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The Impact of Agricultural Factor Inputs, Cooperative-Driven on Grain Production Costs

Han Zhang and Dongli Wu *

College of Economics and Management, Shenyang Agricultural University, Shenyang 110866, China; zhangh@stu.syau.edu.cn
* Correspondence: wdl@syau.edu.cn

Abstract: The problem of high grain production costs, which is not conducive to sustainable agricultural development and food security, is highlighted in the context of China's "large country and small household farmers". Reducing the grain production costs through factor allocation and organizational drive has become particularly important. Based on 768-grain peasant households in China, this paper uses OLS regression and robust regression to examine the effects of agricultural factor inputs and cooperatives on grain production costs. It analyzes the synergistic and substitution effects between farmers' factor inputs and cooperatives in grain production. It was found that: (1) in farmers' grain production, reductions in the grain production costs can be realized by expanding the area under cultivation, improving the use of agricultural machinery, and increasing technological inputs; (2) a reduction in the grain production costs can also be realized through cooperatives driving farmers into grain production; (3) cooperatives can provide farmers with various types of agricultural production services in grain production and cooperative-driven substitution effects between the agricultural factor inputs of farm households. The findings of this paper contribute to the enrichment of research in the field of agricultural production and are important for enhancing agricultural sustainability and reducing grain production costs.

Keywords: farm households; agricultural production factors; cooperatives; food production; production costs; synergistic effects; substitution effects

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1. Introduction

In China, the problem of increasing grain production costs has been highlighted by the impact of smallholder farming and yield-oriented agricultural policies [1]. With the new trend of quality in China's grain demand and concentration of the grain supply in the main production areas [2], the rising cost of grain production has become a new problem that needs attention [3]. The rising cost of grain production has led to the declining function of grain cultivation to support the livelihood of farming households and the reduced willingness of farming households to grow grain, which has a massive impact on the issue of grain security [4]. Based on the current value of the CNY, taking the data from 1990 to 2019 as an example, the total cost of wheat and rice cultivation increased from 1926.60 CNY/ha and 2539.20 CNY/ha to 15,433.65 CNY/ha and 18,626.55 CNY/ha, respectively, with rises of 701.08% and 633.56%, and the average annual growth rate of 7.44% and 7.11%, respectively. And from the point of view of cost composition, the proportion of labor cost per ha of wheat and rice to the total cost increased from 31.61% and 35.29% in 1990 to 33.13% and 38.19% in 2019, respectively; the proportion of land cost to the total cost also increased from 6.54% and 6.49% in 1990 to 21.18% and 19.42% in 2019, respectively [1]. Against the background of "three costs rising together" (material costs, labor costs, and land costs are all rising), labor costs and land costs have become the main reason for the increase in the cost of grain production. Other things being equal, the reduction in costs is consistent with the increase in economic efficiency [5]. Reducing grain production costs has become an urgent concern in China's agricultural development.

The agricultural factor inputs of farmers influence grain production costs. The factors that farmers invest in grain production are mainly land, farm machinery, technology, and labor. Expanding the scale of land cultivation can produce a scale effect, which is conducive to grain production, reducing grain production costs [5]. Given the trend of rising labor prices [6], the utilization of agricultural machinery can reduce the input of labor, change factor allocation through the substitution of capital factors for labor factors, and also affect the cost of grain production [7]. The greater the farmers' mastery of agricultural technology, the more beneficial it is for grain production, and an improvement in technological applications and scientific agricultural production methods can reduce grain production costs [8].

Farmers join cooperatives for unified production and management, which changes farmers' allocation of factors and production technology [9,10] and also affects the cost of grain production for farmers. When farmers join cooperatives, the cooperatives can provide farmers with various agricultural production and operation services [11], such as agricultural machinery, technical advice, and agricultural supplies. Providing the above agricultural production services is conducive to driving farmers toward and helping them carry out grain production. Cooperatives give farmers convenient access to various types of agricultural services, and the drive of cooperatives will have a synergistic effect. Agricultural machinery production services will change the input situation of agricultural machinery and labor factors, technical guidance services will change the technical situation of farmers' agricultural production, and agricultural supply services will change the purchase price of agricultural materials for farmers. The agricultural services provided by cooperatives will optimize the configuration and technical condition of farmers' agricultural inputs and affect the cost of grain production. Cooperatives provide various agricultural production services for farmers, which can replace farmers' agricultural factor inputs, and cooperatives drive farmers to take advantage of the substitution effect.

The marginal contribution of this paper is reflected in the following aspects: (1) It includes research on the impact of the four inputs of farmers' land, farm machinery, technology, and labor on grain production cost. Existing research mainly centers on a certain type of factor inputs and does not consider the allocation of farmers' factor inputs. This paper puts farmers' land, agricultural machinery, technology, and labor factors into the same research framework, and at the same time considers whether farmers join cooperatives to discuss the impact of farmers' factor inputs on grain production costs. (2) Cooperatives can drive farmers to engage in grain production and management, which is mainly reflected in the synergistic effect and substitution effect. Farmers join cooperatives to take advantage of unified production and management by cooperatives, which provide all kinds of agricultural production services for farmers, driving farmers to grain production. However, the existing literature focuses on the study of how cooperatives drive the agricultural production of farmers, ignoring the agricultural production services provided by cooperatives to farmers, and the formation of a kind of substitution of farmers' factor inputs. This paper discusses the logic of the impact of farmers' factor inputs and cooperatives on grain production costs in terms of synergies and substitution effects. (3) The least squares method of OLS minimizes the sum of squared residuals as its objective function, and when there are extreme values in the sample, the residuals of these extreme values affect the sum of squared residuals, leading to OLS results that may not be robust. In this paper, robust regression is used to overcome this problem. Robust regression is the use of weighted least squares to identify extreme values, which helps to mitigate the effect of extreme values on the regression results.

