	-2.207***		-1.977***	
	(0.507)		(0.417)	
Endogenous parameter	0.757***		6.071***	
	(0.158)		(0.022)	
Wald chi^2	768.74***		170.97***	
N	527		527	

The estimation coefficient of the first stage shows that the average human expenditure of the sample village will have a significant impact on the free farmland transfer. The endogenous parameters reported by the two models have passed the significance test, indicating that there are endogenous problems in the models, and the instrumental variable method is more appropriate. In the second stage of regression, the variable of free transfer significantly inhibits the transferees from adopting CTT at the level of 1% after eliminating endogeneity. In general, when investigating the economic meaning of regression, the average treatment effect (ATT) of the treatment group should be paid attention. After calculation, the ATT reported by Eregress model is about − 2.207, and that reported by Etpoisson model is about − 1.977. There is no difference in significance and influence direction between the two, but the absolute value of the estimation coefficient of Etpoisson model is smaller, which demonstrates that the assuming the dependent variable is regarded as a continuous variable will lead to biased estimation, which enlarges the

inhibitory effect of free transfer on the adoption of CTT by the transferees. In short, after eliminating the endogeneity of the model, the free transfer significantly reduces the number of 1.977 CTTs adopted by the transferees, and hypothesis 1 is confirmed.

4.3 Correcting Selective Bias: ESR Model

The endogenous treatment effect model assumes that the covariate is independent of the treatment variable to affect the dependent variable. At this time, the treatment effect is only the up and down movement of the regression curve, and the free transfer and the adoption of CTT may be affected by common unobservable factors. The separate estimation of the transfer model and CTT adoption model may lead to inaccurate conclusions due to endogenous problems. Therefore, the Endogenous Switching Regression (ESR) model is introduced in this paper, which assumes that the treatment effect is transmitted by covariates and will change the slope of the regression curve. Compared with ETPR model, ESR model has the following advantages: (1) It can simultaneously deal with the selectivity deviation caused by observable and unobservable factors; (2) The estimated coefficient is allowed to change between paid transfer and free transfer, so as to estimate the influence of free transfer on the adoption of CTT in heterogeneous samples.

Table 4
Regression results of ESR model

Average expected adoption number of CTT	Free transfer	Paid transfer	ATE	ATT	ATU
All samples	0.305	1.412	-1.107***		
	(0.030)	(0.023)	(0.038)		
Free transfer sample	0.094	1.872		-1.778***	
	(0.026)	(0.071)		(0.075)	
Paid transfer sample	0.345	1.315			-0.970***
	(0.035)	(0.028)			(0.045)

It can be seen from Table 4 that the average treatment effect of the adopted number of CTTs by the transferees in paid transfer (ATT) is -0.970, and the average treatment effect of the adopted number of CTTs by the transferees in free transfer (ATU) is -1.778. In addition, the average treatment effect of the number of CTTs adopted in the total sample (ATE) is -1.107.

4.4 Robustness Test

In order to further verify the reliability of the previous regression results, this paper replaces the dependent variable for robustness test. The excessive application of chemical fertilizers has led to serious farmland quality problems such as soil acidification and water eutrophication (Wei, 2017). “The action plan for zero growth of chemical fertilizer by 2020” issued by the Ministry of Agriculture in 2015 specially

emphasizes the reduction of chemical fertilizers to protect farmland quality. Without affecting fertility, the use of organic fertilizer and soil testing formula fertilization is a typical conservation tillage behavior, alternative to traditional chemical fertilizer. Thereby, this paper uses the application intensity of organic fertilizer and formula fertilizer as alternative variables for ESR regression respectively, whose regression results are shown in Table 5.

Table 5
Robustness test of substitution dependent variable

	Free transfer	Paid transfer	ATT
Average expected application intensity of organic fertilizer	0.639(0.127)	2.573(0.402)	-1.934***(0.515)
Average expected application intensity of formula fertilizer	0.308(0.086)	1.047(0.174)	-0.739***(0.107)

To simplify the analysis, Table 5 only reports the average treatment effect of the treatment group (ATT). It can be seen from Table 5 that the free transfer significantly reduces the application of organic fertilizer by 1.934 kg/mu and the application of formula fertilizer by 0.739 kg/mu. Therefore, the Hypothesis 1 is further verified.

4.5 Further Discussion: Heterogeneity Analysis of Different Technical Types

As shown in the above results, compared with the transferees who transfer in farmland with compensation, the transferees in free circulation are generally less willing to adopt CTT. According to Hypothesis 2 in the theoretical analysis, the influence degree of free transfer on the adoption of CTT by the transferees may be different due to the different nature of technology. We still take free transfer as the key explanatory variable, and draw on the research ideas of Cao et al. (2019) to divide the five CTTs into two categories. The application of organic fertilizer, formula fertilizer and pesticide packaging recovery are all labor-intensive technologies, which require additional input of the transferees. Straw mechanical returning is directly returning straw to the field through large-scale agricultural machinery while harvesting, thus farmers only need to purchase corresponding services. The application of applying high-efficiency, low-toxicity and low-residue pesticides only costs more money when purchasing pesticides, and no extra investment is needed in the application process. Therefore, these two types of technologies are typical labor-saving technologies. Accordingly, two sets of count variables of different types of technology are formed. And we still select the “average human expenditure at the village level” as the instrumental variable, and employ Poisson endogenous treatment effect model to analyze the heterogeneity of different types of technology adoption by the transferees in free transfer. The regression results are shown in Table 6.

