Investigating the Relationship between Land and Labor Endowments and Agricultural Mechanization among Chinese Farmers

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Abstract: China maintains a steady yield increase in the past three decades, but farm production is undergoing a great change, especially in the recent decade, due to the change in both economic conditions and the environment along with a sharp decline of rural labor and farming population. Agricultural mechanization, especially agricultural mechanization services (AMS), gains its popularity in recent years. This study examines the adoption of agricultural mechanization, using either self-equipped machinery or AMS; and the factors contributing to the adoption of different types of agricultural mechanization. The empirical analysis uses primary survey data and employs a seemingly unrelated regression model. We find that the agricultural labor endowment improves the adoption of agricultural mechanization, but off-farm labor curbs the adoption. In terms of the land endowment, we find an inverse U-shaped non-linear relationship between the land endowment and the AMS adoption, and land fragmentation reduces the mechanization adoption.

Keywords:

Labor; Land Endowment; Mechanization of Agricultural Production; Agricultural Machinery Service (AMS)

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Two policies of great importance, namely, the household-responsibility system (HRS) and the reform and opening policy (ROP), have been implemented in China since 1978. The HRS, serving as a replacement of the production team system as the unit of production and income distribution, significantly boosted China's economy and improved the wellbeing of rural households. It greatly improved total factor productivity and accounted for about half of the output growth during 1978-1984 (Lin, 1992). Although land fragmentation and small-scale production was one of the significant features of Chinese agriculture since the national implementation of the HRS, it was not a significant concern and agricultural mechanization was not promoted mainly due to abundant labor supply in rural China at that time. Along with the ROP implemented in China in the late 1970's, the nation has experienced rapid economic growth and witnessed a predominant change, the urban-to-rural labor migration. Nonagricultural sectors not only experienced a significant increase of labor demand and offered significantly higher wage since 1990s (Cai, 2010, Ma, et al., 2013). To the end of 2014, the number of migrant workers in China totaled up to 273.95 million (National bureau of statistics 2015) with an annual growth of 3.67% (Yang and Yang, 2009). With the amount of migrant workers increased rapidly, China agricultural is challenged by the agricultural labor shortage and labor quality as elderly, women, and children were more likely to left behind in rural China (Cai, 2010, Ding, 2012). Agricultural mechanization gradually became a political and economic issue. Figure 1 shows a clear steady increase in the total power of agricultural machinery from 1978 to 2013. In 2004 Chinese government established a financial subsidy policy to encourage farmers and cooperatives to purchase agricultural machinery. The first State Law on "Promotion of Agricultural Mechanization" was enacted and became effective on January 1st, 2004. The law requires all government bodies above the county level to put the promotion of agricultural mechanization into the agenda of the national and social development plans and to increase the financial support for agricultural mechanization. As shown in Figure 2, the number of large and medium sized agricultural tractors took off in 2004, which can be attributing to these policy changes.

Several studies examine agricultural machinery investment (Ji, 2010, Liu, et al., 2002) and agricultural machinery services (Fan, 2004, Liu, et al., 2002, Xu and Lu, 2000, Yang, 2015). Yet, the relation between the household endowment of labor and land and the adoption of different mechanization in rural China is not well studied. This study will fill the gap by investigating a) the adoption of agricultural mechanization, using either self-equipped machinery or AMS; and b) the factors contributing to the adoption of different types of agricultural mechanization. The empirical analysis of this study uses primary survey data collected in three main agricultural provinces in China and employs a seemingly unrelated regression model. We find that agricultural labor improves the adoption of agricultural mechanization, but off-farm labor curbs the adoption. In terms of the land endowment, we find an inverse U-shaped non-linear relationship between the land endowment and the mechanization adoption, but land fragmentation reduces the mechanization adoption.