The structure of the rest of this paper is as follows: "Literature review and mechanism analysis" reviews the relevant literature and analyzes the influence mechanism of agricultural factor input and cooperative drive on grain production cost. The Section 2 describes the data and measurement methods used. The Section 4 presents the measurement results. In the Section 5, the views of this paper are compared with the existing research. The Section 6 summarizes the article.

2. Literature Review and Research Hypotheses

2.1. Grain Production Costs Influenced by Agricultural Factor Inputs

The main agricultural factor inputs of farmers are land, farm machinery, technology, and labor.

Adjusting the scale of land cultivation to bring into play the scale effect can reduce production costs. Land is a more critical production factor in agricultural production [5], and the scale operation of land can improve agricultural production efficiency and reduce grain production costs. Gai et al. [12] showed that the total factor productivity of agriculture would increase by 71.02% in the transition from small to large-scale farmers in agricultural production and operation, reducing grain production costs. The expansion of land cultivation [13,14] and the increase in plot size [15] can reduce the frontier cost and the cost of efficiency loss [10], optimize the allocation of land resources, and thus reduce grain production costs. While the scale of land cultivation increases, the need for agricultural supplies also increases, and discounts are available for large-scale purchases of agricultural supplies [16]. Due to the discount on agricultural supplies, the purchase price of agricultural supplies decreases, the average cost shifts overall, and the cost of production decreases. Hypothesis 1a is proposed:

Hypothesis 1a (H1a). *The expansion of the land cultivation scale can reduce grain production costs.*

Mechanized production can improve production efficiency and reduce production costs. After China entered the 21st century, agricultural mechanization developed rapidly. Organized agricultural machinery services widely emerged in rural areas [17], and the average horsepower of agricultural machinery in farm households increased from 2.18 kW/household in 2000 to 5.66 kW/household in 2020. It has been suggested that with the development of agricultural mechanization, the role of draft animals is decreasing; agricultural machinery can effectively replace draft animals, and relying on mechanization can improve technical efficiency [18,19] and form economies of scale, which in turn can reduce production costs [7]. At the same time, there is a substitution effect of machinery for labor in agricultural production [20], and mechanized production can reduce the labor input. Under rising labor prices, production costs can be reduced by replacing labor inputs through mechanized production. Hypothesis 1b is proposed:

Hypothesis 1b (H1b). *The improvement in farm machinery inputs can reduce the cost of grain production.*

The cost of grain production can be reduced by improving technology. Agricultural technology is the first driving force of agricultural development, including the farmers' inherited experience and the agricultural technology promoted by cooperatives, agricultural enterprises, agricultural technology departments, etc. [21]. According to the learning curve effect, the rate of skills or knowledge acquired within a certain period is accompanied by a rise in yield, which shows a negative correlation with production costs. This indicates that skills or knowledge can bring incremental economies of scale [22], which means that the level of technology in the operator's production is negatively correlated with production costs, and the higher the level of technology, the lower the production costs. The improvement in the technical level of the operating agent is conducive to reducing production costs [23]. In agricultural production, technological progress can likewise reduce the cost of grain production [8]. Hypothesis 1c is proposed:

Hypothesis 1c (H1c). *Improvements in technology can reduce the cost of grain production.*

Labor factor inputs are also of great importance in grain production. A large amount of surplus labor exists in Chinese grain production, i.e., the agricultural labor supply is greater than the reasonable demand for agricultural production and operation at a certain labor level. Therefore, some scholars suggest that the labor input–output elasticity in China's grain production should not be positive [24], and the marginal output of labor is zero or negative [25]. Even if part of the surplus labor force is separated, the original adequate labor time and output volume will not be reduced, and the development of agriculture will not be affected. Meanwhile, under the trend of rising labor prices [6], farmers invest more labor in grain production, which will increase the cost of grain production [7]. Farmers can rationally adjust the structure of factor inputs, while farm machinery can replace labor inputs. Hypothesis 1d is proposed:

Hypothesis 1d (H1d). *The increase in labor inputs is not conducive to a reduction in grain production costs.*

2.2. Grain Production Cost Influenced by Cooperative-Driven Factors

Cooperatives can drive farmers to agricultural production, thus creating synergies. At the same time, cooperatives can also substitute for farmers in agricultural production, thus also having a substitution effect.

Farmer input factors affect grain production, in which the drive of cooperatives will play a synergistic effect. Farmers join cooperatives and have their production organized by the cooperatives [26]. By obtaining the specialized and mechanized agricultural production services provided by the cooperatives, farmers can improve their production and operation capacity, optimize factor allocation, obtain more scientific agricultural technology, and reduce the cost of grain production. Farmers join the cooperatives, and the cooperatives provide agricultural services to farmers [27]. Under the unified management, the cooperative provides various agricultural production services for farmers at a relatively low price [10], such as seedlings, fertilizers, pesticides, and other agricultural materials [28] and procurement services for member farmers before production; production services such as cultivation, agricultural machinery, and technical consultation for farmers during production; and acquisition and marketing services for member farmers after production. The agricultural procurement, technical consultation, and production services provided by cooperatives for farmers are conducive to improving farmers' production capabilities, regulating farmers' planting production, and reducing farmers' grain production costs [29,30]. Based on this paper, Hypothesis 2a is proposed:

Hypothesis 2a (H2a). *There is a synergistic effect between farmers' factor inputs and cooperative-driven factors with the impact of reducing grain production costs.*

