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Effects of Agricultural Insurance on Water Pollution in China

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Abstract: ***Water pollution is the most serious environmental problems in China now, water pollution directly affects people's quality of life and the sustainable development of agriculture, and the biggest source of water pollution is agricultural non-point source pollution, so we need to pay more attention to the environmental impact of agricultural production and reduce agricultural non-point source pollution. This paper examines the environmental impact of agricultural insurance on water pollution. Using annual data from 30 provinces across China between 2011 and 2019, this paper employs a two-way fixed-effects model to examine the correlation between agricultural insurance development and agricultural pollutant emissions. Additionally, it takes agricultural carbon emissions and agricultural output value as dependent variables to comprehensively investigate the environmental and economic impacts of agricultural insurance. The research results indicate that the development of agricultural insurance has a significant effect on reducing agricultural water pollution and carbon emissions. The pollutant reduction effect is more significant in the major grain-producing areas. The positive environmental effect of agricultural insurance is based on the fact that the development of agricultural insurance is conducive to reducing the use of pesticides and chemical fertilisers and does not come at the expense of increased agricultural output.***

Keywords: Agricultural pollution, Water pollution, Agricultural insurance, Agricultural carbon emissions**.**

1. Introduction

Since the reform and opening up, China's economy has experienced rapid development, but it has also given rise to serious environmental problems. The most serious of these is the problem of water pollution (Zhang, 2014). The most important source of water pollution is agricultural non-point source pollution (Humenik, 1987). Different from the characteristics of point-source emission of industrial pollution, agricultural non-point source pollution is often dispersed and ambiguous, and the emission is in the form of a surface, and the affected area is more extensive. China's cultivated land area accounts for only 7% of the world's arable land, but it is the country with the largest use of pesticides and fertilizers in the world, of which the use of nitrogen fertilizer and phosphate fertilizer account for more than 30% of the global use. The intensity of pesticide application has been above the international safety limit since 1993. At the same time, chemicals volatilize into the air, forming air pollution.

The aggravation of agricultural non-point source pollution in China is related to the rapid development of China's economy. As far as grain production is concerned, from 1978 to 2002, the sown area of grain crops in China showed a downward trend as a whole, and began to rise after 2002, but until 2020, the total sown area of grain crops in China was 116,768.2 thousand hectares, still down from 120,587.3 thousand hectares in 1978. With the growth of population and the improvement of living standards, the demand for agricultural products in society has grown rapidly, and the total grain output has shown an overall upward trend, increasing from 304.765 million tons in 1978 to 669.492 million tons in 2020, with a growth rate of 120%. In order to provide sufficient agricultural products under the conditions of limited agricultural land, agricultural producers will inevitably use more intensive fertilizers and pesticides, and at the same time, production will develop towards mechanization, centralization and specialization, in order to achieve more output on limited land, which will undoubtedly increase agricultural non-point source pollution.

In order to reduce the bad impact of this irrational choice, the state has also introduced policies such as zero growth of agricultural fertilizers, cancellation of preferential policies for chemical fertilizers, and increasing subsidies for organic fertilizers and low-toxicity pesticides. Although these policies can guide agricultural producers to choose "green" fertilizers, they will not effectively reduce the total amount of fertilizer use due to the subsidy effect (Zuo Zheyu and Fu Zhihu, 2021).

Fundamentally speaking, the reason for the excessive use of pesticides and fertilizers by agricultural producers is the high risk of agricultural production itself, which is prone to natural disasters such as weather changes, pests and diseases, and the use of pesticides and fertilizers can play a certain role in preventing and improving pests and diseases and poor land. However, its risk aversion effect is quite limited, for example, in the event of natural disasters such as floods, droughts, typhoons, etc., whether it is traditional pesticides and fertilizers or green fertilizers, it cannot make up for the losses suffered by agricultural production. The subsidy for green chemical fertilizer cannot fundamentally disperse the production risk of agricultural producers, while agricultural insurance can better protect the return of agricultural production, compensate for the corresponding losses, and fundamentally disperse the risk of agricultural production. Agricultural insurance can play the role of "substitutes" for chemical fertilizers and pesticides, and then affect the production behavior of agricultural producers, such as the choice of planting types, the choice of chemical fertilizers and pesticides, etc., which may help reduce agricultural non-point source pollution from the source.

