Machinery Investment Decision and Off-Farm Employment in Rural China

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Abstract: This paper investigates the endogenous 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-sized machinery investment are gross complements rather than substitutes when machinery services are available in the market. Consequently, farmers with small-sized machinery are more likely to reduce their off-farm employment time. On the other hand, an increase in off-farm employment is more likely to reduce the possibility of possessing small-sized machineries mainly due to substitution effects of market machinery services.

JEL : Q12
Key Words: Small-size Machinery, Off-Farm Employment, Complements, China

1. Introduction

Off-farm employment plays a critical role in many developing and transition economies. Studies find that 20-70 percent of the household income is from off-farm sources (Adams 2001; Benjamin 1992; De Brauw et al. 2002; De Brauw and Rozelle 2008; Wang, Herzfeld and Glauben 2007; Yu and Zhao 2009). However, the role of capital investment is also critical for rural development and economic transition. Some studies claim that capital constraints are a major determinant of the adoption rate of new technologies (Mundlak 1993; Larson et al. 2000), and others believe that capital accumulation is essential for the development of rural communities (De Brauw and Rozelle 2008; Stark 1991; Liu and Wang 2005).

Furthermore, the current literature has pointed out that the linkages between off-farm labor markets and farms' capital investments have important policy implications. Labor market policy tends to spill over to the farm sector via farmers' decisions regarding 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 the off-farm income share in Southwestern Minnesota.

The current literature mainly sheds light on the effect of off-farm work on farmers' (farm or nonfarm) capital accumulation decisions (De Brauw et al. 2002; De Brauw and Rozelle 2008; Shi, Heerin and 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; De Brauw and Rozelle 2008).

A less concerned but perhaps more important issue is the impact of off-farm work on the demand for 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. Wang, Herzfeld and Glauben (2007) indicate that the accumulation of productive assets and the development of livestock production have reducing effects on the off-farm labor supply of households in rural China. Foltz and Aldana (2006) find that wages driven by local economic conditions indeed reduce investments in cows of Wisconsin dairy farmers. However, other researchers presume that farm labor and farm capital are substitutes, which would make the relationship 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. The aggregate effect depends on the relative sizes and signs of the two individual effects. Kada (1991) finds that the substitution effect plays a major role in the case of 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 by the expansion effect.

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

This study will specifically shed light on the relationship between machinery and off-famer employment. There are three reasons for this: 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, the Chinese government started to subsidize agricultural machinery in 2004 and has increased the subsidy to 13.0 billion *yuan* in 2009, so that this study focusing on farmers' joint decision of off-farm employment and machinery investment can help to calibrate the effect of machinery subsidies on the labor market.

Even though a few studies have analyzed the impact of off-farm employment on machinery investment, the other side of the picture, that is to say the feedback of machinery on off-farm employment, has not been well studied. Possibly, the decisions regarding off-farm employment and machinery investment are even made simultaneously, thus causing endogeneity. For instance, Zhao (2002) divided laborers into non-migrants, migrants and

returnees, and found that in rural China the numbers of non-migrants and returnees have a significant marginal effect on machinery investment, while the number of migrants has no significant influence. Even though these results imply that off-farm employment could reduce farm machinery investment, the applied model did not control for other important variables and the endogeneity problem has not been dealt with.

A common shortcoming of agricultural household investment models in the current literature is that the capital services market is neglected and that the investment behavior is regarded to be the same as the production input behavior. However, we cannot deny the fact that the capital services market does exist, especially for agricultural machinery. Indeed, most rural households in China buy some or all of their machinery services from the market. Similar situations can be found in other countries where the average scale of farms is small.

When market services are 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 the demand for machinery service in agricultural production. Usually, the more services are used in production, the more likely the agriculture household is to invest in small self-used machinery. Second, off-farm employment opportunities increase the opportunity costs of laborers operating farm machinery, which makes households more likely to purchase market services. Third, off-farm income relaxes the budget constraints and helps the household to purchase machinery. On the other hand, machinery also impacts off-farm employment decisions. When an agricultural household maintains agricultural machinery, this implies that its shadow costs of machinery services should be lower than the market price,

which would influence both farm and off-farm labor supply. In addition, when more laborers operate tractors, it would also reduce off-farm labor supply.

