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Original Research

Environmental Effects of Agricultural Production Services: A Case Study of Chemical Fertilizer Reduction in China

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Abstract

Developing agricultural production services is a crucial way to promote the green transformation of Chinese agriculture. Investigating the environmental effects of agricultural production services is imperative for ensuring the sustainability of agriculture. This study takes the reduced application of chemical fertilizer in China as an example. Based on data from 992 rice farmers in the China Land Economic Survey, we explored the impact of agricultural production services on chemical fertilizer use. An extended regression model addresses the potential endogeneity and selectivity bias. The results show that introducing agricultural production services can significantly reduce the intensity of chemical fertilizer use and improve its efficiency. The effects of economies of scale and off-farm income play a large part in it. In addition, compared with labor-intensive agricultural production services, technology-intensive agricultural production services have a more significant impact on reducing chemical fertilizer use. This study highlights the positive role of agricultural production services in promoting sustainable agricultural development, as they help promote large-scale and specialized agricultural production.

Keywords: agricultural production services, chemical fertilizer use, economies of scale, off-farm work, chinese rice farmers

Introduction

Chinese folk proverbs say, "Fish flourish in water, and seedlings thrive with fertilizer". Chemical fertilizers serve as the "lifeblood" of grain, playing a pivotal role in boosting crop yields and ensuring food security [1]. In China, chemical fertilizers contribute more than 40% to food production, thereby supporting the nourishment of 22% of the global population using only approximately 9% of the world's arable land [2, 3]. However, on the "other side of the coin" the overuse of chemical fertilizers in many developing countries, such as China, has resulted in a range of challenges, including soil degradation [4], water quality pollution [5], greenhouse gas emissions [6], biological diversity reduction [7], and adverse impacts on human health [8]. Reducing excessive chemical fertilizers is essential for conserving ecological resources, ensuring food security, and reducing pollution [9, 10].

In order to mitigate the negative impacts of chronic over-fertilization and contribute to achieving the United Nations Sustainable Development Goals, countries

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have adopted various strategies, including agricultural subsidies, technology promotion, and knowledge training. For instance, in 2015, the Indian government initiated a comprehensive soil testing program that analyzed 23.6 million soil samples and distributed 93 million soil health cards, test results, and fertilizer recommendations to farmers. In 2016, the Indian government implemented the Municipal Composting Subsidy Scheme, which provides subsidies for municipal composting to companies that produce and market fertilizers to increase the use of organic fertilizers and reduce chemical fertilizer use [11]. In Thailand, the government has long pursued an organic agriculture program to improve farmers' soil nutrient management through extensive training on using organic fertilizers instead of chemical fertilizers [12]. In Europe, based on the cross-compliance requirements of the European Union's Common Agricultural Policy, farmers eligible for the reduction regulations and the Rural Development Subsidy Scheme are obliged to carry out soil nutrient tests and implement the corresponding soil nutrient management plans. For instance, in Ireland, each farmer is legally responsible for the quantity of fertilizers applied to their farm, although not all must have a soil test [13].

Developing agricultural productive services in China is a crucial strategy for fostering sustainable agricultural growth. Agricultural productive services are defined as socialized services in which agricultural service organizations assist farmers in completing operations in agriculture's pre-production, mid-production, and post-production stages [14-16]. By centralizing the procurement of production materials and unifying mechanized operations and standardized production, agricultural service organizations enable smallholders to obtain advanced agricultural factors and business concepts relatively cheaply [17]. Previous evidence shows that agricultural production service plays an important role in promoting agricultural production and improving mechanical efficiency, increasing agricultural output, reducing labor intensity, increasing technical efficiency, and improving household welfare [18-23]. For example, Rocha et al. used the observation data of 5463 cities in Brazil's agricultural census to evaluate the impact of agricultural production service popularization on agricultural production efficiency. They found that agricultural production services can significantly improve agricultural productivity [22]. Lyne et al. assessed the influence of the Lima Rural Development Foundation in providing agricultural production services in the Umzimkhulu District, South Africa. They found that agricultural production services have greatly contributed to household crop income and net income [23].