Theoretical model

Farmers can choose to utilize agricultural mechanization or not in the agricultural production. If they prefer mechanization, they can either use their own machinery or request AMS. Let θ_1 and θ_2 denote the proportion of farm work using own machinery or AMS, respectively, such that $0 \leq \theta_1 \leq 1$, $0 \leq \theta_2 \leq 1$, and $0 \leq \theta_1 + \theta_2 \leq 1$. Agricultural mechanization has at least two effects on production. First, the extensive effect refers that fact that agricultural mechanization and labor input can be substitute. Mechanization reduced the total agricultural labor input needed. Assuming the average labor hours needed for each unit of land is l, agricultural mechanization completes the farm work that would require a total farming labor of $(\theta_1 + \theta_2) * K_a * l$, wherer K_a is the total agricultural land input. Second, let s indicates the efficiency of mechanization if using own machinery, such that $s > 1$. To complete $\theta_2 * K_a * l$ amount of workload, household need to allocate $\frac{\theta_2 * K_a * l}{s}$ amount of labor input if own machinery is utilized. On the other hand, households do not supply their own labor force if AMS is requested. Combining the extensive and intensive effects of machination, the total agriculture labor input would be $(\theta_1 + \theta_2) * K_a * l + \left(L_a - \frac{\theta_2 * K_a * l}{s}\right)$ if the agricultural labor input is L_a. The variable cost per unit of land input for AMS is c_1 and c_2 if using own machinery. The mechanization costs, c_1 reflects the machinery depreciation and costs of labor, fuel, and repair. c_2 reflects the machinery depreciation and costs of fuel, and repair. Assuming a Cobb-Douglas production function, the production function denoted by Y is:

$$Y = A\left\{(\theta_1 + \theta_2)K_a l + \left(L_a - \frac{\theta_2 K_a l}{s}\right)\right\}^{\gamma} K_a^{\beta} \tag{1}$$

Where A indicates the total productivity factor, $(\theta_1 + \theta_2)K_a l + \left(L_a - \frac{\theta_2 K_a l}{s}\right)$ is the total agriculture labor input, and K_a is the land input. The parameters, γ and β, reflect the output elasticities of labor and land inputs, respectively. An individual households' agricultural production profit denoted by π can be written below:

$$\pi = p * Y + w(L_T - L_a) - r(K_a - K_T) - c_1\theta_1 K_a - c_2\theta_2 K_a - z \tag{2}$$

As shown in Equation (2), the revenue consists of the agricultural income $p * Y$, where p is the output price; the off-farm earning expressed in $w * (L_T - L_h)$, where L_T is the total household labor and L_a is the labor input for agriculture production, w is the average off-farm wage. The cost consists of the land rental cost, $r * (K_a - K_T)$, where r is the rental price, K_T is the total household land endowment, and K_a is the total land for agricultural production; the cost of AMS $(c_1 * \theta_1 * K_a)$; the cost of mechanization using own machinery $c_2 * \theta_2 * K_a$; and the fixed cost in agricultural production. The first order conditions with respect to θ_1 and θ_2 when maximizing the profit are

$$\frac{\partial\pi}{\partial\theta_1} = pA{K_a}^{\beta+1}\gamma l\left\{\left[\theta_1 + \theta_2\left(1-\frac{1}{s}\right)\right] * K_a l + L_a\right\}^{\gamma-1} - c_1 * K_a \quad (3a)$$

$$\frac{\partial\pi}{\partial\theta_2} = pA{K_a}^{\beta+1}\gamma l\left(1-\frac{1}{s}\right)\left\{\left[\theta_1 + \theta_2\left(1-\frac{1}{s}\right)\right] K_a l + L_a\right\}^{\gamma-1} - c_2 * K_a \quad (3b)$$

Based on Equations (3a) and (3b), we derive the following condition:

$$\begin{cases} \text{use own machinery} & \text{if } c_1 > \frac{s}{s-1}c_2 \\ \text{adopting AMS} & \text{if } c_1 < \frac{s}{s-1}c_2 \\ \text{either using own mechineary or adoping AMS} & \text{if } c_1 = \frac{s}{s-1}c_2 \end{cases} \quad (4)$$

For each production stage, namely, tillage, planting, and harvesting, it is uncommon to use both own machinery and AMS. Although the profit results from all production stages, for the simplicity, the discussion below focuses on the case either using own machinery or AMS is adopted for mechanization. We can then calculate the optimal value of θ_1 and θ_2:

$$\theta_1{}^* = \frac{\left[\frac{c_1}{pA{K_a}^{\beta}\gamma l}\right]^{\frac{1}{\gamma-1}} - L_a}{K_a l} \quad (5a)$$

$$\theta_2{}^* = \frac{\left[\frac{c_2}{pA{K_a}^{\beta}\gamma l\left(1-\frac{1}{s}\right)}\right]^{\frac{1}{\gamma-1}} - L_a}{K_a l * \left(1-\frac{1}{s}\right)} \quad (5b)$$