Table 6
Heterogeneity analysis of different technical types

	Etpoisson			
	Free transfer	Labor-intensive technology	Free transfer	Labor-saving technology
	Stage	Stage	Stage	Stage
Average human expenditure at the village level	0.894***		0.794***	
	(0.218)		(0.185)	
Free transfer		-2.496***		-0.231***
		(0.520)		(0.042)
Control variables	Yes	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes	Yes
ATT	-0.791***		-0.061***	
	(0.097)		(0.012)	
Endogenous parameter	6.041***		10.717***	
	(0.011)		(0.250)	
Wald chi^2	170.91***		1896.88***	
N	527		527	

The regression results in Table 6 show that the free transfer has a significant negative impact on the transferees' adoption of two types of CTTs at the 1% level. Among them, the number of adoptions of labor-saving CTTs such as straw mechanical returning decreases by 0.231, and the number of adoptions of labor-intensive CTTs such as soil testing and formulated fertilization decreases by 2.496. Obviously, compared with the labor-saving CTT, the free transfer has a stronger inhibition on the transferees' adoption of labor-intensive technology, since the scale of farmland operation of the transferees in the free transfer is not regulated by the marginal cost and output, and the labor force is relatively scarce caused by the free transfer. Therefore, Hypothesis 2 is confirmed. It should be pointed out that this does not prove that the transferees in free circulation are more willing to adopt labor-saving CTT, but only shows that the transferee in free circulation has less relative rejection of adopting labor-saving technology among the two types of technologies.

In order to verify the reliability of the above heterogeneity analysis, this paper further classifies and tests five specific technical types. If the transferees adopt a specific technology, a value of 1 is assigned, otherwise the value equals 0, so five zero-one dummy variables are obtained. In light that the independent

variable and dependent variable are both binary variables, the ivprobit model is selected for regression, and “the average human expenditure at the village level” is still used as the instrumental variable of free transfer. The regression results are presented in Table 7, where the regression coefficients reported are the marginal effects. After the classification test of specific technology types, it is found that the free farmland transfer has a significant negative impact on the other four types of CTTs except for pesticide packaging recovery. Through the comparison of the influence coefficients of specific technical types, the negative impact of free transfer on the transferees’ adoption of two types of labor-intensive technologies is greater than that of two types of labor-saving technologies, so the heterogeneity analysis results of technical types are robust.

Table 7
Classification test of specific technology types

	Labor-saving technology		**Labor-intensive technology**		
	straw mechanical returning	high-efficiency pesticide	organic fertilizer	soil testing and formulated fertilization	pesticide packaging recovery
Free transfer	-0.209***	-0.163***	-1.113**	-0.853*	-0.293
	(0.078)	(0.059)	(0.415)	(0.438)	(0.215)
Control variables	YES	YES	YES	YES	YES
Village fixed effect	YES	YES	YES	YES	YES
N	527	527	527	527	527

5. Conclusions

In the current situation that other rural factor markets in China are imperfect, free transfer, as a special form of resource allocation, has certain rationality and practical significance in the farmland market. Under the current realistic background of emphasizing the policy requirements of high-quality agricultural development and the increasingly severe problem of farmland quality, it is equally important to investigate the impact of free transfer on agricultural production, especially the mechanism of protective production behavior of plots, from the micro level of farmland transferees. Motivated by the existing research, this paper investigates whether and how free transfer affect the transferees’ adoption of CTTs, and empirically examine the influence mechanisms and heterogeneous channel of free transfer in this particular farmland transfer market. Through a quantitative analysis, this paper finds that compared with paid transfer, the transferees who transfer in farmland for free are less inclined to adopt CTTs because the operating area may exceed the optimal scale, and the future income can’t be guaranteed. Specifically, the number of CTT adoptions by the transferees in free circulation decreases by 1.977. This result is still

robust after replacing the dependent variable. Further, the heterogeneity analysis of different types of CTTs indicates that the number of labor-saving CTTs such as straw mechanical returning adopted by the transferees in free transfer decreases by 0.231, and the number of labor-intensive CTTs such as soil testing and formula fertilization decreases by 2.496, which means the free transfer has a stronger inhibitory effect on the transferees' adoption of labor-intensive technologies. This result is also robust after testing by specific technical types.

Given that the imperfect farmland market is relatively common in China and other developing countries, it still makes sense to focus on the phenomenon of free transfer and the influence it brings. More importantly, how to protect land quality and prevent soil degradation have become a common concern of countries around the world, indicating the critical role of the CTT adoptions in the agricultural production. Thereby, some policy implications of the above conclusions are in place. Firstly, it is necessary to change the transaction pattern of weak market-oriented transfer. The research conclusion shows that free transfer is not conducive to encouraging the transferees to invest protectively in cultivated land in agricultural production. From the perspective of effective utilization of farmland, "the farmer with the highest price gets the land" should gradually become the main mechanism of farmland resource allocation in the long run, in order to guide more farmland transferring to farmers with stronger management ability. On one hand, governments should continuously promote the new round of rural land tenure to ensure the safety and stability of the contracted rights of transferors, so that transferors are reassured to transfer farmland to external unfamiliar transferees. On the other hand, governments should accelerate the establishment and improvement of the transfer service platform, expand the scope of transactions and reduce the transaction costs of each link of transfer, in order to attract business entities with stronger ability. Secondly, under the realistic background that there are still many free transfers in China at present, the pertinence and accuracy in the promotion of CTTs should be paid high attention, and different technologies should be popularized according to local conditions. In areas where free transfer is common, the government can give priority to promoting suitable labor-saving technologies through developing social services in combination with the characteristics of local agricultural production, assuring farmers adopt technologies more conveniently. In areas with a high degree of marketization of transfer, governments can further strengthen the publicity and training of labor-intensive technologies, provide a certain amount of operating subsidies, and encourage farmers to adopt CTTs in agricultural production by reducing labor input through technical means.

Declarations

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