Adoption of Agricultural Mechanization Services among Maize Farmers in China: Impacts of Population Aging and Off-farm Employment

Q. Yi;

Institute of Geographic Sciences and Natural Resources Research, Academy of Sciences, , China

Corresponding author email: yiq.15b@igsnrr.ac.cn

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JEL Codes: Q12, J01

#1865

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Keywords: Labor division, Agricultural mechanization services; Population aging; Off-farm employment

JEL Classification: Q16; Q12; J10

1. Introduction

The classic economic theory believes that the division of labor is hard to be achieved in agriculture as most smallholders lack large-scale production with many leisure time generally. Due to the seasonality of agricultural production and the threats of climate risk, the variance of agricultural profits is large so that there isn't a large-scale production and the level of labor division is also lower than manufacture industry (Marshall, 1927). Based on the case of small-scale rice farming in Asia, Ruttan(2000) indicated that it is impossible to form a farm labor market meeting the demand of various production progresses of agriculture, i.e. effective labor division, because of the small-scale production and the lack of investment incentives.

Nevertheless, with the development of agricultural integration, the form of agricultural firms and cooperatives may be a feasible choice to achieve agricultural labor division, wherein a typical case is with regard to the development of agricultural mechanization services. The separation of agricultural mechanization services from the production processes of agriculture represents the division of labor in agriculture and is a kind of innovation in the organization of agricultural production (Allen and Lueck, 2004). In fact, the agricultural mechanization services have emerged in many countries, while the development of agricultural mechanization services varies in countries, such as Malaysia (Chancellor, 1971), Thailand, Brazil (Wander,2003), India (Ghosh, 2010) and other developing countries Africa (Takeshima et al., 2015) as well as the developed counties including American (Olmstead and Rhode, 2001) and Australia (Sheng et al., 2016).

Previous studies suggest that the rising wage income, off-farm employment, farm size and the characteristics of household head are highly related to the adoption of agricultural mechanization services. For instance, Krishnasreni and Thongsawatwong (2004) showed that the off-farm employment of family members is positively associated with the level of mechanization. Manuelli (2014) believed that farmers would not adopt agricultural mechanization representing the labor-saving technology until the use of labor-intensive technology has no profits due to the increase in wage income. Hence, with the increase in the wages of labor, farmers tend to outsource some capital-intensive processes of agricultural production to the specialized services (Yang et al., 2013; Zhang et al., 2017). Farm size (David, 1966; Kislev and Peterson, 1982), irrigation situation, credit, and policy support (Ghosh, 2010) also play a role in farmers' decision to adopt agricultural mechanization services.

While some farmers specializing in the mechanization services of land plowing, sowing and harvesting also emerge in China (Liu, 2003; 2006), the studies on China's agricultural mechanization services from the perspective of micro households are lacking. Particularly, the demographic structure in China is rapidly changing with an increasing proportion of the population being elderly (Min et al., 2015), farmers are getting older and older. With the increasing wages, more and more young farmers migrate to urban for seeking working opportunity (Wang et al., 2011). In this context, a question is raised whether farmers will adopt agricultural mechanization services to complement the decreasing farm labor force in China. Unfortunately, to date, it is still unknown due to the lack of sufficient empirical evidence.

The objective of this study is to better understand the adoption of agricultural mechanization services in China and empirically examine the impacts of population aging and off-farm employment. To achieve it, we use a cross-sectional data of some 600 maize farmers in 7 provinces of China. An instrumental variable approach is used to control for the possible endogeneity of off-farm employ in explaining the adoption of agricultural mechanization services. We employ a seemingly unrelated regression model to assess the choice of agricultural mechanization services and a multivariate probit model to identify the choice of agricultural mechanization services in the specific processes of maize farming.

The results suggest that the mechanization rate of maize farming in China is about 61%, wherein over 46% adopt agricultural mechanization services but less than 15% use own agricultural machines. The adoption of agricultural mechanization services in the specific production processes of maize are heterogeneous. The processes of plowing and harvesting use the largest rate of mechanization services. The proportion of family members aged ≥60 years old in the household negatively affects the off-farm employment of family members and the adoption of agricultural mechanization services including all specific processes of maize farming. Moreover, the percent of family members engaging in off-farm work has a positive effect on maize farmers' agricultural mechanization services adoption. In the context of increasing population aging and the rising wages in China, the demand for agricultural mechanization services will expand.

The rest of this paper is organized as follows. Section 2 briefly introduces the data collection procedure and the descriptive statistics. Section 3 describes the empirical models developed to assess the adoption of agricultural mechanization services in China. In Section 4, we report and discuss the results of our models. The last section consists of a summary and conclusions.