In terms of the environmental effects of agricultural production services, the positive view is that agricultural production services can help reduce the use of chemical inputs. For example, a study by Rahman et al. based on data from farmers in Bangladesh showed that the frequency of access to agricultural production services was negatively correlated with the use of chemical fertilizers and positively correlated with agricultural yields. Agricultural production services help to reduce the use of fertilizers and improve farmers' welfare [24]. Bernard et al.'s survey of villages in western Cameroon suggests that providing agricultural production services to farmers through farmers' cooperatives helps reduce the likelihood of overuse of chemical inputs [25]. Studies by scholars from China have found that agricultural production services contribute to chemical fertilizer reduction. In the context of continued labor migration, the introduction of machinery and green control technologies by agricultural service organizations has improved the division of labor and production specialization, significantly reducing the use of chemical fertilizers [26, 27]. Furthermore, agricultural service organizations' "role model effect" has led farmers to adopt more effective agricultural production management practices, demonstrate a greater willingness to engage in green agriculture, and reduce agrochemical inputs [28, 29].

However, some studies have found that agricultural production services have not been able to reduce the use of chemical inputs. For example, Zhang et al. found that due to the inherent limitations of asymmetric information and monitoring difficulties, farmers may be susceptible to the potential for opportunistic behavior on the part of agricultural service organizations. Agricultural service organizations may collude with agricultural input suppliers to achieve high economic returns through the excessive use of pesticides [30]. Consequently, the adoption of agricultural production services may exacerbate environmental pollution. Chang et al. found that agricultural productive services may discourage farmers from investing in soil improvement measures, leading to further increases in the intensity of agrochemical inputs [31]. Furthermore, the Chinese government has augmented subsidies for cultivating agricultural production service organizations in recent years, and agricultural subsidies may also create economic incentives for increased use of chemical fertilizers [32].

At least for now, the findings remain mixed. Therefore, analysis of the relationship between the adoption of agricultural production services and chemical fertilizer use will provide valuable insights for designing appropriate chemical fertilizer reduction strategies. The contributions of this study include the following aspects: First, we analyzed the impact of farmers' adoption of agricultural production services on chemical fertilizer use, focusing on the intensity of chemical fertilizer use and the efficiency of chemical fertilizer use, and obtained evidence that agricultural production services can contribute to chemical fertilizer reduction. Second, we explored the mechanism of the impact of agricultural production services on chemical fertilizer reduction from two perspectives: economies of scale and non-farm income. Third, we classify agricultural production services into technology-intensive and labor-intensive to examine the role of different agricultural production services in chemical fertilizer reduction. In addition, as a further contribution, we use extended regression models to account for potential endogeneity and selectivity bias.

We use data from rice farmers in Jiangsu Province, China. On the one hand, China is the world's largest rice producer, accounting for 26.85% of global rice production and 17.84% of global harvested area in 2022 [33]. Jiangsu Province is one of China's central grain-producing provinces, where the "rice-wheat" rotation is the main cropping pattern. In 2022, the sown area of rice was 2221.4 kilo-hectares, accounting for 29.48% of the sown area of the province's crops, and the total output of rice reached 19.19 million tons, accounting for 9.55% of the total national production of rice [34]. Therefore, reducing chemical fertilizer use in rice production is crucial for preventing and controlling agricultural surface pollution and guaranteeing food security in China. It is representative to conduct a study on this. On the other hand, Jiangsu Province is one of China's most economically developed provinces, with good agricultural production conditions and an active market for agricultural services. By 2022, the number of agricultural socialized service organizations in Jiangsu Province had reached 72,000, and the operating income of the service organizations exceeded 13 billion RMB [35]. For this purpose, Jiangsu Province, the province with the highest rice yields in China, is a fascinating case.

Theoretical Analysis

Economies of Scale Effect

Agricultural production services help to promote expanding farmers' operations, thereby reducing the use of chemical fertilizers. On the one hand, there is a threshold for economies of scale in agricultural production services, and agricultural service organizations usually need to reach a particular scale of operation to profit from their factor supply. Suppose the farmland area is too small and scattered. In that case, the transaction costs between agricultural service organizations and farmers will increase, which is not conducive to increasing the frequency of transactions between the two parties, thus hindering the increase of market capacity of agricultural production services and the excellent development of agricultural service organizations [36]. On the other hand, although the centralized procurement of agricultural input factors by agricultural service organizations can improve bargaining power [17, 37], the limited land size will still lead to difficulties in reducing the cost of using production factors such as agricultural machinery and environmentally friendly technologies. Therefore, under the limited capital reward and income center of gravity effects, farmers and agricultural service organizations have incentives to rely on large-scale production to reduce the cost of each production link [38]. In other words, to pursue higher production efficiency and economic returns, both parties have an inherent need to expand farm size.