The primary goal of our paper is to examine the simultaneous decision regarding off-farm employment and agricultural machinery investments in the presence of a machinery services market available to agricultural households in China. To meet this goal, we have three specific objectives. First, we introduce the development of the agricultural machinery services market in China and the farmers' choice between purchasing machinery and purchasing market services. Second, we develop a theoretical model that illustrates farmers' endogenous linkages between off-farm employment and machinery investments. Third, we empirically test the above-mentioned relationship using a structural econometric model to identify the endogeneity issues. The data used for our study come from a face-to-face farmer survey in China's Anhui province.

2. Background and Data Description

(1) The development of the agricultural machinery services market in China

Prior to 1980, China was characterized by a centrally planned economic system and the investment decisions regarding agricultural machinery were controlled by the governments. Specifically, the agricultural machinery stations owned by the state or the collectives monopolistically provided machinery services for agricultural production at a planned price. A large production collective was more likely to have large-size machinery. In fact, it was an incorrect perception that large-size machinery cannot be divided and there was a scale economy in agricultural production induced by the adoption of the collective economy,

namely the people's communes in China. For instance, agricultural mechanization had been used as one of the slogans for the collective campaign in the 1950s (Lin, 1990). At the end of 1978, the capacity of large- and medium-sized[1] agricultural tractors was 17.55 million kilowatts, which amounted to about 1.5 times the capacity of small tractors.

After 1978, the collectively owned land was allocated to rural households and at first, farmers could still obtain machinery services from the agricultural machinery stations. Later, the agricultural machinery stations introduced the sub-contract system in order to improve the economic efficiency, and thus allocated the machinery to those selected farmers who provided services at the agreed fees (Feder et al 1992). With an increase in capital accumulation, farmers started to purchase a large number of small and general machines for own use or joint use. The machinery services market characterized by large- and medium-size machinery began to stagnate or even shrink. From 1978 to 1988, the capacity of large- and medium-sized agricultural tractors increased by 65%, while that of the small tractors increased by 354%. Furthermore, from 1988 to 1995, the capacity of large- and medium-sized agricultural tractors even shrunk by 17%, while that of small tractors still grew by 47.5%.

However, after the middle of the 1990s, the development of agricultural machinery in China turned back to an era of specialization and being market-oriented. In this period, the markets for machinery services in the whole nation also began to be integrated. For instance, the same harvesting machines were used to harvest wheat from the south to the north of China, while the market services of plowing, sowing and rice harvesting were no longer

[1] In Chinese statistics, large- and medium-size tractors refer to tractors with capacities of more than 14.7 kilowatts. The small tractors by definition are those with a capacity between 2.2 and 14.7 kilowatts.

confined to individual counties or provinces. Hence, the total capacities of large- and medium-size agricultural tractors started to grow again and its growth rate has been higher than that of small tractors since 1999. The subsidy policies regarding large- and medium-size agricultural machinery, which were launched in 2004, further stimulated the purchase of large- and medium-sized tractors.

Even though there are some regional differences in the agricultural machinery services markets in China, the status quo of the owner structure of agricultural machinery are very heterogeneous, which is true for 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 purchase machinery services provided by owners of large- and medium-size machinery from markets.[2]

(2) Data Description

The data used in this paper were collected in Anhui Province (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 study very representative for the relationship between off-farm employment and agricultural machinery investment. The sample includes 453 agricultural households, which were randomly selected from 24 villages in 8 towns scattered over 4 counties. Two of the counties (Mengcheng County and Lixin County) are located in the Huaibei Plain where there are two cropping seasons in a year, namely a wheat season in spring and a soybean or corn season in autumn. The other two

[2] In 2009 China featured 3.37 large- and medium-sized tractors, 19.39 small tractors and 25.39 draft animals per one hundred rural households. For Anhui province the corresponding figures are 4.85 large and medium-sized tractors, 39.73 small tractors and 5.61 draft animals per one hundred rural households (China National Statistical Bureau 2009).

counties (Changfeng County and Feixi County) are located in the Jianghuai mountainous region, which features plenty of precipitation and allows for two or three cropping seasons per year. The main crops in this area include rice, wheat, rapeseed, and cotton. The survey collected detailed information on households' off-farm activities, agricultural production as well as possession and use of machinery in the past year (i.e. from July 2008 to June 2009).

