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Agricultural Machinery Input, Labor Resource Allocation, and Rural Household Land Transfers

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Abstract: This paper explores the impact of agricultural machinery input on rural households' land transfers, which is conducive to the acceleration of agricultural modernization, agricultural production at scale, and rural revitalization. By using the micro-data on rural households (2014–2018) from China Family Panel Studies (CFPS), we made an empirical analysis of the impact of agricultural machinery input on land transfers and drew three conclusions. First, agricultural machinery input has a positive impact on land transfers, which means the more rural households invest in agricultural machinery, the more willing they are to participate in land transfers. Second, the impact of agricultural machinery input on land transfers is mainly exerted by adjusting the allocation of labor resources for rural households, or rather by increasing the number of farmers engaged in agriculture and reducing the number of farmers-turned traders and workers to facilitate land transfers. Third, the impact of agricultural machinery input on land transfers concerns both the positive transfers-in and the negative transfers-out, and such an impact stays stable across income groups. Accordingly, we should further increase agricultural machinery-related subsidies, improve the agricultural machinery service outsourcing market, and help rural households to reasonably allocate their labor resource endowments and invest in agricultural machinery to increase land transfers.

Keywords: agricultural machinery input, CMP model, land transfers, labor resource allocation

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According to the "No. 1 Central Document" for 2021 (unveiled on February 21, 2021), China should speed up the modernization of agriculture and the countryside, further promote reforms in rural areas and improve land incentives and encourage diverse operations at scale appropriately. The document highlighted the importance of land transfers in comprehensively pushing forward rural revitalization and accelerating agricultural modernization. Ever since the implementation of the system of household contract responsibility, China has developed the world's largest smallholder farming system (Tilt, 2008). With the advancement of industrialization and urbanization, however, agricultural production is increasingly faced with dilemmas, such as land fragmentation, land desolation, and agricultural labor shortages, which, when combined, hinder agricultural development (Huang et al., 2020). Land transfers are an effective approach to the rational allocation of land resources for rural households, as land transfers can address land fragmentation and increase the efficiency of agricultural production (Gao et al., 2020; Peng et al., 2021). Still, land transfers have not yet boosted farmland operations at scale as much as anticipated (Wang et al., 2018). According to the statistics of China's Third National Agricultural Census, as of 2016, the number of rural households engaged in agriculture at scale reached 3.98 million, accounting for 1.92 percent of the total rural households; smallholder production remained the main mode of agricultural operation, with smallholders accounting for over 98 percent of total rural households; the growth of land transfers was on the decline in the years (up to 2016) (Hu et al., 2022). An examination of the available data reveals that China remains "a big country with smallholders" (Xu & Zhang, 2021), and that land transfers still have room for further development.

Agricultural mechanization is an important indicator of agricultural modernization. Relevant data from the National Bureau of Statistics show that China has made remarkable progress in agricultural mechanization over the past 20 years, with its total power of agricultural machinery rising to 100.377 billion kilowatts in 2018 from 525.74 million kilowatts in 2000, an average annual growth rate (AAGR) of 3.59 percent Thanks to the improvement of supply chains, more agricultural machinery has been introduced and used, bringing great changes and opportunities to agricultural production (Brown et al., 2020). In particular, the comprehensive mechanization rate of agricultural production rose to 65.2 percent in 2016 from 32.4 percent in 2000, an AAGR of 2.04 percent The application of agricultural machinery has brought rural households a new approach to increasing production efficiency and improving production modes and positively impacted their allocation of essential factors in agricultural production, particularly on their redistribution of land resources (Feng et al., 2010) for purposes such as agricultural operation at scale. As agricultural productivity increases and agricultural operation at scale develops in a coordinated way, technological factors have exerted a far-reaching impact on rural households' decision-making. Although the comprehensive mechanization rate of agricultural production in China reached 70 percent in 2019, the per capita ownership of machinery remains relatively low (Fang et al., 2020). The modernization of agricultural production

requires a higher level of agricultural mechanization, which has already shaped farmers' production behavior profoundly in the model of land fragmentation. In such a context, agricultural machinery input has become a key driving force behind the acceleration of land transfers in China to maximize profit margins (Li et al., 2021).