However, farmers' demand of agricultural insurance is generally not strong, so in order to improve the participation rate of agricultural insurance, the government needs to promote it through subsidies. At the same time, agricultural insurance is also one of the green box policies that allow the government to support agriculture under WTO rules, so it is also a common practice in the world to subsidize agricultural insurance. In 2007, the pilot work of agricultural insurance premium subsidy of China's central government began to be launched, which was first carried out in six provinces and regions of Inner Mongolia, Jilin, Jiangsu, Xinjiang, Sichuan and Hunan, and in 2012, policy-based agricultural insurance was promoted nationwide. Policy subsidies have greatly promoted the development of agricultural insurance, and the national agricultural premium income in 2012 was 24.085 billion yuan, about 28.5 times that of 847 million yuan in 2006.

2. Theoretical Analysis and Research Hypotheses

The main applicable structural effect of environmental pollution in China mainly refers to the impact of policy-based agricultural insurance on the environment by influencing agricultural producers' choice of production types and production inputs (the use of chemical fertilizers, pesticides, agricultural films and other chemicals). China's policy-based agricultural insurance is preferentially carried out in the field of grain crops (rice, corn, wheat), and the subsidies are also greater (full cost insurance and income insurance are also piloted in food crops), and the demand for pesticides and fertilizers for food crops is lower than that of other crops, so from this point of view, the development of agricultural insurance in China will reduce agricultural pollution. Agricultural insurance, as a tool to disperse the risk of agricultural production, is a "substitute" for active agricultural production inputs (such as pesticides, fertilizers, hard labor, etc.), because of the existence of agricultural insurance, agricultural producers can obtain agricultural insurance even if they do not use pesticides and fertilizers, and the output is poor, they can also obtain the full compensation of agricultural insurance, so the motivation for producers to use pesticides and fertilizers to actively produce will weaken, and the development of agricultural insurance will make producers reduce pesticides, fertilizers and other inputs, and then have a positive impact on the environment.

From this, hypotheses can be proposed:
H1: The development of policy-based agricultural insurance in China is conducive to reducing agricultural pollution.
H2: The development of policy-based agricultural insurance in China has prompted agricultural producers to reduce the use of pesticides and fertilizers, which is a channel for agricultural insurance to reduce agricultural pollution.

3. Empirical Research

3.1 Model Settings

In order to analyze the environmental effects of the development of agricultural insurance in various provinces of China from a macro perspective, this paper constructs a two-way fixed effect model to study the impact of agricultural insurance development on the emission of pollutants from agricultural sources.

$$y_{it} = \partial_0 + \partial_1 insurance_{it} + \partial_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{1it} \quad (1)$$

i denotes provinces and cities, and t denotes the year. y_{it} is the explanatory variable, which represents the pollution emission intensity of province i in year t, and the specific indicators are the chemical oxygen demand per unit area and the total ammonia nitrogen emission per unit area. $insurance_{it}$ is an explanatory variable, which represents the level of agricultural insurance development of province i in year t, and the specific indicator is the agricultural insurance income per unit area. $Controls_{it}$ is the control variable that changes with the year and the province and city, the μ_i is individual effect of each province and city, the δ_t is fixed effect of the year, and the ε_{1it} is error term.

3.2 Sample Selection and Data Sources

Due to data availability, the data used in this article include 30 provinces and cities in China (excluding Taiwan Province and Hong Kong and Tibet Autonomous Region) of the year. Among them, the data of agricultural insurance premium income, agricultural carbon emissions, pesticide use, fertilizer use and control variables are from 2007 to 2019, a total of 13 years. The pollutant emissions (total ammonia nitrogen emissions and chemical oxygen demand) of agricultural source water are from 2011 to 2019, with a total of 9 years of data, and the data are from the China Rural Statistical Yearbook, Insurance Yearbook and EPS database in each year. In order to reduce the impact of extreme values, the data used in this paper are tailed by 1% or above.

3.3 Variable Description and Descriptive Statistics

3.3.1 Dependent variables

The dependent variable is the emission intensity of agricultural source water pollutants, and the total amount of ammonia nitrogen emissions per unit area of agricultural sources and the total amount of ammonia nitrogen emissions per unit area are used in this paper (Yang Qian, 2016, Zhao Dan, 2016, Wang Kai, 2017, Li Zhenzhen, 2018). Chemical oxygen demand is a chemical measurement of the amount of reducing substances in a water sample that needs to be oxidized. The higher the chemical oxygen demand, the more serious the pollution of the water body by organic matter. Total ammonia nitrogen emissions are the total amount of synthetic nitrogen emissions in the form of free ammonia and ammonium ions. Ammonia nitrogen is a nutrient in water bodies, which can lead to eutrophication of water bodies, is the main ozone-depleting pollutant in water bodies, and is toxic to fish and some aquatic organisms. In the robustness test, agricultural carbon emissions are taken as the explanatory variables. In further analysis, the gross output value of agriculture, forestry, animal husbandry and fishery was taken as the explanatory variable.