Almost every household in the sample uses certain kinds of machinery services in its farm production, such as plowing, sowing, non-till planting, harvesting, threshing, or spraying of pesticides. Out of the 453 surveyed households, 191 (42.2%) do not possess any agricultural machinery. 247 households (54.5%) possess certain kinds of agricultural machinery for own use, most of which are small tractors for towing and plowing, seeders or transport equipment. Households who do not have these kinds of machinery can purchase the services from the market. Other kinds of machinery services such as harvesting, ditching, non-till planting or corn threshing are mainly provided by markets, because the necessary machines can provide services far beyond one household's needs and the households with small tractors generally do not purchase these equipments. Totally, there are 15 households (3.3%) in the sample which provide machinery services for others.

Our survey also shows that agricultural households in Anhui province are extensively involved in off-farm activities. Average off-farm employment time per laborer is 5.44 months. Compared to the households without agricultural machinery, more laborers are found in the households with agricultural machinery, and those laborers are less engaged in off-farm employment. This indicates a positive correlation between the possession of farm machinery and agricultural labor input, or equivalently a negative correlation between farm machinery

and off-farm labor input.

3. Theoretical model

Theoretically, agricultural households have three options to obtain machinery services: Purchasing machinery, renting machinery or buying machinery services. However, the second option is very rarely chosen in China, so that it can be neglected. We also ignore some of the agricultural households which purchase large- or medium-size machinery for business purposes as they are usually not counted as farmers. We will only focus on agricultural households' choices between purchasing machinery for own use and purchasing market services.

A lot of studies noted the imperfections of labor markets in developing countries and hence production (labor input) and consumption (leisure) decisions of agricultural households are non-separable and are simultaneously determined（Nakajima 1969; Singh and Strauss 1986; Wang, Herzfeld and Glauben 2007）. In a classical paper, Benjamin (1992) points out that nonseparability relies on the market imperfections, which he cannot reject for the case of the Indonesian island Java. After 30 years of reforms, the market system is not well established in China. The off-farm labor market is not as restricted as it was 30 years ago, and the local governments are even encouraging off-farm employment as they regard it as a main source of farm income. When labor and output markets are well functioning, we believe production and consumption to be separable and regard farmers as profit-maximizing agents.

Hence, we can assume that a rural household can supply residual time for non-farm activities at the market wage rate w, hence the household can be taken as making production

and consumption decisions separately referring to the exogenous wage rate. Here the off-farm wage rate w is discounted by the prospect of unemployment in urban areas and the transaction costs (including psychic costs) (Zhao, 1999).

Following Zhao (1999) we assume that a rural household maximizes its total income by allocating the labor endowment (not including leisure) across farm work, operating machinery and off-farm work. The farm production function is as follows:

$$y = f(l, k, n)$$

where l, k, and n are farm labor input, machinery services input, and land input. Machinery services include two parts, namely services provided by the household itself and services bought from the market. We furthermore assume that they are perfect substitutes in agricultural production, that is $k = ks + km$, where ks and km are own supply and bought machinery services, respectively.

Land subleasing and hiring of agricultural labor are extremely rare[3] in our survey. The land is equally distributed among farmers for the reason of food security, hence the average farm size in China is very small. The number of laborers in each household is high enough for agricultural production, so households do not need to hire additional laborers. Furthermore, most farmers in China do not sublease their land to others. They rather let it lie idle for tenure security reason in times when they cannot cultivate it (Zhang et. al. 2011). Hence, we presume that the land size is fixed for each household and that the farm labor inputs comprise only family labor, which fits the reality in China well.

[3]According to the Production Cost Survey (State Price Bureau, 2010), in 2009 the total labor input for wheat is 5.82 days/mu, the labor input from family members is 5.72days/mu, and the hired labor input is only 0.06 days/mu, which is only 1% of total labor input. The land costs are 103.88 yuan/mu, the shadow rent costs of family land are 99.18yuan/mu, and the rent costs is 4.7 yuan/mu, which is 4.5% of the total land cost.

The household self machinery service function is defined as:

$$ks = g(m, l_r, v)$$

where m denotes the quantity of machinery possessed by the household, which we assume the household can adjust by buying and selling. Furthermore, v and l_r are the input of labor used for operating machinery and other variable inputs, such as fuel and lubricants, respectively.