2. Data collection and descriptive statistics

2.1. Data collection

This survey was conducted by Center for Chinese Agricultural Policy (CCAP) in the summer of 2016. Based on the geographical location, economic development level, and agricultural production characteristics, China is divided into 7 regions[1], including East China, South China, North China, Central China, Northeast, Southwest, and Northwest. Northeast and North China are the main grain producing region in China, have a relatively high mechanization rate, and start mechanization outsourcing more early. In order to get the whole picture of Chinese agriculture's development, 2 provinces were selected in Northeast and North China, respectively, while 1 provinces were chosen in each other regions (Figure 1).

[1] 7 regions in mainland China are distributed as following: 1. East China :Shanghai, Zhejiang, Jiangsu, Anhui; 2. South China :Guangdong, Guangxi, Fujian, Hainan; 3. North China :Beijing ,Tianjin, Hebei ,Shanxi ,Inner Mongolia ,Shandong; 4. Central China :Hubei, Henan, Hunan Jiangxi; 5. Southwest :Chongqing, Sichuan Yunnan Guizhou; 6. Northeast China :Liaoning Jilin Heilongjiang; 7. Northwest :Shaanxi Ningxia Qinghai, Xinjiang, Gansu .

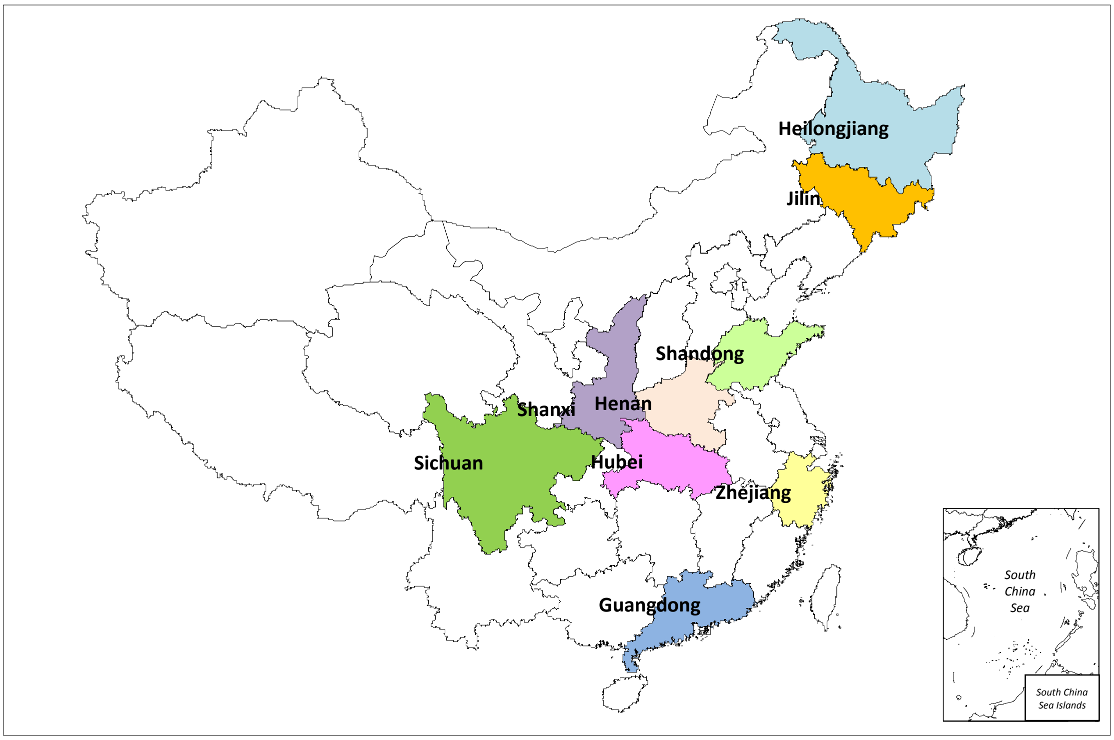

Figure 1: Sample province distribution

The sampling approach within the Northeast and North China regions is slightly different from that of other regions, and the specific sampling methods are as follows. (a) the sampling method in Northeast and North China is as follows: first, 2 rice planting counties and 2 maize planting counties were randomly selected from Heilongjiang and Jilin respectively, and in Shandong and Henan, three counties, which plant wheat and maize, were chosen in each province. Second, under the preconditions that the main crops in the townships are consistent with those grown in the counties, we randomly choose 2 towns in each selected county. Third, we use the same sampling method to choose two villages from each sample township. Last, we select 10 rural households as a sample, in the principle that each village should include 3 family farms or large farms and 7 ordinary rural households. If there was no family farms or large farms, 10 rural households were randomly selected.

(b) the sampling method for other provinces is as follows: First, according to per capita industrial output, counties of each province were divided into five levels, and one county was randomly selected from each level. Second, using the same indicator, put the country into two groups, and one township was randomly selected from each level. Third, applying the same stratified random sampling method to select 2 sample villages from each township. Finally, in each village, we randomly selected 10 sample households. Because the small-scale and fragmentation of land are common problems in those regions, we did not emphasize the large family's extraction.