3.3.2 Independent variables

The independent variable is the development level of agricultural insurance in each province, which is represented by agricultural insurance premium income per unit area, total agricultural insurance premium income and agricultural insurance density, respectively. The premium income of agricultural insurance per unit area can reflect the insurance intensity of the sown area of crops per unit in various provinces and cities, reflect the development level of agricultural insurance, and reflect the protection level of agricultural insurance in various provinces and cities; The total agricultural insurance premium income intuitively measures the development level of agricultural insurance in each province and city in the form of absolute value from a relatively macro perspective. The density of agricultural insurance is the ratio of agricultural insurance premium income to the number of employees in the primary industry, which reflects the degree of participation in agricultural insurance in the primary industry in the province. In this paper, the agricultural insurance income per unit area is used for benchmark regression, and the total agricultural insurance premium income and agricultural insurance density are used for robustness test regression.

3.3.3 Control variables

In this paper, other factors that may affect agricultural pollutant emissions are included in the empirical analysis as control variables, including the per capita disposable income of rural households, the level of fiscal support for agriculture, the sown area of crops, the total power of agricultural machinery, the proportion of employees in the primary industry, the average number of years of education of the labor force, the proportion of the primary industry and the proportion of the secondary industry.

3.3.4 Mechanism variables

Combined with the the proposed hypothesis H2, this paper refers to the research of Sun Weilin et al. (2019) and selects pesticide application intensity (converted to pure amount) (ton/1000 hectares) and agricultural fertilizer application intensity (converted to pure amount) (ton/1000 hectares) as mechanism variables to study the transmission mechanism of agricultural insurance on environmental pollution. Agricultural insurance disperses the production risk of agricultural producers, so that the "sense of security" of agricultural producers no longer depends only on the use of pesticides and fertilizers. As a "substitute" for pesticide and fertilizer inputs, the development of agricultural insurance will prompt agricultural producers to reduce the use of pesticides and fertilizers. Therefore, we predict that the development of agricultural insurance will have a negative impact on pesticide application intensity and fertilizer application intensity.

3.3.5 Descriptive statistics

As can be seen from Table 1, the average total ammonia nitrogen emission in China is 3.290 tons/1000 hectares, the chemical oxygen demand is 49.346 tons/1000 hectares, and the premium income of agricultural insurance is 329,910 yuan/1000 hectares. The 30 provinces were divided into two groups: the main grain producing areas and the main grain producing areas, and the total ammonia nitrogen emissions per unit area, chemical oxygen demand per unit area and the average agricultural insurance premium income per unit area of the main grain producing areas were lower than those of the main grain producing areas, and the corresponding standard deviation was also smaller.

