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EDITED BY
Yingnan Zhang,
Zhejiang University, China

REVIEWED BY
Jin Liu,
Shanghai University of Finance and Economics, China
Xuanchang Zhang,
Chinese Academy of Sciences (CAS), China

*CORRESPONDENCE
Peixin Zhu,
zpx@njau.edu.cn

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Agricultural machinery service adoption and farmland transfer-in decision: evidence from rural China

Yujiao Zhang[1], Jian Zhang[2], Yang Liu[1] and Peixin Zhu[1,3]*

[1]College of Public Administration, Nanjing Agricultural University, Nanjing, China, [2]Research Center for Land Utilization and Ecological Security Governance in Mining Areas, China University of Mining and Technology, Xuzhou, China, [3]China Resources & Environment and Development Academy, Nanjing Agricultural University, Nanjing, China

With the deepening of China's agricultural labor division, the rapid development of agricultural machinery service has had a profound impact on farmland scale management. Based on the new classical economic and transaction cost theories, this paper investigates the impact mechanism of agricultural machinery service on farmers' farmland transfer-in decision from the dual perspectives of transaction cost and benefit of labor division, and uses the national rural survey data on the Chinese Family Database to conduct empirical research by using the ordinary least square (OLS) model and limited information maximum likelihood (LIML) method. The study finds that, first, agricultural machinery service expands farmers' farmland transfer-in decision by encouraging them to obtain the economic efficiency of labor division. Not only agricultural machinery service can alleviate the constraint of farmers' farmland transfer in labor and capital but also reduce the service transaction cost and increase farmers' share of the division of labor economy, which further stimulates farmers to expand the scale of management. Second, with the deepening of labor division of agricultural machinery services, the higher transaction efficiency of agricultural machinery service promotes farmers' farmland transfer-in participation. As long as the marginal net benefit obtained is greater than zero, farmers have incentives to expand the scale of farmland. Therefore, in order to promote China's farmland scale management, the professional, whole-process, and large-scale development of agricultural machinery services should be further promoted, and the service capacity and fields should be expanded so that outsourcing services can be better provided to agricultural production demanders. At the same time, the technical standards, supervision system, and service platform of agricultural machinery should be established and improved so as to enhance the bargaining position of farmers in service outsourcing transactions, thus promoting the development of agricultural division of labor to a higher level and realizing the mutual promotion and mutual benefit of agricultural machinery service subjects and agricultural land scale management subjects.

KEYWORDS

service outsourcing, farmland scale management, transaction cost, division economy, agricultural modernization

1 Introduction

Farmland scale management is an important way to enhance agricultural competitiveness, ensure food security, and realize agricultural modernization (Zhang et al., 2014; Chen et al., 2022a). The issue of how to build a strong connection between small farmers and modern agriculture has become a key task in a small farming system in China. Large-scale agricultural production is considered a way to improve agricultural productivity and increase farmers' income and livelihoods (Ma et al., 2020; Zhang et al., 2020; Tian et al., 2021). In recent years, with the expansion of farmland transfer to realize the agricultural scale management area, by 2017, 21% of the land cultivated by Chinese farmers was leased through the agricultural land rental market. There are also increasing constraints to realizing agricultural scale management through land transfer, and the expansion of the agricultural land scale requires enough assets and machinery technology (Van Loon et al., 2020). The developed services outsourcing market can help farmers who suffer from the shortage of agricultural production input factors, improve their ability to expand the agricultural scale and production, and have far-reaching significance for ensuring food security (Zhang et al., 2021; Liu et al., 2022). In this context, agricultural machinery service outsourcing is a way to alleviate agricultural scale management and realize agricultural modernization, which has attracted the attention of Chinese agricultural producers and policymakers.

With the deepening of the agricultural labor division and the development of market, service outsourcing, as a new type of agricultural production and management, has been developing rapidly in China (Xie et al., 2021; Liao et al., 2022). By the end of 2021, the number of China's agricultural social service organizations has reached 955,000, with a service area of more than 1.67 billion mu and more than 78 million small farmers served (Bai et al., 2021). The rapid development of service outsourcing is mainly due to the widespread application of agricultural mechanization, which gradually shifts the processes of plowing, weeding, pesticide, irrigation, and harvesting, which are mainly carried out by farmers' family labor, to specialized service outsourcing subjects, simplifying and reducing manual labor, and promoting the refinement of the social division of labor (Gong, 2020; Lu et al., 2022). With the continuous development of agricultural mechanization, the service outsourcing and technical divisibility of agricultural production activities are further enhanced, and farmers can hand over part or even all of their production and operation activities to the service outsourcing main entities, which expands the space and scale of farmers' production and operation while reducing their production losses (Tang et al., 2018; Li and Lee, 2022). In view of this, China's No. 1 Central Document from 2013 to 2023 has repeatedly clearly supported and encouraged the development of specialized agricultural socialized services: for example, "focus on building a new management system that combines intensification, specialization, organization, and socialization," "support various new agricultural service entities to carry out specialized and large-scale services," "develop and strengthen specialized socialized agricultural service organizations and introduce advanced and applicable varieties, inputs, technologies, and equipment to small farmers," and "implement agricultural socialized service promotion actions and encourage the construction of regional comprehensive service platforms." The central policy documents take agricultural specialization and scale services as the basic way and strategic initiative to develop modern agriculture, strengthening the demand for socialized services brought by the deepening of agricultural labor division.

With the strong central policy support and increased demand for farmers' services, specialized and large-scale agricultural services have been further developed. In many Asian regions, including Japan and South Korea, the land owned by small farmers is increasingly being merged into larger-scale production units (Ji et al., 2016). At the farmer level, farmers' participation in service outsourcing can induce a vertical division of labor in agricultural production, resulting in positive outcomes such as improved agricultural productivity, increased food production, and higher farmer income (Mi et al., 2020; Qu et al., 2021; Peng et al., 2022; Zang et al., 2022). Service outsourcing subjects replace farmers as the main production subjects of agricultural management, introducing advanced technology, production factors, and management experience into agricultural production. With the improvement of labor division in all aspects of agriculture, farmers can share the benefits of agricultural modernization on a larger scale, and more and more small farmers choose agricultural services to improve agriculture income (Paudel et al., 2019; Cai and Wang, 2021; Zheng et al., 2022).