Farmers invest in factors for grain production, in which the drive of cooperatives will also play a substitution effect. First, agricultural mechanization has become a trend in the context of agricultural modernization. At the same time, labor prices continue to rise; agricultural machinery has become an important factor in producing grain farmers' input. Agricultural machinery can be invested by farmers, and cooperatives provide agricultural machinery services for farmers, which can be used as a substitute for farmers' agricultural machinery inputs. Secondly, cooperatives have technical advantages in grain production. Farmers join cooperatives, which unify grain production arrangements, while providing technical guidance for farmers, replacing farmers' planting techniques with techniques mastered by cooperatives. Finally, farmers' expansion of planting scale will bring into play the scale effect; for example, they can get discounts for purchasing agricultural products in large quantities, thus reducing the cost of grain production. Farmers joining cooperatives and purchasing agricultural products through cooperatives can also reduce the purchase price of agricultural products. The scale effect of farmers' expanding farmland investment and the cooperative-driven effect are mutually substituted. Hypothesis 2b is proposed:

Hypothesis 2b (H2b). *There is a substitution effect between farmers' factor inputs and cooperative-driven factors with the impact of reducing grain production costs.*

3. Study Design

Farmers input factors for grain production, and the differentiated factor inputs will generate different grain production costs. By contrast, cooperatives drive farmers to adopt unified grain production and management, and by providing farmers with various agricultural production services, they will change the farmers' factor allocation and technology status, which will also affect farmers' grain production costs. Specifically, in grain production, both farmers and cooperatives have cost-saving motives. Cooperatives can help farmers produce grain by providing agricultural production services to farmers, and a synergistic effect is produced between farmers' factor inputs and the cooperatives' drive. At the same time, farmers join cooperatives for unified production and operation. The agricultural services provided by cooperatives for farmers can replace farmers' factor inputs, and farmers' factor inputs and cooperatives' drive combine to produce a substitution effect. This paper empirically examines the effects of agricultural factor inputs and cooperative-driven factors on grain production costs using OLS regression and robust regression with the help of research data on grain farmers in Henan Province, China in 2022. The research framework diagram is shown in Figure 1.

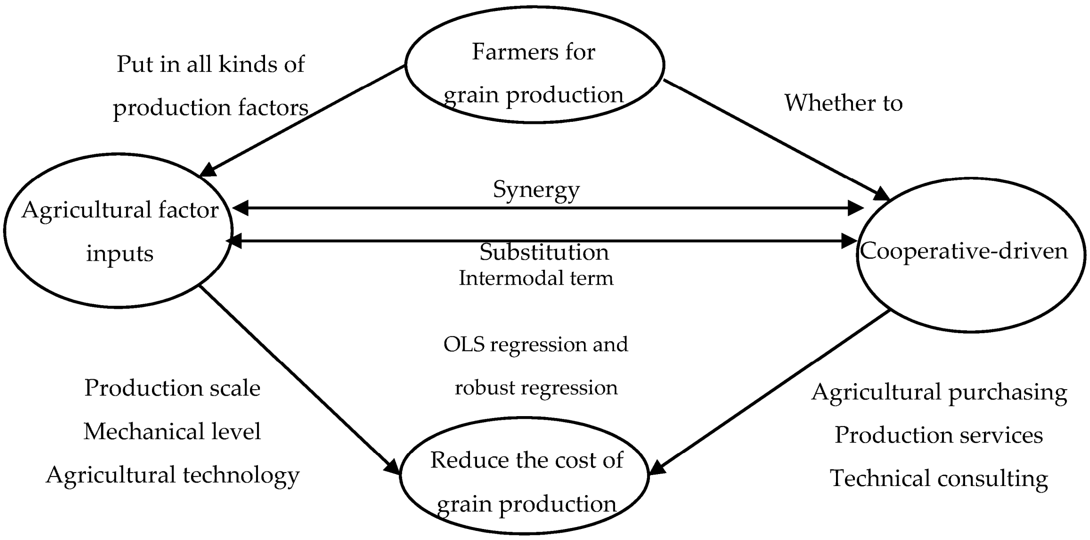

Figure 1. Research framework diagram.

3.1. Data Sources

The data sample of this study was obtained from the research on the production and operation of grain peasant households in Henan Province conducted by a group from the School of Economics and Management of Shenyang Agricultural University and a group from the School of Economics and Management of Nanyang Normal College, from January to February 2022.

The main grain-producing areas in China include thirteen provinces: Liaoning, Hebei, Shandong, Jilin, Inner Mongolia, Jiangxi, Hunan, Sichuan, Henan, Hubei, Jiangsu, Anhui, and Heilongjiang. The grain output of these 13 major grain-producing areas accounts for 75.4% of China's total grain output, and 95% of China's grain production increase also comes from these 13 areas. In these major grain-producing areas of China, the main grain crops are wheat, rice, corn, and soybean. Among them, wheat, rice, and corn are the main cereal crops. Henan Province is located in the middle and lower reaches of the Yellow River in the south of North China Plain. Its topography is mainly plain, most of which is located in the warm temperate zone, and the south is subtropical. It belongs to the continental monsoon climate of transition from the north subtropical zone to the warm temperate zone, with moderate precipitation, sufficient sunshine, and a long frost-free period all year round, which is suitable for the growth of various crops. At the same time, Henan

Province is a major grain-growing province. In 2021, the province's grain planting area was 107,723,100 hectares, and its grain output was 65,441,900 tons, ranking second in China.

The research used a combination of stratified and random sampling according to indicators such as geographical location and farmers' net income per capita. In Henan Province, seven cities were selected from south to north: Xinyang, Nanyang, Zhumadian, Zhoukou, Shangqiu, Anyang, and Puyang. Considering farmers who cooperate with agricultural enterprises, which drives farmers to engage in grain production and operation, will also affect farmers' grain production. To avoid sample bias, this paper only keeps the sample of farmers who joined cooperatives for unified production and operation in the data and the sample of farmers who did not cooperate with agricultural enterprises and cooperatives. A total of 790 data from grain-growing farmers (wheat and rice) were compiled for this paper. After eliminating the samples with logical inconsistencies, missing answers, and missing values of key variables, we finally obtained 768 valid questionnaires. In the survey sample, there are 587 wheat farmers, accounting for 76.43% of the total sample, and 181 rice farmers, accounting for 23.57% of the total sample. At the same time, this study only investigated the region of Henan Province where the geographical and climatic differences are small, and the differences in the way farmers grow grain are also small.

