

Article

Research on the Relationship between Agricultural Insurance Participation and Chemical Input in Grain Production

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Abstract: As an important agricultural policy, agricultural insurance will affect farmers' production input, such as fertilizers and pesticides. Its development needs to consider the environmental impact and adapt to the needs of sustainable development. In addition, farmers' chemical input behavior during the agricultural production process may also affect their agricultural insurance participation behavior. Based on data from a survey of 1318 farmers in the Shandong, Liaoning, Jiangxi, and Sichuan provinces of China, this paper established a simultaneous equations model to explore the interaction between farmers' agricultural insurance participation behavior and chemical input in the grain production process. The results show a mutual causality between the decision to obtain insurance and chemical input in grain production. Farmers who input fewer chemical fertilizers and more pesticides per mu are more inclined to purchase agricultural insurance. Agricultural insurance participation significantly increases the input of chemical fertilizers and reduces the input of pesticides in the grain-production process. On this basis, the following policy recommendations are proposed: firstly, we should pay attention to the increasing role of agricultural insurance in agricultural sustainable development and further improve the agricultural insurance policy system; secondly, we should innovate and develop "green"-oriented agricultural insurance policies to accelerate the high-quality development of agricultural insurance; third, we should increase publicity and guidance to encourage more farmers to engage in green production.

Keywords: agricultural insurance; insurance participation behavior; chemical input; agricultural sustainable development; simultaneous equations model



Citation: Zhang, L.; Yang, Y.; Li, X. Research on the Relationship between Agricultural Insurance Participation and Chemical Input in Grain Production. *Sustainability* **2023**, *15*, 3045. <https://doi.org/10.3390/su15043045>

Academic Editor: Michael S. Carolan

Received: 4 January 2023

Revised: 3 February 2023

Accepted: 6 February 2023

Published: 7 February 2023



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1. Introduction

China attaches great importance to agricultural sustainable development. In 2017, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the "Opinions on Innovating System and Mechanism to Promote Green Agricultural Development," proposing that green agricultural development should be placed in a priority position in the overall construction of ecological civilization, and comprehensive, green, eco-oriented institutional systems should be established. We aimed to achieve the goal of zero growth in the use of fertilizers and pesticides for major crops by 2020. However, agricultural sustainable development, especially the green production process, faces many risk factors, such as natural risks, policy risks, and market risks, leading farmers to "retreat" from agricultural green production technology. Farmers would often prefer to choose traditional production technology, which contains fewer production risks. However, agricultural insurance can effectively disperse the above risks, motivating farmers to adopt environmentally friendly production technology, and effectively promote the agricultural sustainable development [1,2].

Since China's Central Government began to implement the agricultural insurance premium subsidy policy in 2007, the scale of agricultural insurance premiums has increased from CNY 5.184 billion in 2007 to CNY 96.518 billion in 2021; the variety of agricultural

insurance subsidized by the central government increased from 5 to more than 270 in 2022; the total risk coverage of agricultural insurance increased from CNY 112.6 billion in 2007 to CNY 4.78 trillion in 2021; the scope of full-cost insurance and income insurance for food crops, especially the three major staples, has been continuously expanded. The full coverage of major grain-producing counties in 13 major grain-producing provinces will be realized in 2022, and the guaranteed level could reach up to 80% of the growing income of corresponding varieties. Agricultural insurance has played an increasingly significant role in the agricultural support and protection policy system.

In the context of agricultural sustainable development, while agricultural insurance maintains a rapid pace of development and provides risk coverage for food production, we should also pay more attention to its environmental effects. Existing studies have pointed out that agricultural insurance will affect farmers' input behaviors regarding production factors such as fertilizers, pesticides, and films. The excessive input of these agricultural chemicals has a direct impact on the effectiveness of green agricultural development [3]. Meanwhile, farmers' chemical input behavior during the agricultural production process may also affect their agricultural insurance participation behavior, and this could have an impact on the adoption of environmentally friendly production technology. Therefore, agricultural insurance should take the initiative to connect with the goal of "peak carbon dioxide emissions and carbon neutrality" and the strategic needs of agricultural sustainable development. While conducting in-depth research on the mechanisms and paths that could support green agricultural development, it is necessary to innovate and develop green agricultural insurance to reduce the use and improve the efficiency of chemical fertilizers and pesticides [4]. Therefore, based on the perspective of agricultural sustainable development, this paper takes grain-growers in Shandong, Liaoning, Jiangxi, and Sichuan provinces of China as its research objects. Based on a theoretical analysis, this paper explores the interaction between farmers' agricultural insurance participation behavior and chemical input during the grain production process, and analyzes its influence mechanism to provide an empirical basis and policy suggestions for further improvements to the agricultural insurance system, giving full play to its role in promoting agricultural sustainable development.

