agriculture

Article

The Impact of Socialized Agricultural Machinery Services on Land Productivity: Evidence from China

Siyu Yang and Wei Li *

College of Applied Science and Technology, Beijing Union University, Beijing 100012, China
* Correspondence: nanliwei@buu.edu.cn

Abstract: Under the background of urbanization, rural hollowing out, and aging, it is increasingly urgent to solve the problem of "who will farm the land" to stabilize the foundation of national food security. The socialized agricultural machinery service undoubtedly provides a feasible solution. From the perspective of land productivity, and based on field survey data from 597 farmers in four major wheat-producing provinces in China, this study applied an endogenous switching regression model. By constructing a "counterfactual" analysis framework, this paper's empirical analysis showed that the socialized agricultural machinery service had a positive impact on the land productivity of wheat production. At the same time, the impact of socialized agricultural machinery services on land productivity was heterogeneous due to the differences in planting scale, terrain, and concurrent business. It can give full play to the positive influence of socialized agricultural machinery services on stable grain yields and increases. It is necessary to guide and support the effective supply of socialized agricultural machinery services in the key links of food production, and to reasonably guide the main providers of socialized agricultural machinery service to provide high-quality services that meet the production needs of small farmers according to local conditions, so as to promote the organic connection between small farmers and the development of modern agriculture.

Keywords: food production; land productivity; socialized agricultural machinery services; endogenous switching regression model

check for updates

Citation: Yang, S.; Li, W. The Impact of Socialized Agricultural Machinery Services on Land Productivity: Evidence from China. *Agriculture* **2022**, *12*, 2072. https://doi.org/10.3390/agriculture12122072

Academic Editor: Sanzidur Rahman

Received: 19 October 2022
Accepted: 25 November 2022
Published: 2 December 2022

1. Introduction

Food security concerns China's national security. China's cultivated land resource constraints are obvious, and the agricultural labor cost is rising. In order to ensure the popularization and utilization of agricultural mechanization and new agricultural technology, the key problem of China's agricultural development is to realize the continuous improvement of land productivity. The level of agricultural mechanization is the key index to measure agricultural productivity [1]. It also plays an important role in improving land productivity and ensuring national food security. According to statistics, the total power of China's agricultural machinery increased from 640.28 million kilowatts in 2004 to 1.03 billion kilowatts in 2019, constituting an increase of 60.41%. Correspondingly, China's grain output also increased from 469.47 million tons in 2004 to 663.84 million tons in 2019, constituting an increase of 41.40% (Figure A1). However, most Chinese farmers use agricultural machinery by purchasing a wide range of socialized agricultural machinery services, rather than by renting agricultural machinery or purchasing agricultural machinery themselves [2,3]. The socialized agricultural machinery services refer to the mechanical operation services provided by agricultural machinery service organizations and agricultural machinery households to farmers in the agricultural industry, including mechanical farming, mechanical sowing, mechanical harvesting, plant protection, irrigation, and drainage. Socialized agricultural machinery is a concept with Chinese characteristics. Since China's No. 1 central document first put forward the concept of "social service" in 1983, it has always been closely linked with China's agricultural reform and policy discourse system.

From the international academic literature [4,5], many studies have directly used the concept of agricultural services for a long time. According to the professional division of labor, there are different levels of labor within enterprises and within society. Compared with the collectivized production in the period of the people's commune, the household management of Chinese peasant households obviously belongs to a relatively low level of intra-enterprise division of labor, which cannot effectively undertake many production contents suitable for the completion of the social division of labor [6]. Therefore, agricultural services developed rapidly, which may be the reason why the political documents of the Communist Party of China, guided by Marxism, referred to agricultural services in the context of "socialization". In the process of establishing a socialized service system for agricultural machinery and promoting moderate scale operation, labor substitution services focusing on machine farming, machine sowing, and machine harvesting and technology substitution services focusing on plant protection, irrigation, and drainage are becoming more and more popular. The socialized agricultural machinery service has brought new changes to wheat production, with the highest level of comprehensive mechanization found in the relationship between cultivated land, sowing, and harvesting [7]. As a new type of production factor, the socialized agricultural machinery service runs through the whole agricultural industry chain, plays a bonding role between different production factors, and serves grain production. The socialized agricultural machinery service involves agricultural management families in the division of labor activities and leads small farmers toward modern agricultural development [8]. Under the premise of not reducing farmers' income and not endangering food security, the problems of who will farm and how to farm the land have been solved, the dilemmas related to land scale operations have been solved, and a new way of dealing with scaled-up operations has been developed.

Although the research conclusions on the promotion of grain land productivity by machinery and socialized agricultural machinery services have been relatively stable, there is still a lack of comprehensive research on the influence of wheat crop socialization services on land productivity [9]. There is also a lack of investigation on the differences between the impacts of social services on the land productivity of farmers with different characteristics, to a certain extent. The endowment differences between farmers directly affect land productivity [10], and the impacts of social services on farmers with different endowment conditions should be marginal. In this study, an endogenous switching regression model was used to measure the treatment effects to eliminate endogeneity. The results of this study are beneficial in relation to wheat, an important ration crop in northern China. It provides marginal contributions to the impact of socialized agricultural machinery services on farmers' land productivity from the perspective of the differential impacts. Through this study, we hope to promote a discussion on the impact mechanism and differential impacts of China's agricultural machinery socialization services, as well as provide support for grassroots social service organizations to provide differentiated and efficient services for farmers with different characteristics. The improvement of land productivity is related to the increase in food production and is one of the important goals of current agricultural work. Policymakers hope that the adoption of socialized agricultural machinery services can improve land productivity, but whether the socialized agricultural machinery services can improve land productivity and to what extent is the question. This study makes a corresponding answer for this question.

2. Literature Review

Land productivity is measured by output per unit area [11,12]. This traditional concept conveys that the main factors affecting grain land productivity are seeds, fertilizers, pesticides, and water [13]. Existing studies have also shown that planting scale [14], fertilizer application [15], agricultural technology progress [16], rural labor mobility [17], agricultural subsidies [18], mechanization level [19,20], climate change [21], credit constraints [22], etc. also have an impact on grain production per unit area. The directions and sizes of various factors show differences in terms of their varied economic development stages and different regions.

The agricultural mechanization level is an important standard to measure agricultural modernization and one of the fundamental ways to develop agricultural productivity. The level of agricultural mechanization plays an important role in improving land productivity and ensuring national food security. Agricultural machinery is an advanced production tool. It is the material base of modern agriculture and the key factor to promote the transformation from traditional agriculture to modern agriculture. In 2004, the Chinese government promulgated the Law on the Promotion of Agricultural Mechanization. China's subsidies for agricultural machinery have increased year by year to promote the strategy of agricultural modernization and increase the country's grain production capacity. At the same time, the influence of related aspects of agricultural machinery on land productivity has also begun to attract the attention of scholars. The relevant research is mainly divided into two aspects.