3.2. Selection of Indicators

Dependent variable. The dependent variable in this paper is the grain production cost for farmers, which is the total cost of production per unit of grain output. The agricultural production process for farmers mainly consists of land costs, machine tillage and irrigation costs, labor costs, seed costs, fertilizer costs, and pesticide costs [5]. Drawing on relevant studies [5,14,31], this paper defines the production cost of a farmer producing a grain crop as the total cost of production per unit of output. The land cost per hectare is calculated by consulting the "National Compilation of Agricultural Product Costs and Benefits" for each grain crop per hectare of self-camp discounted rent. Labor cost per hectare was calculated by referring to the methods of Xu et al. [5] and Li et al. [24], mainly considering hired labor fees and discounted family labor. In addition, we calculated the cost of production by drawing on existing studies [5,31] and dividing the total cost per unit area by the total yield per unit area to arrive at the cost of production per unit of the crop. The above calculations are consistent with the use of total cost divided by total yield. In this paper, we have only borrowed the formulae from existing studies. According to the method defined by the Price Division of the National Development and Reform Commission, the discounted price for household labor = the amount of household labor used × the daily labor price. Using the costing method of agricultural products, the daily labor price of a family in a certain year = local per capita net income of rural residents in the previous year × (local rural population in the previous year ÷ local rural workers in the previous year) ÷ number of labor days (365 days) in a year. The per capita net income of rural residents in Henan Province, the rural population numbers, and the number of rural workers are obtained from the Henan Statistical Yearbook. The cost per hectare of machine tillage and irrigation, the cost per hectare of seed, the cost per hectare of fertilizer, and the cost per hectare of pesticide are all calculated by the actual expenditure amount.

Independent variables. The independent variables in this paper are farmers' agricultural factor inputs and participation in cooperatives. Considering the factor inputs involved in grain production, this paper mainly focuses on farmers' inputs of land, farm machinery, technology, and labor. Farm machinery input is measured by the presence or absence of farm machinery, defined as 0 for farmers who do not own farm machinery and assigned a value of 1 for those who own farm machinery. The presence or absence of farm machinery in turn represents an increase in farm machinery input [24]. Farmers' land inputs were expressed in terms of actual cultivated areas [25]. Farmers' cultivation technology has an important impact on farmers' production and management [26], and the government actively improves farmers' agricultural production technology through agricultural training [27]. Considering this paper studies the technology input in grain production of farm households, drawing on related literature [28], the technology input of farm households is measured by the type of agricultural technology training received by farm households. And the specific agricultural technologies are classified as rational fertilizer application, rational pesticide application, land preparation technology, planting technology, straw return to the field, green planting, agricultural machinery training, water-saving technology training, and other technologies. Farmers' labor input is measured by the number of year-round agricultural workers in a farmer's family. Meanwhile, farmers' participation in cooperatives for unified production and management will also affect farmers' grain production. This paper assigns a value of 1 to farmers who join cooperatives for unified production and management and 0 to farmers who grow crops individually and do not participate in cooperatives.

Control variables. Drawing on relevant studies [5,31], this section selects characteristic variables, such as the individual characteristics of farmers and land management characteristics, as control variables. Individual farm household characteristics include the age, gender, and health of the head of household. This paper adds the variable of farmers' varieties of grain to the control variables, through the question, "Are the seedlings you buy general products easily available in the market?" The description and descriptive statistics of each variable are shown in Table 1.

Table 1. Descriptions of variables and descriptive statistics.

Variables	Variable Description	Average Value	Standard Deviation
Dependent variable			
Grain production cost	(cost of machine tillage and irrigation per hectare + labor cost per hectare + land cost per hectare + seed cost per hectare + fertilizer cost per hectare + pesticide cost per hectare) ÷ main product yield per hectare	0.4446	0.1305
Independent variables			
Agricultural machinery inputs	Household with or without farm machinery: Yes = 1; No = 0	0.2031	0.4025
Arable land input	Arable land area	1.7540	2.1545
Technical input	Types of agricultural technology training received	7.5572	1.4512
Labor input	Number of permanent farmers	2.2265	0.6424
Cooperative-driven	Joined cooperative unified production and management: Yes = 1; No = 0	0.5651	0.4960
Control variables			
Age of household head	Actual age	54.5132	5.6233
Gender of household head	Male = 0; Female = 1	0.1170	0.3215
Health level of household head	Poor = 1; fair = 2; good = 3	2.2311	0.5256
Planting varieties	Seedlings are general products easily available on the market: Yes = 1; No = 0	0.0117	0.1076
Growing crops	Wheat = 0; Rice = 1	0.2356	0.4246

Note: Based on Stata software results.

3.3. Model Construction

To analyze the effects of farmers' factor inputs and cooperative-driven factor inputs on grain production costs, this paper represents the above costs by the production cost per unit of grain output. Drawing on Xu et al. [5], this paper adds farmers' farm machinery inputs, technical inputs, and participation in cooperatives to the model. It selects a suitable model from linear, semi-logarithmic, and double-logarithmic models by comparing R^2 and F values, and finally chooses the semi-logarithmic model. The specific model is shown as follows:

$$lny_i = \alpha_{0i} + \alpha_{1i}land + \alpha_{2i}mac + \alpha_{3i}tec + \alpha_{4i}lab + \alpha_{5i}con + \alpha_{6i}H + \varepsilon_i \quad (1)$$

In Equation (1), y_i is the cost of grain production of the *i* farm household, *land* denotes the area of land planted by the farm household, *mac* denotes the farm machinery input situation of the farm household, *tec* denotes the technology situation of the farm household, *lab* indicates labor inputs of farm households, *con* indicates whether the farmers have joined a cooperative, *H* denotes the control variables, and ε is the disturbance term.