Following the sampling method above, we conducted the survey and totally interviewed 1565 rural households. We collected the detailed information on the family, nonfarm employment and productive process of grain. In this study, we take maize farming as a case and finally employ 676 sample maize farmers. As shown in Table 1, the sample maize farmers are widely distributed in 7 provinces[2].

Table 1: The distribution of maize farmers in each province

Province	Maize farmers
Heilongjiang	66
Henan	95
Hubei	67
Jilin	115
Shandong	107
Shanxi	129
Sichuan	97
Total	676

[2] Considering the representative of the sample, we drop some observations which are maize farmers and only a few sample farmers plant maize in the province.

2.2. Descriptive Statistics

Since the 1970s, great changes have taken place in the mode of agricultural production in China. Mechanization is an important characteristic of agricultural development. Besides buying machines to replace manual labor, many farmers choose to adopt agricultural mechanization services. Farmers chose how to do their work in different agricultural production processes respectively, and almost all farmers will use the same operating mode for all his number of parcels in one production process.

Considering the energy consumed at each production process is quite different, tilling one acreage can't directly compare to harvesting one acreage. Ji and Zhong (2013) designed the concept of " Standard Paddy and Wheat Harvest Acreage (SPWHA)". The acreage of one grain's certain production process now can converse into the comparable SPWHA [3]. Following this approach, we find that the mechanization rate of maize farming is higher than 61.2%, and its percentage used mechanized outsourcing（46.6%） is larger than that operating by own machines（14.6%）. There are significant differences in the use of machinery in different production processes. Land preparation (Plowing) is the most mechanized process, and the area tilling by outsourcing service almost the twice of that by buying tractors. Harvesting is the second mechanized process. Like land preparation, the ratio of mechanical replacement labor is also very high at this link, but much more farmers chose to hire combine to do the work. Fertilization and spraying have the lowest mechanization rate., that is, the percentage of no mechanization is 65.5% in maize

[3] The coefficient of SPWHA is 0.85 for machine tillage, 0.35 for machine sowing, 0.25 for fertilization, spraying pesticide and herbicide, 1 for paddy or wheat harvest, and 1.2 for maize harvest.

farming, but mechanization outsourcing is still the preferable way to do the job.

Table 2: Percentage of mechanization outsourcing in total sown area of maize farming

Type of mechanization	Land preparation (Plowing)	Seeding	Fertilization and spraying	Harvesting	Total
no mechanization	21.7	39.7	65.5	39.1	38.8
Mechanization outsourcing	52.0	41.8	20.9	52.1	46.6
Owned machine	26.3	18.5	13.6	8.7	14.6

With the level of aging continuing to increase, the number of old people (Age ≥ 60 years old) in the rural area becomes large, the challenge of who will plant the land becomes an increasingly prominent, and receives a focus of China. In our sample, about 20% rural registered populations are over 60-year-old, and the peanuts who older than 80-year-old are over 1.3% of all the samples (Figure 2).