First, the impact of agricultural machinery on land productivity is analyzed from the perspective of agricultural machinery. Some scholars believe that the use of agricultural machinery promotes the progress of agricultural technology and plays a significant role in improving land productivity. Zhou and Kong [1] concluded that agricultural mechanization has a significant positive impact on food output. Its impact elasticity was 1.28. Yamauchi [23] believes that agricultural mechanization can promote agricultural production based on data from Indonesia. Ma et al. [24], based on the survey data of 493 farmer households in China, concluded that agricultural machinery has a significant positive impact on corn yield—the use of agricultural machinery increased corn yield by 74 kg/mu. Zhou X et al. [25] applied a quantile regression model and found that the use of agricultural machinery at selected quantiles (except 80% quantiles) significantly increased corn yield. Furthermore, compared with high-productivity farmers, low-productivity farmers used agricultural machinery to increase corn yield even further. However, Binswanger (1986), through a comprehensive analysis of the agricultural experience of developing and developed countries, found that the effect of agricultural machinery on increasing grain production only occurred in a specific environment. Agricultural machinery must be coupled with high-quality seed and fertilizer inputs, or it will be difficult to achieve increased production. Ito (2010) constructed the machinery development index of all county-level units in China and found that the contribution rate of the machinery development index to China's agricultural output did not change greatly from 1991 to 2004.

The second aspect is to analyze the impact of agricultural machinery on land productivity from the perspective of socialized agricultural machinery services. China has a vast territory and multi-latitude agricultural production. There is a time difference between the north and the south when wheat is ripe and harvested. In the 1990s, the rise of agricultural machinery cross-area operations began, that is, agricultural machinery socialization services began in their embryonic form.

In addition to focusing directly on factor input, the effect of socialized agricultural machinery services on land productivity has also been verified [26,27]. Irrigation and drainage, mechanical farming services, and planting planning have had significant effects on rice yield, while the rules of pest control and the unified purchasing of the means of production have had no significant effects. Chen C. et al. [7], based on the four-year follow-up survey data of three counties in Jiangsu Province, found that the socialized services of rice transplanting and pest control had a significant positive impact on rice yield. Socialized services in the harvesting process had no significant impact on rice yield. This is mainly because the harvesting process is not part of the production process and cannot have an objective impact on rice output. To distinguish the heterogeneity of socialized services, different socialized services can be classified into the following categories: technology-intensive socialized services and labor-intensive socialized services. Technology-intensive social services (prevention and control of plant and seedling diseases) refer to farmers with advanced planting technology or professional social service organizations instead of small-scale farmers with limited skills to engage in more technical production links [28]. Labor-intensive social services (cultivation, transplanting, and harvesting) mainly substitute machinery for labor [29]. The use of socialized agricultural machinery services has accelerated the savings made regarding labor input and may have a small impact on rice yield. Zhang and Yi [30] found that social services have a significant positive impact on rice yield. Labor-intensive social services have had no significant impact on rice yield, while technology-intensive social services have had a significant positive impact on rice yield.

The conditions for the division of labor in grain production are becoming more and more complete, the space for deepening the division of labor in grain production has been effectively widened [31], and the socialized agricultural machinery services have involved agricultural household management in the division of labor activities, as well as extended the process of grain production [32–34]. The socialized agricultural machinery services have realized the specialized division of labor and brought the scale economy of each grain production link into play [35,36]. According to Young's theorem, "the division of labor affects the market scale, and the market scale depends on the division of labor, and there is a positive interaction between the two". The market scale of socialized agricultural machinery services is also expanding [37]. As far as wheat production is concerned, under the constraints of the agricultural labor force, cultivated land, self-owned agricultural machinery, and other factors, farmers outsource all or part of their grain production to socialized agricultural machinery service organizations by purchasing socialized agricultural machinery services. This makes up for the shortage of agricultural labor, limited arable land, and the lack of agricultural machinery, and is conducive to improving the land productivity under the constraints of the agricultural land scale.

The socialized agricultural machinery service has changed the traditional agricultural production mode, optimized the factor allocation of farmers, effectively replaced the family agricultural labor force, and reduced the technical requirements for farmers to engage in wheat production. Huang Jikun et al. [38] found that it is difficult for small farmers to effectively control the frequency of plant protection, while the unified control after the use of socialized agricultural machinery services can control the frequency of plant protection, save the cost of application, improve the quality of application, and have a positive impact on the land productivity of grain production.

The path of labor input alleviates a situation in which the opportunity costs of agricultural labor are rising when rural labor enters into non-agricultural sectors, and the establishment of socialized agricultural machinery service systems also enables farmers to choose alternative factors [39]. Farmers use socialized agricultural machinery services to achieve relatively cheap and abundant agricultural machinery to replace the relatively expensive and scarce labor force, which alleviates the labor constraints of farmers and breaks down the limitations of the original resource endowment [40], so as to improve the land productivity of food production. In conclusion, socialized agricultural machinery services affect land productivity through three paths: the capital input path, the labor input path, and the technical efficiency path.

In the capital input path, the role of agricultural machinery in increasing production, improving efficiency, and saving costs is more than that of human and animal power [41]. Socialized agricultural machinery services provide various types of agricultural machinery (such as rotary tillers, film spraying machines, seeding machines, power sprayers, anti-aircraft drones, tractors, and harvesters), which farmers can use on their farms for various purposes (such as farming land, sowing seeds, spraying pesticides, fertilization, irrigation, drainage, and harvesting). The service capacity of large-scale indivisible investment can be fully utilized to reduce the diseconomy caused by repeated investments from single households [42], can simplify the grain production process, and can have a positive impact on the land productivity of grain production.

The path of technical efficiency breaks through the passivity of small-scale farmers' adoption of agricultural technology [43], and socialized agricultural machinery services act as transmitters of human capital and knowledge capital, which realize the introduction of advanced technologies, such as plant protection, deep ploughing, and rice transplantation into grain production. Through efficient management methods and modern organization systems, the scientific and technological content and output of grain production can be improved, while the land productivity of grain production can also be improved to a certain extent [44].

This study takes wheat growers as an example. It uses endogenous switching regression modeling to analyze whether socialized agricultural machinery services affect farmers' production. It also examines the differences in the effects of socialized agricultural machinery services on increasing the output of farmers in different groups.

3. Materials and Methods

3.1. Data

The data used in this study are from a questionnaire survey of 600 wheat farmers in 60 villages from 12 counties (cities, districts) in 4 provinces—Shandong, Jiangsu, Hebei, and Henan—conducted by the National Institute of Agricultural and Rural Development of China Agricultural University in 2019. First, Shandong, Jiangsu, Hebei, and Henan were selected based on the principle of the large yield and large number of farmers involved. Then, we selected 3 counties (cities, districts) in each province that carry out socialized agricultural machinery services, have a high wheat yield, are in different regions of the province, and represent different levels of economic development in the province. Finally, five administrative villages were selected from each county (city, district). After determining the administrative villages, 10 wheat growers were randomly selected in each village according to the register. A questionnaire survey was conducted through a household survey. A total of 60 sample villages and 600 households were investigated, and a total of 600 questionnaires were collected. After excluding the questionnaire samples with incomplete data and obvious errors, a total of 597 valid questionnaires were obtained, with an effective rate of 99.5%. The design of the questionnaire fully considered the existing research results on socialized agricultural machinery service and wheat production and, before the formal survey, some farmers were randomly selected for a pre-survey to further improve the questionnaire. The content of the questionnaire involved the use (or not) of a socialized agricultural machinery service, the endowment characteristics of householders, the operation of families, the characteristics of the external environment, and inquiries.