2. Literature Review

Many scholars have analyzed the impact of agricultural insurance participation behavior on the chemical input in the agricultural production of farmers from theoretical and empirical perspectives but have not reached a consistent conclusion [5–8]. Some scholars believe that agricultural insurance will encourage farmers to put more chemicals into their arable land. For example, Niu et al. [9] researched the panel data of 31 provinces in China from 2000 to 2020. The results showed that policy-based agricultural insurance would lead to excessive fertilization by farmers, thus aggravating agricultural non-point source pollution. Other scholars came to the opposite conclusion; they believed that agricultural insurance would reduce farmers' investment in chemicals. For example, Quiggin's [10] research on corn and soybean growers in the Midwest of the United States showed that agricultural insurance and chemical inputs formed a substitution relationship, and purchasing agricultural insurance would allow for farmers to reduce the use of pesticides and fertilizers. Some scholars believe that agricultural insurance will impact the farmers' chemical input during agricultural production. Still, the direction of this impact is uncertain, and mainly depends on the characteristics of the chemical being used. Horowitz et al. [11] concluded that pesticides are risk-reducing input elements, while chemical fertilizers and agricultural film are risk-increasing input elements; that is, the higher the probability that farmers purchase agricultural insurance, the more likely they are to apply fewer pesticides and invest in more agricultural film and fertilizers. The empirical research results of Zhong et al. [12] also verify this viewpoint. Scholars have not yet reached a consensus on the role that agricultural insurance plays regarding the chemical input of farmers; Chen et al. [13] believed the main reason for this is that there are significant differences in

terms of agricultural production conditions, agricultural insurance coverage levels, and farmers' risk preferences in different regions. Zhang et al. [14] believed that the inconsistent conclusions resulted from a lack of consideration of the type of arable land and the intensity of the agricultural insurance subsidy. Agricultural insurance subsidies may only stimulate the scale expansion of low- and medium-yield arable land, with little impact on the chemical input of high-yield arable land. Moreover, only when the premium subsidy and security levels are high enough will agricultural insurance encourage farmers to expand the scale of low- and medium-yield arable land and increase their chemical inputs.

Some scholars believe that farmers' chemical input behavior during the agricultural production process will affect their agricultural insurance participation behavior. Ning [15] established a theoretical analysis framework for the environmental and economic effect of the agricultural insurance system based on the anticipated utility theory and believed that farmers' insurance was interrelated with the input of agrochemical factors. Zhong et al. [12] studied the insurance participation behavior and agrochemical application behavior of cotton growers in the Manas River Basin in Xinjiang and found that farmers who used more fertilizers and agricultural films were more inclined to buy agricultural insurance, while farmers who applied more pesticides were more inclined not to purchase agricultural insurance. Based on the survey data of rice growers in Fujian Province, Ma et al. [16] believed that increasing the input of chemical fertilizers would increase farmers' willingness to buy insurance, while increasing the input of pesticides will reduce their desire to buy insurance.

In summary, although there are many theoretical and empirical studies on farmers' agricultural insurance participation and chemical investment behavior, we can still find some limitations: firstly, the actual role that agricultural insurance plays in farmers' chemical investments has not yet been clarified; secondly, the existing studies mostly focus on the impact of agricultural insurance on farmers' chemical input behavior, while there are few studies on the interaction between these two. Related studies on food crops are particularly lacking. Although a consistent conclusion has not been reached regarding the role that agricultural insurance plays in farmers' chemical input behavior, it is unquestionable that agricultural insurance will impact agricultural sustainable development by affecting the chemical inputs of agricultural households [17–20]. Consequently, to promote the high-quality development of agricultural insurance and agricultural sustainable development, as well as to ensure food security, it is necessary to conduct in-depth research on the relationship between farmers' agricultural insurance participation behavior and their chemical investment behavior in food production to provide the basis for improvements in the agricultural insurance system, innovate green-oriented agricultural insurance products, and guide farmers in the rational application of chemical fertilizers and pesticides.

3. Theoretical Basis

According to the farmer theory, farmers are assumed to be "homo economicus" and will use risk-aversion or profit-maximization to maximize the expected utility. Therefore, farmer behavior aims to reduce agricultural production risks and increase agricultural production income. Based on the needs of risk management and obtaining expected utility, farmers will purchase agricultural insurance. Farmers play two "roles" in their agricultural insurance participation and production behavior: firstly, as consumers, meaning that government premium subsidies will improve their ability to pay and increase the possibility of farmers participating in insurance; secondly, as producers, meaning that government premium subsidies and insurance claims payments will change farmers' expected utility. Based on the maximization of expected utility, farmers will change their agricultural production input [21].

3.1. As Consumers, Analysis of the Mechanism That Affects Farmers' Insurance Participation

According to the expected utility model of agricultural insurance constructed by Chambers [22], the following expected utility function for farmers can be established:

$$EU = \int_{R_{min}}^{R_{max}} U[R + I(y) - \sigma - \omega x] dG(R, x). \quad (1)$$

In Formula (1), the food-growing income of farmers is $R = py$, p is the grain price, and y is the output, which can be defined as $y = f(x, \theta)$, where x represents each input element, and θ represents the random variable, indicating the risk factors in the grain production process (climate, natural disasters, etc.). $I(y)$ is the agricultural insurance claims payment related to the output y . The insurance claims will be triggered when the actual output is lower than the critical output. σ is the insurance cost of farmers, and ω is the factor price. The farmers' profit can be expressed as: $\pi = R + I(y) - \sigma - \omega x$. Therefore, factor input affects farmers' yield, and their utility level is related to their profit. The farmers' utility level determines whether they will participate in the insurance. At the same time, farmers' insurance participation decision also depends on factors such as age, land endowment, farmers' risk perception, and their perception of insurance, as well as whether there is an alternative agricultural risk management method [18,23].