Furthermore, previous studies have shown that service outsourcing can expand the scale of farmland management by relaxing the labor, technology, and capital constraints of farming operations and alleviating the constraints of farmers' original resource endowments on the scale of farmland management (Aryal et al., 2019; Yang et al., 2019; Jiang et al., 2020; Zheng et al., 2021; Qu et al., 2022). At the same time, service outsourcing can promote further deepening of the agricultural labor division, reduce transaction costs, and increase farmers' willingness to operate on a large scale (Olmstead and Rhode, 2001; Yang et al., 2013). When farmers' land management reaches a certain scale, they can improve the efficiency of agricultural production and operation by purchasing specialized service outsourcing (Benin, 2015; Deng et al., 2020; Chen et al., 2022b). In general, the production process of large-scale farmers who obtain farm income by transferring farmland also depends heavily on service outsourcing, and the positive effect of service outsourcing on production efficiency is significant (Qing et al., 2019). In addition, the factor mitigation effect of service outsourcing supply is more significant for large-scale operators than small farmers, expanding the scale of farmland before the marginal return of farmland decreases to zero and further increasing the farmland management income (Yamauchi, 2016; Otsuka et al., 2016; Qiu et al., 2021a; Qiu et al., 2021b).

Existing studies have given enough attention to the development of service outsourcing and the benefits of labor division by involving farmers in the service outsourcing division of labor, which explains, to some extent, the influence of service outsourcing on farmers' farmland transfer-in. However, rational economic people often make trade-offs to determine how to obtain the maximum benefit at the minimum cost before implementing a certain behavior. In reality, the development of service outsourcing has not only brought the benefits of labor division but also generated transaction costs. Then, what impact does this have on farmers' farmland transfer-in decisions and farmland scale management development? This is less mentioned in existing studies.

For this purpose, this paper examines the impact of agricultural machinery service on farmers' farmland transfer-in from both theoretical and empirical perspectives using the 2017 Chinese Family Database (CFD) publicly released in 2020 by Zhejiang University. Current studies have mainly focused on the impact of economic benefits of labor division brought by service outsourcing on farmland scale management, while less attention has been paid to the possible offsetting the benefits of labor division by the transaction costs incurred by farmers' purchase of service outsourcing, making the study of the impact of service outsourcing on scale management less comprehensive. However, it should be noted that with the deepening of the labor division in the agricultural machinery service market, farmers have the opportunity to purchase more links of service outsourcing, which leads to an increase in transaction costs and also promotes the improvement of service transaction efficiency, which largely depends on the reduction of transaction costs brought by new technologies or improved machinery process conditions. This may increase farmers' access to the benefits of the labor division and motivate farmers to further expand their operation to obtain more benefits of labor division. Therefore, based on the ideas of new classical economic and transaction cost theories, this paper incorporates the labor division benefits and transaction cost of agricultural machinery service into a unified analytical framework, and conducts theoretical analysis and empirical research on the path of agricultural machinery service, affecting farmers' farmland transfer-in, which makes the explanation of the influence mechanism more objective and comprehensive. The research results can provide theoretical support and empirical reference for the understanding of the influence mechanism of agricultural machinery service on farmers' farmland transfer-in, construct an effective mechanism to promote moderate agricultural scale management, and further enrich the current research on the formation and development mechanism of farmland scale management.

The rest of the paper is organized as follows: Section 2 introduces the theoretical framework and research hypotheses, Section 3 describes the dataset and estimation strategy, Section 4 reports the econometric results, and a discussion and main findings are presented in Section 5 and Section 6, respectively.

2 Theoretical analysis and hypothesis

Adam Smith, the originator of modern economics, first put forward the classical statements of "Smith's theorem" that "the evolution of labor division is limited by the scope of market transactions" and "the development of labor division and specialization is the source of economic growth" in his book "The Wealth of Nations" (Smith, 1776), which opened the research on the theory of the evolution of labor division. On the basis of Smith's theory, Allyn Young proposed Young's theory that "the evolution of labor division depends on the size of the market, which, in turn, depends on the labor division" (Young, 1928). Since then, new classical economists represented by Yang and Ng (1995) have incorporated the evolution of labor division and transaction efficiency into a unified analytical framework, arguing that the evolution of labor division not only depends on market size but is also closely related to transaction efficiency, and the higher the transaction efficiency, the larger the trade-off between the benefits of labor division and the transaction costs generated by labor division, and the higher the level of labor division (Yang and Ng, 1995). The introduction of the concepts of transaction efficiency and transaction cost makes up for the deficiency that the original labor division research only focuses on the efficiency of labor division independently but ignores the transaction cost and transaction efficiency of the market after the labor division, and enables a more comprehensive understanding of the internal motivation of the evolution of labor division and the impact of labor division on market size. Therefore, this paper draws on this framework to analyze the mechanism of the impact of agricultural machinery service on farmers' farmland transfer-in, to understand more comprehensively the internal motivation of agricultural machinery service development and its impact on farmers' farmland transfer-in.

The emergence of agricultural machinery services has led to fundamental changes in agricultural production conditions and agricultural management modes. On one hand, through the specialized labor division in service outsourcing, farmers alleviate the constraints of insufficient household resource endowment on large-scale operation and provide the possibility to promote farmland scale operation. On the other hand, with the deepening of the labor division in agricultural services, the efficiency of service transactions has improved, expanding the space for trade-offs between the division of labor economies and transaction costs, and increasing the economic feasibility of expanding the scale operation of farmland. As shown in Figure 1, the influence mechanism of agricultural machinery service on the farmers' farmland transfer-in is as follows.

2.1 Agricultural machinery service alleviates operational constraints and reduces transaction costs

2.1.1 Agricultural machinery service alleviates factor constraints of farmers' farmland transfer-in

Service outsourcing offers farmers the possibility to transfer-in farmland, thereby increasing the scale of operation by alleviating the constraints of labor, technology, capital, and other resource endowments faced by farmers' production and operation (Yang et al., 2019). First, the development of service outsourcing enables farmers to obtain relatively cheap and abundant agricultural machinery services through the market, replacing relatively expensive and scarce labor input, which helps farmers alleviate the constraints of labor shortage in the process of expanding the operation scale (Qiao, 2017; Daum and Birner, 2020; Qiu and Luo, 2021; Belton et al., 2021). Second, service outsourcing can integrate high value-added capital and technology into the agricultural production chain. With the development of service outsourcing, professional technologies and equipment such as deep tillage of farmland, soil testing fertilization, and plant protection drones are widely used in agriculture, alleviating the capital and technology constraints in farmers' production (Sims and Heney, 2017; Shikuku, 2019; Zhou et al., 2020; Cheng et al., 2022). Third, due to the asset specificity and high value of machinery, farmers face higher sunk