Previous studies have shown that a moderate expansion of farm operations can help reduce fertilizer use [39-42]. According to neoclassical economic theory, the marginal output of smallholder production has an inverted "U" structure. According to the law of diminishing marginal rate of technological substitution, expanding the cultivation scale will improve the efficiency of production factor allocation and reduce the marginal cost of production factors [42, 43]. Therefore, under the premise of moderate-scale operation, the expansion of farm size can help reduce the cost of using production factors such as agricultural machinery and green technology, thus increasing the probability of farmers adopting mechanical fertilizer application and green production technology, which in turn improves the efficiency of chemical fertilizer utilization and reduces the use of chemical fertilizers [29, 44]. In addition, larger farms in China are more likely to have access to financing loans from rural financial institutions and access to green production technologies and modern management practices [45]. At the same time, larger farms are also more likely to be monitored and regulated by the government and the market, thus reducing the use of chemical fertilizers.

Off-farm Income Effects

Agricultural production services can help increase farm households' off-farm income, thereby reducing the use of chemical fertilizers. On the one hand, agricultural production services have a labor substitution effect, whereby farmers can release their household labor from agricultural production by adopting agricultural production services and transferring it to non-farm sector employment with higher wage rates to earn higher non-farm incomes [19]. Li et al. found that farmers' demand for agricultural production services (especially agricultural machinery services) usually increases with the increase in non-farm employment because the agricultural service market provides farmers with factor substitution options [17]. They can use the market mechanism to obtain cheap and abundant factors of production, such as machinery and technology, to substitute for expensive and relatively scarce agricultural labor.

On the other hand, higher non-farm incomes can help reduce the use of chemical fertilizers because higher incomes allow farmers to adopt better agricultural production services and increase investments in green production practices such as soil improvement and organic fertilizer inputs, thus reducing the use of chemical fertilizers [13]. In addition, some previous studies have shown that the participation of farmers in off-farm work may lead to an increase in the use of fertilizers, as farmers will use fertilizers more often as a substitute for labor to reduce the risk of agricultural production [46-48]. Introducing agricultural production services can correct farmers' excessive fertilizer application behavior because agricultural service organizations can contribute to the standardization of agricultural production, improve the efficiency of chemical fertilizer use, and thus reduce the use of chemical fertilizers [38].

Based on the above theoretical analysis, we believe that agricultural production services contribute to reducing chemical fertilizer use, with the economies of scale effects and off-farm income effects playing a part.

Materials and Methods

Data Sources

The data comes from the 2020 China Land Economic Survey (CLES). A rural survey was conducted in August 2020 in Jiangsu Province. CLES uses probability proportionate to size sampling to select 26 counties in 13 cities in Jiangsu Province, 2 sample townships in each county, 1 village in each township, and 50 randomly selected farmers in each village, and ultimately obtains the data from 2,628 sample farmers distributed in 52 villages. The CLES questionnaire covers various aspects such as household situation, land use, agricultural operation, and ecological environment. Since the theme of this paper is the impact of agricultural production services on chemical fertilizer use, we deleted the farmers who did not plant rice and kept only the farmers' samples who planted rice. After removing the missing values, wrong values, and outliers, this paper uses 922 samples of rice growers in 24 counties in 13 cities in Jiangsu Province for the empirical analysis.

Variable Selection

Dependent variables: This paper uses chemical fertilizer intensity and efficiency as dependent variables. Due to the wide variety of fertilizers farmers use, many farmers are not sensitive to the actual amount of fertilizer used. However, they can clearly remember the money invested in fertilizer. Therefore, on the one hand, this paper adopts the cost of chemical fertilizer use per mu of rice production to measure the intensity of chemical fertilizer use (CNY/mu); the higher the average cost of chemical fertilizer per mu, the higher the intensity of chemical fertilizer use [49]. On the other hand, this paper adopts the cost of chemical fertilizer use per 50 kg of rice production to measure the efficiency of chemical fertilizer use, which can more reasonably reflect the rice farmers' chemical fertilizer use. It was calculated as follows: (Chemical fertilizer use per mu/ Rice yield per mu)*100. It should be noted that this indicator is an inverse indicator of chemical fertilizer use efficiency, and the lower the value, the higher the chemical fertilizer use efficiency.