3.2. As Producers, Analysis of the Mechanism That Affects Farmers' Production Input Behavior

If the farmers choose to participate in agricultural insurance and the critical output that triggers the claim is y^0 , the profit function of farmers can be expressed as follows:

$$\pi = \begin{cases} R - \sigma - \omega x, & y \geq y^0 \\ R + I(y) - \sigma - \omega x, & y < y^0 \end{cases}. \quad (2)$$

Formula (2) can be specified as:

$$\pi = \begin{cases} pf(x, \theta) - \sigma - \omega x, & f(x, \theta) \geq y^0 \\ pf(x, \theta) + I[f(x, \theta) - y^0] - \sigma - \omega x, & f(x, \theta) < y^0 \end{cases}. \quad (3)$$

Formula (3) shows that farmers' participation in insurance will affect their profits, thus changing their production input behavior. Therefore, the agricultural insurance participation behavior and production input behavior of farmers should be comprehensively considered. There may be unobservable variables that affect farmers' insurance and production input behavior; additionally, there is a mutual influence process between farmers' insurance participation behavior and their production input behavior. Therefore, agricultural insurance is not an exogenous variable, and there are some endogenous issues [15,18]. In addition, due to the difference in the attributes and risk properties of fertilizers and pesticides, this paper will consider the simultaneous relationship between the fertilizer and pesticide application decisions and agricultural insurance participation decisions of farmers [15].

4. Model and Data Description

4.1. Model Setting and Research Methods

According to the above analysis, there is a two-way influence mechanism between farmers' insurance participation and their chemical fertilizer and pesticide input behavior. Drawing on the studies by Zhong [12], Ma [16], and Xu [24], this paper selected corresponding variables and established the following simultaneous equations model:

$$INS = \alpha_0 + \alpha_1 FER + \alpha_2 PES + \alpha_3 EDU + \alpha_4 \ln TI + \alpha_5 \ln PI + \alpha_6 TA + \alpha_7 RISK + \alpha_8 PVT + \alpha_9 PAY + \sum_{i=2}^5 \sigma_{1i} AWN_i + \sum_{i=2}^5 \sigma_{2i} IPT_i + \sum_{i=2}^6 \sigma_{3i} CDR_i + \alpha_{10} DISR + \mu \quad (4)$$

$$FER = \beta_0 + \beta_1 INS + \beta_2 EDU + \beta_3 CI + \beta_4 WRK + \beta_5 CA + \beta_6 YID + \beta_7 PVT + \beta_8 EFT + \varepsilon \quad (5)$$

$$PES = \gamma_0 + \gamma_1 INS + \gamma_2 EDU + \gamma_3 CI + \gamma_4 WRK + \gamma_5 CA + \gamma_6 YID + \gamma_7 PVT + \gamma_8 EFT + \omega \quad (6)$$

Formulas (4)–(6) are the decision-making equations for farmers' insurance participation, fertilizer application, and pesticide application, respectively. *INS*, *FER*, and *PES* are core variables, which are also endogenous variables. All other variables are control variables (see Table 1 for the specific names and related descriptions of each variable). *INS* shows whether farmers will participate in the insurance; *FER* is the fertilizer cost per mu; *PES* is the pesticide cost per mu; *EDU* is the farmers' education level in years; *TI* is the total household income; *PI* is the farming income of farmers; *TA* is the self-owned cultivated land area of farmers; *RISK* is the type of agricultural risks faced by farmers; *PVT* is whether farmers carried out risk prevention; *PAY* is farmers' insurance claims experience; *AWN_i* is farmers' understanding of agricultural insurance; *IP_{Ti}* is farmers' perception of the importance of agricultural insurance; *CDR_i* is farmers' satisfaction with the work of insurers; *DISR* is whether the farmer has been affected by disasters; *CI* is the average grain income per mu; *WRK* is the number of migrant workers; *CA* is the area of grain cultivation; *YID* is the grain yield per unit; *EFT* is whether agricultural insurance has an impact on farmers' production; μ , ε , and ω are random error terms. Equations (4)–(6) show that the simultaneous equations model is identifiable; hence, this paper will use the three-stage least square (3SLS) method for estimation [25]. 3SLS is a system estimation method which can estimate all equations in the simultaneous equations model as a whole. Compared with the single equation estimation method and two-stage least squares method (2SLS), this is more efficient and can better reveal the causal relationship. However, it is important to note that the sample size must be large enough for 3SLS to be used, and every equation in the model must be correctly set and recognizable.

Table 1. Variable description and descriptive statistics.

Variable Type	Variable Name	Variable Unit and Description	Mean	Standard Deviation
Basic characteristics of farmers	Education years (<i>EDU</i>)	Education years (year)	6.98	3.26
	Household income (<i>TI</i>)	Household income in 2020 (yuan)	90,918.81	113,461.30
	Farming income (<i>PI</i>)	Farming income in 2020 (yuan)	50,203.97	152,477.50
	Income per mu (<i>CI</i>)	Income from growing crops per mu (yuan/mu)	1356.92	1164.90
	Number of migrant workers (<i>WRK</i>)	Number of long-term migrant workers in the family (person)	0.86	1.03
Agricultural production characteristics	Cost of fertilizer (<i>FER</i>)	Cost of fertilizer per mu (yuan/mu)	134.20	108.66
	Cost of pesticide (<i>PES</i>)	Cost of pesticide per mu (yuan/mu)	55.30	56.20
	Arable land area (<i>TA</i>)	Self-owned arable land area (mu)	12.09	10.31
	Grain growing area (<i>CA</i>)	Grain growing area (mu)	33.00	91.51
	Grain yield (<i>YID</i>)	Grain yield (kg/mu)	147.53	228.19
Agricultural risk cognition	Type of risks	Types of risks faced (type)	1.67	1.02
	Risk prevention (<i>PVT</i>)	Whether agricultural risk prevention measures have been taken (1 = yes, 0 = no)	0.28	0.45
Agricultural insurance cognition	Insured or not (<i>INS</i>)	Insured or not (1 = yes, 0 = no)	0.61	0.49
	Impact of insurance (<i>EFT</i>)	Whether agricultural insurance has an impact on your agricultural production (1 = yes, 0 = no)	0.63	0.48
	Claims payment history (<i>PAY</i>)	Prior insurance claims experience (1 = yes, 0 = no)	0.44	0.50
	Understanding of insurance (<i>AWN_i</i>)	Understanding of agricultural insurance (do not understand; do not understand very well; generally understand; relatively understand; very well-understood. Dummy variables were set with reference to "do not understand" during model estimation: 1 = yes, 0 = no)	—	—

Table 1. Cont.