Table 1: Descriptive statistics

	variable	Observations	mean	standard deviation	minimum	maximum
Dependent variables	Total ammonia nitrogen emissions per unit area (tonnes/1000 hectares)	270	3.290	4.313	0.000	23.667
	The main grain producing areas	117	2.747	2.748	0.001	8.566
	Non-major grain producing areas	153	3.705	5.173	0.000	23.667
	Chemical oxygen demand per unit area (tonnes/1000 hectares)	270	49.346	63.970	0.002	415.550
	The main grain producing areas	117	45.334	50.552	0.517	213.110
	Non-major grain producing areas	153	52.413	72.594	0.002	415.550
	Total ammonia nitrogen emissions (tonnes)	270	14484.170	19678.262	0.000	71038
	Total Chemical Oxygen Demand (tonnes)	270	213067.660	302243.050	7.000	1294985
	Total ammonia nitrogen emissions per capita (tons/10,000 people)	270	19.679	23.587	0.000	96.302
	Chemical oxygen demand per capita (tonnes/10,000 people)	270	326.291	414.179	0.037	1876.036
	Agricultural carbon emissions per unit area (ton/1,000 hectares)	390	696.344	270.800	256.450	1609.949
	The total output value of agriculture, forestry, animal husbandry and fishery per unit area (million yuan/1,000 hectares), taken as logarithmic	390	4.033	0.568	2.612	5.670
Independent variables	Agricultural insurance premium income per unit area (10,000 yuan/1,000 hectares)	390	32.991	64.124	0.188	560.674
	The main grain producing areas	169	18.437	12.450	0.257	59.497
	Non-major grain producing areas	221	44.120	82.856	0.188	560.674
	Total income of agricultural insurance (million yuan)	390	1000.297	1048.138	9.200	4822.640
	Agricultural Insurance Density (RMB/Person)	390	4.472	1.516	0.580	7.470
Control variables	Per capita disposable income of rural households (1,000 yuan/person), taken as logarithmic	390	2.158	0.541	0.973	3.365
	The level of financial support for agriculture	390	0.110	0.032	0.040	0.181
	Proportion of population in the primary sector	390	0.190	0.084	0.016	0.373
	Average years of education in the labour force (years)	390	8.950	0.946	6.790	12.680
	The area sown with crops (thousand hectares), taken as logarithms	390	8.194	1.104	4.980	9.600
	Proportion of primary sector (%)	390	10.322	5.379	0.362	26.100
	Proportion of secondary sector (%)	390	45.322	8.540	19.262	59.000
Mechanism variables	Total power of agricultural machinery (10,000 kilowatts), take the logarithm	390	7.625	1.092	4.585	9.427
	Pesticide use per unit area (ton/1,000 hectares)	390	12.055	9.241	1.680	56.441
	Agricultural fertilizer application per unit area (ton/1,000 hectares)	390	364.301	123.822	135.501	799.328

3.4 Benchmark Regression

To test the impact of policy-based agricultural insurance development on pollutant emissions, the regression results on model (1) are shown in Table 2. Columns (1) and (3) are the regression results without considering the control variables, and columns (2) and (4) are the results with the control variables, and the regression coefficients are both significantly negative, indicating that the development of agricultural insurance has a significant emission reduction effect on the emission of agricultural pollutants (chemical oxygen demand and total ammonia nitrogen emissions), which is consistent with the hypothesis H1. After considering the control variables, R^2 is increased, and the explanatory power is enhanced. Columns (1) and (2) show the impact of agricultural insurance development on the total ammonia nitrogen emissions per unit area. Specifically, without considering the control variables, for the empirical data, the total ammonia nitrogen emissions decreased by 0.037 tons for every 10,000 yuan of agricultural insurance premium income per 1,000 hectares of sown land, and 0.014 tons for every 10,000 yuan of agricultural insurance premium income increased under the control variables. Columns (3) and (4) show the impact of agricultural insurance development on COD emissions per unit area. Specifically, for every 1,000 hectares of sown land, the chemical oxygen demand decreases by 0.563 tons for every 10,000 yuan of agricultural insurance premium income and 0.611 tons for every 10,000 yuan of agricultural insurance premium income without considering the control variables. The above results indicate that agricultural insurance has a significant reduction effect on the discharge of pollutants from agricultural source water, and there are positive environmental externalities.

The regression results of the control variables showed that the per capita disposable income of rural households had a significant positive impact on the two pollutant indicators, which may be due to the higher the per capita disposable income of rural households, the more able to bear the expenditure of pesticides and fertilizers, the more pesticides and fertilizers they will use, and the more serious pollution they cause, which is consistent with the predictions. The greater the proportion of fiscal expenditure used in agriculture, forestry, animal husbandry and fishery, and the more pollutant emissions are discharged, the possible explanation is that the greater the fiscal support for agriculture, the more subsidies the government directly pays to agricultural producers, and the more agricultural producers can afford the expenditure of fertilizers, pesticides, machinery, etc., which will increase the input of these factors, and then increase the pollutant emissions, which is consistent with the prediction. The proportion of population in the primary industry has a significant negative impact on the emissions of the two pollutants, indicating that the more people engaged in the primary industry in a region, the higher the importance of the primary industry, and the more mature the agricultural development, the more conducive to reducing the intensity of agricultural pollution emissions. The average number of years of education of the labor force also has a significant negative impact on the emissions of the two pollutants, indicating that the higher the education level of agricultural producers, the more scientific production methods may be adopted in agricultural production, reducing the waste of pesticides and fertilizers, and reducing pollution, which is consistent with the prediction. The sown area of crops has a significant positive impact on the total ammonia nitrogen emission per unit area, but has a significant negative effect on the chemical oxygen demand per unit area, indicating that the impact of crop sown area on the emission intensity of agricultural pollutants is uncertain, and the impact depends on the specific situation. The proportion of the primary industry has a negative impact on the emission intensity of the two pollutants, indicating that the more important the primary industry, the higher the economic contribution, the higher the level of agricultural development, and the higher the level of agricultural insurance development, which is conducive to reducing agricultural pollution emissions, which is consistent with the prediction. On the contrary, the proportion of the secondary industry has a positive impact on pollutant emissions, which is in line with the forecast. The total power of agricultural machinery has a negative impact on the total ammonia nitrogen emission per unit area, but has a positive effect on the chemical oxygen demand per unit area, which also indicates that the impact of the total power of agricultural machinery on the emission intensity of agricultural pollutants is uncertain, which is consistent with the prediction.