Independent variables: The core independent variable is agricultural production services. In China, rice production is usually divided into six stages: plowing, nursery, planting, pesticide spraying, harvesting, and straw returning to the field. Farmers can adopt agricultural production services at each stage. In this paper, we measure the degree of agricultural production services by the number of farmers' participation in agricultural production services, with the value ranging from 0 to 6 [14, 17]. In the robustness testing stage, this paper uses a dummy variable to measure the adoption of agricultural production services, assigning a value of 1 if the rice farmer adopts any of the agricultural production services and 0 otherwise [27]. In addition, in order to explore the effects of different types of agricultural production services on chemical fertilizer reduction, this paper examines agricultural production services by dividing them into technology-intensive and labor-intensive based on rice farmers' dependence on agricultural factors [21, 50].

Mechanism Variables: This paper's theoretical analysis concludes that agricultural production services contribute to chemical fertilizer reduction, and the economies of scale effects of land and the off-farm income effects play a part in it. Therefore, we use the farm operation scale to characterize the scale effect and the farmer's off-farm work income to characterize the off-farm income effect [40, 41, 49].

Instrumental variable: Agricultural production services are not an utterly exogenous variable, and the decision to adopt agricultural production services and chemical fertilizer use behavior may be influenced by farmers' characteristics, household endowment, and agricultural production conditions simultaneously, leading to sample selection bias. In addition, when farmers face factor constraints in carrying out arable land quality protection, they may alleviate the factor constraints of arable land quality protection by adopting agricultural production services. Thus, there may be a reverse causation problem. In order to overcome the possible endogeneity problem, we use the average level of agricultural production service adoption by farmers in the same village (other than the sample farmers) as the instrumental variable [14].

In addition, similar to previous studies [29, 41, 47], we controlled for rice farmer characteristics, household characteristics, and agricultural production characteristics in terms of control variables. Table 1 shows the definitions and basic statistical information of the variables used.

Table 1. Descriptive statistics of variables.

Variables	Definition	Mean	S.D.
APSs	The number of agricultural production services adopted by rice farmers, ranging from 0 to 6	2.306	1.787
APS_option	1 = if the rice farmers adopt agricultural production service, 0 = otherwise	0.719	0.449
Tech_APSs	The number of services adopted by rice farmers in seedling, spraying, and straw returning	0.807	0.809
Lab_APSs	The number of services adopted by rice farmers in planting, plowing, and harvesting	1.498	1.134
CF_intensity	Cost of chemical fertilizer use per mu of rice production (CNY/mu)	192.823	80.531
CF_efficiency	Cost of chemical fertilizer use per 50 kg of rice production (CNY/50 kg)	17.796	8.909
Age	Age of the household head (years)	61.489	9.904
Edu	Formal education of the household head (years)	6.995	3.494
Health	Health conditions of the household head: 1=incapacitated, 2 = poor, 3 = moderate, 4 = good, 5 = excellent	3.933	1.088
Labor	The percentage of the labor force to the total household population	0.630	0.284
Training	The number of persons in the household trained in agricultural technology	0.650	0.964
Land tenure	The area of land contracted in the second round (mu)	6.166	9.439
Grain sowing	The percentage of the area of major grain to the total sowing area	0.933	0.159
Paddy field area	The percentage of paddy field area to the total area	0.849	0.282
Soil fertility	Soil fertility: 1 = poor, 2 = moderate, 3 = good	2.387	0.637
IV	The average number of APSs adopted by other rice farmers in the same village	2.308	0.692
Economies of scale effect	Total farm operating area (mu)	46.784	220.493
Non-farm income effect	The percentage of non-farm income to total household income	0.838	0.356

Note: In China, 1 mu is equal to about 0.67 hectares.

Empirical Model

Since the adoption of agricultural production services is a result of 'self-selection' by farmers, their decisions to adopt agricultural production services and invest in chemical fertilizers may be influenced by both observed household and farm-level characteristics (e.g., age, paddy size, and soil fertility) and unobserved factors (e.g., farmers' risk preferences and innate abilities) [38, 51]. Using OLS to analyze the impact of agricultural production services on chemical fertilizer inputs leads to sample selection bias. Therefore, we use extended regression models to account for potential endogeneity and selectivity bias.