3.2. Empirical Model Setting

3.2.1. The Role of Socialized Agricultural Machinery Services on Land Productivity

To analyze the impact of the socialized agricultural machinery services on land productivity, we considered the primary goal of improving land productivity to ensure food security. We chose wheat food crops as the research object. The increase in grain production (increased land productivity) is reflected in the increase in wheat production per unit area. The model used was the extended Cobb–Douglas (C–D) production function. We made appropriate adjustments based on this research; the constructed model is shown in formula (1). The explained variable of the model is the land productivity of wheat production (denoted by Y). The core explanatory variable is the socialized agricultural machinery service (expressed by service). Control variables (denoted by z) include total farm income, subsidies per mu, wheat sown area, agricultural labor force per mu, material input per mu, and technology adoption [45,46]. α, β, γ are the parameters to be estimated, and ε is the random interference term.

$$\ln(Y_i) = \alpha + \beta \mathrm{service}_i + \gamma \ln Z_i + \varepsilon_i \quad (1)$$

3.2.2. Endogenous Switching Regression Model

The common method to deal with selective bias is the propensity matching score method, but it can only control the heterogeneity of observable variables, so the endogenous switching regression model was selected [47,48]. Unlike Heckman's two-step method, which only focuses on observable equations, the endogenous switching regression model (ESR) proposed by Maddala (1983) [49] deals with unobserved variables as missing values and estimates the selection equation and the result equation, respectively. The ESR model generally contains two stages of estimation. In the first stage, a Probit or Logit model is used to estimate the selection equation of farmers socialized agricultural machinery services. In the second stage, a determination equation of farmers' land productivity was established to estimate the change in land productivity caused by farmers' adoption of socialized agricultural machinery services. Specifically, the ESR model simultaneously estimates the following three equations:

The Behavior equation (whether to adopt socialized agricultural machinery services):

$$A_i = \delta' Z_i + k' I_i + \mu_i \tag{2}$$

The Results Equation (1) (treatment group: land productivity equation of the socialized agricultural machinery service adopters):

$$Y_{ia} = \beta_a' X_{ia} + \varepsilon_{ia} \tag{3a}$$

The Results Equation (2) (control group: land productivity equation of households that have not adopted socialized agricultural machinery services):

$$Y_{in} = \beta_n' X_{in} + \varepsilon_{in} \tag{3b}$$

where A_i represents the binary choice variable of whether farmers adopt the socialized agricultural machinery service; Z_i is a variety of factors affecting whether farmers adopt socialized agricultural machinery services; μ_i is the error term; and I_i is the utility variable vector to ensure the recognition of the ESR model. It should be noted that, in this study, the socialized service level of agricultural machinery in the village was selected as the instrumental variable in the conventional way, that is, the proportion of the scale of other farmers using the socialized agricultural machinery service in the village. This was added into the decision-making model for farmers' use of the socialized agricultural machinery service. The reason is that this variable only affects farmers' decisions to use the socialized agricultural machinery service but does not directly affect farmers' land productivity. Y_{ia} and Y_{in} represent the land productivity of the two sample groups—socialized agricultural machinery service adopters and non-adopters, respectively. X_{ia} and X_{in} are a series of factors that affect farmers' land productivity. ε_{ia} and ε_{in} are the error terms of the resulting equation.

The estimation results of the ESR model give the differential impact of various factors on the land productivity of farmers who adopt and those who do not adopt socialized agricultural machinery services. However, to evaluate the overall impact of socialized services on farmers' land productivities, it is necessary to use the estimated coefficient of the ESR model and further apply the counterfactual analysis framework. By comparing the expected land productivity of the households that adopt the socialized agricultural machinery service with the households that do not adopt the socialized agricultural machinery service in the real and counterfactual scenarios, the average treatment effect of the impact of the socialized agricultural machinery service on the land productivity of farmers can be estimated.

The expectation of land productivity of adopters of the socialized agricultural machinery service (treatment group) is defined as follows:

$$E[Y_{ia}|A_i = 1] = \beta_a' X_{ia} + \sigma_{\mu a} \lambda_{ia} \tag{4}$$

The expectation of land productivity of households not adopting the socialized agricultural machinery service (control group) is defined as follows:

$$E[Y_{in}|A_i = 0] = \beta_n' X_{in} + \sigma_{\mu n} \lambda_{in} \tag{5}$$

The expectation of land productivity under the circumstance that socialized agricultural machinery service users decide not to adopt the service is defined as follows:

$$E[Y_{in}|A_i = 1] = \beta'_n X_{ia} + \sigma_{\mu n}\lambda_{ia} \quad (6)$$

The expectation of land productivity under the circumstance that the socialized agricultural machinery service is not adopted by households is defined as follows:

$$E[Y_{ia}|A_i = 0] = \beta'_a X_{in} + \sigma_{\mu a}\lambda_{in} \quad (7)$$

Then, the average treatment effect of farmers' land productivity who actually adopt the socialized agricultural machinery service, namely the average treatment effect (ATT) of the treatment group, can be expressed as the difference between Equation (4) and Equation (6):

$$ATT_i = E[Y_{ia}|A_i = 1] - E[Y_{in}|A_i = 1] = (\beta'_a - \beta'_n)X_{ia} + (\sigma_{\mu a} - \sigma_{\mu n})\lambda_{ia} \quad (8)$$

Accordingly, the average treatment effect of the land productivity of the farmers who did not adopt the socialized agricultural machinery service, namely the average treatment effect (ATU) of the control group, can be expressed as the difference between Equation (5) and Equation (7):

$$ATU_i = E[Y_{in}|A_i = 0] - E[Y_{ia}|A_i = 0] = (\beta'_n - \beta'_a)X_{in} + (\sigma_{\mu n} - \sigma_{\mu a})\lambda_{in} \quad (9)$$

In conclusion, the average value of ATT_i and ATU_i will be used in this paper to investigate the average treatment effect of the socialized agricultural machinery service on farmers' land productivities.

3.3. Variable Selection

The core explanatory variables are whether farmers use the socialized agricultural machinery service in general. While "0" means that no socialized agricultural machinery service is used, "1" means that a socialized agricultural machinery service (of any type) is used.

In addition to the socialized agricultural machinery service that may affect land productivity, other factors that may affect land productivity also need to be controlled to overcome the endogenous problems caused by missing variables. This study was based on existing research considering subsidies per mu [1,22], wheat sown area [12,20], the proportion of agricultural labor force [30], and technology adoption [11]. In addition, terrain [33] and part-time operation [30] are set as grouping variables of the model.

Finally, this study also added a set of regional dummy variables (Shandong Province, Jiangsu Province, Hebei Province, and Henan Province) to the land productivity model to control the unobservable geographical location, hydrological conditions, climatic factors, and agricultural production habits in different regions. This eliminates the influence of regional factors on land productivity. The definition, explanation, and descriptive statistics of all relevant variables are shown in Table 1.

Table 2 shows the comprehensive comparison of the differences in the values of various variables between the farmers who adopted the socialized agricultural machinery service and those who did not. There was no significant statistical difference in the proportion of agricultural labor force, terrain and concurrent employment between the two groups, but there were significant differences in other control variables. It is specific noted that farmers who adopted the socialized agricultural machinery service had higher per mu subsidies, wheat sown area, and technology adoption than those who did not.

Table 1. Variable definitions and descriptive statistics.

Type	Variable	Variable Code	Variable Definition and Description
Dependent variable	Land productivity	Output	Farmer's wheat production per unit area (half a kilogram/mu)
Core explanatory variables	socialized agricultural machinery service	Service	Adopted = 1, not adopted = 0
Control variable	Subsidy per mu	Sub	Direct subsidies for planting grain + subsidies for improved seeds + comprehensive subsidies for agricultural materials + subsidies for agricultural machinery + subsidies for large grain farmers + subsidies for key production technologies + subsidies for agricultural insurance premiums
	Wheat sown area	Acre	Farmers' wheat sown area (mu)
	Proportion of agricultural labor force	Agi	Number of family farm labor/number of family population
	Technology adoption	Tec	Use any agricultural technology = 1, not use = 0
Grouping variables	Terrain	Top	Flat land = 0, sloping land = 1
	Concurrent business	Concu	Pure agricultural households (non-agricultural income does not exceed 10% of the total income) = 0, part-time farmers (non-agricultural income exceeds 10% of the total income) = 1
Instrumental variable	This village's socialized agricultural machinery service level	Vser	The proportion of land scale of other farmers using socialized agricultural machinery services in the village

Table 2. The difference between farmers who adopt socialized agricultural machinery services and those who do not.