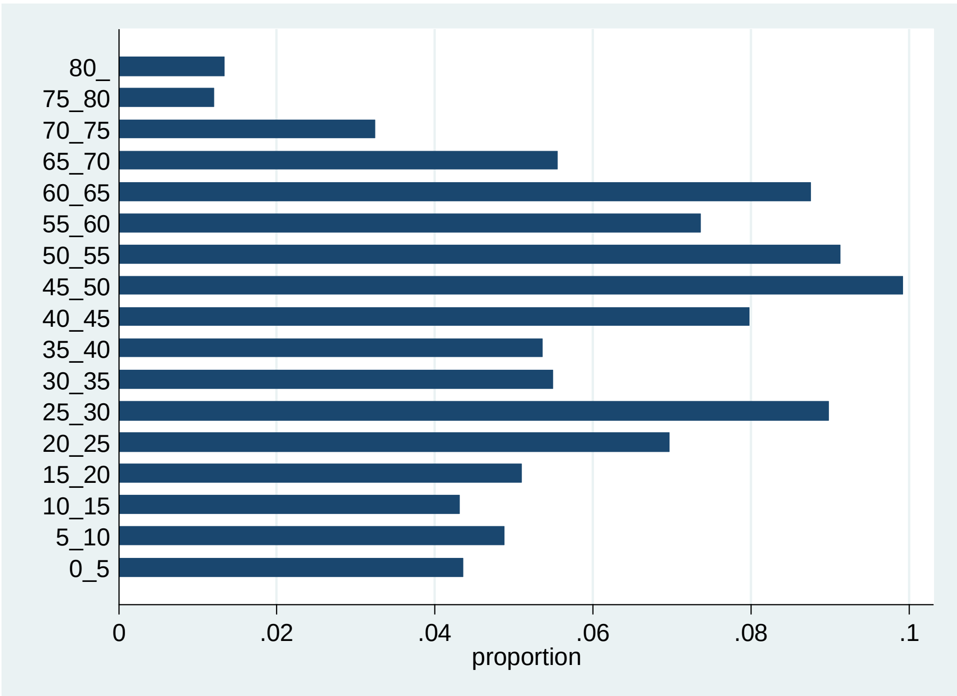

Figure 2: The age distribution of maize farmers

The total rate of off-farm employment of rural family members is 28.5%, and there are different between regions. Agriculture is modernized in the Northeast regions, so farmers there more rely on agriculture operation. Heilongjiang has the lowest nonfarm employment rate, which is 14.7%, and Jilin province also has low a nonfarm employment rate. Hubei and Shanxi witness about 35.6% and 33.4% of rural residents to do nonfarm work, respectively (Table 4).

Table 3: Rate of off-farm employment

Province	Off-farm employment (%)
Heilongjiang	14.7
Henan	27.3
Hubei	35.6
Jilin	24.2
Shandong	30.6
Shanxi	33.4
Sichuan	29.6
Total	28.5

Ageing may have an influence on the off-farm employment of family members (Figure 3). There is more than one third (38.6%) rural households have no member over 60 years old. Their percent of nonfarm employment is about 38.6%. Families, whose percent of family members over 60 less than 25%, occupy 31.8% of our efficient samples. 30.3% of sample families' percent of family members over 60 is between 25% and 50%. Still, 15.8% of families have more than a half members are over 60 years old. The trend is obvious that the more elderly population in a rural household, the less proportion of family members engage in off-farm work.

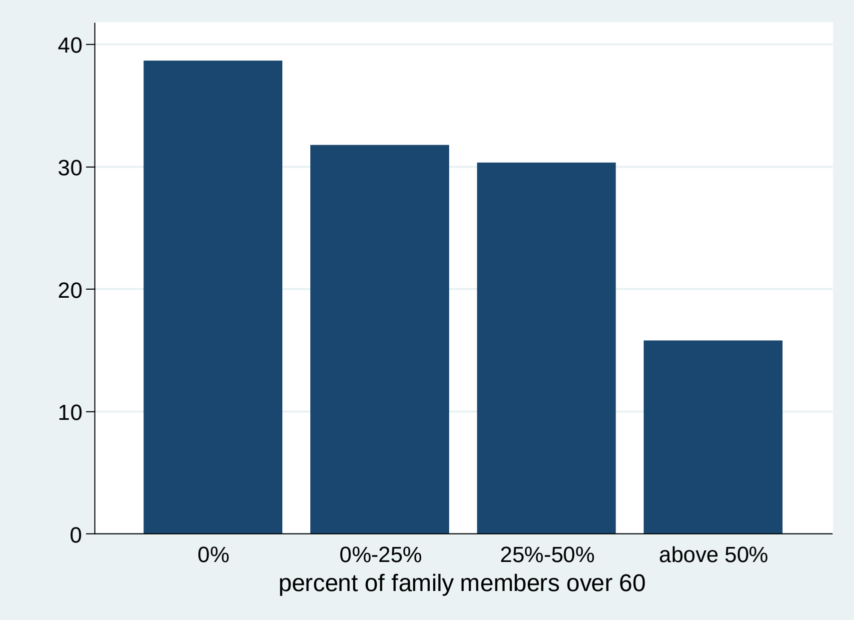

Figure 3: Correlation between off-farm employment and the percentage of people aged 60 and above

Families with different structures vary in the way of agricultural production. On average, the households with family members over 60 have the higher mechanization rate. No matter what kind of scale, the households with elder family members tend to adopt agricultural mechanization services. With the increase in the scale of the arable area, the percentage of no mechanization goes down, while the area percentage of using owned machine rises. When farmers plant maize over 1 ha, buying own machine seems a more cost-effective way.

Table 4: Family structure and the percentage of mechanization outsourcing

Family structure	the scale of the arable area	0-0.2 ha	0.2-0.4 ha	0.4-1 ha	over 1 ha
No family member over 60	no mechanization	60.6	48.7	25.0	13.1
	owned machine	4.1	8.1	14.2	36.4
	mechanization outsourcing	35.3	43.3	60.7	50.5
Have family member over 60	no mechanization	67.8	43.9	26.7	13.4
	owned machine	6.5	4.1	7.6	29.4

	mechanization outsourcing	25.7	52.0	65.7	57.2

The types of employment also have an impact on the adoption of agricultural mechanization services. When the cornfield is small, less the 0.2 ha, the farmers who have nonfarm work use more machines to save time to do other things. When the scale is larger than 0.2 ha, the farmers without off-farm work use a more manual operation to make full use of family labor force; otherwise, they use less mechanization outsourcing than the households with off-farm employment. The adoption rate of agricultural mechanization services also has an inflection point in the scale of 0.4-1 ha. When the scale larger than 0.2 ha,

