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Machinery Investment Decision and Off-Farm Employment in Rural China

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Abstract: This paper investigates the linkages between farmers' machinery investment decision and off-farm employment in China. Both the theoretical model and the empirical results based on a survey of 453 households in Anhui Province indicate that agricultural labor input and small-size machinery investment are gross complements rather than substitutes when machinery service is available in the market. Consequently, farmers with small machinery are more likely to reduce their off-time employment time.

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Key Words: Small-size Machinery, Off-Farm Employment, Complements, China

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1. Introduction

Even though off-farm employment plays a critical role in many developing and transition economies on the one hand, and the studies find that 20-70 percent of the household income is from off-farm resources (Adams 2001; Benjamin 1992), the role of capital investment is critical for rural development and economic transition on the other hand. Some studies claim that capital constraint is a major determinant of adoption rate of new technologies (Mundlak 1993, 2000), and others believe capital accumulation is essential for development of rural communities (de Brauw 2003; Stark 1991; Liu & Wang 2005).

Furthermore, the current literature has pointed out that the linkages between off-farm labor markets and farms' capital investment has important policy implications. Labor market policy tends to spill over to farm sector via farmers' decision of labor and capital inputs, while agricultural policy affects both rural and urban labor markets (Ahituv and Kimhi 2002; Rosenzweig 1980). Ahituv and Kimhi (2002) find that off-farm labor supply and farm capital are negatively correlated in Israel and indicate that farmers' capital investments enhanced by heavily subsidized credit prevent them from seeking off-farm employment opportunities. Similarly, Lagerkvist et al (2007) find that farmers' capital accumulation has a negative impact on off-farm income share in Southwestern Minnesota.

The current literature mainly sheds light on the effect of off-farm work on farmer's capital (farm or nonfarm) accumulation decision (De Brauw et al. 2002;De Brauw and Rozelle 2008; Sh, Heerin, Qu, 2007). It is important to note that the capital markets are less complete in developing economies and off-farm income can finance capital accumulation when the agriculture household is subject to borrowing constraints (Reardon 1997; de Brauw et al. 2002).

A less concerned but perhaps more important issue is the impact of off-farm work on the demand of farm capital. Some studies suggest that labor and capital are complements in farm production, so that off-farm work opportunities (or the wage level) would reduce farm capital demand. Foltz and Aldana (2006) find that wages driven by local economic conditions indeed reduce investment in cows for Wisconsin dairy farmers. However, other researchers presume farm labor and farm capital are substitutes, then the relationship becomes complicated: the substitution effect of inputs in farm production results in a positive correlation between off-farm employment and capital accumulation, while the expansion effect which denotes that a decrease in agricultural output due to less labor input leads to less demand for capital could cause a negative correlation. Kada (1991) finds that the substitution effect plays a major role for Japanese rice farms as farm labor and capital are negatively associated. Interestingly, even though Ahituv and Kimhi (2002) and Liu et al (2002) similarly find that off-farm employment and farm capital are negatively correlated, they explain it the expansion effect.

In farm production, certain types of capital (e.g. dairy cows) are complements to labor, while others (e.g. tractor) are substitutes for labor. Therefore, we should pay attention to the differences in the relationship between capitals and off-farm employment for different types of capital in the analysis.

This study will specifically shed light on the relationship between machinery and off-famer employment. There are three reasons: First, machinery investment is the largest part of farm investment in Chinese crop production and it is important for technical progress in agricultural production (Liu and Wang, 2005); Second, machinery and labor are obvious substitutes in farm production, and the relationship between off-farm employment and machinery investment is hence ambiguous as aforementioned and thus it needs an empirical analysis for clarification; Third, Chinese government started to subsidize agricultural machinery from 2004 and the subsidy has increased to 13.0 billion *yuan* in 2009, so that this study focusing on farmers' joint decision of off-farm work and machinery investment can help assess the impact of machinery-subsidy policies on labor market .

Even though a few studies have studied the impact of off-farm employment on machinery investment, the other side of the picture---the feedback of machinery on off-farm employment, has not been well studied. Obviously, the decisions of off-farm employment and machinery investment are possibly simultaneously made and they are endogenous. For instance, Zhao (2002) divided labors into non-migrants, migrants and returnees, and she finds that in rural China the numbers of non-migrants and returnees increase farm machinery investment significantly while the number of migrants has no significant influence. Even though the result implies that off-farm employment could reduce farm machinery investment, her model did not control other important variables and the endogenous problem is not tackled.