Take the derivative of equations (5a) and (5b) with respect to the land and labor endowments yields

$$\frac{\partial\theta_1{}^*}{\partial L_a} = -\frac{1}{K_a l} < 0 \quad (6a)$$

$$\frac{\partial\theta_2{}^*}{\partial L_a} = -\frac{1}{K_a l * \left(1-\frac{1}{s}\right)} < 0 \quad (6b)$$

$$\frac{\partial\theta_1{}^*}{\partial K_a} = \frac{\left\{\left(\frac{\beta+\gamma-1}{1-\gamma}\right) * \left(\frac{c_1}{pA\gamma l}\right)^{\left(\frac{1}{\gamma-1}\right)} * \left[K_a^{\left(\frac{\beta}{1-\gamma}\right)}\right]\right\} L_a}{l{K_a}^2} \quad (6c)$$

$$\frac{\partial \theta_2{}^*}{\partial K_a} = \frac{\left\{\left(\frac{\beta+\gamma-1}{1-\gamma}\right)*\left(\frac{c_2}{pA\gamma l\left(1-\frac{1}{s}\right)}\right)^{\left(\frac{1}{\gamma-1}\right)}\left[K_a{}^{\left(\frac{\beta}{1-\gamma}\right)}\right]\right\}+L_a}{lK_a{}^2*\left(1-\frac{1}{s}\right)} \tag{6d}$$

The sign of the equation (6a) and (6b) are negative, which shows the household labor endowment and mechanization are substitutes. The greater the agricultural labor endowment, the smaller the mechanization level. The quality of labor has effect on labor allocation, as non-farm sector offers significantly higher wage than agricultural work, the higher of labor's quality, the more opportunity they can get a job in non-farm sector, the less labor will allocated in agricultural work, the more they will adopt agricultural machinery.

Hypothesis 1: Farm working labor endowment decrease the probability of using the AMS or own machinery, while households' labor quality (e.g., better education and/or health) increase the adoption of agricultural mechanization.

If the production exhibits economy of scale, $\gamma + \beta > 1$, we have $\frac{\partial \theta_1{}^*}{\partial K_a} > 0$ and $\frac{\partial \theta_2{}^*}{\partial K_a} > 0$. Otherwise, the sign of Equations (6c) and (6d) depends on their nominator. In both scenarios, equations (6c) and (6d) suggest a nonlinear relationship between the land endowment and the mechanization level. We expect an inverse U-shaped relationship that will be tested empirically.

Hypothesis 2: The relation between the household land input and the adoption of AMS is non-linear and can be represented by an inverse U-shape.

Survey Data and Key Variables

The data set used for this study come from the rural household survey conducted in three major agricultural provinces (Henan, Hebei, Shandong) by the students in the School of Agriculture Economic and Rural Development at Renmin university of China in June-August, 2014. As shown in Figure 3, these three provinces are located in northern China near the Yangtze River Delta region. Per capital annual income of rural areas in 2013 was ¥10,620 and ¥9,102 for Shangdong and Henan exceeding the national average (¥8,896), while it was smaller for Hebei province (¥8,475). These three provinces are China's major grain and corn production provinces. Based on total grain output in 2013, Henan, Shandong, and Hebei provinces ranked the second, third, and seventh in the nation (National bureau of statistics, 2013). We chose ten counties in each province based on of climate conditions, crop types, and economic conditions. We then randomly chose up to 10 individual farm households in each county. Among 850 households who participated in the survey, 780 completed the survey. 614 out of 780, are maize farmers which used for the analysis. As shown in Table 1, the sample households from Shandong account for the largest proportion (40%), followed by Hebei (31%), and the least in Henan (29%). The survey questionnaire covers the majority aspects of agricultural production, including agricultural and nonagricultural labor, total land for agricultural production, agricultural machinery, income sources, and mechanization level of agriculture in each production stage (tillage, planting, and harvesting).