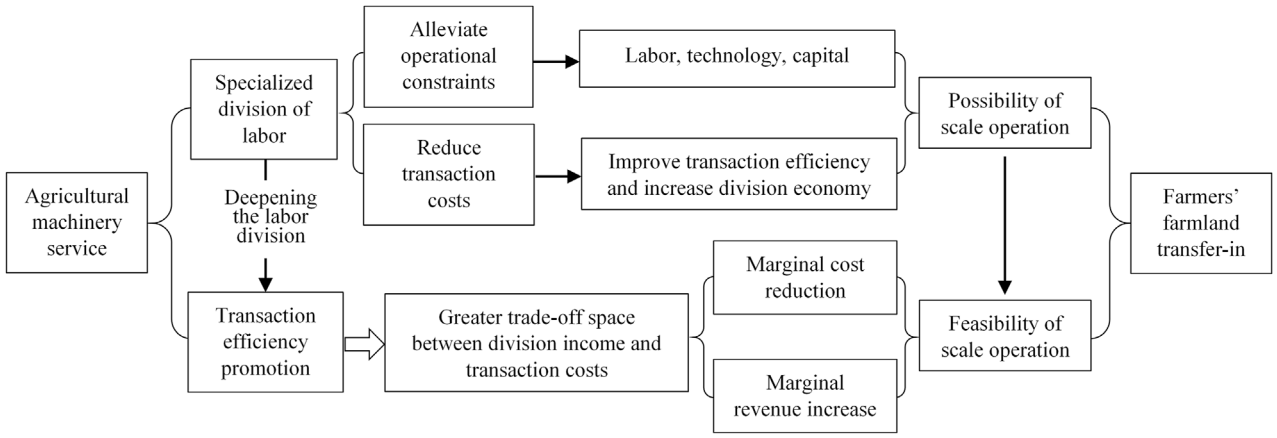

FIGURE 1
Theoretical framework of the impact of agricultural machinery service on farmers' farmland transfer-in.

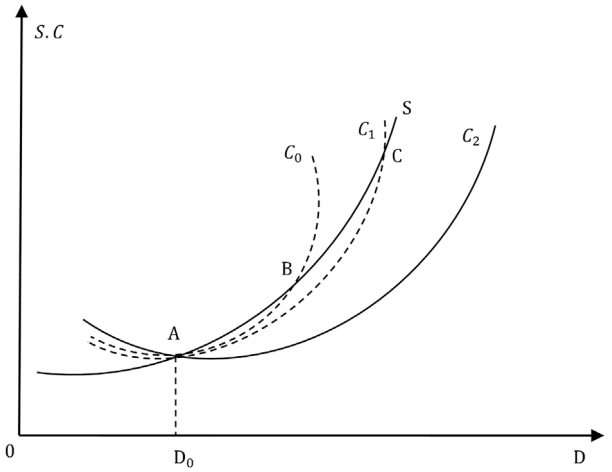

FIGURE 2
Agricultural machinery service benefits of labor division and transaction costs.

costs and hold-up risks in agricultural production. Because of the differences in agricultural machinery in different links, if farmers purchase the machinery needed for each link, it will increase the burden and capital risk associated with their high capital investment (Mottaleb et al., 2017; Gao et al., 2020). Under the condition of service outsourcing market development, farmers can conveniently obtain machinery services instead of purchasing these machines, reducing the cost and risk of using machines and easing the financial constraints of farmers' scale operations.

2.1.2 Agricultural machinery service reduces transaction costs and increases the division income

Agricultural machinery service is a specialized division of labor, and it is the key to improving returns (Zhang et al., 2017). However, when farmers purchase services to obtain the economic labor division, transaction costs are also incurred. Specialized division of labor in agricultural machinery services can continue to evolve when the benefits of labor division obtained by farmers through service outsourcing still have a surplus after offsetting the transaction costs. The deepening of the labor division in service outsourcing means the improvement of service transaction efficiency, which helps farmers further obtain the benefits of labor division. Service outsourcing, as a carrier of new technology invention or technical condition improvement of agricultural machinery, the emergence of new machinery usage technology, and advancement of the machinery process condition will improve the transaction efficiency (Yang, 2003), thus helping farmers better weigh the benefits of labor division against transaction costs (Figure 2).

Figure 2 shows the trade-off between the benefits of labor division and the transaction costs obtained by farmers purchasing agricultural machinery services. The horizontal axis represents the degree of labor division in service outsourcing (D), the vertical axis represents the benefits of labor division (S) and transaction costs (C), and S is the benefits of the labor division curve. As the degree of labor division increases, both the benefits of labor division and the transaction costs faced by farmers will increase but not at the same rate for both. The invention of new agricultural technologies or improvement of technologies provides the possibility of further deepening the labor division in agriculture, enabling farmers to better balance the benefits of the labor division and the transaction costs of purchasing service outsourcing. The invention of new technologies and the improvement of technological conditions in agriculture can reduce the transaction costs of service outsourcing and increase the benefits of labor division for farmers. The longer the chains of the labor division in agricultural production, the higher the efficiency can be realized (Liu et al., 2018). In Figure 2, the improved agricultural machinery technology and the increased standardization and supervision of machinery help reduce the transaction costs of purchasing service outsourcing. With the improvement of the transaction efficiency, the transaction cost curve gradually shifts from the original C_0 to C_1 and even to C_2, which means that transaction costs increase at a

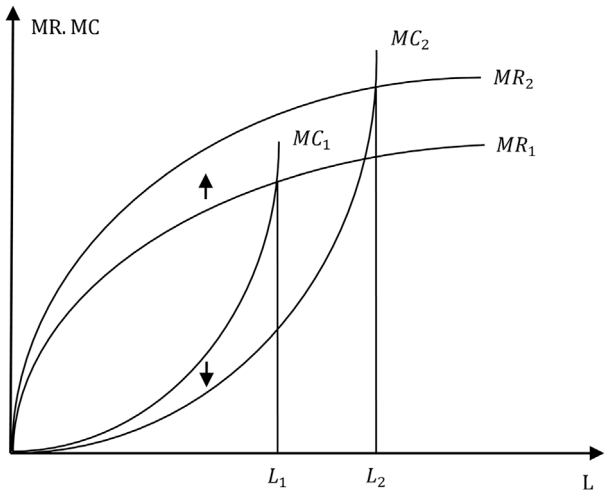

FIGURE 3
Impact of the agricultural machinery service division deepening on farmers' farmland transfer-in.

slower rate with technological progress. The original economic scope of labor division gradually expands from the area bounded by S and C_0 curves between points A and B to the area bounded by S and C_1 curves between points A and C, and even to a larger area bounded by C_2 and S curves to the right of point A. Similarly, the improvement of the agricultural machinery transaction's efficiency can gradually shift the division of the labor income curve S so that the division of the labor income curve S grows faster and faster, which also makes the economic scope of the labor division gradually increase, thus promoting the further deepening of the agricultural labor division.