Previous studies of agricultural mechanization focused on analyzing the development status of agricultural machinery (Mainuddin & Kirby, 2015), its influencing factors (Fang & Huang, 2019), and its impact on agricultural productivity and production scale (Peng et al., 2021; Zhong et al., 2020). Previous studies of land transfers were conducted from the perspectives of institutional arrangements (Cheng et al., 2016; Hong & Wang, 2019; Li & Zhong, 2020; Liu & Xu, 2016; Zhao & Li, 2014) and off-farm employment (Hu, & Hong, 2019; Kung, 2002; Qian, 2008) to analyze factors affecting land transfers under the regulation of "visible and invisible hands," including factors such as the use of the Internet (Zhang & Zhang, 2020), financial literacy (Zhu et al., 2020), and social capital (Qian & Qian, 2017). Previous studies of the impact of agricultural mechanization on land transfers mainly focused on household-owned agricultural machinery and socialized agricultural machinery services (Qian et al., 2021; Xu & Zhang, 2021) to explore how they could act on rural households' participation in land transfers. For rural households, the purchase of agricultural machinery and the purchase of agricultural machinery services are two main approaches to their participation in agricultural mechanization and their investments. The relevant studies failed to probe the endogeneity problem such as reverse causality. In this paper, we explore the impact of rural households' agricultural machinery input on land transfers at the micro level and attempt to address the endogeneity problem by creating panel data and instrumental variables.

Theoretical Analysis and Research Hypothesis

The widespread implementation of the system of household contract responsibility gave full play to farmers' initiative in agricultural production and greatly increased the productive forces and productivity in rural China. However, the resulting model of farmland fragmentation has seriously hindered China's agricultural modernization and improvement of agricultural productivity (Thapa & Gaiha, 2014). Besides, alongside an aging rural population, and rapid industrialization and urbanization in China, there is an increasingly serious shortage or loss of labor for agricultural production (Research Team of the Transfer of Rural Labor in the Process of Urbanization, 2011). In such a context, agricultural machinery input has become a rational choice for rural households to effectively cope with the shortage of labor for agricultural production (Ji et al., 2011). With the continuous advancement of agricultural mechanization and popularization of machinery in agricultural production, the traditional mode of agricultural production will be changed, and the modern model of

agricultural development will be preferred; accordingly, rural households will change the way of their input in factors of production to loosen the bonds of resource endowments step by step (Xu & Zhang, 2021).

First, agricultural machinery input can effectively make up for the shortage of labor for agricultural production. Due to industrialization and urbanization in China, there has been an influx of rural populations to urban areas, where they shift from the agricultural sector to the non-agricultural sector. With some rural populations working away from home, the burden of agricultural labor falls on their left-behind families (Qian et al., 2022; Zhang et al., 2018). The agricultural labor force is increasingly dominated by older men and women, and the absence of laborers in the prime of life has seriously affected the agricultural production of rural households (He & Ye, 2014; Pan & Dong, 2020; Yang et al., 2019). Since 2003, the surplus labor in rural China has been on the wane, for which reason the rising labor cost has become a major restriction of agricultural development (Yamauchi, 2016). The opportunity cost of farming grows bigger, and the actual output generated from the same factor input varies significantly. Due to labor shortages and the high cost of labor, rural households are inclined to rely more on agricultural machinery. Their application of agricultural machinery contributes to the increase of agricultural productivity and alleviates the shortage of agricultural labor, thus laying a material foundation for rural households to scale up their agricultural production and thereby engage in land transfers.