The objective function of the household can thus be written as:

$$\max_{(l\geq 0, m\geq 0, v\geq 0, l_r\geq 0, k_m\geq 0)} I = p_y f(l, g(m, v, l_r) + km, n) - p_k km - p_m m - p_v v + w(\bar{L} - l - l_r)$$

where p_i ($i = y, k, m, v$) denotes the exogenous producer prices. The rental rate of machinery is given as $p_m = q(r + \delta)$, with q representing the value of machinery and r and δ denoting the interest rate and the natural depreciation rate, respectively. Finally, $\bar{L} - l - l_r$ is the off-farm employment time.

In the objective function the machinery investment m and the off-farm employment $\bar{L} - l - l_r$ are simultaneously determined. Assume that both the farm production function and the self machinery service function are well-behaved (continuous and concave) so that there are interior solutions. The first order conditions are:

（1） $p_y f_l = w$；　　（2） $p_y f_k = p_k$；　　（3） $p_y f_k g_m = p_m$；

（4） $p_y f_k g_v = p_v$；　（5） $p_y f_k g_{l_r} = w$。

By substituting equation (2) into equations (3), (4) and (5), we obtain：

（3a） $p_k g_m = p_m$；　　（4a） $p_k g_v = p_v$；　　（5a） $p_k g_{l_r} = w$

Equations (3a), (4a) and (5a) are the first order conditions for the optimal service production. Equation (1) and (2) in turn are the first order conditions for the optimal farm

production.

Then, the solutions for m, l_r, l and k are:

(6) $m^* = m(p_k, p_m, p_v, w)$ (Machinery demand function)

(7) $l_r^* = l_r(p_k, p_m, p_v, w)$ (Machinery-operating labor demand function)

(8) $l^* = l(p_y, p_k, w, n)$ (Farm labor demand function)

(9) $k^* = k(p_y, p_k, w, n)$ (Machinery services demand function)

As we know, labor inputs and machinery services are normally gross substitutes in agricultural production. In equation (9) we can reasonably assume that $\partial k(p, p_k, w, \bar{n}) / \partial w > 0$.

Off-farm labor supply will be:

(10) $l_o^* = \bar{L} - l_r^* - l^*$

In the above analysis it is assumed that the self-use machinery is dividable and that the rural households use both own machinery and purchased machinery services. A number of results emerge from the model:

Equation (6) indicates that the labor costs for operating machinery will increase in the off-farm employment wage and that the substitution (or complementary) effect and the expansion effect in self machinery service will affect machinery investment. Furthermore, if the agricultural household is subject to borrowing constraints, the off-farm income can finance machinery by lowering the financial costs p_m, which makes the household invest more in machinery.

Equation (10) links the machinery-operating labor to the off-farm labor supply, which indirectly implies that the off-farm labor supply will be affected by the machinery rent. As the

machinery rent decreases, more machinery services can be produced, and hence the household will purchase less market services. However, the total machinery services input and the labor input in farm production will stay the same.

However, the farmers' own supply of machinery is often undividable. Most Chinese agricultural households only cultivate a very small piece of land and small-sized machinery can satisfy all of their needs, so that for certain machinery investments, the decision for households is to buy or not to buy. In mathematical terms, the decision is either $ks = 0, k = km \geq 0 \quad or \quad k = ks \geq 0, km = 0$. Thus, the above model should be modified.

Assume there is only one particular type of small-sized machinery for the purpose of own use and its price is q. It will generate $\overline{K}$ units of service if fully used. We presume that agricultural households only need to buy one unit of machinery. As aforementioned, the costs of maintaining a machine are $q(r+\delta)$. In particular, we further assume that the self machinery service function is of the Leontief form: To provide 1 unit of machinery services, $1/a$ units of operating-labor (l_r) and c units of other variable inputs (v) are needed. Hence, the average costs of a unit of self-supply machinery service can be given as:

$$AC(ks) = w/a + p_v c + q(r+\delta)/ks \quad if \quad \overline{K} \geq ks > 0$$

In order to minimize the machinery service costs in farm production, the household will compare the average costs of self-supply services with the market price and will decide for the cheaper option.

$$m = \begin{cases} 0 & if \quad AC(ks^*) = w/a + p_v c + q(r+\delta)/k(p, w/a + p_v c, w, n) > p_k \\ 1 & if \quad AC(ks^*) = w/a + p_v c + q(r+\delta)/k(p, w/a + p_v c, w, n) \leq p_k \end{cases}$$

Figure 2 illustrates the machinery investment decisions of a household.