The extended regression model consists of two stages; in the first stage, we examine the adoption behavior of agricultural production services and build the following econometric model.

$$APS_i = \omega Z_i + \mu_i \tag{1}$$

In Equation (1), APS_i denotes the level of adoption of agricultural production services, which is the key independent variable in this paper; Z_i is the factor affecting the adoption of agricultural production services by rice farmers; ω is the coefficient to be estimated, and μ_i is the random error term.

In the second stage, we examine the impact of agricultural production services on chemical fertilizer use; the following two Equations are constructed:

$$CF\_intensity_i = a_1 APS_i + \gamma_1 X_i + \varepsilon_{1,i} \tag{2}$$

$$CF\_efficiency_i = a_2 APS_i + \gamma_2 X_i + \varepsilon_{2,i} \tag{3}$$

In Equations (2) and (3), $CF\_intensity_i$ and $CF\_efficiency_i$ denote the chemical fertilizer use intensity and efficiency, respectively; APS_i denotes the level of adoption of agricultural production services; X_i denotes the other variables affecting the use of chemical fertilizers; α_1 and γ_1, α_2 and γ_2 are the coefficients to be estimated, $\varepsilon_{1,i}$ and $\varepsilon_{2,i}$ are the random error terms.

Results and Discussion

Impact of Agricultural Production Services on Chemical Fertilizer Use

This paper used rice farmers' chemical fertilizer use intensity and efficiency as dependent variables and estimated (Table 2). Model (A1) results show that the estimated coefficient of agricultural production services is significantly negative at the 1% level, suggesting a significant inhibitory effect of agricultural production services on the intensity of chemical fertilizer use. Model (A2) results show that the estimated coefficient of agricultural production services is significantly negative at the 1% level, suggesting a significant improvement effect of agricultural production services on the efficiency of chemical fertilizer use. The above evidence suggests that introducing agricultural production services significantly reduces the intensity of chemical fertilizer use and improves its efficiency. Agricultural production services are essential in reducing chemical fertilizer use [17, 52].

Table 2. Impact of agricultural production services on chemical fertilizer use.

Variables	(A1)		(A2)	
	APSs	CF_intensity	APSs	CF_efficiency
APSs	——	-29.547***	——	-1.549***
		(6.228)		(0.601)
Age	-0.008	-0.257	-0.008	0.027
	(0.007)	(0.390)	(0.007)	(0.038)
Edu	0.006	-0.032	0.003	-0.127
	(0.017)	(0.943)	(0.017)	(0.092)
Health	-0.066	-6.386**	-0.067	-0.293
	(0.051)	(2.962)	(0.052)	(0.292)
Labor	-0.434**	-14.523	-0.463**	1.708
	(0.216)	(12.535)	(0.216)	(1.230)
Training	-0.113**	-3.428	-0.105*	-0.334
	(0.057)	(3.372)	(0.058)	(0.331)
Land tenure	0.002	-0.073	0.003	-0.104*
	(0.006)	(0.318)	(0.010)	(0.054)
Grain sowing	1.685***	27.677	1.704***	0.613
	(0.352)	(22.044)	(0.351)	(2.153)
Paddy field area	0.509**	27.231**	0.523***	1.238
	(0.202)	(12.024)	(0.201)	(1.177)
Soil fertility	-0.123	-11.165**	-0.134	-1.751***
	(0.085)	(4.919)	(0.085)	(0.482)
IV	0.733***	——	0.748***	——
	(0.081)		(0.081)	
Constant	-0.002	293.106***	0.001	24.126***
	(0.718)	(40.683)	(0.718)	(3.979)
Corr	0.544*** (0.081)		0.313*** (0.102)	
Wald chi2	27.54***		30.15***	
Log likelihood	-7343.038		-5165.702	
Observations	922		922	

Note: Standard errors are in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Mechanism Analysis

Theoretically, agricultural production services can affect the chemical fertilizer use behavior of farmers in terms of both farm size expansion and off-farm income enhancement. The above estimation results suggest that agricultural production services are conducive to reducing farmers' chemical fertilizer use. However, whether agricultural production services are conducive to farm size expansion and off-farm income enhancement needs further investigation. Based on the previous theoretical analysis and data availability, this paper takes "farm size" and "off-farm income" as the explanatory variables. It uses the extended regression model to test them.