Second, agricultural machinery input helps maximize the margin of agricultural business and diversify the sources of household income. Small-scale farmland operations, which have resulted from farmland fragmentation, have a great potential to develop into advanced farmland operations at scale (Wang et al., 2021). All else being equal, the more rural households invest in agricultural machinery, the more willing they are to further scale up their production and operations, and thus the more willing they are to participate in land transfers. Compared with the traditional farming model, machinery-enabled farming helps rural households to generate much more farming income through intensive management at scale (Alwarritzi et al., 2015; Yang & Lin, 2021). The machinery-enabled farming sways rural households' decisions on agricultural production and acts on their land transfers (Xu & Zhang, 2021). The application of agricultural machinery means the reallocation of labor resources for rural households, as well as the substitution of labor. More specifically, the application of agricultural machinery has reduced the demand for energy and time on individual farmers, and elderly farmers are able to engage in family farming with agricultural machinery, thus enabling rural households to better allocate their labor resources for part-time or off-farm development (Li et al., 2022). In this way, the application of agricultural machinery helps rural households to diversify income sources and reduce dependence on agricultural income, while the off-farm allocation of labor resources can, to a certain extent, impel rural households to transfer their allotted land (Qian & Hong, 2016; Xu et al., 2011).

Based on the above analysis, the following two hypotheses are proposed: (a) agricultural machinery input can effectively promote the participation of rural households in land transfers; (b) agricultural machinery input can promote the participation of rural households in land transfers by adjusting their allocation of labor resources.

Data Source and Empirical Design

Data Source

The data used in this paper are from China Family Panel Studies (CFPS), a program implemented by the Institute of Social Science Survey (ISSS) of Peking University to reflect changes in Chinese society, economy, demographics, education, and health by tracking and collecting data at the individual, household, and community levels. As the samples were taken from 25 provincial-level administrative units (provinces, autonomous regions, and municipalities directly under the central government) in China (exclusive of China's Hong Kong SAR, Macao SAR, Taiwan, Xinjiang Uygur autonomous region, Tibet autonomous region, Qinghai, Inner Mongolia, Ningxia, and Hainan), they are quite comprehensive and representative. To demonstrate the impact of rural households' machinery input on land transfers, we chose the data from 2014, 2016, and 2018 for this study. To avoid the influence of missing values and outliers on the reliability of research results, we screened the collected data before finalizing the information from 19,713 rural households. The specific screening process involved three steps: (a) pooling data and deleting the missing values of core variables (i.e., land transfers-out and transfers-in); (b) keeping only samples aged between 16 and 85 to ensure the independence of decision-makers; (c) clearing the values of the remaining control variables.

Variable Selection

Explanatory variable.

The explanatory variable is land transfers. There were two questions in our questionnaire. Question 1: "Have you transferred in any allotted collective land from another rural household over the past year?" Question 2: "Have you rented out any of your allotted collective lands to others?" A rural household was marked as "transfers-in" (assigned the value of "1") if it used another household's allotted collective land; a rural household was marked as "transfers-out" (assigned the value of "1") if it let others use its allotted collective land. After a comprehensive assessment, both the land transfers-in and the land transfers-out were collectively marked as "land transfers." In other words, if a rural household was involved in land transfers, whether transfers-in or transfers-out, it was assigned the value of "1," otherwise it was "0" (Zhang, 2022).

Core explanatory variable.

The core explanatory variable is agricultural machinery. As this study focuses on the impact of rural households' own agricultural machinery input on land transfers, we chose the gross value of rural households-held agricultural machinery, a physical capital input related to rural households' land transfers, to assess their agricultural machinery input. Other studies have revealed significant substitutability between agricultural machinery input and socialized agricultural machinery services (Qian et al., 2021), but no complementarity has been found between the two. Given that, the gross value of their combined input is taken as the dependent variable in the robustness test for further analysis in this paper.

Intermediate variable.

The intermediate variable is labor resource allocations. Based on the theoretical analysis above, we adopted the following indexes to measure the allocation of labor resources in rural households: the proportion of farmers engaged in agriculture in the population of rural households, the proportion of farmers-turned traders in the population of rural households, and the proportion of farmers-turned workers in the population of rural households (Zhu & Song, 2020).