A common shortcoming of agricultural household investment models in the current literature is that the capital service market is neglected and the investment behavior is looked as the same as production input behavior. However, we cannot deny the fact that the capital service market does exist especially for agriculture machinery. The fact in China is that most rural households buy some or all of the machinery service from market, similar in other countries where the scale of farm is small.

When the market service is available, the relationship between off-farm employment and machinery investment becomes even more complicated. On the one hand, off-farm employment influences machinery investment through three channels. First, off-farm employment influences machinery service demand in agricultural production. Usually, more services used in production, more likely the agriculture household invests in small self-used machinery. Second, off-farm employment opportunity increases the opportunity labor costs of machinery-operating work for farmers, which makes households more likely to purchase the market services. Third, off-farm income relaxes the budget constraints and helps the household purchase machinery. On the other hand, the machinery also impact off-farm employment decisions. When an agriculture household maintains agricultural machinery, it implies that her/his shadow cost of machinery service should be lower than the market price, which would influence both farm and off-farm labor supply. In addition, the tractor-operating work would also reduce off-farm labor supply.

The primary goal of our paper is to examine the simultaneous decision of off-farm employment and t agricultural machinery investments when there is a machinery service market for agriculture households in China. To meet this goal, we have three specific objectives. First, we introduce the development of agricultural machinery service market in China and farmers' choice between purchasing machinery and purchasing the market services. Second, we develop a theoretical model that illustrates farmers' the endogenous linkages between off-farm employment and machinery investment. Third, we empirically test the above-mentioned relationship using a structural econometric model to identify the endogeneity issues. The data for our study are collected from a face-to-face farmer survey in Anhui Province of China.

2. Investment in Small machinery or Purchasing Market Services

(1) The development of agricultural machinery service market in China

Prior to 1980, China adopted a central-planned economy system, and the investment decision of agricultural machinery was controlled by the governments. Specifically, the agricultural machinery stations owned by the state or the collectives monopolistically provided machinery services for agriculture production at planned price. A large production collective were more likely to have large-size machinery. In fact, it was the incorrect perception that large-size machinery cannot be divided and there was a scale economy in agriculture production induced the adoption of the collective economy, name people's commune in China. For instance, agricultural mechanization had been used as one of the rationales for the collective campaign in the 1950s (Lin, 1990). Until the end of 1978, the capacity of large- and medium-sized[1] agricultural tractors was 17.55 million kilowatts, which is about 1.5 times of the capacity of small tractors.

After 1978, the collectively-owned land was allocated to rural households and farmers still could obtain machinery services the agricultural machinery stations at first. Later, the agricultural machinery stations also introduced the sub-contract

[1] In Chinese statics, large- and medium-size tractors refer to a tractor with capacity more than 14.7 kilowatts. The small tractors are the ones with capacity between 2.2 and 14.7 kilowatts.

system in order to improve the economic efficiency, and the machinery were allocated to those selected farmers who provided services at the contracted fees (Feder et al 1992). With increase in accumulation, farmers started to purchase a large number of small and general machinery for own-use or joint-use. The machinery service market characterized by large- and medium-size machinery began to be stagnant or even shrink. From 1978 to 1988, the capacity of large- and medium-sized agricultural tractors increased by 65%, while the small tractors increased by 354%. Furthermore, from 1988 to 1995, large- and medium-sized agricultural tractors even shrunk by 17%, while the small tractors grew by 47.5%.

However, after the middle of 1990s, the development of agricultural machinery in China turned back to an era of specialization and being market-oriented. In this period, the markets of machinery service in the whole nation began to be integrating. For instance, the market services of plowing, sowing and rice harvesting are no longer confined in a province. Hence, the large- and medium-size agricultural tractors began to grow again, and its growth rate has been higher than small tractors since 1999. Then the subsidy policies for large- and medium-size agricultural machinery launched in 2004 further stimulate the purchase of large- and medium-sized tractors.