4. Results

4.1. The Basic Regression Results

This section empirically tests the effect of farmers' factor inputs on the cost of grain production using OLS regression based on a study of planting farmers in Henan Province. The R^2 value of the regression is 0.6623, which indicates that the model fits well, the independent variable explains the dependent variable to a high degree, and the regression results are robust. Considering the problem of multicollinearity, this part uses the method of hierarchical regression, and the indicators of each factor, namely farmers' land, farm machinery, technology, and labor, are gradually inserted into the regression to obtain Models 1–4 (Table 2). The regression results of each factor input by farmers on the cost of grain production are given in Table 2. From the regression results in Table 2, the effect of the core explanatory variable, farmer's factor inputs, on the farmers' production cost per unit of grain is consistent with our expected results, and all reach the 1% significance level. The different factor inputs of farmers affect their grain production costs. Therefore, hypotheses 1a, 1b, and 1c proposed in this paper are verified, but hypothesis 1d does not pass the empirical test.

Table 2. Model estimation results of the effect of farmers' factors on grain production costs.

Variable Name	Model 1	Model 2	Model 3	Model 4
Arable land input	−0.0010 *** (0.0001)	−0.0006 *** (0.0002)	−0.0005 ** (0.0002)	−0.0005 ** (0.0002)
Agricultural machinery inputs		−0.0359 *** (0.0092)	−0.0383 *** (0.0097)	−0.0378 *** (0.0099)
Technical input			−0.0055 ** (0.0025)	−0.0057** (0.0026)
Labor input				0.0009 (0.0036)
Age of household head	0.0037 *** (0.0005)	0.0038 *** (0.0005)	0.0034 *** (0.0005)	0.0034 *** (0.0005)
Gender of household head	0.0011 (0.0063)	0.0026 (0.0065)	0.0034 (0.0062)	0.0033 (0.0064)
Health level of household head	−0.0058 (0.0061)	−0.0100 * (0.0057)	−0.0129 ** (0.0062)	−0.0135 ** (0.0063)
Planting varieties	−0.1234 *** (0.0366)	−0.1220 *** (0.0374)	−0.1178 ** (0.0399)	−0.1228 *** (0.0376)
Growing crops	Control	Control	Control	Control
N	768	768	768	768
Prob > F	0.0000	0.0000	0.0000	0.0000
R^2 (Pseudo R^2)	0.6614	0.6632	0.6684	0.6623

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels. Robust standard errors are given in parentheses.

The effect of farmer's factor inputs on the cost of grain production: First, as shown in Model 1 in Table 2, the coefficient of arable land input is negative and passes the 1% significance level test. It shows that farming inputs have a negative effect on grain production costs. This result suggests that as farmers increase the scale of cultivation, their cost of production per kilogram of grain will decrease. Hypothesis 1a proposed in this paper was thus confirmed. Second, from Model 2 in Table 2, it can be obtained that the coefficient of farmers' farm machinery input is negative and passes the 1% significance level test. This indicates that farmers' production through mechanization is beneficial to reducing the cost of grain production. Hypothesis 1b proposed in this paper was thus confirmed.

Third, as seen from Model 3 in Table 2, the coefficients of farmers' technical inputs are all negative, and all pass the 5% significance level test. This shows that the more agricultural training farmers receive and the more comprehensive the range of agricultural production technology they master, the greater the benefit to the reduction in grain production costs. Hypothesis 1c proposed in this paper was thus confirmed. Fourth, as seen from Model 4 in Table 2, the coefficient of farm household labor input is positive but does not pass the 10% significance level test. Hypothesis 1d presented in this paper has not been confirmed. This result may also be caused by the problem of multicollinearity, where the farmer labor input variable is highly correlated with other factor input variables of farmers, such as that the larger the farming area, the more labor the farmers tend to put in, and the correlation between the two is high. Hence, the estimation result is insignificant after adding the farmer labor input variable. This result may therefore be due to the limitations of the sample in this paper.

4.2. Moderating Effects Test

This section uses the moderating effects test to analyze the impact of cooperative-driven factor on grain production costs. To test hypotheses 2a and 2b, this section inserts the variable of cooperative-driven factors into the econometric model to test the synergistic effect of cooperative-driven factors (H2a). It adds the cross-product term of farmer's factor inputs and cooperative-driven factors to test the substitution effect of cooperative-driven factors (H2b). The estimated results are shown in Table 3.

Table 3. Model estimation results of farm household factors on the cost of grain production.