Control variable.

We chose control variables at the individual, household, and village levels from the research findings of previous studies (Hu & Hong, 2019; Li & Zhong, 2020; Zhang & Zhang, 2020). The control variables, respectively, are age, the square of age, gender, years of education, marital status, health, household income per capita, gift spending, transportation convenience, and terrain (see Table 1).

Model Specification

Since the explanatory variable of land transfers in this paper is a dichotomous variable, we adopted a binary probit model (see below) to study the impact of agricultural machinery input on land transfers according to its distributed data structure.

$$Prob\,(Transfer_{it} = 1) = \Phi(\beta_0 + \beta_1 Mech_{it} + \beta_2 X_{it} + \beta_5 v_{it}) \quad (1)$$

In the above equation, $Transfer_{it}$ denotes the land transfers of household i in period t, a binary dummy variable on land transfers-out and transfers-in. In this paper, we used both land transfers-out and transfers-in to measure land transfers, while other studies mostly relied on a single aspect (either land transfers-out or transfers-in) to measure land transfers. $Mech_{it}$ denotes the agricultural machinery input of household i in period t; X denotes the control variables at the (individual) household head, household, and village levels; v denotes a random error term.

According to our theoretical analysis, agricultural machinery input impacts on land

transfers by adjusting the allocation of labor resources for rural households. To further demonstrate how agricultural machinery input acts on rural households' land transfers, we added labor resource allocations as the intermediate variable and built the following model based on the mediating effect model and test method developed by Wen Zhonglin and Ye Baojuan (2014).

$$Transfer_{it} = \mu_0 + \mu_1 Mech_{it} + \mu_2 X_{it} + \upsilon_{it} \quad (2)$$

$$Med_{it} = \beta_0 + \beta_1 Mech_{it} + \beta_2 X_{it} + \upsilon_{it} \quad (3)$$

$$Transfer_{it} = \gamma_0 + \gamma_1 Mech_{it} + \gamma_2 Med_i + \gamma_3 X_{it} + \upsilon_{it} \quad (4)$$

In the above equation, Med_{it} denotes the labor resource allocation of household i in period t. According to the process of the mediating effect test, the first step is to test whether the coefficient μ_1 in Equation (2) is significant. If significant, there is a mediating effect, with μ_1 being the total effect; otherwise, the equation is analyzed as a masking effect. Whether the coefficient is significant, or not, follow-up steps are taken. The next step is to test whether the coefficients β_1 and γ_2 in Equation (3) and Equation (4) are significant in turn. If both are significant, the indirect effect is significant. If at least one is not significant, the coefficients β_1 and γ_2 need to be tested for significance with the bootstrap method. If significant, the indirect effect is significant; if not, the analysis is stopped. The last step is to test whether the coefficient γ_1 in Equation (4) is significant. If not significant, then there is no significant direct effect, only a mediating effect. If significant, there is a significant direct effect; the coefficient γ_1, if identical to the coefficient $\beta_1 * \gamma_2$, indicates a partial mediating effect, and the coefficient γ_1, if different from the coefficient $\beta_1 * \gamma_2$, indicates a masking effect.

Table 1 Variable Definition and Descriptive Statistics

Variable	Variable definition and assignment	Mean value	Standard deviation	N
Land transfers-out	No=0; Yes=1	0.130	0.340	19713
Land transfers-in	No=0; Yes=1	0.140	0.340	19713
Land transfers	No=0; Yes=1	0.260	0.440	19713
Agricultural machinery input	Gross value of household-owned agricultural machinery (RMB)	3168	16658	19713
Agricultural machinery rental	Equipment rental expense (RMB)	400	1275	19713
Number of farmers	Number of self-reliant farmers	1.480	1.270	19713
Number of traders	Number of self-reliant traders	0.120	0.460	19713
Number of workers	Number of rural migrant workers	0.850	1.030	19713
Age	Age of household heads	50.88	14.11	19713
Square of age	Square of age	2788	1439	19713
Gender	Male=1; female=0	0.560	0.500	19713