Even though there are some regional differences in the agricultural machinery service markets in China, the status quo of the owner structure of agricultural machinery are very divergent, which is quite similar within most provinces. Some farmers own small agricultural machinery (or draft animals) for the purpose of own-use, while others do not retain any machinery at all and they purchase machinery services from markets provided by owners of large- and medium-size machinery.[2]

(2) Data Description

The data used in this paper were collected from Anhui Province of China in June and July 2009 by face-to-face interviews. Anhui is one of the largest producers of grain crops and one of the largest off-farm labor suppliers in China, which makes this

[2] In 2009 per hundred Chinese rural households owe 3.37large- and medium-sized tractors, 19.39 small tractors and 25.39 draught animals. And per hundred Anhui rural households owe 4.85 large and medium-sized tractors, 39.73 small tractors and 5.61 draught animals (China national statistical bureau, 2009).

study very representative for the relationship between off-farm employment and agricultural machinery investment. The sample includes 453 agriculture households randomly selected from 24 villages in 8 towns scattered in 4 counties. Two of the counties (Mengcheng County and Lixin County) are in Huaibei Plain where there are two cropping seasons in a year, namely wheat in spring and soybean or corn in autumn. Other two counties (Changfeng county and Feixi county) are located in the Jianghuai mountainous region with plenty of precipitation where there are two or three cropping seasons per year, and the main crops include rice, wheat, rapeseed, and cotton. The survey collected detailed information on households' off-farm activities, agricultural production, possession and use of machinery in the past year (namely, from July 2008 to June 2009).

Almost every household in the sample uses certain kinds of machinery services in their farm production, such as plowing, sowing, non-till planting, harvesting, threshing, and spraying of pesticides. In the 453 surveyed households, 191 do not have any agricultural machinery, accounting for 42.2%; 247 have certain kinds of agricultural machinery for own-use most of which are small tractors for towing and plowing, seeders and transport equipments. Households who do not have these kinds of machinery can purchase the services from market. While other kinds of machinery service such as harvesting, ditching, non-till planting, corn threshing are mainly provided by markets, because these services generally require large- and medium-size machinery, and the households with small tractors generally do not purchase these equipments. Totally, there are 15 households in the sample who provide machinery services for others, accounting for 3.3%.

Our survey also shows agricultural households in Anhui province are extensively involved in off-farm activities. Average off-employment time per laborer is 5.44 months. Comparing to the households without agricultural machinery, more laborers are found in the households with agricultural machinery, and they conduct less off-farm employment. It indicates a positive correlation between farm machinery and farm laboring, or equivalently a negative correlation between farm machinery and off-farm laboring.

3. Theoretical model

Theoretically, agriculture households have three options to obtain machinery services: purchasing the machinery, renting the machinery or buying the machinery service. However, the second option is very rare, so that it can be neglected. We also ignore some of the agriculture households who purchase the large- and medium-size machinery to do business. We will only focus on agriculture households' choice between purchasing machinery for own-use and purchasing the market services.

Assume there is only one particular type of small-size machinery for own-use, and its price is q. It will generate $\overline{K}$ units of service if fully used. Most Chinese agriculture households only cultivate a very small piece of land and a small-size machinery can satisfy their needs, so that we presume agriculture households only need to buy one machine. Further assume the interest rate is r, the nature depreciation rate is δ, and the fixed cost of maintaining the machinery is $q(r+\delta)$. If a farmer does not retain machinery, s/he can buy machinery services from the market by the price p_k.

When a farmer does not retain machinery, we assume that s/he maximizes its total income by purchasing machinery service and allocating a fixed labor endowment ($\overline{L}$) between farm and off-farm activities. Farm production function is as follow:

$$y = f(l, k, \overline{n})$$

where l, k, and $\overline{n}$ are farm labor input, machinery service input, and land endowment. The objective function of the household is thus written as:

$$\max_{(l\geq 0, k\geq 0)} I_0 \quad I_0 = pf(l, k, \overline{n}) - p_k k + w(\overline{L} - l) \qquad (1)$$

where p is the price vector of agricultural products, p_k is the price of machinery service, w is the wage rate of off-farm activities, and $\overline{L}-l$ is the off-farm work time.