Variable Name	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Arable land input	−0.0003 **	−0.0017 ***	−0.0006 ***	−0.0004 *	−0.0003 *	−0.0015 ***
	(0.0001)	(0.0004)	(0.0003)	(0.0002)	(0.0001)	(0.0004)
Agricultural machinery inputs	−0.0413 ***	−0.0386 ***	−0.0771 ***	−0.0415 ***	−0.0411 ***	−0.0568 ***
	(0.0069)	(0.0067)	(0.0090)	(0.0095)	(0.0082)	(0.0107)
Technical input	−0.0041 *	−0.0037 *	−0.0030	−0.0112 **	−0.0050 **	−0.0093 ***
	(0.0023)	(0.0020)	(0.0022)	(0.0024)	(0.0025)	(0.0025)
Labor input	0.0025	0.0036	0.0047	0.0062 *	0.0158 ***	0.0186 ***
	(0.0036)	(0.0036)	(0.0034)	(0.0036)	(0.0057)	(0.0054)
Cooperative-driven	−0.0199 ***	−0.0397 ***	−0.0334 ***	−0.0118 ***	−0.0234	−0.0764 **
	(0.0057)	(0.0067)	(0.0072)	(0.0027)	(0.0165)	(0.0305)
Arable land input × Cooperative-driven		0.0015 ***				0.0010 **
		(0.0003)				(0.0004)
Agricultural machinery inputs × Cooperative-driven			0.0723 ***			0.0335 *
			(0.0105)			(0.0175)
Technical input × Cooperative-driven				0.0130 ***		0.0098 ***
				(0.0034)		(0.0034)
Labor input × Cooperative-driven					−0.0196 **	−0.0176 **
					(0.0070)	(0.0069)
Control variables	Control	Control	Control	Control	Control	Control
N	768	768	768	768	768	768
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R^2 (Pseudo R^2)	0.6665	0.6652	0.6800	0.6721	0.6696	0.6660

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels.

Table 3 Model 5 reports the estimation results of the effect of cooperative-driven factor inputs on the cost of grain production, Models 6–9 report the estimation results of adding the cross-multiplication term of each farmers' factor input and cooperative-driven factor input, respectively, and Model 10 reports the estimation results of adding the cross-multiplication term of each farmers' factor input and cooperative-driven factor input.

The effect of cooperative-driven factors on the cost of grain production: The cooperative-driven variable is negative and passes the 1% significance level test. This indicates that farmers joining cooperatives for grain production can reduce the cost of grain production, which verifies Hypothesis 2a; that is, cooperatives have a synergistic effect on farmers' grain production. Through the provision of various agricultural production services, cooperatives can assist farmers in agricultural production, improve their productivity, and reduce production costs.

The effect of the cross-product term on the cost of grain production: As shown in Models 6–10 in Table 3, the coefficients of the cross-product terms of farm household arable land inputs and cooperative-driven factors in Models 6 and 10 are positive, and both pass the test at the 5% significance level. This indicates a substitution effect between the effect of farmer's arable land input on grain production cost and the effect of cooperative-driven factors on grain production cost. Second, the cross-multiplication term coefficients between farmers' farm inputs and cooperatives in Models 7 and 10 are positive, and both pass the 10% significance level test. This indicates that mechanized production can reduce the cost of grain production. And the inputs for farm machinery can be through farmers' inputs or through cooperatives. Third, the cross-multiplication term coefficients between farmers' technical inputs and cooperatives in Models 8 and 10 are positive, and both pass the 1% significance level test. This indicates a substitution effect between farmers' technical inputs and cooperatives in grain production. The explanation for this is that farmers can reduce the cost of grain production by improving their technical skills and scientific planting techniques in grain production, which farmers can obtain through various types of training or by cooperatives providing relevant technical guidance, and the above two channels of obtaining technology can be substituted for each other. Fourth, the coefficients of the cross-multiplication term between farmers' labor input and cooperatives in Models 9 and 10 are negative, and both pass the test of a 5% significance level. Meanwhile, the coefficient of the labor input variable in the combined Models 9 and 10 is positive. This indicates that excessive labor input in grain production will increase production costs. However, farmers' participation in cooperatives and production driven by cooperatives can restrain the impact of labor input on grain production costs. Based on the above results, Hypothesis 2b is confirmed.

4.3. Robustness Test

This section examines the robustness of the baseline regression results by the replacement of measurement methods. This section uses robust regressions for robustness testing because the possible discrete values of the sample farmers may introduce bias into the regression results. Table 4 reports the regression results of the alternative measures. From the regression results, it can be seen that the coefficients of arable land input, farm machinery input, and technology input variables in Model 11 are negative, and all pass the 5% significance level test, while the coefficients of labor input variables are positive but do not pass the significance level test; the coefficients of cooperative-driven variables in Model 12 are negative and pass the 1% significance level test. In Model 13, the coefficients of arable land input and cooperative-driven cross-multiplier, farm machinery input and cooperative-driven cross-multiplier, and technology input and cooperative-driven cross-multiplier were positive. All passed the 5% significance level test, while the coefficients of labor input and cooperative-driven cross-multiplier were negative and passed the 5% significance level test. The regression results after the replacement of measurement methods are consistent with the baseline regression results, so it can be shown that the relevant conclusions are still robust after the replacement of the measurement methods.

4.4. Heterogeneity Analysis

The growth characteristics of different food crops are different, so in this part a heterogeneity analysis is performed by planting crop type. In this part, the sample data were divided according to different planting crop types, and regression analysis was performed separately. The results are shown in Table 5. Model 14 is the result of regression on wheat growers' data, and Model 15 is the result of regression on rice growers' data.

Table 4. Estimation results of robustness tests.

Variable Name	Model 11	Model 12	Model 13
Arable land input	−0.0006 *** (0.0001)	−0.0006 *** (0.0002)	−0.0014 ** (0.0003)
Agricultural machinery inputs	−0.0292 *** (0.0078)	−0.0320 *** (0.0076)	−0.0378 *** (0.0088)
Technical input	−0.0041 ** (0.0020)	−0.0071 *** (0.0019)	−0.0111 ** (0.0018)
Labor input	0.0058 (0.0038)	0.0092 ** (0.0038)	−0.0079 *** (0.0036)
Cooperative-driven		0.0224 *** (0.0058)	0.0580 * (0.0033)
Arable land input × Cooperative-driven			0.0009 ** (0.0003)
Agricultural machinery inputs × Cooperative-driven			0.0573 *** (0.0144)
Technical input × Cooperative-driven			0.0085 ** (0.0033)
Labor input × Cooperative-driven			−0.0219 ** (0.0084)
Control variables	Control	Control	Control
N	768	768	768
Prob > F	0.0000	0.0000	0.0000
R^2 (Pseudo R^2)	0.7312	0.7416	0.7517

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels.