Variable	Variable definition and assignment	Mean value	Standard deviation	N
Years of education	In year(s)	5.600	4.530	19713
Marital status	Married=1; single=0	0.950	0.210	19713
Health	Self-rating: 1-5 (very healthy—unhealthy)	3.160	1.280	19713
Household income per capita	In RMB	14554	43376	19713
Gift spending	In RMB	3339	5253	19713
Transportation convenience	Distance from county seat (*li*)	53.18	38.37	19713
Terrain	Flatland=1; non-flatland=0	0.340	0.470	19713

Quantitative Analysis

The Benchmarking Regression of Agricultural Machinery Input on Land Transfer

Table 2 shows the results from the benchmarking regression of agricultural machinery input on rural households' land transfers. The regression results in columns 1–3 are from analytical tests with stepwise inclusion of control variables, regional effect, and year effect. Column 1 is an analytical test without the inclusion of any control variable, regional effect, and year effect. The result shows that the coefficient of agricultural machinery input is significantly positive and that higher machinery input from rural households can effectively increase land transfers. With the stepwise inclusion of control variables at the individual, household, and village levels in columns 2–3, the agricultural machinery input's coefficient and level of significance are basically consistent with those in Column 1, supporting the first hypothesis that agricultural machinery input can effectively promote the participation of rural households in land transfers to be correct. The results, which are similar to the previous research findings, indicate that during the advancement of agricultural modernization, individual households' decision on agricultural machinery input has a far-reaching impact on the increase of land transfers and is an important driving force behind agricultural production at scale, agricultural mechanization, and rural revitalization.

Of the control variables, the age of household heads has a significant, positive impact on land transfers-out, indicating that aging, which impairs labor capability and energy, leads to rural households' decision to transfer their land out. Judging from the square of age, however, there is an inverted-U relationship. As time goes by, rural households first actively participate in land transfers and then gradually withdraw from them. One possible explanation can be: rural households in the prime of life are more willing to transfer land in so that they can scale up their agricultural production, while rural households in their old age prefer to keep their allotted land due to their physical weakness and need for elderly care. The health of household

heads has a significant, positive impact on land transfers, which means the healthier and stronger the household heads are, the more willing their households are to participate in land transfers. Better health provides internal support for participation in land transfers. The impact of household income per capita on land transfers is significantly positive, which can be for two reasons. First, higher income can better support rural households to scale up their production and thus encourages them to transfer more land in. Second, if higher income comes from rural households' off-farm business, it likely encourages them to transfer more land out. The positive impact of gift spending on land transfers indicates that social capital plays an important role in rural land transfers, that land transfers bound by no contract rely more on the support of social capital, and that traditional rural societies, with an emphasis on relationships, contribute significantly to agricultural production at scale. By contrast, transportation convenience has a significant negative impact on land transfers. This negative impact may be explained as follows: On the one hand, rural households near the county seat can have more off-farm employment opportunities and engage less in agricultural production; on the other hand, as off-farm employment is vulnerable to external factors, it is a rational choice for rural households to retain their allotted land against possible livelihood risks. The terrain of villages positively impacts on land transfers, which indicates that the flatter the terrain is, the more willing rural households are to participate in land transfers. After all, flatland is more conducive to the formation of large-scale cultivation for increased profits.