Maize is one of the most important crops in the three provinces. The technology of mechanization is quite mature for maize production. Three approaches have been used to measure the mechanization level in the literature: measure for one production stage such as harvesting (Yang, et al., 2013), the land area where mechanization is applied for (Ji, 2010), and mechanization index that is calculated by the adoption of mechanization in each stage of the agricultural production (Wu, 2013). The mechanization index is used in this study. We divide agricultural production into three stages, namely, tillage, planting, and harvesting. For each production stage, the level of agricultural mechanization is calculated by the share of land used either own machinery or AMS. The overall mechanization index is the weighted average of the three stages, where the weight of tillage, planting and harvest is respectively 0.4, 0.3 and 0.3 based on the literature(Wu, 2013). As shown in Table 1, approximately 61% of the agricultural land is cultivated using machineries, where 57% use AMS and the other 4% use own machinery.

We measure the labor endowment by quantity and quality. We separate the labor force into agricultural and non-agricultural labor. Labor quality is reflected by the average year of schooling and the self-reported health condition. An average household has about 1-2 agricultural labor and 2-3 non-agricultural labor. The average year of schooling for is approximately seven years – finishing the elementary school plus one year in the middle school. The households reported a reasonably good health condition -- 89% of the household heads is healthy based on their self-reported health condition and only 9% have at least one family member critically ill or disabled.

We use several variables to measure the land endowment. In addition to the total agricultural land, we incorporate the number of land parcels to reflect land fragmentation. As shown in Table 1, China's rural households operate not only in quite a small land lot, it is also highly segmented – an average household has almost three land parcels with a total of 0.42 hectare for agriculture.

We use several variables to measure the cost of mechanization. Service costs might be dramatically different due to the heterogeneities of topography, soil conditions, field conditions, and land fragmentation. As shown in Table 1, the average cost of AMS was ¥140 per unit of land in mu (equivalent to 0.067 hectare). Household investment in agricultural machinery is ¥2,468. Only 3% of households are the providers of the AMS. We use the average off-farm annual wage of family members as earning potential for off-farm jobs. The self-assessment of households' economic condition and the share of non-farm income are also incorporated as control variables.

Table 2 provides summary statistics based on the mechanization level. Out of 614 households, only nine households do not take any advantage of mechanization and nine households only use own machinery for farming. The majority of the households adopt the AMS if they prefer machination, including 440 partial AMS households, 123 completely AMS households, 10 using both AMS and own machinery, and 15 using AMS and own machinery for some agricultural work but no mechanization for other agricultural work. Compared with households adopt mechanization at some degree, households without any agricultural mechanization have more agricultural labor, fewer off-farm labor, and poor land endowment. The agricultural labor, year of schooling of household labor force, land size, and the perceived economic condition are either more or better for households with own machineries. Those who adopt the AMS have more non-agricultural labor, greater non-farm wage than other household types. Yet, the relationship between household endowments of labor and land and mechanization is still not clear based on Table 2. An empirical analysis is needed to further analyze such relationship.

4 Empirical models and results

Assuming that an individual household *i* decided on the adoption of agricultural mechanization *j*, either using own machinery (*j* =1), requesting the AMS (*j* = 2), or choosing no mechanization at all (*j* = 0). The mechanization decision, denoted by y_{ik}, can be written below:

$$\begin{cases} y_{i1} = \gamma_1 l_{i1} + \beta_1 k_{i1} + \tau_1 m_{i1} + \alpha_1 w_{i1} + \varphi_1 g_{i1} + e_{i1} \\ y_{i2} = \gamma_2 l_{i2} + \beta_2 k_{i2} + \tau_2 m_{i2} + \alpha_2 w_{i2} + \varphi_2 g_{i2} + e_{i2} \end{cases} \quad (7)$$

where *l* and *k* denote the household endowments of labor and land, *m* represents mechanization related variables, *w* represents income and wage related variables at the household level, and *g* denotes geographic factors. Following Zellner (1962), we assume that error terms e_{i1} and e_{i2} are correlated and, therefore estimating the parameters using seemingly unrelated regression (SUR) approach. The null hypothesis of the Breusch-Pagan test for independence of two error terms is that no statistically significant correlation. As shown in Table 3, the Chi-square statistics with degree of one is 77.80 which exceeds the critical value (6.64) at the 1% significance level. Therefore, we reject the null hypothesis and conclude that the SUR approach performs. We run two models, one is a SUR model distinguishing different types of agricultural mechanization (M1) and the other model for the overall machination (M2). The estimation results reported in Table 3 are discussed below.