Table 2: Baseline regression results

variable	(1) Total ammonia nitrogen emissions per unit area	(2) Total ammonia nitrogen emissions per unit area	(3) Chemical oxygen demand per unit area	(4) Chemical oxygen demand per unit area
Premium income from agricultural insurance per unit area	-0.037***	-0.014**	-0.563***	-0.611***
	(0.005)	(0.006)	(0.063)	(0.086)
Per capita disposable income of rural households		6.404*		151.141***
		(3.666)		(54.206)
The level of financial support for agriculture		61.893***		791.712***
		(12.329)		(182.300)
Proportion of population in the primary sector		-18.772*		-419.820***
		(9.841)		(145.506)
The average number of years of education in the labor force		-1.346*		-30.448***
		(0.768)		(11.354)
Crop sown area		9.980***		-125.544***
		(2.084)		(30.820)
Proportion of primary sector (%)		-0.015		-0.373
		(0.121)		(1.794)
Proportion of secondary sector (%)		0.000		1.164
		(0.058)		(0.855)
Total power of agricultural machinery		-0.989		25.697**
		(0.874)		(12.926)
constant	6.740***	-71.160***	95.971***	858.073***
	(0.376)	(20.344)	(5.270)	(300.803)

Time effect	control	control	control	control
Individual effects	control	control	control	control
Observations	270	270	270	270
R^2	0.727	0.816	0.717	0.787

Note: ***, ** and * indicate significant at the 1%, 5% and 10% levels, respectively, and the standard error in parentheses is the same below.

3.5 Robustness Test

In order to improve the reliability of the results of benchmark regression analysis, the explanatory variables and explanatory variables are replaced for robustness test. The explanatory and explanatory variables of benchmark regression are insurance premium income per unit area and pollutant emissions, while the indicators commonly used to measure the level of insurance development include total insurance income and insurance density in addition to premium income per unit area. Therefore, firstly, the explanatory variable is replaced with the total agricultural insurance premium income per unit area, and the explanatory variable is also replaced by the total pollutant emission of each province. Secondly, the explanatory variable is agricultural insurance density, and the explanatory variable is replaced by per capita pollutant emissions (total pollutant emissions/number of employees in the primary industry) (ton/10,000 people). As can be seen from the regression results in Table 3, the regression results are still significantly negative regardless of whether the absolute value level data is used for regression or the per capita level data for regression, which is consistent with the benchmark regression results. It proves that the development of agricultural insurance has a significant emission reduction effect on chemical oxygen demand and ammonia nitrogen emissions, can effectively reduce water pollution, has a significant protective effect on the ecological environment, and meets the requirements of green development.