The regression results are shown in Table 3. The results of models (B1) and (B2) indicate that adopting agricultural production services can significantly contribute to expanding farm size and increasing non-farm income. The estimation results are consistent with the theoretical expectations. Thus, we deduce that agricultural production services help reduce the use of chemical fertilizers, and the economies of scale and off-farm income effects play a part in it.

Table 3. The results of the mechanism test.

Variables	(B1)		(B2)	
	APSs	Economies of scale effect	APSs	Off-farm work effect
APSs	——	0.216**	——	0.057**
		(0.093)		(0.024)
Age	-0.008	-0.037***	-0.006	0.005***
	(0.007)	(0.006)	(0.007)	(0.002)
Edu	0.005	-0.008	0.000	0.005
	(0.017)	(0.014)	(0.017)	(0.004)
Health	-0.062	0.142***	-0.061	0.008
	(0.051)	(0.044)	(0.052)	(0.011)
Labor	-0.408*	0.505***	-0.370*	0.048
	(0.216)	(0.187)	(0.218)	(0.048)
Training	-0.116**	0.396***	-0.087	-0.020
	(0.057)	(0.051)	(0.059)	(0.013)
Land tenure	0.002	0.028***	0.002	-0.004***
	(0.006)	(0.005)	(0.006)	(0.001)
Grain sowing	1.602***	-0.338	1.563***	0.147*
	(0.351)	(0.325)	(0.350)	(0.083)
Paddy field area	0.476**	-0.131	0.514**	-0.131***
	(0.202)	(0.179)	(0.202)	(0.046)
Soil fertility	-0.135	-0.032	-0.156*	0.009
	(0.085)	(0.074)	(0.086)	(0.019)
IV	0.732***	——	0.753***	——
	(0.081)		(0.082)	
Constant	0.096	2.869***	-0.041	0.305*
	(0.718)	(0.611)	(0.721)	(0.156)
Corr	-0.314*** (0.102)		-0.271*** (0.105)	
Wald chi2	277.92***		42.86***	
Log likelihood	-3296.949		-2093.549	
Observations	922		922	

Note: Standard errors are in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Robustness Test

(1) Replacement model: This paper uses the conditional mixed process method for robustness tests [53]. It can also deal with potential endogeneity problems in the model. The estimates obtained using the conditional mixed process method are similar to those obtained using extended regression models (Table 4). The estimation results of models (C1) and (C2) confirm that introducing agricultural production services is beneficial for reducing chemical fertilizer use intensity and improving efficiency.

(2) Replacement independent variable: In this paper, "whether to adopt agricultural production services" is used as the independent variable. Since the variable is binary, we use the treatment effect model for estimation (Table 5). The estimation results of models (D1) and (D2) confirm the existence of a significant positive effect of agricultural production services on the reduction of chemical fertilizer use.

Extended Research

The above studies show that agricultural production services help reduce the intensity of chemical fertilizer use and improve its efficiency. However, different stages of rice production have different labor and agricultural technology needs, and the differentiated effects of different types of agricultural production services need to be considered. In terms of factor substitution effects, when the factor of labor becomes a scarce resource, labor-intensive services mainly achieve the substitution

Table 4. Robustness tests: CMP model.

Variables	(C1)		(C2)	
	APSs	CF_intensity	APSs	CF_efficiency
APSs	——	-29.606*** (6.242)	——	-1.588*** (0.615)
IV	0.731*** (0.081)	——	0.732*** (0.081)	——
Control variables	YES	YES	YES	YES
atanhrho_12	0.612*** (0.115)		0.333*** (0.116)	
LR chi2	165.51***		160.80***	
Log likelihood	-7348.693		-5200.496	
Obs.	922		922	

Note: Standard errors are in parentheses. ***p<0.01, **p<0.05, *p<0.1

Table 5. Robustness tests: Replacement independent variable.

Variables	(D1)		(D2)	
	ASS_option	CF_intensity	ASS_option	CF_efficiency
ASS_option	——	-26.988** (11.185)	——	-10.694*** (2.627)
IV	1.610*** (0.195)	——	1.147*** (0.329)	——
Control variables	YES	YES	YES	YES
athrho	0.156* (0.088)		0.854*** (0.245)	
lnsigma	4.386*** (0.089)		2.289*** (0.088)	
Wald test of indep. eqns.	3.10*		12.16***	
Wald chi2	11.47*		35.19***	
Log pseudolikelihood	-6016.809		-3841.471	
Obs.	922		922	

Note: Standard errors are in parentheses. ***p<0.01, **p<0.05, *p<0.1.