The Relationship between the labor endowment and agricultural mechanization: Hypothesis 1 suggests a negative relationship between agricultural mechanization and agricultural labor, which is confirmed by the estimation results. The estimated coefficient of agricultural labor is negative in both models, but only significant for those farmers who use their own machinery and for the aggregate agricultural mechanization. Furthermore, off-farm labor increases the adoption of the AMS and increase the overall agricultural mechanization significantly. It suggests that households with lesser agricultural labor are more likely to adopt agricultural mechanization, especially when the family members take off-farm jobs. In terms of labor quality, well-educated and healthy farmers have a higher chance to find non-farm jobs, which results in lesser agricultural labor. Such households are more likely to adopt machination. In addition, well-educated farmers may use machinery better and have less capital constraint in purchasing agricultural machinery. The estimated coefficients of the average year of schooling and the self-reported health condition in two models are positive, but not statistically significant.

Relationship between the land endowment and agricultural mechanization: Hypothesis 2 suggests a non-linear relationship between the land endowment and agricultural mechanization. We therefore incorporate the square term of the household land endowment in both models. The estimation results confirm Hypothesis 2. In the case of the AMS, land size has a positive and statistically significant relationship with the AMS ratio at the 1% level and the coefficient of the quadratic term is negative and statistically significant at the 1% level. The findings show an inverted U-shaped relationship between the land endowment and the AMS adoption. That is, at the smaller land size (in this case, up to 7.96 hectare), the AMS adoption goes up as agricultural land expands; but the AMS adoption declines with land expansion once agricultural land reaches a certain size (above 7.96 hectare). In the case of using own machinery for mechanization, the coefficient of land size is positive and statistically significant at the 1% level and the coefficient of the quadratic term is also positive but not statistically significant. The results show with the expanding of land size, the usage of own machinery will do not decline. The findings based on the SUR models show that large size farmer (the land size is more than 7.96 hectare) more likely to purchase own machinery instead of requesting AMS if controlling for everything else. Furthermore, we also find the inverse U-shaped relationship between the land endowment and the aggregated mechanization level and the effects are statistically significant at the 1% level. The turning point is 10.91 hectare, which is higher than the area of AMS's turning point(7.96 hectare).

Land fragmentation and the resulted small scale land operation are often cited as one main reason for the low level of mechanization in rural China. Some studies call for land transfer to expand the land scale and promote agricultural mechanization and modernization (Blarel, et al., 1992, Leng, 1996, Otsuka, 2013, Pingali, 2007, Rahman and Rahman, 2009, Van Hung, et al., 2007). Others argue that agricultural mechanization is still possible for the small-scale land operation. In particular, the AMS can not only help numerous small farms who do not own machinery to operate more efficiently, but also avoid the duplication of investment on agricultural machinery (Cao and Hu, 2010, Ji, 2010). We find that the coefficient of the number of cultivated land parcels is negative in the two models and statistically significant in the AMS equation and the aggregate mechanization equation after controlling for the total land input. The results show that land fragmentation has a negative effect on the adoption of agricultural mechanization, especially for the AMS and the overall mechanization level.

Effect of other control variables on agricultural mechanization: The coefficient of the AMS cost is negative in the AMS equation and positive in the using-own-machinery equation, which shows that the higher the AMS cost, the lower the AMS adoption and the greater usage of own machinery. The coefficient of machinery investment and whether a household being a AMS provider are negative and statistically significant at the 10% level in the AMS equation, while are positive and statistically significant at the 1% level in the using-own-machinery equation, which shows that the greater investment in machinery, the less they will use the AMS, but more likely use own machinery. The coefficient of non-farm wage is positive and statistically significant at the 1% level in the AMS equation but not statistically significant in the using-own-machinery equation. The results imply that a higher earning potential of non-farm jobs increases the AMS adoption, but provide no incentive to buy own machinery as using own machinery requires labor inputs. Overall, the non-farm earning potential increases agricultural mechanization as indicated in the overall mechanization index. The perceived economic position has no statistical effect on agricultural mechanization. We also find regional difference in agricultural mechanization. For example, farm households in Henan province prefer to invest in agricultural machinery and farm households in Hebei province prefer to adopt AMS.