2.2 With the deepening of labor division in the agricultural machinery service, the scale of farmers' farmland transfer-in has expanded subsequently

The increasing returns of specialized labor division arise from the specialized economy and labor division economy (Yang and Ng, 1995). The specialized labor division of service outsourcing can realize the improvement of the service transaction efficiency and promote the roundabout production of agriculture and the extension of the industrial chain. The more agricultural production links involved in the labor division, the more surplus after the benefits of labor division offset the transaction costs, and the more benefits generated by the agricultural labor division, thus promoting farmland scale operation. Figure 3 illustrates the farmers' farmland transfer-in decisions in the context of obtaining the benefits of labor division and facing transaction costs during the deepening of the agricultural labor division.

In Figure 3, MR denotes the marginal return from the deepening labor division of the agricultural machinery service, MC denotes its corresponding marginal cost, and L denotes the agricultural farmland scale operation. With the deepening of the service outsourcing labor division, the efficiency of agricultural machinery transactions gradually improves, indicating that the greater the trade-off space between the benefits of the agricultural labor division and the transaction costs generated by the labor division, the more benefits of the labor division that farmers can obtain (Yang, 1998). On one hand, the specialized division of labor in service outsourcing enables the agricultural process to be standardized and programmed, and the quantity and quality of production can be easily measured and supervised, improving farmers' production and transaction conditions, and reducing the marginal transaction costs of production. On the other hand, the introduction of specialized service outsourcing can alleviate various constraints (such as capital, technology, labor, and product sales) for farmers to expand the scale of operation, and at the same time, the agricultural production efficiency can be improved to increase the marginal revenue of their production, which, in turn, stimulates farmers to expand the scale of land operation and achieves the lowest operating cost per unit of the land to obtain more land operation income (Sims and Kienzle, 2017; Chaya et al., 2019; Li et al., 2021a). Therefore, in the case of increased marginal revenue of agricultural production, lower transaction costs, and expandable land scale, more agricultural production links and production activities are included in the service scope of the labor division (the vertical labor division refers to link incorporation, and the horizontal labor division refers to scale expansion) (Cai et al., 2016; Ji et al., 2017), while more production scales are included in the labor division and transaction scope, leading to more scale effects of labor division and lower transaction costs, both of which promote the expansion of land-scale operation and realize the deepening of labor division in service scale operations. As shown in Figure 3, the change of farmland scale operation is observed from L_1 to L_2.

Farmland scale management is an important way to achieve optimal allocation of land resources by making a proper trade-off between reducing the transaction costs arising from the specialized labor division and obtaining more benefits from the labor division. Under the condition that the marginal net profit of service outsourcing is greater than zero, according to the profit maximization principle, farmers will include more production links into service outsourcing vertically and expand the scale of land operation horizontally, thus including larger-scale production links into service outsourcing. At the same time, the market scale of service outsourcing is also expanded, the specialization of labor division and scale effect becomes more significant, and the service efficiency is continuously improved, which further attracts more agricultural production links into specialized services, thus forming the coordinated development of agricultural machinery services and farmland scale management. Therefore, the specialized labor division and development of service outsourcing are the main driving forces for farmland scale management.

Based on the aforementioned analysis, this paper proposes the following two research hypotheses.

Hypothesis 1. Agricultural machinery service has a positive effect on farmland scale management, and the deeper the division of labor, the larger the positive effect will be on farmland scale management.

Hypothesis 2. With higher efficiency of agricultural machinery service transactions, more significant benefits of service outsourcing can be realized, and it will have a higher impact on farmland scale management.

3 Data, variables, and estimation strategy

3.1 Data

The data used in this paper come from the 2017 CFD publicly released by Zhejiang University in 2020, which involves comprehensive information on Chinese rural families, including the basic family structures, agricultural production and management, and land use and transfer. The data cover 77,132 people from 24,764 families in 29 provinces (municipalities and autonomous regions), which are representative at the national, provincial, and rural levels.

To accurately reflect the decision-making factors of farmers on agricultural production and prevent omitted variables, this paper combines farm household characteristic data, household member data, community data, and province data to reflect the sample household characteristics as completely as possible. The database processing and sample selection process are briefly described as follows: first, farm household characteristic data, household member data, and community data are merged by unique codes of individuals and communities. In this paper, the questionnaire respondents know the family situation and are the family decision-makers. Second, this paper selects the sample according to the following criteria: 1) farmers whose household type is rural according to the urban–rural division criteria of the China Bureau of Statistics, and 2) farmers who own contracted land are selected. After excluding samples with missing key information and serious outliers, 1,275 farm household samples finally passed the screening and entered the benchmark regression. Because of the missing variables, the actual effective sample size varies in the different regression analyses.

3.2 Variables

3.2.1 Dependent variable

This paper studies the impact of agricultural machinery service on farmers' farmland transfer-in. Referring to relevant studies, the dependent variable is set as the amount of farmland transferred-in (Li et al., 2020; Yu et al., 2021). The CFD household questionnaire provides the question "what is the amount of farmland transferred by your family?", which characterizes the farmers' farmland transfer-in decisions. To narrow the variable scale for calculation, the variable is logarithmically treated in this paper.

3.2.2 Independent variables

This study investigates the impact of agricultural machinery service on farmers' farmland transfer-in, so agricultural machinery service is the core explanatory variable. Referring to Li et al. (2020), this paper selects the CFD household survey questionnaire provided by "how much did your household spend on renting farm machinery and farm transport vehicles" as a measure of agricultural machinery service and logarithmically processes it. Meanwhile, "which parts of your agricultural production use machinery services in the plowing/fertilization, sowing, harvesting, transporting, and spraying pesticide?" to measure the transaction efficiency of agricultural machinery services. The more machinery links used by farmers indicates the higher efficiency of agricultural machinery service transactions, and it reflects the degree of farmers' participation in the labor division.

3.2.3 Control variables

Referring to the literature on the factors affecting farmland scale operation and the impact of service outsourcing on farmland scale operations (Yang et al., 2019; Ntihinyurwa and de Vries, 2020; Cai and Wang, 2021; Belton et al., 2021), the main control variables are set as surveyed farmers' characteristics, household characteristics, village characteristics, and regional characteristics. Farmers' characteristics included four variables gender, age, education level, and health status; family characteristics included four variables: whether any family members are village cadres, the number of farming family members, whether to get agricultural technology guidance, and the number of farmland plots; village characteristics included three variables: *per capita* disposable income, distance from the village committee to the township, and village population over 60 years old; and regional dummy variables are introduced to control regional differences. The variable definitions and descriptive statistics of this paper are shown in Table 1.