Table 2 Benchmarking Regression Analysis

	(1)	(2)	(3)
Variable	Land transfers	Land transfers	Land transfers
Agricultural machinery input	0.030***	0.030***	0.029***
	(0.004)	(0.004)	(0.004)
Age		0.032***	0.020***
		(0.008)	(0.008)
Square of age		-0.000***	-0.000*
		0.000	0.000
Gender		-0.031	-0.028
		(0.036)	(0.035)
Years of education		0.002	-0.002
		(0.004)	(0.004)
Marital status		0.110	0.052
		(0.085)	(0.085)
Health		0.046***	0.048***
		(0.012)	(0.012)

	(1)	(2)	(3)
Variable	Land transfers	Land transfers	Land transfers
Household income per capita			0.036***
			(0.009)
Gift spending			0.046***
			(0.006)
Transportation convenience			-0.001***
			0.000
Terrain			0.300***
			(0.042)
Regional effect	N	Y	Y
Year effect	N	Y	Y
Constant	-1.100***	-2.940***	-3.159***
	(0.027)	(0.485)	(0.484)
Observations	19,713	19,708	19,708

Discussion on Endogeneity

Agricultural machinery input is a personal choice that may create an endogeneity problem due to omitted-variable bias and reverse causality. Given that there may be reverse causality between the endogenous variable (i.e., agricultural machinery input) and land transfers, we used an instrumental variable to weaken the possible endogeneity problem. The choice of an instrumental variable must satisfy correlation and exogeneity, which means the instrumental variable is correlated with the endogenous variable but does not directly affect the explanatory variable. We followed relevant scholars' practice (Su & Peng, 2022; Zhou & Hua, 2017) by choosing "the mean value of agricultural machinery inputs from samples (other than the very rural households) living in the same village" as the instrumental variable and corrected the above regression results. Given the similarity in agricultural machinery inputs within the same village, individual agricultural machinery input was influenced by the average agricultural machinery input from others in the same village. However, rural households' decisions on land transfers were not directly related to the level of others' agricultural machinery inputs. Theoretically, the chosen instrumental variable met the requirements for relevance and exogeneity.

To avoid biased estimation caused by reverse causality, we realized from previous studies (Miao et al., 2021; Zhang & Zhang, 2020) that we needed to use the IVProbit model and conditional mixed process (CMP) models to address the endogeneity problem. The CMP model is a mixed model that can effectively estimate different explanatory variables

and has a special advantage when categorical variables and censored data variables are used as endogenous variables (Liu et al., 2020). As the regression results in Column 1 of Table 3 show, the Wald test of exogeneity denies the original hypothesis that there is no endogeneity in agricultural machinery input and suggests that the instrumental variable result is significantly different from the original result. After correcting for endogeneity, agricultural machinery input remains significantly positive at the one percent level, which further confirms the positive impact of agricultural machinery input on land transfers. The atanhrho_12 in Column 2 is the residual correlation of the regression models in the two stages. The regression results illustrated in Table 3 show that its coefficient is significant at the five percent level, indicating endogeneity between the models and the necessity of a mixed model-enabled test. With the remaining variables under control, the estimated coefficient of agricultural machinery input is significantly positive and is higher than the regression coefficient of the benchmarking model, indicating that the absence of endogenous treatments with instrumental variables leads to an underestimation of the positive impact of agricultural machinery input on rural households' land transfers.

Table 3 Endogeneity Test

	(1)	(2)
	IVProbit	CMP
Variable	Land transfers	Land transfers
Agricultural machinery input	0.0472***	0.0470***
	(0.0103)	(0.0100)
Control variable	Y	Y
Regional effect	Y	Y
Year effect	Y	Y
Wald test	5.69	-
P-value	0.0171	-
Atanhrho_12	-	-0.0908**
	-	(0.0381)
Observations	19,708	19,713

Robustness Test

Land transfers-out and transfers-in were used in this study to measure rural households' land transfers. To test for robustness, we divided and analyzed the samples according to macro factors that affected households' decision-making, while taking into account the complementarity between socialized machinery services and household-owned agricultural

machinery. We used the "log values of equipment rental expense and gross value of household-owned agricultural machinery" to measure the overall level of rural households' agricultural machinery input, changed the original core explanatory variable, and replaced the original regression model with the logit model in the analysis.