5 Conclusions and policy implications

This study provides both theoretical framework and empirical analyses to examine a) the adoption of agricultural mechanization, using either self-equipped machinery or AMS; and b) the factors contributing to the adoption of different types of agricultural mechanization. We find that the agricultural labor endowment improves the adoption of agricultural mechanization, but off-farm labor curbs the adoption. In terms of the land endowment, we find an inverse U-shaped non-linear relationship between the land endowment and the mechanization adoption, but land fragmentation reduces the mechanization adoption.

This study provides several policy implications. First, agricultural mechanization is not just for big size farmers. Households who have a small land size and/or lack of agricultural labor can utilize the AMS. Thus, consolidation and transfer of land is not the only way to achieve agricultural mechanization although large land size potentially increases the efficiency of agricultural mechanization. Second, machinery investment plays an important role in mechanization. The financial subsidy policy that became effective in 2004 encourages farmers and cooperatives to purchase agricultural machinery. Such policy provides farmers financial incentives to improve mechanization for their own agricultural production and provide the AMS to other farmers.

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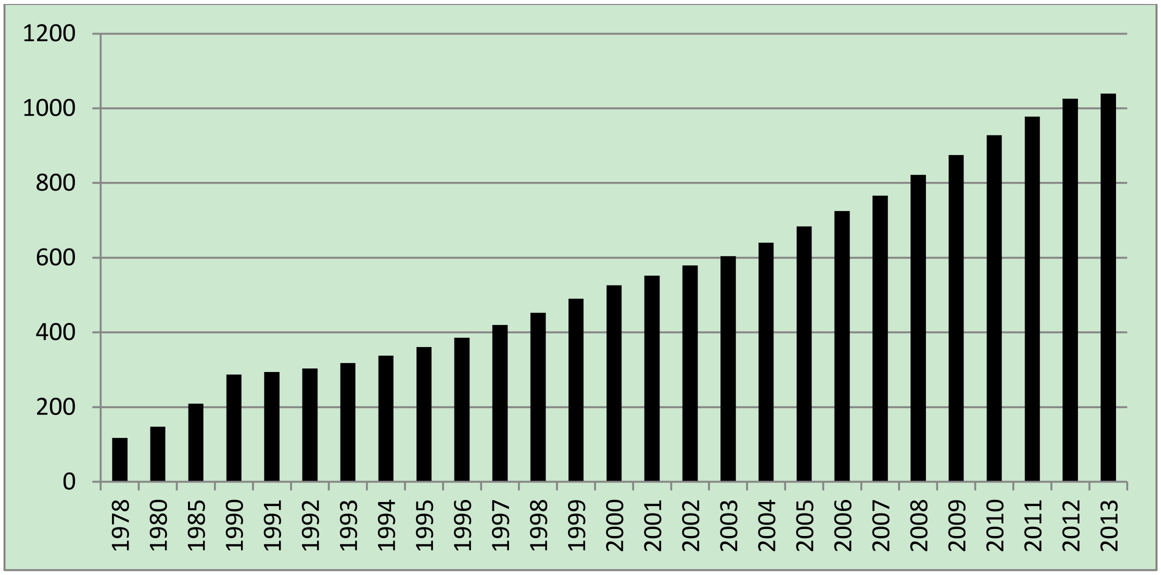

Figure1. Total power of agricultural machinery in China (million kW)