The Variable Name	Adoption Service Farmers		Farmers not Adopting Service		Mean Difference (t-Test)
	Mean	Std Dev	Mean	Std Dev	
Land productivity	951.374	5.687	909.328	17.250	42.046 ** (18.378)
Subsidy per mu	110.053	10.574	91.001	10.401	19.052 *** (6.513)
Wheat sown area	10.401	1.272	8.194	1.908	2.207 *** (0.096)
Proportion of agricultural labor force	0.613	0.014	0.572	0.037	0.041 (0.044)
Technology adoption	0.955	0.231	0.893	0.010	0.062 * (0.036)
Terrain	0.020	0.020	0.059	0.012	−0.038 (0.036)
Concurrent business	0.780	0.019	0.775	0.060	0.005 (0.062)

Note: *, **, ***, respectively indicate that the results of "mean difference t test" are significant at the statistical levels of 10%, 5% and 1%.

The adoption of socialized agricultural machinery services by farmers showed the characteristics of getting more subsidies per mu. Because the Chinese government vigorously promotes the socialized agricultural machinery service, the farmers who got more per mu subsidies were more active in responding to the socialized agricultural machinery service. Farmers adopting the socialized agricultural machinery service showed the characteristics of larger wheat sown area. The larger the wheat planting area was, the more likely it was to use large agricultural machinery, thus increasing the demand for socialized agricultural machinery services. The adoption of socialized agricultural machinery services by farmers showed more adoption of technology. The socialized agricultural machinery service acts as the conveyer of human capital and knowledge capital, which breaks through the passivity of small-scale farmers in adopting agricultural technology and realizes the introduction of advanced technology into food production.

Without considering other influencing factors, the land productivity of the farmers who adopted the socialized agricultural machinery service was significantly higher than that of the farmers who did not adopt the service (the difference was significant at the statistical level of 5%). Considering whether farmers adopt agricultural machinery socialization services is essentially a kind of self-selection behavior. The difference in land productivity does not necessarily come from the direct influence of socialized agricultural machinery service. Therefore, it is necessary to establish a counterfactual research framework and to use the ESR method to measure the net effect of socialized agricultural machinery services on farmers' land productivities.

4. Results

4.1. Function form Test

Before the empirical analysis, we need to test the suitability of the stochastic boundary model. The test statistics are as follows:

$$\lambda = -2[L(H_0) - L(H_1)] \tag{10}$$

Among them, $L(H_0)$ is the log likelihood value of the original hypothesis, and $L(H_1)$ is the log likelihood value of the alternative hypothesis. We compare the statistic λ with the critical value of the chi square distribution, and the test results are shown in Table 3.

Table 3. Hypothesis test of random boundary model of Cobb–Douglas (C–D) production function.

Explanation of Hypothesis	Log Likelihood	Test Statistics	Decision
H1: stochastic boundary model of C–D production function	172.098		
H0: technical inefficiency does not exist	163.742	59.98 ***	Refuse
H0: the socialized agricultural machinery service has no influence on the scale of operation	170.266	4.23 **	Refuse
H0: stochastic boundary model of transcendental logarithmic production function	175.133	7.03	Don't refuse

Note: ** and *** respectively indicate that the original hypothesis is rejected at the statistical level of 5% and 1%.

The first suitability test is to examine whether the invalid rate term U_i of the stochastic boundary model exists. The original assumption is "H_0: technical inefficiency item does not exist", $\sigma_U^2 = 0$. The result significantly rejects the original hypothesis, which indicates that the inefficiency of agricultural production technology exists significantly. The second suitability test examines whether the characteristics of socialized agricultural machinery services have an impact on the inefficiency of agricultural production technology. The coefficient δ_{Sj} of the characteristic variable S_{ji} of socialized agricultural machinery services in the model is 0 under the original hypothesis. The test results significantly reject the original hypothesis, which indicates that the characteristic variable of socialized agricultural machinery services has a significant impact on agricultural technical efficiency. The third suitability test examines whether the setting of the production function is appropriate. The original hypothesis set the agricultural production function as the transcendental logarithm function, and the likelihood ratio test did not reject the original hypothesis, indicating that there were no significant differences between the transcendental logarithm function and the C–D production function. Therefore, it is reasonable to use the C–D production function in this study.

4.2. Analysis of Socialized Agricultural Machinery Service Adoption and Land Productivity Based on Endogenous Switching Regression Model

Farmer adoption of socialized agricultural machinery services is significantly related to wheat planting area, adoption of new technology, terrain and part-time businesses. Among them, farmers with larger wheat planting areas and more labor input in wheat production were more likely to adopt socialized agricultural machinery services. When compared with the farmers in plain areas, the proportion of agricultural machinery services was lower in slope areas, which was due to the undulating terrain and fragmentary land, which reduces the convenience of agricultural machinery use. The higher the degree of part-time business, the higher the opportunity cost of wheat production, which made farmers tend to adopt socialized agricultural machinery services in wheat production to save more on the labor force and participate in non-agricultural industry. Technology adoption narrows the scope of core technology in wheat production, increases the separability of wheat production links, promotes farmers to outsource production links to social service providers, and realizes the intra-industry division of wheat production. At the land scale, the terrain on farms and the part-time situations of farmers have an impact on the adoption of socialized agricultural machinery services. It is necessary to distinguish between different scales, terrain types, and part-time situations in order to study the heterogeneity of the impact of socialized agricultural machinery services on land productivity.

To improve the recognition degree of the model, this paper introduces "the socialized service level of agricultural machinery in the village" as the instrumental variable of whether farmers adopt socialized agricultural machinery services. The Wald test for socialized agricultural machinery services is significant at the statistical level of 1%, which indicates that the fitting condition is good, and there are sample selection errors caused by unobservable variables. It therefore appropriate to use the endogenous switching regression model.

Based on the above regression results for the endogenous transformation model of socialized agricultural machinery services (Table 4), this paper considers the land productivity expectations of farmers in four situations: adopted and not adopted under actual conditions, and assumed not to have adopted and assumed to have adopted under counterfactual conditions. To eliminate the influence of other factors, the average treatment effect was calculated [50,51].

Table 4. Estimation results of endogenous switching regression model.

Variable	Selection Equation		Adopt Socialized Agricultural Machinery Service		Not Adopting Socialized Agricultural Machinery Service	
	Coefficient	Z Value	Coefficient	Z Value	Coefficient	Z Value
LnSub	0.037	1.04	0.128 **	2.19	0.054	0.93
LnAcre	0.214 ***	3.18	0.178 ***	2.73	0.065 **	1.98
Agi	−0.189	1.07	0.032	0.19	0.223	0.81
Tec	0.112 ***	2.97	0.082	0.77	0.102 ***	3.41
Top	−0.206 ***	3.94	−0.146 **	2.35	−0.257 ***	3.02
Concu	0.171 **	2.28	0.086 **	2.01	0.125	0.62
Vser	0.158 ***	3.13				
Regional dummy	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant	−1.762 ***	3.27	−1.255 **	2.01	−2.691	0.88
Log Likelihood	−1076.13					
Wald test	17.93 ***					

Note: ** and *** respectively indicate that the estimated value of variable coefficient is significant at the statistical level of 5% and 1%.