3.3 Estimation strategy

To accurately identify the impact of agricultural machinery service on farmers' farmland transfer-in, the article sets the benchmark model as follows.

$$Landin_i = a_0 + \chi_1 Service_i + \sum_{j=0}^{4} \alpha_{sj} self_{ji} + \sum_{j=0}^{4} \alpha_{fj} far_{ji} + \sum_{j=0}^{3} \alpha_{cj} cou_{ji} + \sum_{j=0}^{3} \alpha_{pj} pro_{ji} + \mu_i. \quad (1)$$

Equation 1 is the farmer's land transfer-in equation, where the subscript i denotes i_th farmers, and the subscript j denotes j_th variables. $Landin_i$ is the farmland transfer-in decision variable, which represents the area of farmland transfer-in of the i_th farmers, and $Service_i$ is the agricultural machinery service variable, which represents the cost of renting agricultural machinery by i_th farmers. To reduce the measurement error and mitigate the heteroskedasticity problem, the aforementioned two variables are taken as logarithms. Since the dependent variable, farmers' farmland transfer-in area, is a continuous variable, the ordinary least square (OLS) model is used for the estimation in the article.

The selected control variables include the following: $self_{ji}$ is the farmer's characteristics, far_{ji} is the family characteristics, cou_{ji} is the village characteristics, and pro_{ji} is the regional dummy variable. Considering the regional characteristics of agricultural production, the study area was divided into three types of regions: east, central, and west. χ_i is the main parameter of interest to be estimated, and μ_i is the random error term.

The increase in transaction efficiency stems from the invention of new technologies or the improvement of the technical conditions of machinery, when more mechanical links are used, indicating the higher transaction efficiency and the degree of farmers' participation in the labor division. The higher degree of farmers' production participation in the agricultural labor division can reduce agricultural losses and improve the product quality (Yang and

TABLE 1 Variable definitions and descriptive statistics.

Variable	Definition	Mean	Standard deviation
Dependent variable			
Farmland transfer-in	Amount of farmland transferred in (mu)	2041.032	77849.430
Independent variables			
Agricultural machinery service	Rental farm machinery service and vehicle costs (yuan)	988.864	3312.554
Agricultural machinery service degree	Number of links using agricultural machinery services: not use = 0; one link = 1; two links = 2; three links = 3; four links = 4; and five links = 5	1.078	1.569
Control variables			
Farmers' characteristics	Gender: male = 1; female = 0	0.541	0.498
	Age: under 30 years old = 1; 30–39 years old = 2; 40–49 years old = 3; 50–59 years old = 4; and over 65 years old = 5	3.730	1.251
	Education level: no attended school = 1; primary school = 2; junior high school = 3; high school, technical secondary school, vocational high school = 4; and junior college and above = 5	2.584	1.034
	Health status: very healthy = 1; relatively health = 2; generally health = 3; relatively unhealthy = 4; and very unhealthy = 5	2.717	1.067
Family characteristics	Whether any family members are village cadres: yes = 1; no = 0	0.065	0.247
	Number of farming family members (persons): no one = 0; one person = 1; two persons = 2; three persons = 3; four persons = 4; and five or more persons = 5	1.898	.852
	Whether to get agricultural technology guidance: yes = 1; no = 0	0.112	0.315
	Number of farmland plots: number of farmland plots operated	4.955	5.507
Village characteristics	Per capita disposable income (yuan)	7875.966	6541.647
	Distance from the village committee to town (km)	7.163	8.775
	Population over 60 years old	398.534	347.066
Regional characteristics	Eastern region = 1; otherwise = 0	0.458	0.498
	Central region = 1; otherwise = 0	0.289	0.453
	Western region = 1; otherwise = 0	0.253	0.435

Zhang, 2003; Qu et al., 2021). To investigate the transaction efficiency of agricultural machinery service, drawing on the existing scholars' measures of the labor division (Luo et al., 2019), the article uses the number of mechanical links to describe the transaction efficiency of agricultural machinery service and constructs the measurement indicators as follows:

$$\boldsymbol{Ams\_te_i} = \sum_{i=0}^{5} \boldsymbol{h_i}. \tag{2}$$

In Equation 2, Ams_te_i denotes the transaction efficiency of agricultural machinery service, and h_i denotes the machinery use links, including the five links of plowing/fertilizer applications, seeding, harvesting, transporting, and pesticide spraying.

$$\boldsymbol{Landin_i} = \boldsymbol{\beta_0} + \sum_{j=0}^{5} \boldsymbol{\delta_{aj} Ams_{teji}} + \sum_{j=0}^{4} \boldsymbol{\beta_{sj} self_{ji}} + \sum_{j=0}^{4} \boldsymbol{\beta_{fj} far_{ji}} + \sum_{j=0}^{3} \boldsymbol{\beta_{cj} cou_{ji}} + \sum_{j=0}^{3} \boldsymbol{\beta_{pj} pro_{ji}} + \boldsymbol{\omega_i}. \tag{3}$$

In Equation 3, Ams_te_{ji} represents the traxnsaction efficiency of agricultural machinery services of i_th farmers, δ_{aj} is the main parameter to be estimated, other variables are the same as in Equation 1, and ω_i represents the random error term.

4 Econometric results

4.1 The influence of the agricultural machinery service on farmers' farmland transfer-in

Using Stata 13.0 software, this paper first investigated the impact of agricultural machinery service on farmers' farmland transfer-in. The regression results showed (Table 2) that the agricultural machinery service had a significant positive impact on farmers' farmland transfer-in, which passed the 1% statistical significance level test, indicating that agricultural machinery service would promote farmland scale operation. The specialized labor division of service outsourcing can bring specialization economy and labor division economy, which not only alleviates the constraints of farmers' farmland scale operation but also reduces the service transaction costs, improves the production efficiency of final products, and enables farmers to obtain the benefits of agricultural labor division. With the deepening of the agricultural labor division, farmers can get more benefits from the labor division and have

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TABLE 2 Baseline regression of the agricultural machinery service on farmers' farmland transfer-in.