Let us now focus on the effect of off-farm employment wage on farm machinery

investments. First, as the off-farm employment wage increases, the labor costs for operating machinery will increase too. In Figure 2, both the marginal cost curve (MC) and the average cost curve (AC) shift upwards. However, the average maintenance costs $\frac{q(r+\delta)}{k^*(p, w/a + p_v c, w, \bar{n})}$ will decrease because of the gross substitution effect between labor and machinery services $\partial k(p, w/a + p_v c, w, \bar{n}) / \partial w > 0$, so that in Figure 2, when the demand for machinery services D_k shifts upwards, ks^* increases, and $AC(ks^*)$ decreases. The overall impact depends on the gross substitution effect between labor and machinery services and we will specifically examine it in the following empirical analysis for the case of China. Second, if the agricultural household is subject to borrowing constraints, the off-farm income can finance machinery by lowering financial costs and the maintenance costs. In Figure 2, this implies that the average fixed costs (AFC) curve and the AC curve shift downwards.

Machinery investments also impact off-farm employment decisions. When an agricultural household maintains agricultural machinery, this implies that its shadow marginal cost of machinery services (MC curve in Figure 2) should be lower than the average costs and the market price. Hence, the input substitution effect would increase and the expansion effect would decrease the labor input in farm production. Moreover, the increased machinery operating work could obviously reduce the off-farm labor supply.

Because the theoretical framework predicts different possible relationships between machinery investment decisions and off-farm employment decisions, we should go down to the earth to look into the reality in China. In the following section we will examine the specific relationship between them using the survey data from Anhui province.

4. Empirical methods

4.1 Empirical models

The theoretical model has shown that the time allocation between farm activity and off-farm employment and machinery investments are interrelated, and with the overall effect being ambiguous from a theoretical perspective. We use the following simultaneous equations to estimate the linkages between off-farm employment and farm machinery investments:

$$y_{1i} = a_1 y_{2i} + \boldsymbol{\beta_1 x_{1i}} + \varepsilon_{1i} \quad \text{(off-farm employment equation)}$$
$$y_{2i} = a_2 y_{1i} + \boldsymbol{\beta_2 x_{2i}} + \varepsilon_{2i} \quad \text{(owning farm machinery equation)}$$

where y_{1i} , and y_{2i} denote the off-farm employment time and the possession of machinery (1=possession of machinery, 0=otherwise), respectively. $\mathbf{x_{1i}}$ and $\mathbf{x_{2i}}$ are vectors of exogenous variables and ε_{1i} and ε_{2i} are random error terms following normal distributions with means of zero. Specifically, ε_{2i} follows a standard normal distribution.

Because not every agricultural household is involved in off-farm activities, a censoring issue underlies the empirical model, so that a Tobit model with endogenous variables is recommended for the off-farm employment equation, while for the farm machinery investment equation, a probit model with endogenous variables is applied. Since there are endogenous variables in those two models, we estimate the models separately using instrumental variable (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 exogenous and constant and are therefore not included in the empirical models, while

the off-farm employment wage (i.e. the opportunity costs) varies across agricultural households and is assumed to be determined only by human capital and local economic conditions. The price of machinery services varies only across villages. the price for the wheat/rice combine harvesting for example varies between 40 *yuan/mu* and 80 *yuan/mu*, while the prices for machinery services within a village are usually equal due to competition among providers, even though the costs of the services might be different due to the heterogeneities of topography, soil conditions, the conditions of field roads, the concentration of agriculture, and the fragmentation of land. The differences between market service prices across villages mainly reflect the differing utilization efficiencies of large- and medium-sized machinery. Particularly, the utilization efficiencies of the more flexible small-sized machinery are less affected by those conditions, so that the higher the market price is, the more likely a household is to retain small machinery.