In general, socialized agricultural machinery services had a positive treatment effect on farmer land productivity, and this treatment effect is significant at the statistical level of 1%. According to the calculation results of the counterfactual method, the ATT (treatment group) of the effect of adopting socialized agricultural machinery services on land productivity was 0.394, and the ATU (control group) of the potential effect of farmers' families not adopting socialized agricultural machinery services was 0.054. This shows that socialized agricultural machinery services can significantly improve farmers' land productivities.

4.3. The Overall Effect and Group Estimation of Socialized Agricultural Machinery Services on Land Productivity

Studying the impact of socialized agricultural machinery services on land productivity in wheat production can better investigate the impact of socialized agricultural machinery services on land productivity on different scales and in terms of farming households [52]. Based on the farmer household survey, the overall sample was divided into three subsamples with the same sample size, namely the samples of farmers with Area $\leq$ 3 mu, the samples of farmers with 3 < Area $\leq$ 5 mu, and the samples of farmers with Area > 5 mu.

Table 5 shows that, in terms of the overall average effect, socialized agricultural machinery services were conducive to improving land productivity, which confirms the research results of Li and Wang [27]. On the one hand, the logic lies in the fact that farmers introduce advanced agricultural technology into the grain production process through production outsourcing, which improves the grain production per unit area. On the other hand, the socialized agricultural machinery service makes up for the efficiency loss caused by labor shortages caused by urbanization by replacing agricultural labor [53].

Table 5. The average treatment effect of the socialized agricultural machinery service on farmer land productivity.

Farmers Category	Adoption Services	Unaccepted Service	ATT	ATU
Socialized agricultural machinery service adopt households	8.018	7.624	0.394 ***	—
Socialized agricultural machinery service did not adopt households	7.163	7.109	—	0.054 ***

Note: *** means significant at the level of 1%; ATT and ATU respectively represent the average treatment effect of households that adopt the socialized agricultural machinery service and households that do not.

Table 6 examines the effect of farmers' adoption of socialized agricultural machinery services on land productivity. Among them, socialized agricultural machinery services had a significant positive effect on the land productivity of small-scale (area $\leq$ 3) and medium-scale (3 < area $\leq$ 5) farms and, when comparing medium-scale farms (the ATT was 0.428) with small-scale farms (the ATT was 0.556), it is clear that socialized agricultural machinery services had a greater effect on small-scale farms, but no significant effect on large-scale (area > 5) farms. To a certain extent, this reflects the positive effect of the Chinese government in realizing the organic connection between small-scale farmers and modern agricultural development through social services. However, for large-scale farmers, there is a strong relationship between their own wheat production machinery and labor force, so they cannot make rapid adjustments in the short term, which results in a mismatch between the original production technology and the expanded business scale, which makes it difficult to attain improvements in land productivity.

The results of distinguishing land terrain (Table 7) show that socialized agricultural machinery services had a positive effect on the land productivity of flat farmers, but had no significant effect on the land productivity of sloping mountain farmers [54]. Because the cross-sectional data cannot reflect the transformation of the terrain [55], this may affect the significance of the model, and cannot negate the restrictions of sloping land and mountainous area on farmers' applications of agricultural machinery.

Table 6. The impact of socialized agricultural machinery service on land productivity based on scale heterogeneity.

	Farmers Category	Adoption Services	Unaccepted Service	ATT	ATU
Acre ≤ 3	Socialized agricultural machinery service adopt households	8.079	7.523	0.556 ***	—
	Socialized agricultural machinery service did not adopt households	7.183	7.117	—	0.066 ***
3 < Acre ≤ 5	Socialized agricultural machinery service adopt households	8.065	7.637	0.428 ***	—
	Socialized agricultural machinery service did not adopt households	7.154	7.071	—	0.083 ***
Acre > 5	Socialized agricultural machinery service adopt households	8.003	7.608	0.395	—
	Socialized agricultural machinery service did not adopt households	7.162	7.093	—	0.069

Note: *** means significant at the level of 1%; ATT and ATU respectively represent the average treatment effect of households that adopt the socialized agricultural machinery service and households that do not.

Table 7. The impact of socialized agricultural machinery service on land productivity based on the heterogeneity of terrain and part-time jobs.

	Farmers Category	Adoption Services	Unaccepted Service	ATT	ATU
Flat farmers	Socialized agricultural machinery service adopt households	8.087	7.638	0.449 ***	—
	Socialized agricultural machinery service did not adopt households	7.194	7.125	—	0.069 ***
Sloping mountain farmers	Socialized agricultural machinery service adopt households	8.002	7.744	0.258	—
	Socialized agricultural machinery service did not adopt households	7.031	6.960	—	0.071
Pure agricultural farmers	Socialized agricultural machinery service adopt households	8.150	7.617	0.533 ***	—
	Socialized agricultural machinery service did not adopt households	7.176	7.031	—	0.145 ***
Part-time farmers	Socialized agricultural machinery service adopt households	8.064	7.502	0.562 ***	—
	Socialized agricultural machinery service did not adopt households	7.185	7.119	—	0.066 ***

Note: *** means significant at the level of 1%; ATT and ATU respectively represent the average treatment effect of households that adopt the socialized agricultural machinery service and households that do not.

Socialized agricultural machinery services had a positive effect on the land productivity of both pure agricultural households and part-time farmers, which indicates that the socialized agricultural machinery services can help purely agricultural households adopt advanced agricultural technology and improve their management skills. For part-time farmers, the emergence of socialized agricultural machinery services can effectively alleviate the dual lack of agricultural labor and agricultural technology caused by part-time farmers [56]. However, one problem that still needs to be considered is that part-time farmers are engaged in both agricultural production and non-agricultural production. Farmers who do not rely solely on agricultural income may have a reduced enthusiasm to engage in food production with socialized agricultural machinery services. In addition, the number of part-time farmers in agricultural labor supervision is lower than in purely agricultural households, and the effect of socialized agricultural machinery services on land productivity is lower than in purely agricultural households.

5. Discussion and Policy Implications

Farmers are often tired of farming and wish to escape the countryside. However, in today's rural China, farming has completely subverted the tradition. With the development of socialized agricultural machinery services, many farmers are no longer going to the field, but can still farm their land successfully. With the outflow of a large amount of Chinese agricultural labor, the opportunity cost of agricultural labor continues to increase. Under the constraints of small-scale operations based on household contracts, China's agriculture has not substantially expanded per capita or in terms of the cultivated land scale of small farms. The service scale replaces the land scale, which represents a new path (with Chinese characteristics) for China's agricultural modernization, with small farmers as the main body at the present time [57]. The part-time nature, aging, and feminization of the rural labor force make it difficult for farmers to complete all grain production targets, which leads to a demand for socialized agricultural machinery services. With the development of agricultural machinery and technology, socialized service organizations can carry out large-scale and specialized operations in grain production, which promote the supply of socialized agricultural machinery services [58]. Socialized agricultural machinery service organizations realize the advantages of large-scale continuous service, and drive small-scale farmers to engage in grain production with lower service prices and higher service quality.