Table 5: Percent of nonfarm employment and percentage of mechanization outsourcing

Type of employment	the scale of the arable area	0-0.2 ha	0.2-0.4 ha	0.4-1 ha	over 1 ha
no nonfarm work	no mechanization	61.9	60.3	40.8	12.4
	owned machine	6.6	6.4	10.8	41.4
	mechanization outsourcing	31.5	33.2	48.4	46.3
have nonfarm work	no mechanization	65.1	44.6	22.0	13.7
	owned machine	5.2	6.2	10.8	29.0
	mechanization outsourcing	29.7	49.2	67.2	57.3

3. Empirical models

To more accurate to capture the impacts of population aging and off-farm employment on the adoption of agricultural mechanization services, we propose two empirical models: 1) a seemingly unrelated regression model is employed to assess the choice of agricultural mechanization services at the total level; 2) a multivariate probit model is used to identify the choice of agricultural mechanization services in the specific processes of maize farming.

$$\begin{cases} y1 = \alpha_1 + \beta_1 off + \gamma_1 Aging + \theta_1 Z + u_1 \\ y2 = \alpha_2 + \beta_2 off + \gamma_2 Aging + \theta_2 Z + u_2 \\ y3 = \alpha_3 + \beta_3 off + \gamma_3 Aging + \theta_3 Z + u_3 \end{cases} \tag{1}$$

and

$$\begin{cases} p1 = \alpha_1' + \beta_1' off + \gamma_1' Aging + \theta_1' Z + u_1' \\ \quad\quad\quad\quad\quad\quad\quad\quad \cdots \\ p8 = \alpha_8' + \beta_8' off + \gamma_8' Aging + \theta_8' Z + u_8' \end{cases} \tag{2}$$

where all variables are defined and described in Table 2.

Moreover, to control for the possible endogeneity of off-farm employ in explaining the adoption of agricultural mechanization services, an instrumental variable approach is used. Firstly, the model of off-farm employment (equation (3)) is supposed to be estimated.

$$off = \alpha_1^{''} + \beta_1'' IV + \gamma_1'' Aging + \theta_1'' Z + u_1'' \tag{3}$$

where the IV employed is defined as the average wage of off-farm work in the county following the previous studies. According to the estimation results of equation (3), we can yield the predicted variable ($\widehat{off}$) for off.

Then, by replacing off in the models (1) and (2) to $\widehat{off}$, the two models can be changed as:

$$\begin{cases} y1 = \alpha_1 + \beta_1 \widehat{off} + \gamma_1 Aging + \theta_1 Z + u_1 \\ y2 = \alpha_2 + \beta_2 \widehat{off} + \gamma_2 Aging + \theta_2 Z + u_2 \\ y3 = \alpha_3 + \beta_3 \widehat{off} + \gamma_3 Aging + \theta_3 Z + u_3 \end{cases} \tag{4}$$

and

$$\begin{cases} p1 = \alpha_1' + \beta_1' \widehat{off} + \gamma_1' Aging + \theta_1' Z + u_1' \\ \quad\quad\quad\quad\quad\quad\quad\quad \cdots \\ p8 = \alpha_8' + \beta_8' \widehat{off} + \gamma_8' Aging + \theta_8' Z + u_8' \end{cases} \tag{5}$$

Thus, the model (4) can be estimated by a seemingly unrelated regression. As the sum of $y1$, $y2$ and $y3$ is 1, the first equation for $y1$ (The percent of no machine) would be omitted automatically. The model (5) can be estimated by the multivariate probit regression.

Table 6: Description of variables

Variables	Mean	Standard Deviation
y1: The percent of no machine (%)	38.75	35.82
y2: The percent of mechanization outsourcing (%)	46.65	35.59
y3: The percent of own machine (%)	14.60	24.07
p1: Whether use machine in soil preparation(0=no 1=yes)	0.58	0.49
p2: Whether hire mechanization outsourcing in soil preparation (0=no 1=yes)	0.38	0.49
p3: Whether use machine in seed (0=no 1=yes)	0.61	0.49
p4: Whether hire mechanization outsourcing in seed (0=no 1=yes)	0.42	0.49
p5: Whether use machine in fertilization and spraying (0=no 1=yes)	0.60	0.49
p6: Whether hire mechanization outsourcing in fertilization and spraying (0=no 1=yes)	0.38	0.49
p7: Whether use machine in harvest (0=no 1=yes)	0.61	0.49
p8: Whether hire mechanization outsourcing in harvest (0=no 1=yes)	0.53	0.50
Off: percent of nonfarm work (%)	33.59	25.56
Aging: percent of over 60 (%)	0.20	0.28
Z		
number of family members (head)	4.47	1.90
number of parcels (plot)	3.58	2.77
percent of the linked parcel (%)	8.11	24.53
Wealth (ten thousand yuan)	22.28	31.83
arable area of household (mu)	41.36	98.62
sown area of corn (mu)	29.72	80.06
the distance to township (km)	5.18	4.44
mean arable area of per household in the village(mu per household)	8.12	7.32
the proportion of plain in the village (%)	0.78	0.39
distance to the road (km)	1.59	2.82
whether have agricultural materials store (0=no 1=yes)	1.45	0.50
Total arable area of village (mu)	4668.71	5108.77
The number of household in village (hu)	550.89	286.41
Northeast (0=no 1=yes)	0.27	0.44
Central China (0=no 1=yes)	0.24	0.43
East China (0=no 1=yes)	0.16	0.37