Based on the above justification and the work of Stark (1991), the independent variables used in the off-farm employment time model mainly include farm machinery, characteristics of the household and its members (such as land endowment, labor force, average age of labor force, and average schooling of labor force), and the local off-farm employment opportunities, represented by mean migration time and mean wage of male and female laborers in other families of the village, and mean local non-farm work time and mean wage of male and female laborers in other families of the village. Particularly, the variables regarding employment opportunities are constructed by the cluster-effect, the mean of off-farm employment time and off-farm employment wage for other households in the village, and can thus be used as instrumental variables in machinery investment, as they are presumably

correlated with off-farm employment time but not with the small-sized machinery investment decision. The cluster-effect instruments have been widely used in the current literature, such as by Benjamin (1992).

The independent variables used in the farm machinery investment model include off-farm employment time, labor force, land endowment, and market price of machinery service. The farm machinery is mainly operated by the household heads and young male laborers. Consequently, the characteristics of the household head and the share of young male laborers within the household are also included in the investment model, which can be regarded as the instruments in off-farm employment as we assume that the off-farm employment decision is made by households, not individuals. The wealth of households can both help laborers to conduct non-farm business and can facilitate households to buy farm machinery. Therefore, we will put this variable into both equations. In light of this, both of the behavioral equations can be identified in the econometric analysis.

5. Results and discussion

5.1 Off-farm employment equation

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

The variable of special interest in this equation is the one representing farm machinery.

The estimated coefficient for it amounts to -12.94 and is statistically significant at the 1% level. This suggests that an agricultural household that retains farm machinery is less involved in off-farm activities. This is an interesting result and seems to be contradictory to the common knowledge that machinery can reduce the total labor input in agriculture and thus encourages off-farm labor supply. However, this is not the case when machinery services are available on the market. Because labor and machinery are complements in self machinery service, the agricultural households, which supply machinery services, in turn supply less off-farm labor. Similar results are reported by Wang, Herzfeld and Glauben (2007) who state that the accumulation of productive assets and the development of livestock production have reducing effects on a household's off-farm labor supply in rural China.

As shown in Table 3, the number of laborers and laborers' average age are important factors for determining off-farm labor supply. The number of laborers has a positive impact on off-farm labor supply, because labor surplus in agricultural households is a main motivation for off-farm employment. The average age of laborers is negatively associated with off-farm work because the younger laborers are more likely to be involved in off-farm activities. The schooling of laborers has a positive impact on off-farm employment but it is not statistically significant. However, the reality in China is that most of the rural laborers are not well educated and can only find low-skilled manual jobs in cities. The results also indicate that other variables, such as land size and asset value, are not important for off-farm employment.

5.2 Owning machinery decision equation

We estimate the farmers' owning machinery decision 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 employment 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 impact on machinery investments while the off-farm employment has a significantly negative impact on machinery investments. Our findings are consistent with the results of Zhao (2002) regarding the relationship between migration and farm machinery investments, as well as with the results of Ahituv et al. (2002) and Liu et al. (2002) with respect to the relationship between off-farm employment and total farm investments.

A lot of research has suggested that the negative impact of off-farm employment on farm machinery investments is due to a relatively larger expansion effect in farm production (Ahituv and Kimhi, 2002; Liu et al, 2002). To identify this effect, we replace the dependent variable by the machinery services input in farm production we find opposite results. This indicates that the input substitution effect plays a main role, as farm labor and machinery services are negatively correlated. Then the negative relationship between off-farm employment and machinery investments must be caused by the machinery services market, since farmers prefer market services to investing in own farm machinery when they are involved in off-farm activities. In other words, the agricultural labor devoted to off-farm activities is replaced mainly by hired machinery services rather than by own machinery, which eventually leads to a negative impact of off-farm employment on farm machinery investments.

The signs of the other variables are in line with the theoretical expectation. Land has a positive effect on farm machinery investments, but the effect is not statistically significant. The effect of machinery service prices is positive and highly significant. This indicates that farmers are more likely to retain farm machinery when the service prices are high. The wealth level has a positive and statistically significant effect due to the effect, that machinery becomes more affordable. The share of young male laborers forces has a positive effect and the age of the household head has a negative effect, because it needs strength to operate a tractor and to handle the tractor towing machinery in rural China. Therefore, when a household lacks this kind of laborers, it is more likely to purchase market services.