Table 5. Estimated results of heterogeneity analysis.

Variable Name	Model 14	Model 15
Arable land input	−0.0007 *** (0.0001)	−0.0022 ** (0.0009)
Agricultural machinery inputs	−0.0465 *** (0.0106)	−0.0178 (0.0059)
Technical input	−0.0085 *** (0.0022)	−0.0226 ** (0.0059)
Labor input	0.0071 * (0.0039)	0.0052 (0.0043)
Control variables	Control	Control
N	587	181
Prob > F	0.0000	0.0000
R^2 (Pseudo R^2)	0.3337	0.3095

Note: *, **, *** indicate significance at the 10%, 5%, and 1% levels.

From the regression results in Table 5, it can be seen that there are differences in the impact of agricultural factor inputs on different food crops. As can be seen from model 14, the land, agricultural machinery, and technology factors are negatively correlated with wheat production costs, and all of them have passed the test at a 1% significance level. This indicates that increasing the land, agricultural machinery, and technology factors is favorable to reducing the cost of wheat production. The labor factor is positively related to wheat production cost and passed the test at a 10% significance level. This indicates that an increase in labor factor inputs is not conducive to reducing the cost of wheat production. Wheat cultivation can be mechanized to replace labor in production and reduce the cost of wheat production. From model 15, it can be seen that the land and technology factors are negatively correlated with rice production cost and all of them passed the test at a 5% significance level. This indicates that an increase in the land and technology factor inputs is conducive to reducing the cost of wheat production. The effect of agricultural machinery inputs and labor factor inputs on rice production costs did not pass the test at the given significance level. The possible explanation is that there are differences between the two crops, wheat and rice, and the impact of various types of agricultural factor inputs on them is not the same. Rice is a labor-intensive crop with a low mechanization rate compared to wheat, and rice cultivation requires a certain amount of labor input. Agricultural machinery and labor are both substitutable and highly correlated, which may give rise to multicollinearity problems. Therefore, in the sample used in this section, the impact of mechanization and labor on rice production is not significant.

5. Discussion

5.1. Agricultural Factor Inputs Influence the Grain Production Costs

Farmers input factors for grain production, and the differentiated factor inputs will generate different grain production costs.

(1) Among the factor inputs in agriculture, land inputs affect the cost of grain production. A possible explanation is that Chinese farmers predominantly manage small-scale land operations. Therefore, increasing the scale of the land operations of farmers is conducive to reaching the zone of economies of scale and reducing the cost of grain production. This is consistent with the findings of Xu et al. [5] that there are economies of scale in agricultural production and that scaled agricultural production is beneficial to reducing production costs. At the same time, the larger the scale of production, the more agricultural supplies are needed, and buying agricultural supplies in large quantities is conducive to obtaining more purchase discounts [32]. Reducing the unit price of agricultural supplies purchased is also conducive to reducing the cost of grain production. At the same time, the expansion of the planting area is also conducive to mechanized production [33].

(2) Mechanization of agricultural production helps to reduce the cost of grain production. The explanation for this is that the use of farm machinery in agricultural production can replace manual labor to a certain extent and reduce the labor input [34], and under the trend of rising labor prices, increasing the input of farm machinery and reducing the labor input can reduce the cost of grain production through the substitution relationship between factors [35].

(3) Improved agricultural technology contributes to lowering the cost of grain production. This is because the more agricultural production techniques farmers have mastered [36], the more scientific their production methods, and the better their production systems [37,38], the more efficient the input production factors will be [39,40], which is therefore conducive to reducing the cost of grain production.

(4) This paper fails to validate the effect of labor inputs on the cost of grain production. Farmers can rationally adjust their planting structure and agricultural factor input structure. Reducing labor inputs in grain production can boost grain production [41]. However, in the sample used in this paper, there are two categories, wheat growers and rice growers. The production of the two crops, rice and wheat, is different, thus leading to the results of this paper not passing the test. This also confirms the view of Zheng et al. that the effect of labor on grain production will lead to different conclusions depending on the sample [42].

5.2. Cooperative-Driven Factors Influence the Grain Production Costs

By contrast, cooperatives drive farmers to engage in unified grain production and management, and by providing farmers with various agricultural production and management services, they will change farmers' factor allocation and technology status, which will also affect farmers' grain production costs.

There are synergies in grain production where cooperatives can assist farmers. Farmers join the cooperative as members, and the cooperative provides services related to agricultural production and operation to farmers. The cooperatives provide various agricultural production and management services for member farmers at relatively low prices [10], providing seedlings, fertilizers, pesticides, and other agricultural supplies; supply and procurement services for member farmers before production; production management services such as cultivation, technical consultation, and farm machinery for member farmers during production; and acquisition and marketing services for member farmers after production. The cooperative provides agricultural procurement, technical guidance, production management [43], and other services for member farmers, which are conducive to improving farmers' production and management capabilities [44], regulating farmers' planting and production, and reducing farmers' grain production costs. This also confirms the conclusions obtained from relevant studies [29,30]. Specifically, first, cooperatives can provide agricultural supply services for farmers, and farmers can purchase more affordable raw materials such as seeds and fertilizers, reducing the cost of grain production. Cooperatives provide raw material supply services for farmers, and contracted farmers can generally buy raw materials at lower prices, reducing purchase prices and achieving savings in grain production costs. Second, cooperatives can provide agricultural production services such as farm machinery for farmers, reducing farmers' labor input and realizing lower grain production costs. Cooperatives can provide agricultural machinery and other production services for farmers, reducing labor input through agricultural machinery and replacing labor with capital to reduce production costs. Third, cooperatives can provide technical guidance services for farmers to grasp scientific production technology and extensive planting information, reducing the cost of grain production. Cooperatives provide technical support for farmers to improve their agricultural production techniques. The greater the farmers' mastery of agricultural technology, the more beneficial it is to implement more scientific agricultural production methods, thus efficiently carrying out agricultural production, controlling factor inputs, and saving production costs through technological progress. Farmers choose to join cooperatives, which are unified in production and management and are driven by the cooperatives to engage in grain production and obtain various agricultural production services, which can reduce the cost of grain production.