Data source: Data are from China Statistical Year Book 2013

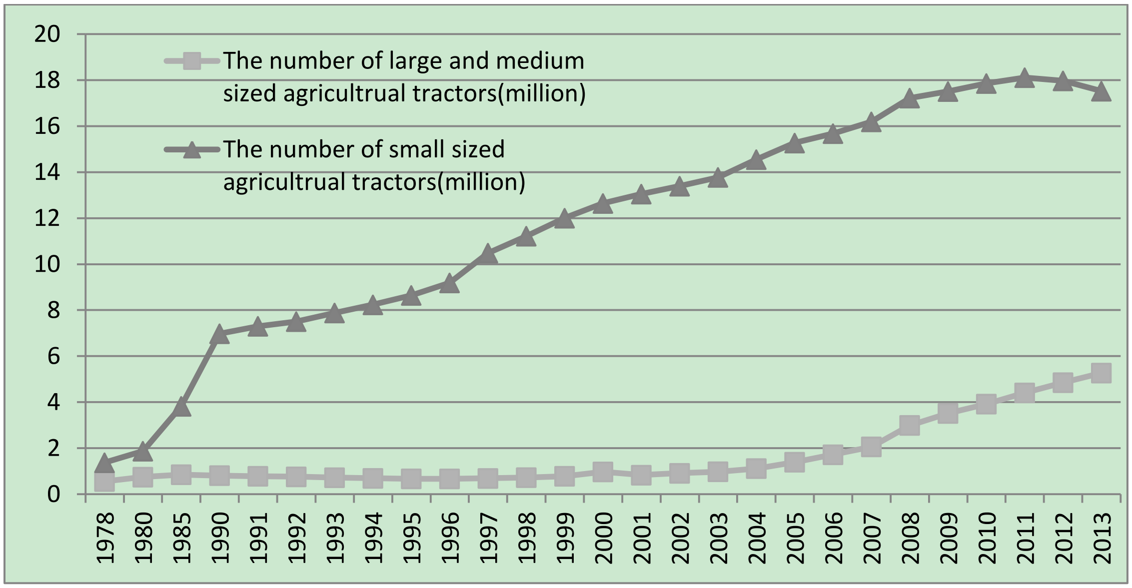

Figure2. The number of different types of tractors in China (1978-2013)

Data source: Data are from China Statistical Year Book 2013

Figure 3 Survey regions

Table 1. Descriptive statistics of variables

Type of Variables	Descriptions	Average	Std. Error.	Min	Max
Dependent Variables	Total agricultural mechanization rate	0.607	0.264	0	1
	The AMS adoption rate	0.568	0.276	0	1
	Mechanization rate by own machinery	0.042	0. 163	0	1
Independent Variables	The amount of labors working in agricultural production	1.52	1.01	0	5.83
	The amount of labors working in non-farm sector	2.04	1.37	0	7
	Average years of schooling of household labors (unit: Year)	7.714	2.902	0	20
	Health of household head (0= unhealthy; 1= healthy)	0.891	0.312	0	1
	Having family member critically ill or disabled (0= no; 1= yes)	0.0928	0.290	0	1
	Agricultural land inputs (hectare)	0.402	0.865	0.013	20.00
	Number of land parcels	2.684	1.789	1	15
Control Variables	AMS cost in per unit of land(10,000/mu)	0.014	0.005	0.001	0.048
	Investment in agricultural machinery (10,000 yuan)	0.246	1.505	0	17.2
	Whether a AMS provider	0.0325	0.178	0	1
	Non-farm annual wage (10,000 yuan)	2.709	1.646	0	12
	Perceived economic condition of the household (0=below average ;1= on or above average level)	0.720	0.449	0	1
	Ratio of non-farm annual income to the total household income	0.765	0.237	0	1
	Households in Henan province	0.290	0.454	0	1
	Households in Hebei province	0.313	0.464	0	1
	Households in Shandong province	0.397	0.490	0	1