Variable Type	Variable Name	Variable Unit and Description	Mean	Standard Deviation
Agricultural insurance cognition	Importance of Insurance (IPT_i)	Importance of agricultural insurance (completely unimportant; not very important; generally important; relatively important; very important. Dummy variables were set with reference to “completely unimportant” in model estimation: 1 = yes, 0 = no)	—	—
	Evaluation of insurers (CDR_i)	Satisfaction with the work of agricultural insurers (do not care; very dissatisfied; dissatisfied; generally satisfied; satisfied; very satisfied. dummy variables were set with reference to “do not care” in model estimation; 1 = yes, 0 = no)	—	—
Natural characteristics	Disaster experience ($DISR$)	Disaster experience (1 = yes, 0 = no)	0.37	0.48

4.2. Data Source

The data in this paper derive from a survey on China’s rural financial inclusion in Shandong, Liaoning, Jiangxi, and Sichuan provinces, conducted by the School of Economics and Management of China Agricultural University from July to August 2021. The survey adopted a random stratified sampling method, and the survey content mainly included the basic information of household heads and households, production and income characteristics, risk perception, insurance perception, willingness to participate in insurance, purchase behavior, farmers’ satisfaction with insurance, the impact of insurance on agricultural production, etc. The survey locations were in Dezhou, Jinan and Weifang City in Shandong Province, Fuxin, Liaoyang and Tieling City in Liaoning Province, Ganzhou City in Jiangxi Province, as well as Meishan and Guang’an City in Sichuan Province, involving a total of 28 townships and 97 villages (communities, streets). A total of 1671 samples were collected, and 1318 valid samples were obtained after excluding invalid questionnaires, of which 805 were insured, and 513 were not insured.

4.3. Descriptive Analysis

The specific variable settings and descriptive statistics are shown in Table 1. The selection of variables is primarily divided into five aspects: farmers’ essential characteristics, agricultural production characteristics, agricultural risk cognition, agricultural insurance cognition, and natural characteristics. Table 1 shows that the educational level of the surveyed farmers was generally low, with an average education period of 6.98 years. The average total household income in 2020 was 90,918.81 yuan, of which the average planting income was 50,203.97 yuan. The average income per mu from growing food crops was 1356.92 yuan, and the average number of long-term migrant workers who leave for more than six months each year was 0.86 per household. From the perspective of agricultural production characteristics, the average cost of fertilizers for farmers was 134.2 yuan per mu, and the cost of pesticides was 55.3024 yuan. Each household’s average self-owned arable land was 12.09 mu, and the average grain growing area was 33 mu. The average yield of grain crops was 147.53 kg per mu; with regard to farmers’ awareness of agricultural risks, they face an average of 1.67 types of agricultural production risks, and 28% of farmers have taken risk prevention measures; in terms of agricultural insurance cognition, farmers generally believed that agricultural insurance is important, but their understanding of agricultural insurance and their satisfaction with the work of agricultural insurers was general. The participation rate of agricultural insurance was 61% among the surveyed rural households, and 63% of the insured farmers believed that agricultural insurance has an impact on their agricultural production. A total of 44% of the farmers had experience with receiving claims payments from insurance companies, and 37% of farmers had experience with disaster.

5. Results and Discussion

5.1. Endogeneity Test of Equations

Before using the simultaneous equations model for estimations, it is necessary to test its endogeneity. Suppose the explanatory variables of equations in the model are related to random error terms. This would prove that the equations are simultaneous, which indicates that it is efficient to use the 3SLS method to estimate them. Otherwise, the ordinary least squares (OLS) method should be used for estimation [25,26]. In this paper, the Hausman test method was used to test the endogeneity of equations in the model. The specific steps are as follows: firstly, the OLS is used to regress the endogenous variables and all exogenous variables of an equation in the model to obtain the residual value, bringing this value into the equation of endogenous variables for regression. If the residual value is significant, then the null hypothesis that “the equation does not have endogeneity” is rejected, proving the simultaneousness of equations. The results of the Hausman test on equations in the model are shown in Table 2. The residual coefficients of the three equations in the model are all significant at the 1% level, indicating the simultaneousness of equations; hence, the 3SLS method can be used for estimation.

Table 2. Hausman test results of equations.

Equation	Residual Coefficient	Standard Error	t Statistics
Insurance participation decision equation	1.0015 ***	0.0083	120.18
Fertilizer application equation	0.9996 ***	0.0069	144.46
Pesticide application equation	0.998 ***	0.0083	120.89

Note: *** indicates significance at the 1% level.