Variable	Farmers' farmland transfer-in				
Agricultural machinery service	0.036***	0.039***	0.039***	0.043***	0.024***
	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)
Gender		0.149**	0.058	0.098	0.122
		(0.073)	(0.080)	(0.079)	(0.076)
Age		−0.253***	−0.239***	−0.210***	−0.173***
		(0.036)	(0.040)	(0.040)	(0.037)
Education level		−0.010	0.016	0.021	0.012
		(0.043)	(0.048)	(0.049)	(0.046)
Health status		−0.112***	−0.119***	−0.141***	−0.144***
		(0.031)	(0.034)	(0.035)	(0.033)
Village cadres			−0.016	0.018	0.031
			(0.135)	(0.140)	(0.136)
Farming family members			0.066	0.038	0.043
			(0.070)	(0.073)	(0.069)
Agricultural technology guidance			0.113	0.141	0.170*
			(0.102)	(0.102)	(0.093)
Number of farmland plots			0.167***	0.200***	0.212***
			(0.060)	(0.060)	(0.056)
Per capita disposable income				−0.168***	−0.148***
				(0.024)	(0.024)
Distance from the village committee to town				0.046	0.059
				(0.050)	(0.047)
Population over 60 years old				0.162***	0.088**
				(0.046)	(0.044)
Eastern region					0.126
					(0.104)
Central region					0.791***
					(0.081)
Constant	1.912***	3.087***	2.609***	2.889***	2.614***
	(0.065)	(0.215)	(0.280)	(0.439)	(0.420)
Obs.	1275	1274	973	924	924
R-squared	0.010	0.073	0.088	0.136	0.217

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

more incentives to further expand the farmland operation scale, which proves Hypothesis 1. After adding control variables such as farmers' characteristics, family characteristics, village characteristics, and regional characteristics, the agricultural machinery service still had a significant positive effect on farmland transfer-in, indicating that the research results of this paper are reliable.

4.2 The impact of deepening the labor division of the agricultural machinery service on the farmers' farmland transfer-in

With the deepening of the labor division of agricultural machinery service, the agricultural machinery service brings the benefits of labor division while also generating transaction

TABLE 3 Impact of the agricultural machinery service transaction efficiency on farmers' farmland transfer-in.

Variable	Farmers' farmland transfer-in		
	Model 1 agricultural machinery service degree	Model 2 agricultural machinery service degree improvement	
Agricultural machinery service division of labor deepening	0.290***	One link	0.171
	(0.022)		(0.117)
		Two links	0.243**
			(0.124)
		Three links	0.642***
			(0.131)
		Four links	0.861***
			(0.123)
		Five links	1.529***
			(0.135)
Farmers' characteristics	Control		
Family characteristics	Control		
Village characteristics	Control		
Regional characteristics	Control		
Constant	1.653***	1.852***	
	(0.404)	(0.405)	
Obs.	1020	1020	
R-squared	0.345	0.359	

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

costs. Therefore, examining the internal mechanism of service outsourcing affecting farmers' farmland transfer-in requires further analyzing the effect of the agricultural machinery service transaction efficiency on farmland transfer-in. The empirical results are shown in Table 3. Model 1 explored the impact of the agricultural machinery service transaction efficiency on farmers' farmland transfer-in. The efficiency of agricultural machinery service transaction promoted farmland transfer-in and passed the 1% statistical significance level test. Model 2 discussed that with the improvement of agricultural machinery service transaction efficiency, the scale of farmers' farmland transfer-in gradually expands, and the statistical significance level keeps increasing, finally significant at the 1% level. The results indicate that farmers' production and transaction conditions are improved, the constraints of expanding the land operation scale are alleviated, the marginal cost of farmers' production is reduced, the marginal benefit from purchased services is increased, and the scale of farmland operation is further expanded to obtain more benefits from the land operation. Thus, Hypothesis 2 of this article is verified, that is, the expansion of the farmland operation scale is the result of the continuous improvement of the agricultural machinery service transaction efficiency.

4.3 Endogeneity test

The previous studies have argued that the agricultural machinery service promoted farmers' farmland transfer. However, the expansion of the farmland scale also promoted the increase of service outsourcing to a certain extent (Qu and Zhao, 2021). There is a mutual causality endogeneity problem between the two, and there may be other endogeneity problems due to omitted variables. For this purpose, the article uses the proportion of machinery used for harvesting at the village level as an instrumental variable for agricultural machinery service and uses the limited information maximum likelihood (LIML) method to test for endogeneity. On one hand, the proportion of machinery used for harvesting at the village level is correlated with the agricultural machinery service, and the larger proportion of machine harvesting in the village, the easier farmers' service outsourcing demand can be satisfied, which meets the correlation requirement of the instrumental variable; on the other hand, the proportion of machinery used for harvesting at the village level is not directly correlated with farmers' farmland transfer-in behavior, which meets the exogeneity requirement of the instrumental variable. The steps of the endogenous test are as follows: first, the regression equation was tested for heteroskedasticity, and after the Breusch–Pagan/

TABLE 4 Estimation results of the instrumental variable of the agricultural machinery service and farmland transfer-in.

Variable	Farmers' farmland transfer-in		
	OLS	2SLS	LIML
Agricultural machinery service	0.024**	0.214***	0.214***
	(0.011)	(0.050)	(0.050)
Farmers' characteristics	Control		
Family characteristics	Control		
Village characteristics	Control		
Regional characteristics	Control		
Constant	2.614***	1.814***	1.814***
	(0.456)	(0.600)	(0.600)
Obs.	924	689	689
R-squared	0.217	.	.

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

Cook–Weisberg test for heteroskedasticity ($p = 0.0000 < 0.05$), the homoskedasticity hypothesis for errors was rejected and heteroskedasticity may exist. The Durbin–Wu–Hausman test using the OLS and instrumental variable (IV) estimators showed that $p = 0.000 < 0.05$, rejecting the null hypothesis, and concluding that agricultural machinery service was endogenous and the instrumental variable was set reasonably. Second, the validity of the instrumental variable is tested according to the correlation condition, which means that the higher the degree of correlation, the higher will be the level of explanatory variation and more accurate the estimation. The instrumental variable validity was tested by observing the first stage F-test of the two-stage least square (2SLS) method, and according to the golden thumb rule (Staiger and Stock, 1997), F = 51.14 > 10 at the 1% significant level, it can be considered that the instrumental variable selected in this paper did not have a weak instrumental variable problem. For robustness, the LIML method, which is more insensitive to weak instrumental variables, is used for estimation in this paper. The regression model is shown in Table 4. The coefficient estimated by the LIML method is consistent with the 2SLS method, which confirmed from the side that there is no weak instrumental variable problem and further illustrated that the agricultural machinery service had a significant positive effect on farmers' farmland transfer-in, and the result was still robust after controlling the endogeneity.