Objective function (1) equals:

$$I_0 = \pi + w\overline{L} \qquad (2)$$

where $\pi = pf(l,k,\overline{n}) - wl - p_k k$ is r farm profit, and $w\overline{L}$ stands for the value of labor endowment.

So the income maximization problem is transformed into a profit maximization problem. Assume that production function is well-behaved (the first derivative is positive, and the second derivative is negative) and there are interior solutions. The first order conditions are:

$pf_l = w$, and $pf_k = p_k$.

And the solutions for l and k are:

$$l_0^* = l(p, p_k, w, \overline{n}) \qquad \text{(Farm labor demand function)} \qquad (3)$$

$$k_0^* = k(p, p_k, w, \overline{n}) \qquad \text{(Machinery service demand function)} \qquad (4)$$

As we know, labor inputs and machinery service are normally gross substitute in production. So for equation (4) we can reasonably assume that $\partial k(p, p_k, w, \overline{n}) / \partial w > 0$

The off-farm labor supply will be:

$$l_{n0}^* = \overline{L} - l_0^*$$

And we can obtain the maximum profit and income:

$$\pi_0^* = \pi(p, p_k, w, \overline{n}), \text{ and } I_0^* = \pi_0^* + w\overline{L} \qquad (5)$$

When an agriculture household retains agricultural machinery and produce machinery service for herself/himself, we assume that s/he maximizes the total income by allocating the labor endowment among farm work, machinery-operating work and off-farm work. For the sake of simplicity, we further assume that the machinery service production function has the Leontief form: to provide 1 unit of machinery service needs $1/a$ units of operating-labor (l_o) and c units of other variable inputs represented by v, such as fuel and lubricants to run the machinery. That is,

$$l_o = k/a \,; v = ck$$

The objective function of the household is thus rewritten as:

$$\max_{(l\geq 0,\bar{K}\geq k\geq 0)} I_1 \quad I_1 = pf(l,k,\bar{n}) - p_v v + w(\bar{L} - l - l_0) - q(r+\delta)$$
$$= pf(l,k,\bar{n}) - p_v ck + w(\bar{L} - l - k/a) - q(r+\delta)$$
$$= pf(l,k,\bar{n}) - (p_v c + w/a)k - wl + w\bar{L} - q(r+\delta)$$
$$= \pi + w\bar{L} - q(r+\delta) \tag{6}$$

where p_v is the price vector of variable inputs in machinery service production, $\pi = pf(l,k,\bar{n}) - (p_v c + w/a)k - wl$ is the farm profit.

We can solve equation (6) by the same way in equation (2) and obtain following results,

$l_1^* = l(p, p_v c + w/a, w, \bar{n})$; $k_1^* = k(p, p_v c + w/a, w, \bar{n})$; $l_{n1}^* = \bar{L} - l_1^* - k_1^*$

$p_1^* = p(p, p_v c + w/a, w, \bar{n})$; $I_1^* = \pi_1^* + w\bar{L} - q(r+\delta)$

If retaining machinery results in higher total income, that is $I_1^* - I_0^* \geq 0$, the agriculture household would buy the machinery, and vice verse.

$$I_1^* - I_0^* = \pi(p, p_v c + w/a, w, \bar{n}) - \pi(p, p_k, w, \bar{n}) - q(r+\delta) \tag{7}$$

The first-order Taylor expansion approximation shows:

$$\pi(p, p_v c + w/a, w, \bar{n}) \approx \pi(p, p_k, w, \bar{n}) + \frac{\partial \pi(p, p_k, w, \bar{n})}{\partial p_k}(p_k - p_v c - w/a) \tag{8}$$

According to Hotelling Lemma, $\frac{\partial \pi^*}{\partial p_k} = -k^*$, thus equation (8) can be written as:

$$\pi(p, p_v c + w/a, w, \bar{n}) \approx \pi(p, p_k, w, \bar{n}) - k(p, p_k, w, \bar{n})(p_v c + w/a - p_k) \tag{9}$$

Substituting equation (9) into equation (7), we obtain:

$$I_1^* - I_0^* = k(p, p_k, w, \bar{n}) * (p_k - p_v c - w/a) - q(r+\delta) \tag{10}$$

So that $I_1^* - I_0^* \geq 0$ equals to

$$p_k \geq p_v c + w/a + \frac{q(r+\delta)}{k^*(p, p_k, w, \bar{n})} \tag{11}$$

where $p_v c + w/a + \frac{q(r+\delta)}{k^*(p, p_k, w, \bar{n})}$ is the opportunity costs of own-provided machinery service, including running and operating costs $p_v c + w/a$ and maintaining costs $\frac{q(r+\delta)}{k^*(p, p_k, w, \bar{n})}$.