5.2. Effects of Farmers' Chemical Input Behavior on Insurance Participation Decisions

Table 3 shows the estimated results of the decision-making equation for farmers' insurance participation. The results show that the core variables of chemical fertilizer cost and pesticide cost per mu significantly affect farmers' insurance participation decisions. Every increase of 1 yuan in the chemical fertilizer cost per mu will lead to a 0.44% reduction in the probability of farmers participating in insurance. Every increase of 1 yuan in the chemical pesticide cost per mu will lead to a 0.51% increase in the probability of farmers participating in insurance. The production of food crops has a trend of diminishing marginal returns. The input of chemical fertilizers is mainly related to the yield. To maximize profits, farmers may reduce other production costs, such as agricultural insurance, while increasing the cost of chemical fertilizers. The property of pesticides and fertilizers is different, and their effect on yield is mainly reflected in the reduced the risk of yield reduction rather than any increase in the expected yield. Therefore, pesticide input can be used to reflect farmers' risk cognition; that is, the greater the pesticide input, the stronger the farmers' risk cognition, and the greater the probability of their participating in insurance. In addition, the area of self-owned farmland positively impacts farmers' participation in insurance, but this effect is not significant. According to the content of the survey questionnaire, among the insurance samples, the main reason for farmers to participate in agricultural insurance is “cadre propaganda and mobilization,” accounting for 72.56% of the total. However, only 3.01% of farmers selected “risk increases with larger planting scale.” It can be seen that the impact of cultivated land area on farmers' insurance participation decision is insignificant in the sample.

The basic characteristics of farmers significantly affect their decision to participate in insurance. Years of education were shown to have a significant negative impact on farmers' decision to buy insurance; the reason for this is that farmers with higher education levels tend to have better risk-management skills [12]. Both the total household income and planting income have a significant impact on farmers' participation in insurance but in the opposite direction. A possible reason for this is that the higher the proportion of migrant

income in the total household income, the smaller the investment in agricultural production, which leads to a decrease in the possibility of purchasing agricultural insurance.

Table 3. Estimated results of the insurance participation decision equation of farmers.

Name of Variables	Coefficient	Standard Error	dy/dx
Fertilizer cost	−0.0044 ***	0.0013	−0.0044
Pesticide cost	0.0051 ***	0.0019	0.0051
Cultivated land area	−0.0002	0.0017	−0.0002
Education years	−0.0245 ***	0.0073	−0.0245
ln total household income	−0.0418 **	0.0182	−0.0418
ln planting income	0.0641 ***	0.0197	0.0641
Type of risks	0.0415 **	0.0164	0.0415
Risk prevention	−0.0697	0.0525	−0.0697
Claims experience	0.2498 ***	0.0471	0.2498
Understanding of insurance			
Do not understand very well	0.0378	0.0609	0.0378
General understanding	0.1443 **	0.0629	0.1443
Relative understanding	0.2496 ***	0.0679	0.2496
Very good understanding	0.1552	0.1001	0.1552
Importance of insurance			
Not very important	0.3598 ***	0.1342	0.3598
Generally important;	0.4355 ***	0.1349	0.4355
Relatively important	0.462 ***	0.1275	0.462
Very important	0.5029 ***	0.1365	0.5029
Evaluation of insurers			
Very dissatisfied	0.3869	0.2895	0.3869
Dissatisfied	−0.1654	0.1188	−0.1654
Generally satisfied	−0.0103	0.074	−0.0103
Satisfied	0.1155 **	0.0514	0.1155
Very satisfied	0.1238 **	0.0621	0.1238
Disaster experience	−0.069 **	0.0337	−0.0723
Constant term	0.2347	0.2200	—
χ^2	183.74 ***		

Note: dy/dx is the marginal effect, representing the change in the probability of farmers participating in the insurance. **, *** represent significance at the 5% and 1% level, respectively.

The more agricultural risks farmers face, the higher their probability of purchasing agricultural insurance. For each additional agricultural risk faced by farmers, the probability of participation in insurance will increase by 4.15%; in addition, farmers who have not taken any risk prevention measures are more inclined to purchase agricultural insurance to avoid agricultural production risks.

From the perspective of agricultural insurance cognition, farmers with experience receiving claims payments from insurance companies know more about agricultural insurance and think that agricultural insurance is more important. Therefore, they have a higher probability of participating in insurance; moreover, satisfaction with the work of agricultural insurers in the village also significantly affects farmers' decision to participate in insurance. When the farmers are very satisfied or satisfied with the work of insurers, they are more likely to participate in insurance.

5.3. Effects of Farmers' Insurance Participation Decisions on Their Chemical Input Behavior

The specific estimation results for the fertilizer application equation and the pesticide application equation are shown in Table 4, and the coefficients of most control variables are significant. Among them, whether to participate in insurance has a substantial impact on farmers' fertilizer and pesticide input. Compared with the uninsured farmers, the fertilizer cost increases by 29.09 yuan per mu for insured farmers, while the pesticide cost reduces by 27.2 yuan per mu in grain production. Therefore, the purchase behavior of agricultural insurance causes farmers to increase the input of chemical fertilizers and reduce

the input of pesticides, which is consistent with the research conclusions of Zhong et al. and Li et al. [12,27]. The reason for this is that participation in both insurance and the application of pesticides will reduce the yield volatility and the probability of farmers receiving claims payment, leading to risk reductions regarding grain production for insured farmers. As risk-prevention factors, pesticides can reduce the yield fluctuation and the possibility of farmers receiving claims payments; thus, insured farmers will reduce their pesticides input; chemical fertilizers, as a risk-increasing factor, can increase the expected value and variance of yield; thus, insured farmers will increase this input [11,15].

Table 4. Estimation results of fertilizer and pesticide application equation for farmers.