4. Estimation results

In order to research the relationship between aging, nonfarm work, and mechanization outsourcing, we could control for the possible endogeneity by using IV. We use wage of nonfarm work in the county, the percent of over 60 in a family and other control variables to obtain the predicted value of the percent of nonfarm work. We use the predicted value to replace the percentage of nonfarm employment in the other models to see its influence on the rate of mechanization outsourcing and the rate of using own machine (in the second row of Table 7). The IV has been confirmed to be valid by using a falsification test.

As shown in the results of Table 7, we find that nonfarm work is mainly decided by farmers' personal characteristics, like percent of over 60 in a rural family and the total sown area of maize and its square. Besides that local overall non-agricultural economic development level, standing by the wage of nonfarm work in the county, and local agricultural production resource endowment have less influence.

In the next, we want to find out what variables influence the choice of hiring mechanization outsourcing and using own machines. There is definitely some same information will have an impact on the two choices of one household, so use seemingly unrelated regression (SUR) will have much efficiency. In econometrics, SUR model developed by Arnold Zellner and first published in Zellner (1962), is a technique for analyzing a system of multiple equations with cross-equation parameter restrictions and correlated error terms. An economic model may contain multiple equations which are independent of each other on the surface: they are not estimating the same dependent variables, they have different independent variables, etc. However, if the equations are using the same data, the errors may be correlated across the equations. SUR is an extension of the linear regression model which allows correlated errors between equations. Otherwise, in general, the bootstrap is used in statistics as a resampling method to approximate standard errors, confidence intervals, and p-values for test statistics, based on the sample data. This method is significantly helpful when the theoretical distribution of the test statistic is unknown like our situation.

The result shows that nonfarm work has significant positive influence on the using of mechanization outsourcing in the aggregation level，but more nonfarm work mean fewer people have time to operate own machine. The more family members over 60 and the more percent of the linked parcel, the more percent of se custom service. The relationship between the rate of using mechanization outsourcing and planting scale of maize is an inverted U-curve, which means when on a small scale, farmers will buy more service until its scale is big enough to buy own machine. Mechanization outsourcing involves drive a machine to serve some, so the geographic features, such as the distance to the township, the convenience of transportation, the topography of the whole region and the mean arable area of per household, all have are important for making the decision of the mode of production. Farmers in Northeast, East China and Central China use more mechanization outsourcing compare to West China. How much percent of the sown area of maize using own machine to do the work consider similar variables, but have inverse coefficient. The result is well understood, because the two methods are often exclusive. When farmers choose to use more mechanization outsourcing, in general, the percent of using own machines will goes down.

Table 8: Estimation results for off-farm employment and SUR

variables	OLS	Seemingly Unrelated Regression	
	IV nonfarm work rate	The rate of mechanization outsourcing	The rate of own machine
IV for nonfarm work		25.63***	-11.66**
		(6.155)	(4.954)
the wage of nonfarm work in the county	0.00207	-0.0508***	0.0243**
	(0.00129)	(0.0129)	(0.0105)
percent of over 60	-23.18***	595.4***	-270.3**
	(4.904)	(142.7)	(114.6)
number of parcels	-0.0623	0.592	0.0380
	(0.240)	(0.710)	(0.620)
percent of the linked parcel	-0.00442	0.126***	-0.0468
	(0.0374)	(0.0477)	(0.0362)
number of family members	-0.375	10.45***	-4.608**
	(0.574)	(2.427)	(1.901)
the worse health state of over 60 people	-1.002	26.40***	-13.03**
	(1.047)	(6.318)	(5.107)
wealth	0.0141	-0.367***	0.183**
	(0.0301)	(0.0975)	(0.0767)
sown area of maize	-0.121***	3.076***	-1.224**
	(0.0349)	(0.754)	(0.592)
the square of the sown area of maize	0.000120**	-0.00312***	0.00123**
	(0.0000561)	(0.000765)	(0.000587)
the distance to township	-0.167	3.376***	-1.954**
	(0.257)	(1.076)	(0.898)
distance to the road	-0.207	6.038***	-2.164**
	(0.402)	(1.252)	(0.970)
Mean arable area of per house in village	-0.329	9.331***	-3.555**
	(0.266)	(2.074)	(1.678)
The proportion of plain in village	3.050	-25.42	39.20**
	(3.196)	(20.21)	(16.03)
whether have agricultural materials store	-0.795	13.41**	-5.032
	(2.053)	(5.717)	(4.385)
Total arable area of village	-0.000350	0.00929***	-0.00384**