Table 3: Robustness test regression results

variable	(1) Total ammonia nitrogen emissions	(2) Total Chemical Oxygen Demand	(3) Total ammonia nitrogen emissions per capita	(4) Chemical oxygen demand per capita
Total income from agricultural insurance	-10.196***	-174.586***		
	(1.543)	(22.204)		
Agricultural insurance density			-0.017***	-0.476***
			(0.004)	(0.080)
Per capita disposable income of rural households	44,968.506**	1567824.355***	76.972***	2,011.861***
	(18,810.899)	(270,724.434)	(17.036)	(322.025)
The level of financial support for agriculture	368,321.886***	2793599.008***	311.965***	1,520.049
	(58,349.417)	(839,758.519)	(55.251)	(1,044.359)
Proportion of population in the primary sector	33,694.771	162,246.065	-171.733***	-3,314.338***
	(50,261.351)	(723,355.946)	(45.282)	(855.933)
The average number of years of education in the labor force	6,158.076	37,037.352	-9.805***	-248.373***
	(3,770.607)	(54,266.166)	(3.503)	(66.221)
Crop sown area	-9,582.582	-717,158.595***	47.584***	-481.232***
	(8,778.362)	(126,337.233)	(7.727)	(146.056)
Proportion of primary sector (%)	2,099.564***	6,693.673	-0.714	-27.170**
	(605.679)	(8,716.867)	(0.557)	(10.521)
Proportion of secondary sector (%)	385.705	6,826.314*	0.328	8.300*
	(287.083)	(4,131.669)	(0.264)	(4.986)
Total power of agricultural machinery	-1,634.247	105,746.476*	-6.624	60.953
	(4,387.242)	(63,140.715)	(4.036)	(76.286)
constant	-107,075.592	1422060.430	-372.399***	2,782.466*
	(90,257.581)	(1298977.372)	(83.614)	(1,580.490)
Time effect	control	control	control	control
Individual effects	control	control	control	control
Observations	270	270	270	270
R^2	0.779	0.795	0.877	0.828

In addition to water pollution, there are also climate problems represented by carbon emissions, which are closely related to agricultural production. In order to test the environmental effects of agricultural insurance more comprehensively, this paper replaces the dependent variable with agricultural carbon emissions per unit area to test the impact of agricultural insurance on carbon emissions. The calculation of agricultural carbon emission data refers to the current general method (Ding Baogen 2022, Ma Jiujie 2021), using the carbon source multiplied by the carbon emission coefficient. There are six main types of carbon sources in agricultural production, namely the use of agricultural diesel, the use of chemical fertilizers, the use of pesticides, the use of plastic films, the irrigation area, and the sown area of crops (tillage), and the sources of agricultural carbon emissions and water pollution overlap greatly. The raw data of carbon sources used in this paper are from the Rural Statistical Yearbooks of each year. The reference sources of carbon emission coefficients are shown in Table 4.

Table 4: Reference table of carbon emission coefficients

Carbon source	Carbon emission coefficient	Reference Sources
diesel fuel	0.59kg/kg	IPCC20131
chemical fertilizer	0.89kg/kg	Oak Ridge National Laboratory, United States
pesticide	4.93kg/kg	Oak Ridge National Laboratory, United States
plastic sheeting	5.18kg/kg	Institute of Agricultural Resources and Ecological Environment, Nanjing Agricultural University
irrigate	266.48kg/hm²	Duan Huaping
tillage	312.60kg/km²	Li Bo et al

$CE = \sum cs_i * ef_i$, CE refer to carbon emission, cs refer to carbon source, i refer to different dimension of carbon source, ef refer to carbon emission factor.

From the regression results in Table 5, it can be seen that agricultural insurance has a significant negative impact on agricultural carbon emissions. On the basis of considering the time effect and individual effect, without considering the control variables, the agricultural carbon emissions will be reduced by about 0.491 tons for every 10,000 yuan of agricultural insurance premium income per 1,000 hectares of crop sown area, and about 0.557 tons for every 10,000 yuan increase in agricultural insurance premium income per 1,000 hectares of crop sowing area. It is worth noting that in the regression analysis of agricultural carbon emissions, the regression coefficient of the control variable total power used by machinery is significantly positive at the 1% significance level, with a coefficient of 145.218, indicating that the use of agricultural machinery has a greater impact on agricultural carbon emissions, because the use of fuel by agricultural machinery directly increases agricultural carbon emissions.

The results of this regression are similar to the basic regression results, and the development of agricultural insurance has a significant negative impact on agricultural carbon emissions, which proves that the development of agricultural insurance has a significant negative impact on water pollution and greenhouse effect, and has a positive spillover effect on the environment.