Adam Smith pointed out in the Wealth of Nations that the limited division of agricultural production restricts the improvement of agricultural labor productivity. But with the progress of technology and the improvement of the external institutional environment, the conditions of the division of labor in agricultural production are becoming more and more complete. The space for deepening the division of labor in agricultural production has been expanded. The socialized agricultural machinery services industry is emerging rapidly. Socialized agricultural machinery services involve agricultural family management in the division of labor activities, prolong the agricultural production process, and improve agricultural production efficiency through roundabout production. Smith's theorem is: "Specialization can improve economic efficiency and promote economic growth." The market scale depends on the division of labor, and the division of labor depends on the market scale. Allyn Younger called this relationship economic progress, and that is what the Smith–Young theorem is all about. This is to say, "division depends on the division of labor." Roundabout production increases the market size and promotes the division of labor [27]. Neoclassical economics believes that specialization can accelerate technological progress and promote technological innovation. However, given the reality that the space of land productivity improvement is more and more narrow, technological progress is the main power source to promote the continuous rise of land productivity. In the current rural environment of China, the adoption of socialized agricultural machinery services is having a significant positive impact on the land productivity of wheat production. In order to realize agricultural modernization and ensure food security, the government actively encourages and supports the development of socialized agricultural machinery service organizations [59]. Through the adoption of socialized agricultural machinery services and the introduction of various advanced technologies into wheat production in the form of outsourcing services, the land elements of farmers and the modern production elements of socialized agricultural machinery service organizations have been organically integrated. Specialized, large-scale, and modern wheat production on land is also conducive to the improvement of wheat production technology [60,61]. The socialized agricultural machinery service can help farmers maximize their existing wheat production [62]. The socialized agricultural machinery service plays an important role in driving traditional, small-scale farmers to produce grain and realize the organic connection with the development of modern agriculture.

The contradiction between farmers' land rights and the effective use of land resources can be solved through socialized agricultural machinery services. At present, with the deepening of China's urbanization process, socialized agricultural machinery services can effectively replace the agricultural labor force as a whole, and alleviate the impact of rural labor shortages, feminization and aging caused by urbanization on food production (to a certain extent). In order to improve the land productivity of grain production, various advanced technology elements are introduced into the process of grain production in the form of outsourcing services. On the basis of not changing farmers' land contract rights or even management rights, socialized agricultural machinery services can be adopted to make up for the serious shortage of small-scale operations and provide convenience for small-scale farmers to achieve a higher level of mechanization. In view of the externality of socialized agricultural machinery services to improve the whole level of grain production technology, agricultural departments should give some policy compensations to socialized agricultural machinery service organizations, as well as support and encourage the development of socialized agricultural machinery service organizations.

Socialized agricultural machinery services have important practical significance for increasing land productivity. In particular, in the context of the accelerating process of urbanization, when issues, such as "who will farm the land" and the demand for comparative benefits in agriculture, have become increasingly prominent, the socialized agricultural machinery service is an effective entry point for improving the yield of wheat. The socialized agricultural machinery service is the key to coping with the challenges of the disappearance of the demographic dividend and the rigid increase in agricultural labor costs [63]. The supply-side structural reform of socialized agricultural machinery services should be further strengthened. It is necessary to improve socialized agricultural machinery services, strengthen the state's subsidies for socialized agricultural machinery services, guide and support the effective supply of socialized agricultural machinery services in key aspects of grain production, avoid the inefficiency caused by the inclusive socialized agricultural machinery service support policy, and improve the efficiency of the support policy.

Socialized agricultural machinery services break through the boundary of the management subject and realize the moderate land scale management of agricultural machinery application, which can be regarded as a sufficient and necessary condition for the improvement of land productivity. Considering that farming households are small and medium scaled, socialized agricultural machinery services have a positive effect on land productivity. In China, under the condition that small-scale farmers still comprise a large group of farmers that will exist for a long time, the moderate scaling operation is a good choice. In the agricultural extension department, we could make full use of socialized agricultural machinery services to strengthen the construction of a socialized system for agricultural machinery services and inject various scientific and technological elements into the agricultural production link in the form of outsourcing services. In addition, farmers are encouraged to use land swaps and other forms of circulation to achieve the appropriate scale and contiguous operation of their land in order to reduce transaction costs due to the land barriers facing socialized agricultural machinery services.

Considering the group differences brought about by the effect of socialized agricultural machinery services, farmers of different categories should be rationally guided to adopt socialized agricultural machinery services. It is possible to formulate policies to give support to farmers who have no endowment advantages. The simultaneous implementation of the policies of "machines suitable for land" and "land suitable for machines" allowed for agricultural productivity and promoted the optimal allocation of resource elements. For sloping and mountainous areas, we can further promote the improvement of land so that it is suitable for machinery. For flat land suitable for farming, a moderate scale of agricultural operations can be developed to provide geographical conditions for the effective application of socialized agricultural machinery services. In addition, the adoption of socialized agricultural machinery services by part-time farmers is a key to solving the problem of "who will farm the land", which is caused by the shortage of agricultural labor [64], and it also promotes an organic connection between small farmers and modern agricultural development.

6. Conclusions

Based on our empirical analysis of the impact of socialized agricultural machinery services on land productivity, this research utilized a rural survey conducted by the National Agricultural Institute of China Agricultural University in four major wheat-producing provinces in 2019. It used the endogenous switching regression model to analyze the effect of socialized agricultural machinery services on land productivity. Overall, in conclusion, socialized agricultural machinery services generally have certain effects on wheat production and can significantly improve land productivity. However, the effects of socialized services are heterogeneous, due to differences in the planting scale, topography, and concurrent business. Specifically, socialized agricultural machinery services have a positive effect on the land productivity of small-scale (Area ≤ 3) and medium-scale ($3 <$ Area ≤ 5) farmers. On the other hand, they have no significant impact on large-scale land productivity (Area > 5) farmers. This also verifies the necessity of advancing agricultural moderate-scale operation and socialized agricultural machinery services in parallel. For part-time farmers, socialized agricultural machinery services could significantly increase their land productivity. For full-time agricultural households, such positive effects were even more significant. In addition, the socialized agricultural machinery services also had a positive impact on land productivity for flat-land farmers. On the other hand, we did not find a significant change in farmers' land productivities on slopes and mountains.

The disadvantage of this study is that, due to the sample limitations, this study cannot introduce more effective control variables. In the follow-up, we will design a questionnaire according to the development of socialized agricultural machinery services to obtain more comprehensive survey data and further test the impact of socialized agricultural machinery services on land productivity. Moreover, the conclusion of this study is based on wheat growers, but it is still to be verified in other industries, and further research should be further expanded in the future. On the other hand, this study only examines whether farmers adopt socialized agricultural machinery services. In the follow-up study, we can also try to include the specific cost of socialized agricultural machinery services into the analysis framework, so as to further study the deep-seated role of socialized agricultural machinery services.

Author Contributions: Conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing—original draft preparation, S.Y.; validation, writing—review and editing, visualization, supervision, project administration, W.L.; funding acquisition, W.L. and S.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Ministry of Agriculture and Rural Affairs of China and the Research Fund for Beijing Union University 2021, grant number SK30202102.

Acknowledgments: The authors thank the National Academy of Agricultural and Rural Development of China Agricultural University for data support. The author sincerely thanks Hailong Cai of the China Agricultural University for his valuable revision opinions.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

As can be seen from this figure, there is a positive correlation between the total power of China's agricultural machinery and China's grain output. Other things being equal, as the total power of China's agricultural machinery increases, so does China's grain output.