6. Conclusions and policy implications

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

The results in this paper have strong implications for China’s policy of subsidizing farm machinery. If the subsidy policy aims at the small machinery for own use it may encourage more agricultural households to purchase this kind of machinery and hence reduces off-farm

labor supply as the own use of farm machinery has a negative effect on off-farm labor supply. However, if the subsidy policy aims at the large-sized machinery, it may reduce the market price of machinery services and encourage agricultural households to purchase more market services instead of investing in small-sized machinery, which will eventually promote off-farm labor supply.

After the reform, Chinese agricultural households initially increased their demand for small self-use machinery. As off-farm employment opportunities now start to absorb a large number of young and male laborers, the agricultural labor force in China tends to become older and more dominated by women as in some advanced economies, such as Japan, the demand for market machinery services has began to increase. In reaction to the changing demand, the Chinese farm machinery policy should support large- and medium-sized 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.

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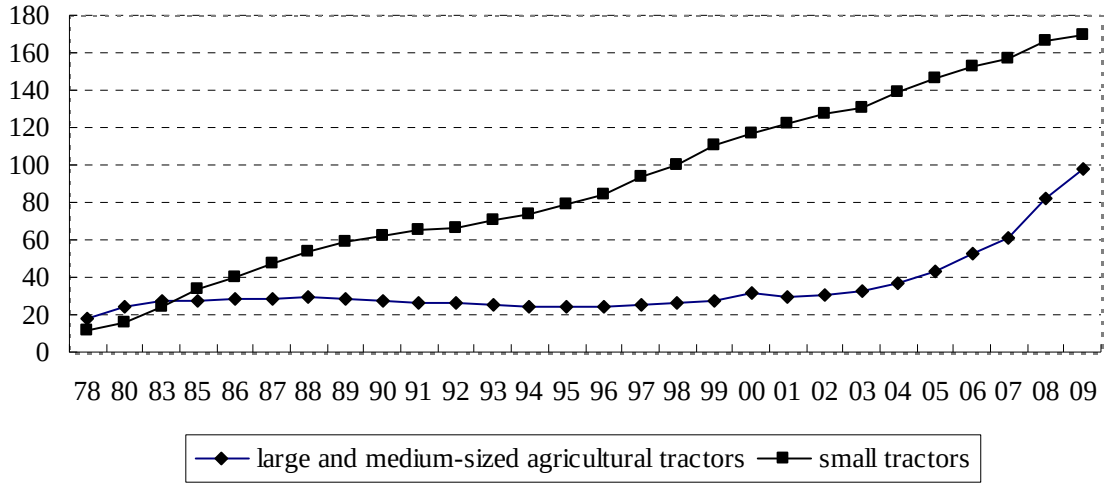

Figure 1: The capacity of different types of tractors after 1978 (million kw)