The regression results illustrated in Table 4 show that with the replacement of the core explanatory variable in the regression model, the impact of agricultural machinery input on land transfers remains positively significant at the one percent level, further indicating the reliability of the benchmarking regression results. In addition, rural households' decisions vary from region to region and from policy period to policy period. We tested the consistency of the impact of agricultural machinery inputs on land transfers under the regulation of macro factors by region and by identification of major grain-producing areas. The regression results in columns 3–7 of Table 4 show that agricultural machinery input still has a robust, positive impact on land transfers, regardless of regional heterogeneity or policy interventions, and that such an impact can be at a lower level in western China due to the local natural environment.

Table 4 Robustness Test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable	Replacement of core explanatory variable	Logit model as replacement	Eastern China	Central China	Western China	Major grain-producing area	Non-major grain-producing area
Agricultural machinery input	0.016***	0.050***	0.046***	0.032***	0.013*	0.022***	0.038***
	(0.003)	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.005)
Regional effect	Y	Y	Y	Y	Y	Y	Y
Year effect	Y	Y	Y	Y	Y	Y	Y
Constant	-3.129***	-5.483***	-3.230***	-2.170***	-2.783***	-2.537***	-3.190***
	(0.485)	(0.864)	(0.577)	(0.359)	(0.341)	(0.299)	(0.525)
Observations	19,708	19,708	7,100	5,632	6,976	10,074	11,411

Mechanism Test

As the regression results in Table 5 show, the coefficient of agricultural machinery input in Column 1 is significantly positive, indicating that agricultural machinery inputs can increase land transfers by engaging more farmers in agriculture; the coefficients of agricultural machinery input in Column 3 and Column 5 are significantly negative, indicating that agricultural machinery inputs can dampen rural households' off-farm employment-oriented allocation of labor resources thus promoting their participation in land transfers and agricultural production and operations at scale. Agricultural machinery input can sway rural households' decisions on land transfers not only because it helps increase productivity and

scale up agricultural production, but also because it offers multiple means of livelihood to rural households. A constant revenue stream is what rural households work for. Agricultural machinery input promotes rural households' participation in land transfers by adjusting the allocation of their labor resources to maximize efficiency. Thus, the second hypothesis is proved to be correct.

Table 5 Mechanism Test

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Proportion of farmers	Land transfers	Proportion of traders	Proportion of land	Proportion of workers	Land transfers
Agricultural machinery input	0.013***	0.033***	-0.001**	0.030***	-0.002***	0.030***
	(0.001)	(0.004)	0.000	(0.004)	0.000	(0.004)
Proportion of farmers		-0.240***				
		(0.050)				
Proportion of traders				0.426***		
				(0.115)		
Proportion of workers						0.146**
						(0.058)
Regional effect	Y	Y	Y	Y	Y	Y
Year effect	Y	Y	Y	Y	Y	Y
Constant	-0.525***	-3.325***	0.042	-3.230***	0.038	-3.202***
	(0.033)	(0.490)	(0.049)	(0.493)	(0.079)	(0.489)
Observations	19,713	19,708	19,713	19,708	19,713	19,708

Further Analysis

Although the above analysis has confirmed the significant, positive impact of agricultural machinery input on land transfers, there is no probe into the specific directions of land transfers, or any revelation of differences in such an impact between land transfers-out and transfers-in. Given that, we now discuss agricultural machinery input's respective impacts on land transfers-in and transfers-out.

The regression results illustrated in Table 6 show that agricultural machinery input dampens land transfers-out and promotes land transfers-in, and has a greater impact on transfers-in, which is consistent with what Qian Long et al. (2021) found. Thus, it indicates that the impact of agricultural machinery input on land transfers primarily concerns land transfers-in, that such an impact stays stable across income groups, and that agricultural machinery input correlates with agricultural production at scale (i.e., agricultural machinery input has a positive impact on land transfers).