In equation (11), the farm machinery investment decisions can be approximately stated as: when the average costs of own-service is lower than the market price the household will invest machinery, and vice verse.

Let's focus on the effect of off-farm employment wage on farm machinery investment. First, as the off-farm employment wage increases the labor costs of machinery-operating will increase too, but the average maintaining costs $\frac{q(r+\delta)}{k^*(p, p_k, w, \bar{n})}$ will decrease because of the gross substitute effect $\partial k(p, p_k, w, \bar{n}) / \partial w > 0$. The overall effect depends on the gross substitute effect between labor and machinery service, and we will specifically examine it in the following empirical analysis for China. Second, if the agriculture household is subject to borrowing constraints, the off-farm income can finance machinery by lowering financial costs, so do the maintaining costs.

Finally, the impact of retaining machinery on off-farm employment time can be given as,

$$\begin{aligned} \Delta l_n = l_{n1}^* - l_{n0}^* = l_0^* - l_1^* - k_1^* / a = l(p, p_k, w, \bar{n}) - l(p, p_v c + w/a, w, \bar{n}) \\ - k(p, p_v c + w/a, w, \bar{n}) / a \end{aligned} \quad (12)$$

The mechanisms between purchasing own-use machinery and purchasing machinery services from the market are totally different. The decision depends on the costs structures: the former includes machinery running and operation costs, and the later is determined by market prices. Nevertheless, the input substitution effect would increase and the expansion effect would decrease the labor input in farm production. Moreover, the machinery operating work will reduce the off-farm labor supply.

In the following part we will test the specific relationship between them using the survey data from China.

4. Empirical methods

4.1 Empirical models

The theoretical model shows that time allocation between farm activity and off-farm employment and machinery investments are interrelated, and the sign of the relation is ambiguous. We use the following simultaneous equations to estimate the linkages between off-farm employment and farm machinery investment:

$$y_{1i} = a_1 y_{2i} + \boldsymbol{\beta}_1 \mathbf{x}_{1i} + \varepsilon_{1i} \quad \text{(off-farm employment equation)}$$
$$y_{2i} = a_2 y_{1i} + \boldsymbol{\beta}_2 \mathbf{x}_{2i} + \varepsilon_{2i} \quad \text{(farm machinery investment equation)}$$

where y_{1i}, and y_{2i} respectively denote off-farm employment time and the possession of machinery (1=possession of machinery , 0=otherwise). $\mathbf{x}_{1i}$ and $\mathbf{x}_{2i}$ are vectors of exogenous variables. ε_{1i} and ε_{2i} are random disturbances, following normal distributions with means of zero.

Because not every agriculture household is involved in off-farm activity, a censoring issue underlies the empirical model, so that a tobit model with endogenous variables is recommended in the off-farm work equation. While for the farm machinery investment equation, a probit model with endogenous variables is applied. As there are endogenous variables in those two models, we analyze the data using instrumental variables (IV) approaches.

4.2 Variables

According to the theoretical model, the explanatory variables in the equations are land endowments, labor endowments and the prices. For the cross-sectional data, the prices are usually constants, and therefore can not be put into the empirical models. The off-farm unemployment wage or opportunity cost is not constant for different agriculture households, and is assumed to be determined by human capital and local economic conditions. The price of machinery services in different villages is also not identical. Take the wheat/rice combine harvesting as an example, the lowest price is 40 *yuan/mu* and the highest price is 80 *yuan/mu*. This can be looked as “the price of pure machinery service (eg, measured by machinery running time) which however is the equal within the village because of the competition among providers, even though the costs of the services might be different due to the heterogeneities of topography, soil conditions, field roads conditions, the concentration of agriculture, and the fragmentation of land. The difference in market service price in different villages mainly reflects the utilization efficiency of large- and medium-sized machinery. The utilization efficiency of the more flexible small-size machinery is less affected by those conditions. Therefore the higher the market price is the more likely a household retains small machinery.