Table 5: Robustness test - the impact of agricultural insurance development on agricultural carbon emissions

variable	(1) Agricultural carbon emissions per unit area	(2) Agricultural carbon emissions per unit area
Premium income from agricultural insurance per unit area	0.491***	-0.557***
	(0.101)	(0.118)
Per capita disposable income of rural households		288.064***
		(72.042)
The level of financial support for agriculture		928.144***
		(235.033)
Proportion of population in the primary sector		317.909**
		(142.245)
The average number of years of education in the labor force		-2.393
		(16.529)
Crop sown area		-737.800***
		(46.033)
Proportion of primary sector (%)		6.554***
		(2.492)
Proportion of secondary sector (%)		3.469***
		(1.168)
Total power of agricultural machinery		145.218***
		(19.778)
constant	654.156***	4,808.258***
	(11.966)	(387.063)
Time effect	control	control
Individual effects	control	control
Observations	390	390
R^2	0.228	0.601

3.6 Heterogeneity Analysis

In 2001, in order to adapt to the changes in the new pattern of grain production and circulation, China divided the main grain producing areas into non-main grain producing areas, of which the main grain producing areas included 13 provinces, including Liaoning Province, Hebei Province, Shandong Province, Jilin Province, Inner Mongolia Autonomous Region, Jiangxi Province, Hunan Province, Sichuan Province, Henan Province, Hubei Province, Jiangsu Province, Anhui Province, and Heilongjiang Province. There are differences in agricultural structure and national policies between the main grain producing areas and the non-grain producing areas, and there may also be differences in the role of agricultural insurance development. Referring to the study of Ma Jiujie et al. (2021), this paper studies the differences in the environmental effects of agricultural insurance development on the main grain producing areas and non-grain producing areas through sub-sample regression.

From the regression results in Table 6, it can be seen that agricultural insurance has a significant effect on the reduction of agricultural pollutants in both the main grain producing areas and the non-main grain producing areas, and the effect is better in the main grain producing areas. Columns (1) and (2) of Table 6 show the impact of the development of agricultural insurance on pollutant emissions in the main grain-producing areas, and columns (3) and (4) show the impact of the development of agricultural insurance on pollutant emissions in non-grain-producing areas. In the main grain-producing areas, for every 10,000 yuan of sown land, the total ammonia nitrogen emissions and chemical oxygen demand decreased by 0.030 tons and 1.354 tons for every 1,000 hectares of sown land, and for every 10,000 yuan increase in agricultural insurance income per 1,000 hectares of sown land, the chemical oxygen demand decreased by 0.684 tons. On the one hand, the main grain producing areas generally have earlier development of agricultural insurance, more policy experience and higher implementation efficiency; On the other hand, it may be because agricultural insurance has a higher degree of protection for food crops on the whole, and the proportion of grain crops in the main grain producing areas is higher. At the same time, the state has more preferential policies for agriculture in the main grain-producing areas, for example, in 2018, the full cost insurance was first carried out in several provinces in the main grain-producing areas.

Table 6: Heterogeneity analysis

variable	The main grain producing areas		Non-major grain producing areas	
	(1) Total ammonia nitrogen emissions per unit area	(2) Chemical oxygen demand per unit area	(3) Total ammonia nitrogen emissions per unit area	(4) Chemical oxygen demand per unit area
Premium income from agricultural insurance per unit area	-0.030*	-1.354***	-0.016	-0.684***
	(0.017)	(0.479)	(0.012)	(0.152)
Per capita disposable income of rural households	-0.002	172.622**	2.756	-12.327
	(2.545)	(71.057)	(8.752)	(112.066)
The level of financial support for agriculture	19.701**	285.252	89.818***	1,164.306***
	(7.767)	(209.223)	(24.404)	(319.604)
Proportion of population in the primary sector	-22.675***	-576.603***	-23.841*	-470.528***
	(6.825)	(199.607)	(13.735)	(164.520)
The average number of years of education in the labor force	-0.697*	-27.802**	-1.251	-32.120*
	(0.407)	(13.073)	(1.366)	(16.789)
Crop sown area	12.460***	-66.946	10.302**	-107.052*

	(1.962)	(53.850)	(4.876)	(63.363)
Proportion of primary sector (%)	-0.037	-0.744	0.064	3.497
	(0.059)	(1.644)	(0.194)	(2.778)
Proportion of secondary sector (%)	0.031	1.950*	-0.028	0.404
	(0.038)	(1.130)	(0.061)	(0.929)
Total power of agricultural machinery	0.631	58.043**	-1.452	23.433
	(0.409)	(25.323)	(1.224)	(17.453)
constant	-107.007***	16.822	-63.579	963.000
	(21.030)	(543.046)	(52.951)	(678.920)
Time effect	control	control	control	control
Individual effects	control	control	control	control
Observations	117	117	153	153
R^2	0.970	0.920	0.861	0.876