	Fertilizer Application Equation		Pesticide Application Equation	
	Coefficient	Standard Error	Coefficient	Standard Error
Insured or not	29.0899 *	17.8786	−27.1961 ***	9.1986
Education years	1.652	1.054	1.6465 ***	0.541
Income per mu	0.0122 ***	0.0028	0.0032 **	0.0015
Number of migrant workers	−8.3355 ***	3.2064	−4.0856 **	1.7974
Area of cultivated land	−0.0219	0.0302	−0.023	0.0169
Per unit area yield	0.049 ***	0.0154	0.0017	0.0083
risk prevention	18.5481 **	0.037	−3.7943	4.5286
Impact of insurance	−4.942	7.3379	−29.6411 ***	3.8321
Constant term	87.6640 ***	20.1633	82.9711 ***	10.362
χ^2	49.8 ***		107.94 ***	

Note: *, **, *** represent significance at the 10%, 5% and 1% level, respectively.

From the perspective of farmers' essential characteristics, years of education positively impact farmers' chemical fertilizer and pesticide application behavior. Still, this impact is only significant in the pesticide application equation. The income from planting grain per mu significantly impacts the input of chemical fertilizers and pesticides. This indicates that the higher the income from producing grain, the more focused the farmers' attention is on grain production. Thus, they are more motivated to increase the factor input to increase the expected yield and income of agricultural output. The number of medium- and long-term migrant workers in a family has a significant negative impact on the input of chemical fertilizers and pesticides; that is, the more migrant workers there are in the family, the lower the amount of chemical fertilizers and pesticides that farmers will invest in during grain production process. As a developing country, China is facing the problem of large-scale urban and rural migration, and many farmers choose to work in cities [27]. Farmers participating in part-time work will reduce the number of people engaged in grain production, and rational farmers will maximize their household income by reducing the input of production factors [28].

The impact of cultivated land area on farmers' fertilizer and pesticide input is negative, indicating that there is a trend of economies of scale expanding the planting scale and reducing the average planting cost per mu, but this impact is not significant. The per unit area yield has a positive impact on the use of chemical fertilizers and pesticides by farmers. Among them, the impact on the application of chemical fertilizers is significant. The per-unit-area yield will affect the chemical input during farmers' production process by affecting their income from growing grain. The impact of risk prevention on the chemical fertilizers and pesticides applied by farmers occurs in the opposite direction. The impact on the cost of chemical fertilizers per mu is significant. Compared with farmers who have not taken any agricultural risk-prevention measures, those who take agricultural risk-prevention measures increase their use of chemical fertilizers by 18.55 yuan per mu on average. This may be similar to the influence mechanism regarding whether to participate in insurance, and its effect on farmers' fertilizer and pesticide input behavior; that is, rational farmers will increase the input of risk-increasing factors while reducing the input of risk-reducing factors. The impact of insurance is negative regarding the input of both fertilizers and pesticides of farmers and has a significant effect on the input cost of pesticides per mu. This indicates that farmers who believe that participating in agricultural insurance

will impact their own agricultural production behave differently from those who think that there is no actual impact in terms of the input of agricultural chemicals, significantly reducing their input of pesticides. This also confirms the regression results regarding whether the core variable is insured in the pesticide application equation to a certain extent.

5.4. Analysis of the Relationship between Farmers' Decision to Participate in Agricultural Insurance and Input of Food Production Chemicals

It can be seen from the results in Tables 3 and 4 that farmers' decisions to participate in agricultural insurance and their chemical input decisions during grain production process affect each other; the influence mechanism is summarized in Figure 1. As homo economicus, farmers' goal during grain production is to maximize profits. Farmers' expected income is determined by the grain output/income and production costs. Farmers' participation in insurance can provide income security against the risks for grain-growing farmers. Agricultural insurance can provide insurance policies to stabilize farmers' income when farmers encounter a reduction in output resulting from natural disasters. Meanwhile, factors such as the growing scale and proportion of revenue from growing grains will also affect farmers' decision to participate in insurance; in addition, farmers need to pay part of the insurance premiums themselves, which means that the insurance participation decision will affect their production costs. Considering the trend of diminishing returns in grain production, farmers may consider participating in insurance when measuring their production costs and expected returns. In terms of the input of production factors, on the one hand, the input of chemical fertilizers and pesticides is directly related to farmers' production costs; on the other hand, it also affects the farmers' income from grain cultivation by affecting the output. This is mainly reflected by the use of chemical fertilizers, which can increase the expected grain yield, while pesticides can reduce the risk of expected declines in yield. In addition, the essential characteristics of farmers, as well as their production characteristics, risk perception, and cognition of agricultural insurance, affect their insurance participation and input behavior regarding production factors to varying degrees. The regression results of farmers' insurance participation decisions are not satisfactory; however, generally, the larger the area of self-owned arable land, the stronger their willingness to participate in insurance. This also has been verified in previous studies [29].

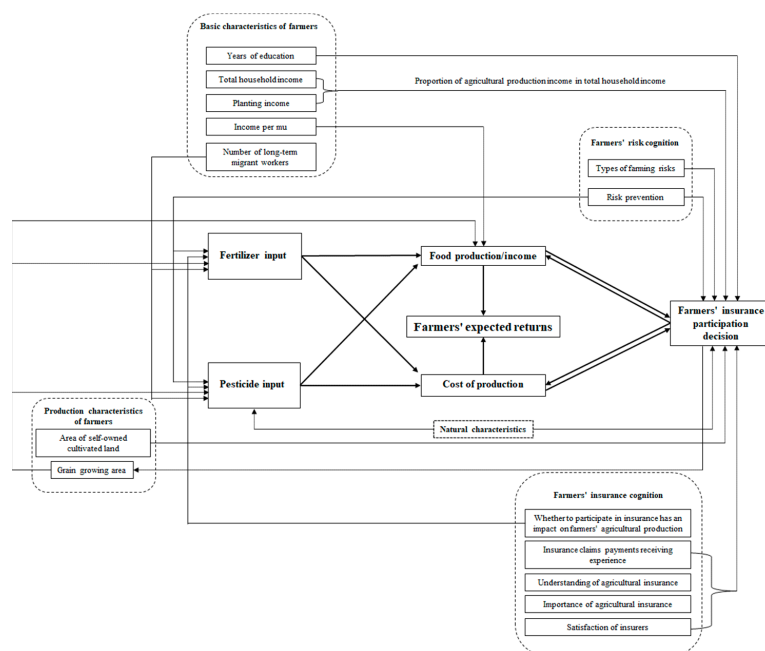


Figure 1. Relationship between farmers' insurance participation and chemical input in grain production.