Based on the above analysis, the independent variables used in the off-farm work time (ofwt) model mainly include farm machinery, land endowment, labor force, average age of labor force, average schooling of labor force, and the local off-farm employment opportunities (represented by off-farm employment time, male wage, and female labors in other families of the village and local non-farm work time, male wage of male, and female labors in other families of the village). Particularly, the variables of employment opportunities can be looked as instrumental variables in machinery investment.

The independent variables used in farm machinery investment (fm) model include off-farm work time, labor force, land endowment, and market price of machinery service. The farm machinery is mainly driven by household head and young male labors, so the characteristics of household head and the share of young male laborers are also included in the investment model which can be looked as the instruments in off-farm employment. The wealth of household both can help laborers to conduct non-farm business and can facilitate household to buy farm machinery, so that we will put this variable into both two equations. In light of this, both of the behavior equations can be identified in econometric analysis.

5. Results and discussion

5.1 Off-farm work equation

Following Smith and Blundell (1986) and Wooldridge (2002, pp531) we estimate the off-farm work time model using the maximum likelihood (Tobit model) and IV approaches. The results are reported in Table 3. The instrumental variables are the exogenous variables in Table 2. And a Wald test rejects the assumption that agricultural machinery is exogenous at the 10% level.

The variable of special interest in this equation is the farm machinery. The estimated coefficient for it is -12.94 and statistically significant at 1%. This suggests that an agriculture household that retains farm machinery is less involved in the off-farm activities. This is an interesting result. The common wise tells us the farm machinery can substitute labor input in farm production and therefore increase non-farm labor supply. But this is not always true especially when the market machinery service is available. As labor and machinery are complements in machinery service production, the agriculture household producing the machinery service for herself or himself supplies less off-farm labor.

As can be seen from Table 3, the number of laborers and laborers' average age are important factors determining the off-farm labor supply. The number of laborers has positive effect on off-farm labor supply, and this is because labor surplus in farm production is a main motivation for off-farm employment. The average age of laborers is negatively associated with off-farm work, because the younger labor is more likely to be involved in off-farm activities. The schooling of laborers has a positive effect on off-farm employment, but the effect is not statistically significant. The fact that most of the rural laborers are not well educated and can only find the low-skilled manual job may be a reason. The results also indicate that other variables such as land size and asset value, are not important for off-farm employment.

5.2 Farm machinery investment equation

We estimate the farm machinery investment model following the method suggested by Rivers and Vuong (1988) and Wooldridge (2003, pp.473-475). The estimation results are reported in Table 4. A Wald test shows that off-farm work time is an endogenous variable, so that the IV approaches are appropriate.

Here we focus on the impact of off-farm employment on the possession of machinery. The number of laborers has a significantly positive effect on machinery investment and the off-farm work has a significantly negative impact on machinery investment. Our findings are consistent with the results by Zhao (2002) for the relationship between migration and farm machinery investment, as well as with the results by Ahituv et al (2002) and Liu et al (2002) for the relationship between off-farm work and total farm investment.

When we replace the dependent variable with the machinery service input in farm production we find opposite results. It indicates that the input substitute effect plays a major role, as farm labor and machinery service are negatively associated. Therefore, the negative impact of off-farm employment on farm machinery investment is not due to the expansion effect as other researchers suggested. It is caused by the machinery service market. The agriculture household prefers the market machinery service to investing in the farm machinery when the labors are involved in off-farm activities.

The sign of other variables are in line with the theoretical expectation. Land has a positive effect on farm machinery investment, but the effect is not statistically significant. The effect of machinery service market price is positive and highly significant. This indicates that an agriculture household will be more likely to retain farm machinery when the service price is high. Wealth level has a positive and statistically significant effect due to the effect of affordability. The share of young male laborers has a positive effect and the age of household head has a negative effect. These are because it needs strong muscles to operate a tractor and to handle the tractor towing machinery in rural China. Therefore when a household lacks this kind of labor forces, it will be more likely to purchase the market service.