3.7 Mechanism Analysis

The environmental impact of agricultural insurance is indirectly generated by influencing the behavior of agricultural producers. In order to study how agricultural insurance affects the environment by influencing the behavior of agricultural producers, this paper examines its influencing mechanism through the mediation effect. In order to avoid the endogeneity of explanatory and mechanistic variables, this paper refers to the two-step method of Jiangzhou (2022) for mediating effect analysis. The impact of the use of pesticides and fertilizers on water pollution is direct and obvious, and it is one of the main sources of agricultural source water pollution (Wu, 1999, Qiu, 2016, Paudel, 2021, Zhang Xiao, 2014), and the use of pesticides and fertilizers by agricultural producers may be affected by agricultural insurance. Where M_{it}^k is the mediating variable, which represents the K-th mediating variable.

$$M_{\mathrm{it}}^k = \beta_0 + \beta_1^k insurance_{it} + \beta_2 Controls_{it} + \mu_i + \delta_t + \varepsilon_{2it} \quad (2)$$

The regression results are shown in Table 7, and the development of agricultural insurance has a significant negative impact on the use of pesticides and fertilizers. On the basis of considering the control variables, for every 1,000 hectares of cultivated land, the use of pesticides will decrease by 0.013 tons and the use of agricultural fertilizers by 0.271 tons for every 10,000 yuan of agricultural insurance premium income. It can be seen that the influence on the use of pesticides and fertilizers is the mechanism of agricultural insurance to produce environmental effects, which is consistent with hypothesis H2 proposed in the theoretical analysis.

In the regression results of the control variables, the per capita disposable income of rural households also had a positive impact on the intensity of pesticide application and chemical fertilizer application, indicating that farmers with higher per capita disposable income have the economic strength to bear more pesticide and fertilizer expenditures, and tend to use higher intensity pesticides and fertilizers, which in turn exacerbates environmental pollution, which is consistent with the previous research conclusions. The greater the proportion of fiscal expenditure for agriculture, forestry, animal husbandry and fishery, the more subsidies the government directly or indirectly gives to agricultural producers, resulting in a "revenue effect", the more agricultural producers will increase the input of chemical fertilizers, pesticides, machinery and other factors, which may increase pollutant emissions. The proportion of population in the primary industry has a positive impact on the intensity of pesticide application and chemical fertilizer application, indicating that the more people engaged in agriculture in a region, the higher the intensity of pesticide and chemical fertilizer application, which may be due to competition and imitation within the region. The average number of years of education of the labor force had a positive effect on the pesticide application intensity, but had a negative effect on the chemical fertilizer application intensity. The results indicated that the more educated agricultural producers were, the more scientific they were in the use of chemical fertilizers, but there was no significant improvement in the use of pesticides. The sown area of crops has a significant negative impact on the intensity of pesticide application and chemical fertilizer application, which may be explained by the larger the sown area of crops and the more large-scale operation, and the use of pesticides and fertilizers may be more scientific and reasonable. The proportion of the secondary industry has a positive impact on the application intensity of pesticides and fertilizers, which may be because the development of industry has led to the development of pesticides and fertilizers, so that agricultural producers can more easily apply pesticides and fertilizers with higher intensity. The effect of the total power of agricultural machinery on the application intensity of pesticides and fertilizers is inconsistent and uncertain.

Table 7: Mechanism analysis

variable	(1) Pesticide application intensity	(2) Fertilizer application intensity
Premium income from agricultural insurance per unit area	-0.013***	-0.271***
	(0.005)	(0.069)
Per capita disposable income of rural households	1.648	159.977***
	(3.128)	(42.141)
The level of financial support for agriculture	44.147***	501.540***
	(10.205)	(137.483)
Proportion of population in the primary sector	3.234	196.674**
	(6.176)	(83.206)
The average number of years of education in the labor force	0.814	-11.295
	(0.718)	(9.669)
Crop sown area	-7.254***	-318.770***
	(1.999)	(26.927)
Proportion of primary sector (%)	0.312***	2.486*
	(0.108)	(1.458)
Proportion of secondary sector (%)	0.124**	2.332***
	(0.051)	(0.683)
Total power of agricultural machinery	-0.013	65.750***
	(0.859)	(11.569)
constant	47.485***	2,095.905***
	(16.806)	(226.412)
Time effect	control	control
Individual effects	control	control
Observations	390	390
R^2	0.232	0.469

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