5.5. Robustness Test

2SLS is another method for estimating simultaneous equations which can be used to solve the problem of equation endogeneity. Different from 3SLS, 2SLS is a single equation estimation method, which ignores the possible correlation between the disturbance terms of different equations. Therefore, although the estimation results are consistent, it is not the most efficient method and cannot explain the causal relationship between different equations [24]. For the robustness test, the model is re-estimated using 2SLS, and the estimation results are shown in Table 5.

Table 5. Estimated results of 3SLS and 2SLS.

	Insurance Participation Equation		Fertilizer Application Equation		Pesticide Application Equation	
	3SLS	2SLS	3SLS	2SLS	3SLS	2SLS
Insured or not			29.0899 *	34.4451 *	−27.1961 ***	−27.3287 ***
			(17.8786)	(18.0158)	(9.1986)	(9.2396)
Fertilizer cost	−0.0044 ***	−0.0046 ***				
	(0.0013)	(0.0014)				
Pesticide cost	0.0051 ***	0.0057 ***				
	(0.0019)	(0.002)				
Education years	−0.0245 ***	−0.0263 ***	1.652	1.8323 *	1.6465 ***	1.624 ***
	(0.0073)	(0.0075)	(1.054)	(1.0596)	(0.541)	(0.5434)
Total household income	−0.0418 **	−0.0307				
	(0.0182)	(0.0215)				
ln Planting income	0.0641 ***	0.0567 ***				
	(0.0197)	(0.0221)				
Income per mu			0.0122 ***	0.0095 ***	0.0032 **	0.0032 **
			(0.0028)	(0.003)	(0.0015)	(0.0015)
Number of migrant workers			−8.3355 ***	−5.1718	−4.0856 **	−4.1639 **
			(3.2064)	(3.521)	(1.7974)	(1.8058)
Area of cultivated land	−0.0002	−0.0006				
	(0.0017)	(0.002)				
Grain-growing area			−0.0219	−0.046	−0.023	−0.0224
			(0.0302)	(0.033)	(0.0169)	(0.0169)
Per-unit area yield			0.049 ***	0.0537 ***	0.0017	0.0016
			(0.0154)	(0.0162)	(0.0083)	(0.0083)
Understanding of insurance						
Do not understand very well	0.0378	0.0146				
	(0.0609)	(0.0732)				
General understanding	0.1443 **	0.1368 *				
	(0.0629)	(0.0752)				
Relative understanding	0.2496 ***	0.2354 ***				
	(0.0679)	(0.0798)				
Very good understanding	0.1552	0.126				
	(0.1001)	(0.1197)				
Evaluation of insurers						
Very dissatisfied	0.3869	0.4647				
	(0.2895)	(0.3474)				
Dissatisfied	−0.1654	−0.2246				
	(0.1188)	(0.1385)				
Generally satisfied	−0.0103	0.0914				
	(0.074)	(0.0838)				
Satisfied	0.1155 **	0.0883				
	(0.0514)	(0.0593)				
Very satisfied	0.1238 **	0.0883				
	(0.0621)	(0.0727)				
Claims payment receiving experience	0.2498 ***	0.3009 ***				
	(0.0471)	(0.0528)				
Importance of insurance						
Not very important	0.3598 ***	0.4516 ***				
	(0.1342)	(0.158)				

Table 5. Cont.

	Insurance Participation Equation		Fertilizer Application Equation		Pesticide Application Equation	
	3SLS	2SLS	3SLS	2SLS	3SLS	2SLS
Generally important	0.4355 *** (0.1349)	0.5145 *** (0.1584)				
Relatively important	0.462 *** (0.1275)	0.5316 *** (0.1504)				
Very important	0.5029 *** (0.1365)	0.5892 *** (0.16)				
Impact of insurance			−4.942 (7.3379)	−8.6393 (7.5055)	−29.6412 *** (3.8321)	−29.5496 *** (3.8493)
Types of insurance	0.0415 ** (0.0164)	0.0466 ** (0.0193)				
Disaster experience	−0.0723 ** (0.0347)	−0.0991 ** (0.0409)				
Risk prevention	−0.0697 (0.0525)	−0.0639 (0.0537)	17.7322 ** (8.805)	20.4651 ** (8.8695)	−3.7943 (4.5286)	−3.8619 (4.5488)
Constant term	0.2347 (0.22)	0.129 (0.2501)	83.6640 *** (20.1633)	85.7413 *** (20.2944)	82.9711 *** (10.362)	83.0187 *** (10.4082)

Note: Values in brackets are standard errors; *, **, *** represent significance at the 10%, 5% and 1% level, respectively.

When comparing the estimation results of 3SLS and 2SLS, the signs and significance of all variables, especially core variables, are basically the same, indicating the robustness of the estimation results and the research conclusions.