Table 2. Descriptive statistics of variables

Variables	AMS only	Hand only	Own machinery only	AMS+ hand	AMS+ own machinery	Hand + own machinery	AMS+ own machinery+ hand
No. of Observations	123	8	9	440	10	9	15
Agricultural labor	1.75 (1.06)	2.04 (0.46)	1.14 (0.84)	1.46 (1.00)	1.55 （0.99）	1.01 (1.01)	1.76 (0.80)
Non-agricultural labor	2.32 (1.36)	1.97 (0.74)	1.93 (0.7)	1.98 (1.38)	1.4 （0.632）	1.71 (1.45)	2.27 (1.83)
Average years of schooling of household labors	8.49 (2.30)	8.70 (2.58)	9.58 （1.29）	7.39 (3.06)	8.29 （2.77）	8.59 (2.05)	8.27 (2.19)
Health of household head (1=Good health)	0.91 (0.29)	0.63 （0.52）	1 （0）	0.88 (0.32)	0.9 （0.31）	1 (0)	0.93 (0.26)
Having family member critically ill or disabled (1=Yes)	0.16 (0.37)	0.13 (0.35)	0 （0）	0.07 (0.26)	0.2 （0.42）	0 (0)	0.13 (0.35)
Agricultural land inputs	0.447 (0.612)	0.15 (0.16)	2.59 (6.53)	0.34 (0.21)	0.72 （0.55）	0.49 (0.28)	0.43 (0.21)
Number of land parcels	1.95 (1.5)	2.63 (2.26)	2.22 (1.30)	2.92 (1.89)	2.7 （1.49）	2.22 (0.97)	2.46 (1.55)
AMS cost in per unit of land (10,000yuan/mu)	0.014 (0.005)	0 (0)	0 (0)	0.014 (0.005)	0.016 （0.005）	0.015 (0.001)	0.014 (0.007)
Investment in agricultural machinery	0 (0)	0 (0)	6.02 (7.3)	0 (0)	1.70 （2.55）	2.84 (4.20)	1.75 (2.82)
Whether a AMS provider	0 (0)	0 (0)	0.56 (0.53)	0 (0)	0.3 （0.48）	0.44 (0.53)	0.33 (0.48)
Non-farm annual wage(10,000yuan)	2.56 (1.69)	2.29 (0.88)	1.64 (1.81)	2.80 (1.61)	2.21 （1.42）	2.82 (2.46)	2.40 (1.91)
Perceived economic condition of the household (1=Excellent)	0.75 (0.44)	0.38 (0.52)	1 (0)	0.71 (0.45)	0.7 (0.483)	0.89 (0.33)	0.67 (0.48)
Ratio of non-farm annual income to the total household income	0.77 (0.21)	0.89 (0.07)	0.643 (0.199)	0.77 (0.24)	0.7 (0.483)	0.66 (0.29)	0.64 (0.34)
Henan	0.47 (0.50)	0.63 (0.52)	0.89 (0.33)	0.20 (0.40)	0.5 (0.527)	0.56 (0.53)	0.53 (0.52)
Hebei	0.48 (0.50)	0 (0)	0 (0)	0.28 (0.45)	0.4 (0.515)	0.11 (0.33)	0.2 (0.414)

Tab.3 Results of the regression models

Variables	Seemingly unrelated regressions(M1)		Generalized least squares(M2)
	AMS	**Using Own Machinery**	**Total agricultural mechanization**
	Labor endowments(l)		
Farm labor	-0.0059	-0.015**	-0.021*
	(-0.51)	(-2.55)	(-1.89)
Off-farm labor	0.0248***	0.003	0.0261***
	(2.83)	(0.64)	(3.11)
Average years of schooling of household labors	0.0044	0.0009	0.00527
	(1.27)	(0.51)	(1.60)
Health of household head (1=Good health)	0.0310	0.0106	0.0394
	(1.02)	(0.70)	(1.35)
Having family member critically ill or disabled (1=Yes)	0.0198	-0.005	0.0160
	(0.59)	(-0.30)	(0.50)
	Land endowments(k)		
Agricultural land inputs	0.120***	0.0396**	0.168***
	(3.13)	(2.06)	(4.56)
Square term of Agricultural land inputs	-0.0075***	0.0002	-0.0077***
	(-3.75)	(0.25)	(-4.00)
Number of land parcels	-0.0175***	-0.0008	-0.0183***
	(-2.91)	(-0.26)	(-3.17)
	Mechanization (m)		
AMS cost in unit land	-1.9047	0.187	-2.065
	(-0.87)	(0.17)	(-0.98)
Investment in agricultural machinery	-0.0178*	0.0275***	0.0057
	(-1.79)	(5.52)	(0.59)
Whether a AMS provider	-0.311***	0.365***	0.0068
	(-3.66)	(8.58)	(0.08)
	Capital endowments(c)		
Non-farm annual wage	0.0013	0.0017	0.0028
	(0.20)	(0.50)	(0.44)
Perceived economic condition of the household (1=Excellent)	-0.0023	0.0537	-0.0034
	(-0.11)	(0.49)	(-0.16)
Ratio of non-farm annual income to the total household income	0.0268	-0.0639**	-0.0253
	(-0.48)	(-2.29)	(0.47)
	Geographic factor(g)		
Hebei	0.2464***	-0.0074***	0.235***
	(9.57)	(-0.58)	(9.54)
Henan	0.2119***	0.043	0.259***
	(7.99)	(3.24)	(10.20)
Constant	0.315***	0.0342	0.349***
	(4.95)	(1.07)	(5.72)
F(14, 599)			18.65
R-squared	0.317	0.506	0.333
Chi2	284.34（0.0000)	628.14(0.0000)	
Observations	614	614	614

Notes: * , ** and *** *denote the 10%,5% and 1% levels of significance, respectively. Figures in parentheses are standard deviation.*