6. Conclusions and policy implications

This paper examines the joint decisions of China rural household to work off-farm and/or to invest farm machinery. The theoretical analysis shows that when the market service is available the relationship between off-farm work and farm machinery investment are more complicated. The empirical study reveals the interaction between them. At the household level, farm machinery (particularly small size machinery) and farm labor are gross complements. On the one hand retaining farm machinery is more likely to reduce off-farm labor supply, and on the other hand participation in off-farm activities reduces the possibility of investing in farm machinery.

The results in this paper have strong implications for China's farm machinery subsidy policy. As the farm machinery has negative effect on off-farm labor supply, if the subsidy policy aims at the small own-use machinery it may encourage more agriculture households to purchase small machinery and hence reduces off-farm labor supply. While if the subsidy policy aims at the large-size machinery it may reduce the market price of machinery service and encourage agricultural households to purchase more market services instead of investing in small-size machinery, and this will eventually promote off-farm labor supply.

After the reform, Chinese agriculture households once increased the demand for small own-use machinery. As off-farm employment opportunities now start to absorb a large number of young and male laborers, the agricultural laborers in China tends to be aging and feminine as in some advanced economies, such as Japan, the demand for market machinery services has began to increase. Reaction to the changing demand, the machinery policy should support large- and medium-size machinery which could lower the market price of machinery services. Such a policy could also increase the supply of off-farm laborers from rural areas in China. .

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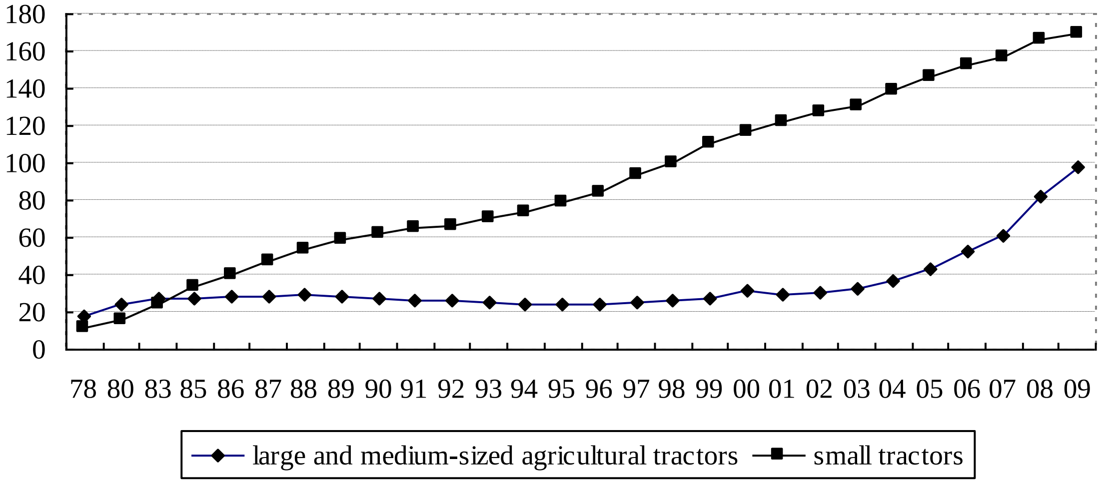

Figure 1: The capacity of different types of tractors after 1978 (million kw)

Source: China national statistical bureau, the large and medium-sized agricultural tractors does not include deformation tractors since 2001.

Table 1: The relationship between farm machinery, labor and off-farm work

	All households	Households without farm machinery	Households with farm machinery
Number of households	453	191	262
Laborers per household	2.88	2.65	3.04
off-farm employment months per laborer	5.44	5.49	5.41