Table 6. Impact of labor-intensive services and technology-intensive services on chemical fertilizer use.

Variables	(E1)		(E2)		(E3)		(E4)	
	APSs	CF_intensity	APSs	CF_intensity	APSs	CF_ efficiency	APSs	CF_ efficiency
Tech_APSs	——	-153.692*** (50.173)	——	——	——	-10.848*** (4.046)	——	——
Lab_APSs	——	——	——	-117.712*** (32.172)	——	——	——	-8.653*** (2.999)
IV	0.163*** (0.044)	——	0.213*** (0.044)	——	0.177*** (0.044)	——	0.222*** (0.044)	——
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Corr	-0.856*** (0.073)		0.786*** (0.080)		0.675*** (0.136)		-0.609*** (0.129)	
Wald chi2	10.59*		15.11*		15.04*		17.41*	
Log likelihood	-4746.476		-4747.109		-3238.457		-3244.448	
Obs.	677		677		677		677	

Note: Standard errors are in parentheses. ***p<0.01, **p<0.05, *p<0.1.

of agricultural labor through the adoption of mechanized farming [17]. When agricultural technology resources are limited, technology-intensive services can introduce professional planting technologies and scientific field management methods for farmers and improve the efficiency of paddy cultivation [18]. In rice production, the three links of plowing, sowing, and harvesting usually require more agricultural labor, and the three links of seedling raising, pesticide spraying, and straw returning to the field are more technical and professional. Therefore, this paper classifies agricultural production services into technology-intensive and labor-intensive to examine the role of different agricultural production services in chemical fertilizer reduction.

The estimation results show that both types of agricultural production services can significantly reduce the intensity of chemical fertilizer use and improve its efficiency (Table 6). Technology-intensive services have a more significant impact on the intensity and efficiency of chemical fertilizer use. They can rapidly introduce new factors of production (e.g., biomass fertilizers, soil-measured formula fertilization) and field management practices. Therefore, when exploring sustainable agricultural development, we should focus on and fully exploit the facilitating effect of technology-intensive services on chemical fertilizer reduction.

Conclusions

This study empirically examined the impacts of agricultural production services on chemical fertilizer use using data from 992 rice farmers in Jiangsu Province, China. An extended regression model addresses the potential endogeneity and selectivity bias. The results showed that introducing agricultural production services can significantly reduce the intensity of chemical fertilizer use and improve its efficiency. The economies of scale effects of land and income effects of off-farm work play a part in it. In addition, compared with labor-intensive agricultural production services, technology-intensive agricultural production services have a more significant impact on reducing chemical fertilizer use. This study highlights the positive role of agricultural production services in promoting sustainable agricultural development, as they help promote large-scale and specialized agricultural production. Our results provide a theoretical basis for developing countries to promote the construction of agricultural socialized service systems.

Based on the above research conclusions, the policy implications are as follows:

First, the government should improve the agricultural service outsourcing market, strengthen policy and financial support for agricultural outsourcing services, encourage agrarian enterprises, agricultural cooperatives, and other types of new agricultural business entities to provide agricultural outsourcing services for farmers and create a market pattern of division of labor, complementary advantages, and healthy competition to promote the development of the agricultural service outsourcing market.

Second, the government should improve the land transfer market and encourage farmers to promote centralized and continuous cultivation through land transfer and appropriate scale management. It should also overcome the constraints of the small-scale and fragmented smallholder production pattern on the green development of agriculture and strengthen the role of agricultural production services in promoting the reduction of chemical fertilizers.

Third, agricultural service organizations should enhance the technological content of agricultural production services. Otherwise, encouraging more rice farmers to adopt agricultural production services will not help. By providing subsidies to agricultural service organizations, the government can guide agricultural service organizations to give the farmers green technologies such as organic fertilizer, improved seed cultivation, soil testing formula, and intelligent water and fertilizer management systems to promote the popularization of green agricultural production technologies, improve agricultural production efficiency, and reduce the use of chemical fertilizers.

Fourth, the government should increase the publicity and promotion of agricultural production services and guide more farmers to adopt them, helping them use modern agricultural production methods to reduce chemical fertilizer.

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Conflict of Interest

The authors declare no conflict of interest.

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