Source： China National Statistical Bureau

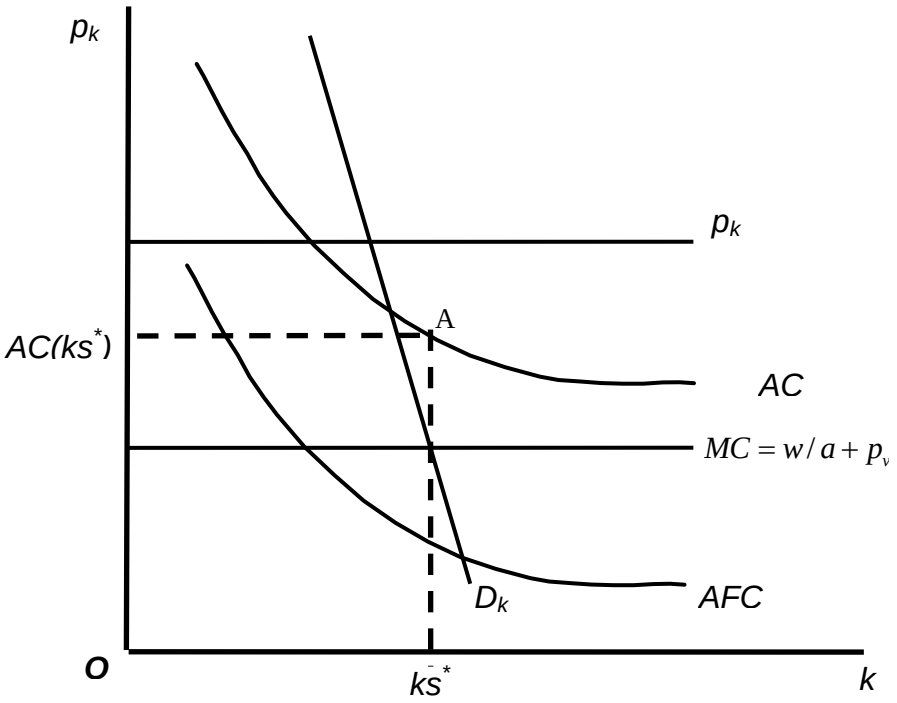

Figure 2: Tradeoff between purchasing machinery and purchasing machinery services in the market

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
Percentage of households involved in off-farm wok (%)	80.79	75.39	84.73
Laborers per household	2.88	2.65	3.04
Off-farm employment in months per laborer	5.44	5.49	5.41

Source: Authors' survey

Table 2: Definitions and descriptive statistics of the variables in the employed models

Variable	Definition	Mean	Standard Deviation
Off-Farm Time	Total off-farm employment time of household last year (month)	15.661	13.470
Machine	Possessing farm machinery or not (1=yes, 0=no)	0.578	0.494
Land	Size of cultivated land（mu）	9.363	9.776
Labor	Number of laborers, defined as persons older than 16 years taking a farm or off-farm job	2.876	1.256
Age	Average age of laborers (year)	43.896	11.084
Edu	Average schooling of laborers (year)	6.037	3.025
Asset	The value of machinery, house, enterprises, and other fixed assets (thousand yuan)	81.001	249.535
Male Time	Migration time of male laborers of other households in the village (months)	5.036	1.271
Female Time	Migration time of female laborers of other households in the village (months)	4.372	1.404
Male Local Time	Local off-farm employment time of male laborers of other households in the village (hours)	79.585	32.806
Female Local Time	Local off-farm employment time of female laborers of other households in the village (hours)	47.131	38.691
Male Wage	Migration wage of male laborers of other households in the village (yuan/ month)	1438.973	283.076
Female Wage	Migration wage of female laborers of other households in the village (yuan/ month)	1075.368	138.190
Male Local Wage	Local off-farm employment wage of male laborers of other households in the village (yuan/ hour)	7.338	5.089
Female Local Wage	Local off-farm employment wage of female laborers of other households in the village (yuan/hour)	5.347	2.361
Young Male Share	Percentage of male laborers younger than age 60 (%)	45.164	24.366
Machinery Service Prices	Market price of machinery services, represented by the rice/wheat combine harvesting price (yuan/ mu)	53.107	12.727
Head Age	Age of household head (year)	51.617	11.547
Head Edu	Schooling of household head (year)	5.525	4.075

Table 3: Estimation results of off-farm employment time equation

	Coefficient	Standard Error
Machine	-12.9434**	5.4896
Labor	8.2312***	0.4091
Mean Age	-0.5050***	0.0853
Mean Edu	0.1705	0.1928
Land	0.0559	0.0685
Asset	0.0009***	0.0020
Male Time	0.9368	0.7615
Female Time	-1.2084	0.8388
Male Local Time	0.0189	0.0302
Female Local Time	0.0227	0.0342
Male Wage	-0.0034	0.0034
Female Wage	0.0130***	0.0047
Male Local Wage	0.1847	0.1164
Female Local Wage	0.3940	0.2715
Intercept	3.2016	9.5815
Wald chi2(14) =708.25***		
Wald test of exogeneity: chi2(1) =3.16*		
Number of obs=453		

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

Table 4 Estimation Results for owning machinery decision equation

	Coefficient	Standard error
Intercept	-1.7712***	0.4913
Off-Farm Time	-0.1099***	0.0158
Labor	1.0287***	0.1184
Young Male Share	0.8949***	0.2697
Land	0.0101	0.0072
Machinery Service Prices	0.0161***	0.0053
Asset	0.0002***	0.0001
Head age	-0.0186***	0.0071
Head Edu	0.0250	0.0159
Wald chi2(8) =267. 74***		
Wald test of exogeneity: chi2(1) =8.08**		
Number of obs=453		

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