4.4 Robustness test

4.4.1 Farmland transfer-in of farmers who own machinery or not

Farmers' owned machinery affects their choice to purchase the agricultural machinery service, and the robustness of the impact of agricultural machinery service on farmers' farmland transfer-in is further analyzed by distinguishing whether farmers own machinery or not. The regression results are shown in Table 5. In model 1, for farmers who own machinery, the agricultural machinery service had a significant positive effect on farmers' farmland transfer-in. In model 2, for farmers who own no machinery, the agricultural machinery service also had a significant positive effect on farmers' land transfer-in. The results showed that the agricultural machine service positively influenced farmers' farmland transfer-in decisions, regardless of whether farmers owned agricultural machinery or not, which further proved the robustness of this study's findings. In addition, the standardized coefficient of the impact of the agricultural machinery service on the farmland transfer-in of farmers who owned machinery was 0.114, and the standardized coefficient of the impact on the farmland transfer-in of farmers who owned no machinery was 0.210, indicating that the agricultural machinery service had a larger impact on the farmland transfer-in of farmers who owned no machinery, that is, the deeper the labor division of the agricultural machinery service, the more it will promote the farmers' farmland transfer-in and obtain the benefits of labor division.

4.4.2 Farmland transfer-in of farmers growing food crops and cash crops

Farmers who grow food crops and cash crops may differ in their choice of service outsourcing, which then affects farmers' farmland transfer-in decisions. To further verify the robustness of the empirical results, we distinguish the impact of agricultural machinery services for food crops and cash crops on farmers' farmland transfer-in. Based on the control of other variables, models 1 and 2 in Table 6 report the impact of agricultural machinery services on farmers' farmland transfer-in decisions of farmers growing food crops and cash crops, respectively. The regression results show that agricultural machinery services positively affect farmers' farmland transfer-in, regardless of whether they grow food crops or cash crops, and significantly positively affect farmers who grow food crops at the 1% level, indicating that agricultural machinery services significantly promote farmland transfer-in of farmers who grow food crops.

Because the agricultural machinery service has a significant promoting effect on farmland transfer-in of farmers growing food crops, to further analyze the agricultural machinery services on farmers' farmland transfer-in behavior of growing food crops, the article further examines the farmland transfer-in behavior of farmers growing rice, wheat, and maize. The regression results are shown in Table 7. In regression models 1–3, the impact of the agricultural machinery service on farmland transfer-in decisions of farmers growing rice, wheat, and maize, respectively, is reported. The regression results show that the agricultural machinery service of farmers growing rice, wheat, and maize significantly and positively affects farmers' farmland transfer-in at the 5%, 5%, and 1% levels, respectively, indicating that the agricultural machinery service promotes farmland transfer-in decisions of farmers growing rice, wheat, and maize, which proves the results of this article have certain robustness.

4.5 Further discussion: heterogeneity analysis

There is regional heterogeneity in the geographical location of different regions, and the impact of agricultural machinery services

TABLE 5 Impact of the agricultural machinery service on farmers' farmland transfer-in with and without machinery.

Variable	Farmers' farmland transfer-in			
	1) Own machinery	Standardized coefficient	2) Own no machinery	Standardized coefficient
Agricultural machinery service	0.040***	0.114	0.073***	0.210
	(0.013)		(0.026)	
Farmers' characteristics	Control			
Family characteristics	Control			
Village characteristics	Control			
Regional characteristics	Control			
Constant	2.830***		−0.285	
	(0.499)		(0.847)	
Obs.	656		256	
R-squared	0.247		0.137	

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

TABLE 6 Farmland transfer-in of farmers growing food crops and cash crops.

Variable	Farmers' farmland transfer-in	
	1) Food crops	2) Cash crops
Agricultural machinery service	0.032***	0.010
	(0.010)	(0.015)
Farmers' characteristics	Control	
Family characteristics	Control	
Village characteristics	Control	
Regional characteristics	Control	
Constant	2.276***	3.321***
	(0.433)	(0.680)
Obs.	856	464
R-squared	0.263	0.201

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

TABLE 7 Farmland transfer-in of farmers growing rice, wheat, and maize.

Variable	Farmers' farmland transfer-in		
	1) Rice	2) Wheat	3) Maize
Agricultural machinery service	0.036**	0.052**	0.034***
	(0.014)	(0.021)	(0.011)
Farmers' characteristics	Control		
Family characteristics	Control		
Village characteristics	Control		
Regional characteristics	Control		
Constant	0.904	−1.096	2.320***
	(0.797)	(1.056)	(0.483)
Obs.	416	219	634
R-squared	0.323	0.163	0.307

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

on farmers' farmland transfer-in decisions may be varied in different regions. The northeast regions of Heilongjiang, Jilin, and Liaoning, as important grain-producing regions in China, bear the arduous task of ensuring national food security, and its agricultural development, especially grain production, is more deeply and widely affected by agricultural machinery services (Li et al., 2021b; Lu et al., 2022). Thus, to further analyze the differential impact of the agricultural machinery service on farmers' farmland transfer-in, this paper divides the sample into four regions: eastern, central, western, and northeastern regions of China. The regression results are shown in Table 8. The impact of agricultural machinery services on farmers' farmland transfer-in is positive in the east, central, western, and northeastern regions, with impact coefficients of 0.016, 0.069, 0.027, and 0.029, respectively, and has a significant positive impact at the 1%, 10%, and 10% levels in the central, western, and northeastern regions, respectively, indicating that there are regional differences in the impact of agricultural machinery services on farmers' farmland transfer-in decisions, and the degree of impact is also different. Therefore, in promoting the development of agricultural modernization, the development of agricultural machinery services should continue to be promoted, and the scale of agricultural development should be realized according to local conditions.

5 Discussion

The rapid development of service outsourcing represented by agricultural machinery has the operating characteristics of labor division and scale economy; this rapid development of the agricultural machinery service has accelerated the transformation of China's agricultural management mode and become an important

TABLE 8 Heterogeneity analysis of farmers' transfer-in grouped by region.

Variable	Farmers' farmland transfer-in			
	Eastern	Central	Western	Northeastern
Agricultural machinery service	0.016	0.069***	0.027*	0.029*
	(0.029)	(0.018)	(0.017)	(0.017)
Farmers' characteristics	Control			
Family characteristics	Control			
Village characteristics	Control			
Constant	0.245	0.543	2.634***	5.093***
	(1.611)	(0.869)	(0.640)	(0.879)
Obs.	176	267	245	236
R-squared	0.090	0.246	0.163	0.233

Note: *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$; robust standard errors in parentheses.

way to realize agricultural scale management. The existing literature mainly focused on the benefits of labor division brought by service outsourcing that can alleviate farmers' labor, technology, and capital constraints, while fewer studies analyzed the transaction costs incurred when farmers purchase service outsourcing to obtain the benefits of labor division, making the existing explanations of the impact mechanism of service outsourcing on farmland transfer less comprehensive.