Table 6 Test of Land Transfer-in and Transfer-out

	(1)	(2)	(3)	(4)
Variable	Land transfers-out	Land transfers-in	Land transfers-out (low-income group)	Land transfers-in (high-income group)
Agricultural machinery input	-0.052***	0.092***	-0.056***	0.074***
	(0.006)	(0.005)	(0.009)	(0.006)
Regional effect	Y	Y	Y	Y
Year effect	Y	Y	Y	Y
Constant	-2.677***	-6.307***	-3.758***	-3.758***
	(0.614)	(0.773)	(1.002)	(1.002)
Observations	19,708	19,708	6,113	13,522

Conclusion

At the current stage, agricultural development in China is still characterized by low productivity, and because of this, it is imperative to scale up agricultural production. Farmland fragmentation no longer fits in with the development of productive forces, while land transfers have become an essential prerequisite for operations at scale. In this paper, we examined the impact of agricultural machinery inputs on rural households' land transfers. By using the micro-data on rural households (2014–2018) from CFPS, we made an empirical analysis of the impact of agricultural machinery input on land transfers and drew three conclusions. First, agricultural machinery inputs have a positive impact on land transfers, which means the more rural households invest in agricultural machinery, the more willing they are to participate in land transfers. Second, the impact of agricultural machinery inputs on land transfers is mainly exerted by adjusting the allocation of labor resources for rural households, or rather by increasing the number of farmers engaged in agriculture and reducing the number of farmers-turned traders and workers to facilitate land transfers. Third, the impact of agricultural machinery inputs on land transfers concerns the positive transfers-in and the negative transfers-out, and such an impact stays stable across income groups.

From the above research findings, we generate four insights. First, we should further increase agricultural machinery-related subsidies and reduce the economic burden of agricultural machinery inputs on rural households. At the same time, we should invest more in the development of agricultural machinery and enable targeted development of agricultural machinery according to regions and terrains. For example, the development and popularization of mini-type agricultural implements are particularly conducive to the agricultural production in the hilly areas of western China. Second, we should further

improve the agricultural machinery service outsourcing market. This is because market-based regulation can maximize the value of agricultural machinery, ensure the effective application of agricultural machinery to agricultural production regardless of rural households' operating skills, and help reduce rural households' economic burden arising from their agricultural machinery input. Also, we should strengthen the coordinated development of agricultural machinery outsourcing and household-owned machinery inputs, encourage rural households to purchase mini-type agricultural implements, promote the further development of agricultural machinery outsourcing services, and improve the corresponding service outsourcing system. Third, we should work hard on the diversification of livelihood strategies, which remains a rational choice for rural households at present, although agricultural machinery inputs save manual labor significantly. In addition to further increases in agricultural machinery inputs and land transfers, we should also help rural households to reasonably allocate their labor resource endowments, diversify their income sources, and maintain income diversity. For households relying primarily on agricultural production, we should provide more policy support for them to scale up their operations; for households relying primarily on part-time and off-farm businesses, we should improve the stability of their off-farm employment, reduce the impact of external risks on their livelihood, and offer means of livelihood to them after the land transfers-out. Fourth, we should build a public service platform for land transfers, improve the land transfer market and the relevant management system, develop a scientific and reasonable system of land asset valuation, protect the interests of both sides of land transfers, reduce external risks, and increase farmers' willingness to participate in land transfers.

Although we have analyzed the impact of agricultural machinery inputs on rural households' land transfers by creating panel data, there are still some limitations in this paper. First, the research findings of this paper feature a time lag due to limited public data. Second, in the context of rapid industrialization and digitalization, agricultural machinery is combined with digitalization in China, and the threshold for rural households' use of agricultural machinery is on the rise. Without considering individual human capital constraints, there will be limitations in agricultural machinery inputs in rural China. In our future research, we will consider the digital literacy of rural households to explore the promotion of land transfers by increasing agricultural machinery inputs or changing the input mode in an era when agricultural mechanization is further integrated with digitalization.

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