6. Conclusions and Recommendations

Based on the survey data of Shandong, Liaoning, Jiangxi, and Sichuan provinces of China, this paper established a simultaneous equations model to analyze the relationship between farmers' agricultural insurance participation decision and their chemical input decisions during grain production. The main conclusions are as follows.

Firstly, farmers who input fewer chemical fertilizers and more pesticides per mu are more inclined to purchase agricultural insurance. At the same time, the essential characteristics of farmers also significantly affect their decision to participate in insurance. Farmers with a high proportion of agricultural income in their total household income tend to pay more attention to food production and are more inclined to participate in insurance. In addition, farmers with a higher cognition of agricultural risks and agricultural insurance and higher level of satisfaction with the work of agricultural insurers have a higher probability of participating in insurance. Therefore, we can conclude that farmers' agricultural insurance participation behavior could be significantly heightened by enhancing farmers' risk awareness and understanding of insurance and improving the co-underwriters' service levels.

Secondly, agricultural insurance participation significantly increases the input of chemical fertilizers and reduces the input of pesticides in the grain-production process; that is, agricultural insurance may lead to the possibility of excessive fertilization. This is similar to the macro-research results of Hou and Wang in China, where the agricultural insurance development of green agriculture was found to have a certain inhibitory effect [30]. Farmers with a higher average income per mu tend to pay more attention to food production and are more inclined to input fertilizers and pesticides during the food-production process. Concurrent employment will lead farmers to reduce the input of fertilizers and pesticides in the food production process. Farmers who take risk prevention measures are more inclined to increase the input of chemical fertilizers and reduce the input of pesticides in the food production process, which proves that rational farmers will increase the input of risk-increasing factors and reduce the input of risk-reducing factors. At the same time, compared with the results of other scholars, we believe that the different types of insurance

and insurance objects are among the reasons for the different research conclusions, which should be considered in the follow-up research.

Thirdly, there is an interaction between farmers' decisions to participate in agricultural insurance and their chemical inputs during the food production process. This is consistent with the results of Zhong et al., Ma and Lai, and Zhang et al. [12,16,18]. The influence mechanism can be summarized as follows: Farmers' expected returns are determined by the grain output/income and production costs. Insured farmers can increase their income through insurance companies' claims payments. At the same time, insurance premiums will also increase farmers' production costs and affect their expected returns. On the one hand, the input of chemicals is directly related to their production costs; on the other hand, this affects farmers' income from growing crops by affecting the grain yield. In addition, farmers' essential characteristics, production characteristics, risk cognition, and agricultural insurance cognition affect their participation in insurance and chemical input behavior to varying degrees.

Based on the above conclusions, this paper puts forward the following policy recommendations:

1. Attention should be paid to the increasing role of agricultural insurance in agricultural sustainable development, and the agricultural insurance policy system should be improved.

It is necessary to place more emphasis on the environmental effects of agricultural insurance and integrate "green" policies into the policy objectives of agricultural insurance in China. This will enable agricultural insurance to help with agricultural sustainable development. In general, food crops use less fertilizer than other crops, such as fruit, which means that agricultural insurance development can reduce environmental pollution by promoting crop restructuring [31]. It is necessary to further improve the current agricultural insurance policy, scientifically and accurately determine the rate, formulate reasonable subsidy standards, and improve the level of agricultural insurance coverage. Furthermore, it is also essential to strengthen the training and management of rural insurers and improve their professional proficiency and service level, thus enhancing farmers' enthusiasm to participate in insurance. Moreover, with the continuous improvements in the agricultural insurance coverage level, farmers should be alert to the moral hazard caused by the fluctuations in output that derive from increases the application of chemical fertilizers. It is of great significance to speed up the establishment and improvement of relevant laws and regulations on agricultural insurance, and to make agricultural insurance more refined and standardized, to better satisfy the actual needs of "agriculture, rural areas, and rural residents" and enable agricultural insurance to play a full role in ensuring food security and promoting agricultural sustainable development.

2. "Green"-oriented agricultural insurance products should be innovated and developed, accelerating the high-quality development of agricultural insurance.

It is necessary to further explore and innovate "green"-oriented agricultural insurance products, such as the farmland fertility index insurance, low-carbon insurance, and environmental pollution liability insurance, establishing and gradually expanding the pilot scope. It is also vital to enhance policy support and explore and implement differentiated subsidy methods. Insurance premium subsidies can be increased, or coverage can be improved for farmers who adopt green production methods. Farmers should be encouraged to scientifically allocate elements during the agricultural production process, reducing the use of chemical fertilizers and pesticides and improving efficiency. We need to learn from the experience of other countries while accumulating practical agricultural insurance experience, effectively promote the continuous "expansion of scope and type, and improvement of standards" in agricultural insurance, and promote its high-quality development.

3. Publicity and guidance to encourage farmers to carry out green production should be increased.

We must adhere to green, low-carbon, and cyclic development, and adhere to the policy of saving resources and protecting the environment. The government and insurance companies should actively cooperate to organically combine agricultural insurance with agricultural sustainable development, strengthen the promotion of agricultural insurance and green production technology, and effectively enhance farmers' awareness of insurance and environmental protection. It is also necessary to highlight new types of agricultural entities that allow for reductions in fertilizers and pesticides and increases the efficiency of green agricultural production, guide farmers in the rational allocation of factors in the grain production process, and take multiple measures to promote agricultural sustainable development. From a food safety perspective, the government should actively promote green food and organic produce certification to attract more farmers to participate in sustainable agricultural production.

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

Funding: This research was funded by the National Natural Science Foundation of China (NSFC) “Research on Crop Income Insurance Demands and Coping Mechanism in the Process of Agricultural Scale Management” (71473252).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

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