Our study analyzed that agricultural machinery services affect farmers' farmland transfer-in decisions from the perspective of the benefits of labor division and transaction costs, which makes up for the lack of existing research focusing only on the division of labor economy and ignoring transaction costs and makes the existing research more objective and comprehensive. Then, the study used the national survey data on the CFD, and the use of nationally representative survey data makes the results of this paper representatively nation-wide and the estimation results more accurate. Furthermore, the LIML method was used to examine the endogeneity of service outsourcing and farmers' farmland transfer-in decisions, which makes the endogeneity test more accurate. We also examined the impact of whether farmers own machinery on farmland transfer-in decisions, compared with the farmland transfer-in decisions of farmers growing food crops and cash crops, and analyzed the farmland transfer-in decisions of farmers growing rice, wheat, and maize. In turn, the paper further analyzed the heterogeneous differences in the impact of the agricultural machinery service on farmers' farmland transfer in four regions of eastern, central, western, and northeastern China. As the largest developing country in the world, China has the basic national conditions of "big country and small farmers" and the realistic characteristics of the rapid development of the agricultural machinery service; the research results of farmland scale management are of great practical significance, which can provide experience reference for other developing countries (Pakistan, India, and Vietnam) to realize farmland scale management.

Compared with previous similar studies, the results of this study have some similarities and differences with previous studies. First, most of the existing studies analyzed that service outsourcing can alleviate farmers' operational constraints and bring the division of labor benefits, which helps facilitate farmers' farmland transfer-in decisions (Yang et al., 2019; Yu et al., 2021; Cai et al., 2022), and the result of this paper is consistent with this. However, the existing studies were less concerned that the transaction costs generated by farmers' purchase of service outsourcing may reduce the farmers' access to the benefits of labor division, which then affects farmers' farmland transfer-in decisions. Based on previous studies, this paper further analyzed that the deepening of the labor division in the agricultural machinery service market brings about the improvement of transaction efficiency, which reduces the transaction costs of farmers' purchase of service outsourcing and consequently promotes farmers' farmland transfer-in decisions. Second, the existing research mostly used regional survey data in a small area (Chen and Tang, 2020; Yu et al., 2021; Cai et al., 2022), and the data in a small area may have the problem of insufficient sample representation, which makes the evaluation difference of the farmland transfer scale too small and may lead to inaccurate research results. This paper used the large-sample survey data at the national level of CFD, which can avoid the small-sample representative problems. Third, the existing studies mostly used single crop analysis (Yu et al., 2021; Cai et al., 2022); unlike previous studies, this paper distinguished between food crops and cash crops, whether farmers own machinery or not, and regional heterogeneity, to further verify the impact of the agricultural machinery service on farmland scale operation, which makes up for the shortcomings of existing studies.

There are some shortcomings in this study that can be addressed in future research. 1) Due to the differences in the farmland fragmentation, the crop types grown, and the degree of professional production, which lead to different timing of machinery used in different plots, the demand of small farmers for service outsourcing is often different (Zang et al., 2022; Aryal et al., 2021), thus affecting the farmers' willingness to expand the scale of farmland management. Future research can be subdivided into the degree of land fragmentation, the type of crops grown (cash crops), or the degree of professional production, to further explore

the influence mechanism of service outsourcing on farmers' farmland transfer. 2) We acknowledge that although this paper carefully addressed the endogeneity of agricultural machinery service outsourcing using 2SLS and LIML methods to reduce endogeneity bias, there is the possibility that some unobserved factors that cannot be excluded may be correlated with the instrumental variable due to the cross-sectional data used in the article.

6 Concluding remarks

6.1 Conclusion

Based on the new classical economic and transaction cost theories, this paper empirically examined the impact of the agricultural machinery service on farmers' farmland transfer-in behavior based on the theoretical analysis from the dual perspective of transaction costs and benefits of labor division, using the 2020 CFD publicly released by Zhejiang University. Furthermore, the influence mechanism of the deepening labor division of the agriculture machinery service on farmers' farmland transfer-in was further analyzed. The following conclusions were drawn: 1) the agricultural machinery service had a positive effect on farmland transfer-in. The agricultural machinery service can not only alleviate the constraints of insufficient production factors faced by farmers transferring to farmland but also can reduce the service transaction costs and obtain the division of labor economy. The larger the farmland scale, the more the farmers gain the benefits of labor division, and the more they are inclined to expand the farmland operation management. 2) With the deepening of the labor division of the agricultural machinery service, the improvement of agricultural machinery service transaction efficiency had a significant positive impact on farmland transfer-in. The improved transaction efficiency of the agricultural machinery service increased the net benefit of service outsourcing while reducing the transaction cost of service outsourcing, which motivated farmers to improve their production and operation efficiency and obtain more operational benefits by increasing the agricultural machinery service. The existence of the marginal net benefit of the agricultural machinery service induced farmers to expand their farmland operation to earn more service outsourcing income until the marginal net benefit of service outsourcing returned to zero.

6.2 Suggestions

According to the aforementioned analysis, the policy recommendations of this paper are as follows: first, the market-oriented, professional, and whole process development of agricultural machinery services should be further promoted, and multiple service entities should be guided to strengthen cooperation, form new organizations such as service consortia and service alliances, expand service capacity and service areas, and provide farmers with more advanced varieties, technologies, equipment, and modern management concepts to meet their production needs. Second, the technical standards, quality supervision system, and integrated service platform of the whole process of agricultural machinery services should be improved, and the construction of the "whole process mechanization + comprehensive farming" service center should be explored to provide farmers with "one-stop" field services, thus improving the standardization level of the whole process of service outsourcing, bringing more agricultural production links into the labor division system, and driving the development of the agricultural division of labor to a higher level. Third, the organization and scale of service outsourcing should be improved, the organizational role of village collectives should be played, and the negotiation position of farmers in service outsourcing transactions should be strengthened so as to increase the moderate scale operation entities to obtain more benefits of labor division from service outsourcing and realize the mutual promotion and mutual benefit for agricultural service entities and farmland scale operation entities.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

Conceptualization: PZ and YZ; methodology: PZ, JZ, and YZ; writing—original manuscript preparation: YZ; writing—review and editing: PZ, JZ, YL, and YZ. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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