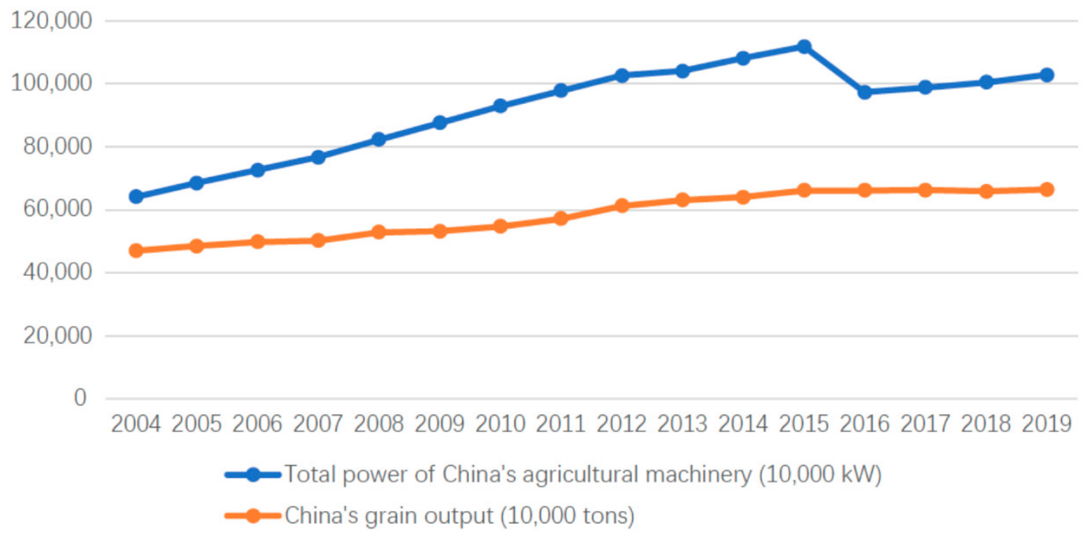

Figure A1. Graph of relationship between the total power of China's agricultural machinery and China's grain output.

References

1. Zhou, Z.; Kong, X.Z. The effect evaluation and policy direction of agricultural mechanization on my country's grain output. *China Soft Sci.* **2019**, *4*, 20–32.
2. Zhang, X.; Yang, J.; Thomas, R. Mechanization outsourcing clusters and division of labor in Chinese agriculture. *China Econ. Rev.* **2017**, *43*, 184–195. [CrossRef]
3. Yang, J.; Huang, Z.; Zhang, X. The rapid rise of cross-regional agricultural mechanization services in China. *Am. J. Agric. Econ.* **2013**, *95*, 1245–1251. [CrossRef]
4. Carney, D. The changing public role in services to agriculture: A framework for analysis. *Food Policy* **1995**, *20*, 521–528. [CrossRef]
5. Ragasa, C.; Golan, J. The role of rural producer organizations for agricultural service provision in fragile states. *Agric. Econ.* **2014**, *45*, 537–553. [CrossRef]
6. Zhong, Z. Socialized service: The key to the modernization of agriculture with Chinese characteristics in the new era—A review based on theory and polic. *Rev. Political Econ.* **2019**, *10*, 92–109.
7. Chen, C.; Li, Y.Q.; Liao, X.Y. The productivity effect analysis of rice production outsourcing: Based on the panel data of three counties in Jiangsu Province. *China Rural Econ.* **2012**, *2*, 86–96.
8. Belton, B.; Fang, P.; Reardon, T. *Mechanization Outsourcing Services in Myanmar's Dry Zone*; Feed the Future Innovation Lab for Food Security Policy Research Paper; Michigan State University: East Lansing, MI, USA, 2018.
9. Jin, G.; Li, Z.; Wang, Z.; Chu, X.; Li, Z. Impact of land-use induced changes on agricultural productivity in the Huang-Huai-Hai River Basin. *Phys. Chem. Earth* **2015**, *79*, 86–92. [CrossRef]
10. Feng, S.; Heerink, N.; Ruben, R.; Qu, F. Land rental market, off-farm employment and agricultural production in Southeast China: A plot-level case study. *China Econ. Rev.* **2010**, *21*, 598–606. [CrossRef]
11. Wang, J.Y. *Research on the Adjustment of Agricultural Production Mode and Production Efficiency during the Transition Period*; Zhejiang University: Hangzhou, China, 2015.
12. Tang, K.; Wang, J.Y.; Chen, Z.G. The impact of farmland management scale on grain yield and production cost: Based on empirical research across periods and regions. *Manag. World* **2017**, *5*, 79–91. [CrossRef]
13. Raghu, P.T.; Erenstein, O.; Bober, C. Adoption and outcomes of hybrid maize in the marginal areas of India. *Q. J. Int. Agric.* **2015**, *54*, 189–214. [CrossRef]
14. Yan, J.; Chen, C.; Hu, B. Farm size and production efficiency in Chinese agriculture: Output and profit. *China Agric. Econ. Rev.* **2018**, *11*, 20–38. [CrossRef]
15. Diwan, R.; Kallianpur, R. Biological technology and land productivity: Fertilizers and food production in India. *World Dev.* **1985**, *13*, 627–638. [CrossRef]
16. Nakano, Y.; Magezi, E.F. The impact of microcredit on agricultural technology adoption and productivity: Evidence from randomized control trial in Tanzania. *World Dev.* **2020**, *133*, 104997. [CrossRef]
17. Ge, D.; Long, H.; Zhang, Y. Analysis of the coupled relationship between grain yields and agricultural labor changes in China. *J. Geogr. Sci.* **2018**, *28*, 93–108. [CrossRef]
18. Garrone, M.; Emmers, D.; Lee, H. Subsidies and agricultural productivity in the EU. *Agric. Econ.* **2019**, *50*, 803–817. [CrossRef]
19. Ji, C.H.; Guo, S.J.; Yang, J. Outsourcing Agricultural Production: Evidence from Rice Farmers in Zhejiang Province. *PLoS ONE* **2017**, *12*, e170861. [CrossRef]