	(0.000422)	(0.00213)	(0.00168)
Northeast	-2.880	52.81***	-23.40
	(4.553)	(19.18)	(15.89)
Central China	-3.264	82.60***	-33.89**
	(2.763)	(20.46)	(16.28)
East China	-1.999	57.77***	-21.04**
	(3.273)	(12.91)	(10.01)
_cons	43.94***	-1114.6***	503.5**
	(6.250)	(269.7)	(216.2)
N	676	676	
R-sq	0.169	0.501	

Note: Bootstrap standard errors in parentheses, * p<0.1 ** p<0.05 ***p<0.01

Different production processes require different labor intensity, timeliness and the complicity of supervision. After research what has influence of the SPWHA, we check the influence factors to soil preparation, seeding, fertilization and spraying and harvest respectively. In one detail process, the farmers also facing the choice that doing production process by manual labor, by own machines or by hiring mechanization outsourcing. The three choices are mutually exclusive, so we can check the two of them to describe the overall situation. We use mvprobit to do the regression. Mvprobit estimates M-equation probit models, by the method of simulated maximum likelihood (SML). The variance-covariance matrix of the cross-equation error terms has values of 1 on the leading diagonal, and the off-diagonal elements are correlations to be estimated. Mvprobit uses the Geweke-Hajivassiliou-Keane (GHK) simulator to evaluate the M-dimensional Normal integrals in the likelihood function. For each observation, a likelihood contribution is calculated for each replication, and the simulated likelihood contribution is the average of the values derived from all the replications. The estimation results are reported in Table 8.

Table 8: Estimation results for choices of mechanization services for the specific processes of maize farming

Variables	Multivariable Probit							
	soil preparation		seed		fertilization and spraying		harvest	
	whether use the machine	whether hire mechanization outsourcing	whether use the machine	whether hire mechanization outsourcing	whether use the machine	whether hire mechanization outsourcing	whether use the machine	whether hire mechanization outsourcing
IV for nonfarm work	0.0265	0.0666***	0.0556**	0.0412**	-0.0109	0.0327*	0.0362*	0.0437***
	(0.0216)	(0.0212)	(0.0254)	(0.0170)	(0.0421)	(0.0168)	(0.0208)	(0.0162)
Percent of over 60	0.752	1.972***	1.808**	1.670***	-0.118	0.793	1.135*	1.365***
	(0.605)	(0.595)	(0.711)	(0.505)	(1.073)	(0.493)	(0.587)	(0.474)
Number of family members	-0.0571*	-0.0136	0.129***	0.113***	0.000239	0.0232	0.0815*	0.0831**
	(0.0346)	(0.0335)	(0.0463)	(0.0349)	(0.0495)	(0.0363)	(0.0420)	(0.0345)
Number of parcel	-0.0582**	-0.0780***	0.00509	-0.0584**	0.0124	-0.0372	0.00537	-0.0309
	(0.0260)	(0.0223)	(0.0353)	(0.0265)	(0.0442)	(0.0264)	(0.0392)	(0.0207)
Percent of linked parcel	0.00296	0.00136	0.00236	0.00110	0.00275	0.00172	-0.000254	-0.000569
	(0.00215)	(0.00185)	(0.00293)	(0.00234)	(0.00309)	(0.00246)	(0.00261)	(0.00217)
Wealth	-0.00245	-0.00968***	-0.00202	-0.00141	0.00537	-0.000348	-0.000359	0.000527
	(0.00219)	(0.00155)	(0.00246)	(0.00198)	(0.00375)	(0.00203)	(0.00248)	(0.00199)
Sown area of maize	0.00615**	0.00190	0.0102***	-0.00133	0.00940	-0.00260	0.0247***	0.00734***
	(0.00278)	(0.00211)	(0.00395)	(0.00239)	(0.00660)	(0.00251)	(0.00765)	(0.00185)
Square of sown area of maize	-0.000002	0.000004	-0.000009	0.000003	-0.00001	0.000006	-0.00003	-0.00001***
	(0.000003)	(0.000003)	(0.000006)	(0.000004)	(0.00001)	(0.000004)	(0.00002)	(0.000002)
The distance to township	-0.0264	-0.0189	-0.0494**	-0.0134	-0.0455*	-0.0188	-0.0691***	-0.0791***
	(0.0182)	(0.0150)	(0.0226)	(0.0167)	(0.0242)	(0.0186)	(0.0203)	(0.0159)