Source: Authors' survey

Table 2: Definition and descriptive statistics of variables in models

Models			
Tobit(ofwt)=f(fm, land, labors, meanage, meanedu, assets, mmt, fmt, mlt, flt, mmw, fmw, mlw, flw) probit(fm)=f(fm, land, labors, ymls, msp, asset, headage, headedu)			
Variable	Definition	Mean	Standard Deviation
ofwt	Off-farm work time last year (month)	15.661	13.470
fm	Maintaining farm machinery or not (1=yes, 0=no)	0.578	0.494
land	Size of cultivated land（mu）	9.363	9.776
labors	Number of laborers, a laborer is the one I with more than 16 years old and takes a farm or off-farm job	2.876	1.256
meanage	Average age of labors (year)	43.896	11.084
meanedu	Average schooling of labors (year)	6.037	3.025
assets	The value of machinery, house, enterprises, and other fix assets (thousand yuan)	81.001	249.535
mmt	Off-farm employment time of male laborers for other households of the village (months)	5.036	1.271
fmt	Off-farm employment time of female laborers forother households of the village (months)	4.372	1.404
mlt	Local off-farm employment time of male labors for other households of the village (hours)	79.585	32.806
flt	Local off-farm employment time of female labors for other households of the village (hours)	47.131	38.691
mmw	Off-farm employment wage of male laborers for other households of the village (yuan/ month)	1438.973	283.076
fmw	Off-farm employment wage of female labors for other households of the village (yuan/ month)	1075.368	138.190
mlw	Local off-farm employment wage of male laborers for other households of the village (yuan/ hour)	7.338	5.089
flw	Local off-farm employment wage of female labors for other households of the village (yuan/hour)	5.347	2.361
ymls	Percentage of male laborers younger than age 60 (%)	45.164	24.366
pm	Market price of machinery service, represented by the rice/ wheat combine harvesting price (yuan/ mu)	53.107	12.727
headage	Age of household head (year)	51.617	11.547
headedu	Schooling of household head (year)	5.525	4.075

Source: authors' survey

Table 3: Maximum likelihood estimates (Tobit) of off-farm work time equation

	Coefficient	Standard error	z-value	p-value
constant	3.2016	9.5815	0.33	0.7380
fm	-12.9434**	5.4896	-2.36	0.0180
labors	8.2312***	0.4091	20.12	0.0000
meanage	-0.5050***	0.0853	-5.92	0.0000
meanedu	0.1705	0.1928	0.88	0.3770
land	0.0559	0.0685	0.82	0.4140
assets	0.0009***	0.0020	4.65	0.0000
mmt	0.9368	0.7615	1.23	0.2190
fmt	-1.2084	0.8388	-1.44	0.1500
mlt	0.0189	0.0302	0.63	0.5320
flt	0.0227	0.0342	0.67	0.5060
mmw	-0.0034	0.0034	-1.01	0.3140
fmw	0.0130***	0.0047	2.78	0.0060
mlw	0.1847	0.1164	1.59	0.1120
flw	0.3940	0.2715	1.45	0.1470
/alpha	10.0877*	5.6771	1.78	0.0760
/lns	2.1447***	0.0379	56.6	0.0000
/lnv	-0.8909***	0.0335	-26.61	0.0000
s	8.5397	0.3236		
v	0.4103	0.0137		
Wald chi2(14) =708.25***				
Wald test of exogeneity: chi2(1) =3.16*				
Number of obs=453				

Notes: *, **,and ***denote 10%，5%， and 1% significance levels respectively.

Table 4 Estimation Results for machinery investment equation and machinery service input equation

	Probit model for machinery investment equation		OLS model for machinery service input equation	
	Coefficient	Standard error	Coefficient	Standard error
constant	-1.7712***	0.4913	22.2599***	4.6775
ofwt	-0.1099***	0.0158	0.1871***	0.0676
labors	1.0287***	0.1184	-2.1103***	0.7173
ymls	0.8949***	0.2697	0.1438	2.5550
land	0.0101	0.0072	3.5695***	0.0572
pm	0.0161***	0.0053	-0.4235***	0.0429
assets	0.0002***	0.0001	0.0000	0.0000
headage	-0.0186***	0.0071	-0.0616	0.0563
headedu	0.0250	0.0159	0.0750	0.1433
/lnsigma	2.0328***	0.0356		
/athrho	0.9500***	0.3342		
sigma	7.6351	0.2717		
rho	0.7398	0.1513		
	Wald chi2(8) =267. 74***		R-squared= 0.9059	
	Wald test of exogeneity: chi2(1) =8.08**		F(8, 444) = 534.31***	
	Number of obs=453			

Notes: *, **,and *** denote 10%， 5%， and 1% significance levels respectively.