20. Wu, J.Q.; Fang, S.L.; Li, G.C.; Xu, G.T. Analysis of the spatial spillover effect of China's agricultural mechanization development level on grain output: Based on the perspective of cross-regional operations. *China Rural Econ.* **2017**, *6*, 44–57.
21. Kumar, A.; Sharma, P.; Joshi, S. Assessing the Impacts of Climate Change on Land Productivity in Indian Crop Agriculture: An Evidence from Panel Data Analysis. *J. Agric. Sci. Technol.* **2016**, *18*, 1–13.
22. Wang, J.; Bi, S.; Li, Y.; Lv, K.Y. Analysis of the impact of formal credit constraints on farmers' food production. *Agric. Technol. Econ.* **2018**, *5*, 28–39. [CrossRef]
23. Yamauchi, F. Rising real wages, mechanization and growing advantage of large farms: Evidence from Indonesia. *Food Policy* **2016**, *58*, 62–69. [CrossRef]
24. Ma, W.; Renwick, A.; Grafton, Q. Farm machinery use, off-farm employment and farm performance in China. *Aust. J. Agric. Resour. Econ.* **2018**, *62*, 279–298. [CrossRef]
25. Zhou, X.; Ma, W.; Li, G. Farm machinery use and maize yields in China: An analysis accounting for selection bias and heterogeneity. *Aust. J. Agric. Resour. Econ.* **2020**, *64*, 1282–1307. [CrossRef]
26. Wang, X.; Yamauchi, F.; Otsuka, K. Wage growth, landholding, and mechanization in Chinese agriculture. *World Dev.* **2016**, *86*, 30–45. [CrossRef]
27. Wang, Y.B.; Li, Q. Agricultural Productive Services, Food Production Increase and Farmers' Income Increase: An Empirical Analysis Based on CHIP Data. *Financ. Econ.* **2019**, *3*, 92–104.
28. Mottaleb, K.A.; Rahut, D.B.; Ali, A. Enhancing Smallholder Access to Agricultural Machinery Services: Lessons from Bangladesh. *J. Dev. Stud.* **2017**, *53*, 1502–1517. [CrossRef]
29. Wang, X.; Yamauchi, F.; Huang, J. Rising wages, mechanization, and the substitution between capital and labor: Evidence from small scale farm system in China. *Agric. Econ.* **2016**, *47*, 309–317. [CrossRef]
30. Zhang, Z.J.; Yi, Z.Y. Research on the Impact of Agricultural Productive Service Outsourcing on Rice Productivity: Based on the Empirical Analysis of 358 Farmers. *Issues Agric. Econ.* **2015**, *36*, 69–76. [CrossRef]
31. Liu, J.; Xu, Z.; Zheng, Q. Is the feminization of labor harmful to agricultural production? The decision-making and production control perspective. *J. Integr. Agric.* **2019**, *18*, 1392–1401. [CrossRef]
32. Houssou, N.; Diao, X.; Cossar, F. Agricultural Mechanization in Ghana: Is Specialized Agricultural Mechanization Service Provision a Viable Business Model. *Am. J. Agric. Econ.* **2013**, *95*, 1237–1244. [CrossRef]
33. Wang, O.; Tang, K.; Zheng, H.M. The impact of agricultural machinery on labor substitution intensity and grain output. *China Rural Econ.* **2016**, *12*, 46–59.
34. Verma, S.R. Impact of agricultural mechanization on production, productivity, cropping intensity income generation and employment of labour. *Status Farm Mech. India* **2006**, *2006*, 133–153.
35. Tian, L. Division of Labor and Productivity Advantage of Cities: Theory and Evidence from Brazil. Social Science Electronic Publishing: Rochester, NY, USA, 2018.
36. Kreager, P.; Smith, A. The Division of Labor, and the Renewal of Population Heterogeneity. *Popul. Dev. Rev.* **2017**, *43*, 513–539. [CrossRef]
37. Xiao, W. *Mechanism Analysis: Scientific and Technological Progress and Transformation of Industrial Development Mode*; Springer: Berlin, Germany, 2020; pp. 53–77.
38. Huang, J.K.; Qi, L.; Chen, R.J. Technical information knowledge, risk preference and farmers' pesticide application. *Manag. World* **2008**, *5*, 71–76. [CrossRef]
39. Takane, T. Labor use in smallholder agriculture in Malawi: Six village case studies. *Afr. Study Monogr.* **2008**, *29*, 183–200. [CrossRef]
40. Benin, S. Impact of Ghana's agricultural mechanization servicescenter program. *Agric. Econ.* **2015**, *46*, 103–117. [CrossRef]
41. Zhu, W.; Zhang, Z.; Li, X.; Feng, W.; Li, J. Assessing the effects of technological progress on energy efficiency in the construction industry: A case of China. *J. Clean. Prod.* **2019**, *238*, 117908. [CrossRef]
42. Prosterman, R.; Hanstad, T.; Ping, L. Large-scale farming in China: An appropriate policy. *J. Contemp. Asia* **1998**, *28*, 74–102. [CrossRef]
43. Aboki, E.; Jongur, A.A.U.; Onu, J.I. Productivity and technical efficiency of family poultry production in Kurmi local government area of Taraba State, Nigeria. *J. Agric. Sustain.* **2013**, *4*, 52–66. [CrossRef]
44. Godfray HC, J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Toulmin, C. Food security: The challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818. [CrossRef]
45. Xu, Z. Farm Size, Capitalism, and Overuse of Agricultural Chemicals in China. *Capital. Nat. Social.* **2020**, *31*, 59–74. [CrossRef]
46. Ha, T.V.; Fan, H.; Shuang, L. Climate change impact assessment on Northeast China's grain production. *Environ. Sci. Pollut. Res.* **2020**, *28*, 14508–14520. [CrossRef] [PubMed]
47. Baron, R.M.; Kenny, D.A. The Moderator-mediator Variable Distinction in Social Psychological Research: Conceptual, Strategic, and Statistical Considerations. *J. Personal. Soc. Psychol.* **1986**, *51*, 1173–1182. [CrossRef] [PubMed]
48. Wen, Z.L.; Ye, B.J. Analysis of Mediation Effect: Method and Model Development. *Adv. Psychol. Sci.* **2014**, *22*, 731–745. [CrossRef]
49. Maddala, G.S. *Limited Dependent and Qualitative Variables in Econometrics*; Cambridge University Press: Cambridge, UK, 1983. [CrossRef]
50. Chen, Q.; Li, J.; Wang, J.M. Cost efficiency analysis of China's broiler industry based on SFA. *Agric. Technol. Econ.* **2014**, *7*, 68–78.

51. Battese, G.E.; Coelli, T.J. Frontier Production Functions, Technical Efficiency and Panel Data: With application to paddy farmers in India. *J. Product. Anal.* **1992**, *3*, 153–169. [CrossRef]
52. Rada, N.E.; Fuglie, K.O. New perspectives on farm size and productivity. *Food Policy* **2019**, *84*, 147–152. [CrossRef]
53. Ji, Y.; Hu, X.; Zhu, J. Demographic change and its impact on farmers field production decisions. *China Econ. Rev.* **2017**, *43*, 64–71. [CrossRef]
54. Pan, B.; Tian, Z.H. Analysis of the impact of purchase subsidy policy on the efficiency of China's agricultural machinery. *China Rural Econ.* **2018**, *6*, 21–37.
55. Wang, W.; Ye, X. The Potential Supply and Demand of Farmers' Land Contract Rights-Based on 697 Households in Four Provinces of China. *Land* **2020**, *9*, 80. [CrossRef]
56. Yang, S.Y.; Cai, H.L. The effect of agricultural machinery socialization service in different links on the technical efficiency of grain production–taking early rice as an example. *J. China Agric. Univ.* **2020**, *25*, 138–149.
57. Zhang, Q.Q.; Yan, B.B.; Huo, X.X. What Are the Effects of Participation in Production Outsourcing? Evidence from Chinese Apple Farmers. *Sustainability* **2018**, *10*, 4525. [CrossRef]
58. Yang, S.Y.; Cai, H.L. Research on the impact of agricultural machinery socialization service on labor transfer of small-scale farmers. *Agric. Mod. Res.* **2020**, *41*, 417–425.
59. Li, G.C.; Li, Y.Y.; Zhou, X.S. Agricultural mechanization, labor transfer and farmers' income growth what are the causes and effects. *China Rural Econ.* **2018**, *11*, 112–127.
60. Yang, S.W. *Study on Specialization of Wheat Production Region in China*; Southwest University: Chongqing, China, 2011. [CrossRef]
61. Yao, S.F. *Specialization and Agricultural Development*; Southwestern University of Finance and Economics: Chengdu, China, 2004.
62. Yan, H.; Qiao, J. The impact of agricultural producer services on grain production: An empirical study based on China's provincial panel data from 2008 to 2017. *Bus. Res.* **2020**, *8*, 107–118. [CrossRef]
63. Huang, J.; Ding, J. Institutional innovation and policy support to facilitate small-scale farming transformation in China. *Agric. Econ.* **2016**, *47*, 227–237. [CrossRef]
64. Allen, D.W.; Lueck, D. The Nature of the Farm. *J. Law Econ.* **1998**, *41*, 343–386. [CrossRef]