Also, cooperatives can substitute for farmers in grain production. (1) The expansion of land area by farmers generates scale effects, as does the replacement of farmers in agricultural production by cooperatives [45]. Farmers who expand the scale of cultivation will benefit from the scale effect, such as buying a large amount of agricultural supplies to obtain discounts and thus reduce the cost of grain production. At the same time, farmers who join a cooperative and buy agricultural supplies through the cooperative can also reduce the purchase price of agricultural supplies and the cost of grain production. There is a mutual substitution between the scale effect exerted by farmers who expand farmland inputs and the cooperative-driven effect. (2) There is a substitution effect between farmers' farm machinery inputs in grain production and cooperative-driven factors [46]. The explanation for this is that the input of farm machinery in grain production can reduce the cost of grain production by reducing labor input. By contrast, farm machinery can be invested by farmers or through farm machinery services provided by cooperatives. There is a substitution effect between farm machinery input by farmers and agricultural machinery services provided by cooperatives. (3) The technology applied to agricultural production can be mastered by farmers through training and applied to agricultural production [47]. Cooperatives can also drive farmers to engage in agricultural production and provide farmers with technical guidance to promote the application of agricultural technology. (4) There is surplus labor in grain production, and excessive labor input increases the cost of grain production [5]. Farmers join a cooperative and replace part of the labor input through the service of the cooperative [48]. This substitution has improved farmers' agricultural production capacity and marginal output and suppressed the impact of increasing grain production costs due to excessive labor input.

6. Conclusions and Policy Implications

The high cost of grain production has been highlighted in the context of "large country and small household farmers" in China. The rising cost of grain production is not conducive to sustainable agriculture and food security. It is particularly important to reduce the cost of grain production, which can be achieved by changing the farmer's factor inputs and using cooperatives to drive farmers to produce grain [49,50]. Based on 768 research data of grain farmers in Henan Province, this paper uses OLS regression to test the effects of farmers' factor inputs and cooperative-driven factor inputs on the cost of grain production and also analyzes the synergistic and substitution effects of farmers' factor inputs and cooperative-driven factor inputs in reducing the cost of grain production. The following conclusions were obtained: (1) Farmers can reduce the cost of grain production through land scale effects, substituting farm machinery for labor inputs, and relying on better farming techniques. (2) Farmers join cooperatives, which provide a variety of agricultural production services that help reduce the cost of grain production. (3) Cooperatives can replace farmers in agricultural production and have a cost-saving effect.

According to the conclusion of this paper, the following policy suggestions are put forward:

First, to explore the endogenous power of agricultural production of farmers and improve their agricultural production and operation capacity. In the context of China's "large country and small household farmers," farmers are generally constrained by resource factors, making it difficult to engage in agricultural production and operation efficiently. In order to promote agricultural production and improve the agricultural production capacity of farmers, the government should build a perfect agricultural production guidance system for farmers, such as policies to encourage farmers to transfer their land to enable large-scale production, actively carry out agricultural technology training to enable specialized production, provide preferential policies for purchasing agricultural machinery or guide new agricultural business entities to carry out agricultural machinery services to enable mechanized production. We provide farmers with opportunities to use modern agricultural production factors, optimize the allocation of agricultural production resources, improve the efficiency of agricultural production factors, explore the endogenous power of farmers in agricultural production and operation, and promote the improvement of their agricultural production and operation capacity, to achieve a reduction in grain production costs.

Secondly, cooperatives should be promoted to drive farmers' grain production and to utilize the synergistic effect of cooperatives. Therefore, the government needs to encourage cooperatives and farmers to form a cooperative relationship in production. Then, a pattern is established of cooperatives driving farmers to engage in agricultural production, and realize the improvement in grain production efficiency and the reduction in grain production cost. By building an agricultural production organization system that serves farmers and improving the interest linkage mechanism between farmers and cooperatives, the government realizes the trend of agricultural production and operation driven by cooperatives. Through the drive of production and management organizations such as cooperatives, farmers are encouraged to specialize, scale, and mechanize agricultural production, optimize the allocation of factors for farmers, promote the technological progress of agricultural production, and finally realize the improvement in agricultural production efficiency and reduction in grain production costs.

Third, the resource factor allocation of farmers should be optimized, and the substitution effect of cooperatives brought into play. Therefore, the government should actively cultivate cooperatives, diversify agricultural production and operation, and play a role in the organization, coordination, driving, and service of cooperatives. Cooperatives drive farmers to engage in specialized, large-scale, mechanized agricultural production, take advantage of the substitution effect, improve the efficiency of agricultural production, and achieve a reduction in grain production costs.

This study also has some potential limitations. First of all, as far as data and samples are concerned, this study only uses the cross-sectional data of farmers for 2022, which can only explain the agricultural operation of farmers in one year. If panel data are chosen instead, and a longer research period is used, the research can be more detailed and richer in content. Second, the production characteristics of different crops are different, and the impact of agricultural factor inputs on different crops is not exactly the same. More targeted research should be conducted based on differences in the production characteristics of different crops and the results of analyses of different crops compared. This is an interesting question, and it is also the next research direction. Thirdly, this study only uses the survey data of farmers in one area of Henan Province, in China, for analysis and research, so there are limitations with regard to the research area. The conclusions of this paper need further verification in other countries and regions.

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