Per house average arable area	0.0636**	0.0387**	0.118***	0.0232	0.0273	-0.000371	0.0658**	0.0544***
	(0.0276)	(0.0158)	(0.0293)	(0.0164)	(0.0348)	(0.0171)	(0.0258)	(0.0160)
The proportion of plain in village	1.211***	1.397***	4.146***	3.585***	2.770***	10.73**	3.196***	3.512***
	(0.193)	(0.170)	(0.561)	(0.496)	(0.401)	(4.258)	(0.347)	(0.371)
Distance to the road	0.00276	0.0298	0.104***	0.00739	0.0555	0.0334	0.0934***	0.110***
	(0.0248)	(0.0208)	(0.0359)	(0.0284)	(0.0405)	(0.0296)	(0.0350)	(0.0281)
Whether have agricultural materials store	-0.0534	-0.220**	-0.0856	-0.140	-0.0602	-0.248*	-0.182	-0.259**
	(0.127)	(0.107)	(0.157)	(0.125)	(0.159)	(0.135)	(0.151)	(0.126)
Total arable area of village	-0.00004	-0.00004**	0.00002	0.00003	0.00006	0.00002	0.00002	-0.000006
	(0.00003)	(0.00002)	(0.00003)	(0.00002)	(0.00004)	(0.00002)	(0.00003)	(0.00002)
Northeast	0.387	0.199	-0.706**	-0.526*	0.844**	1.032***	-0.558*	-0.365
	(0.369)	(0.255)	(0.343)	(0.287)	(0.377)	(0.306)	(0.314)	(0.266)
Central China	-1.003***	-0.730***	0.515**	0.174	1.338***	0.959***	-0.0289	-0.246
	(0.193)	(0.178)	(0.221)	(0.188)	(0.243)	(0.196)	(0.212)	(0.194)
East China	-2.102***	-2.018***	0.884***	0.363*	1.542***	1.981***	0.365	0.136
	(0.228)	(0.209)	(0.253)	(0.187)	(0.235)	(0.226)	(0.232)	(0.193)
_Cons	-1.006	-2.979***	-7.133***	-5.367***	-2.953	-12.53***	-4.506***	-4.794***
	(1.129)	(1.110)	(1.458)	(1.004)	(2.156)	(4.279)	(1.138)	(0.914)
Atrho21	2.032***		1.479***		1.182***		1.689***	
	(0.209)		(0.161)		(0.173)		(0.156)	
N	676		676		676		676	

Standard errors in parentheses, * p<0.1 ** p<0.05 ***p<0.01

The results show that different production processes have to pay attention to different variables. More family members do nonfarm work all processes will gain the percentage of using mechanization outsourcing, and also gain the percentage of using own machines in seed and harvest. Ageing have very significant influence in all process, except for fertilization and spraying, maybe because that this process consumes less energy and is less time constrained. With the development of aging, social services will be more used. We should notice that the more proportion of plain in the village, which stands for the landform of the villages, the more machine will be used, no matter the ownership.

5. Concluding remarks

As a typical case of labor division in agriculture, agricultural mechanization services have been widely concerned in recent years (Lu et al., 2016; Zhang et al., 2017; Wu et al., 2017; Zhou et al., 2016). However, the adoption of agricultural mechanization services in China is not clear due to the lack of empirical evidence. To fill this gap, in this study we use a household survey data of some 600 maize farmers from 7 provinces in China. The results show the rate of mechanization in maize farming is over 60%, including 15% using own machines and 46% adopting agricultural mechanization services. The adoption rates of mechanization services in the specific processes of maize farming are 52% for plowing, 41.8% for seeding, 21% for fertilizing and spraying, and 52% for harvesting. The heterogeneity in the adoption rates of agricultural mechanization services in the specific processes of maize farming also reflect the improvement potentials of mechanization in each process of maize farming.

The empirical results show that the proportion of family members aged ≥60 years old in the household has a significant and negative effect on the percent of family members engaging in off-farm work, but positively affect the adoption of agricultural mechanization services, regardless of at the total level or for a specific process of maize farming. Furthermore, a household with more family members engaging in off-farm work is more likely to adopt agricultural mechanization services.

The findings of this study not only reveal the extent of agricultural mechanization services adoption in maize farming in China but also contribute to a better understanding of the agricultural development in China in the context of increasing population aging and the raising wages. However, this study, indeed, has two limitations. First, the cross-sectional data cannot identify the trajectory of agricultural mechanization services in China. Second, the analysis only focuses on maize farming and therefore cannot show the whole situation of mechanization services adoption in China's agriculture. Hence, a panel data with more crops are recommended to be employed in future related studies.

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