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IMPACT OF ENVIRONMENTAL PROTECTION POLICY ON NON-POINT SOURCE POLLUTION OF PLANTING INDUSTRY

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Abstract

The control of agricultural non-point source pollution, especially the problem of planting non-point source pollution, is of great significance to comprehensively promote rural revitalization. First, based on the panel data from 2006 to 2020 and using the DID model 30 provinces were classified in China. It is found that environmental protection policies have a significant inhibitory effect on the non-point source pollution of the planting industry, and the effect is more obvious over time. From the perspective of heterogeneity analysis, the eastern region, the economic crop planting region, and the rural areas close to the provincial capital have more significant pollution control. Secondly, the environmental protection policy plays a role in reducing the non-point source pollution emissions of the planting industry through the intermediary effects such as the guiding mechanism, the economic incentive mechanism, and the supervision mechanism. Finally, the corresponding policy implications are proposed.

Introduction

The population of China has reached 1.47 billion in 2022. The national fertilizer and use intensity are 373.5 kg/hm^2 and 9.0 kg/hm^2, respectively, of which the amount of fertilizer used is 4.02 times the world average. The prevention and control of agricultural non-point source is arduous, which not only causes huge environmental costs and economic losses to the society, but also causes huge waste of resources. The Chinese government began to introduce a series of policies on the control of agricultural non-point source pollution in 2015, aiming to take the prevention and control of agricultural non-point source pollution as a major event and resolutely curb the trend of agricultural non-point source pollution (Jia *et al.* 2022). The Implementation Opinions on Making a Good Fight against Agricultural Non-point Source Pollution, implemented in 2015, is China's first administrative regulation focusing on the prevention and control of agricultural and rural non-point source pollution at the national level. Since then, the prevention and control of agricultural non-point source pollution has ushered in a turning point, and a series of documents have been issued (Wang *et al*. 2021).

Chinese scholars roughly divide policy into incentive and constraint categories (Hu 2021). The incentive policy is to encourage the planters to take environmentally friendly actions, (Sullam *et al.* 2012). Restrictive policies regulate the behavior of planting subjects through mandatory means such as laws and regulations (Liu *et al.* 2020). The intensive introduction of a series of environmental policies seems to be the main reason for the decline of pollution in the planting industry (Qian *et al*. 2018). The pollution emissions from the planting industry are jointly affected by multiple factors such as technological progress, planting scale, policy promotion, and legislation (Guo 2019, Yang 2022). Issues related to environmental policy and agricultural planting have been widely concerned by scholars outside China. They mainly focusing on the introduction of experience (Nawaz *et al.* 2021) and comparative analysis of different policy tools (Frondel *et al*. 2007). In terms of policy impact, the micro and macro level mainly focuses on the

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analysis of the impact of environmental policy on farmers' alternative livelihoods (Geneletiti 2013) and on the production level (Tzilivakis *et al.* 1999, Willis and Keller 2007), respectively.

At present, there is a lack of in-depth discussion on the impact mechanism of environmental policies. The present study was aimed to use the double difference and intermediary effect model to carry out a systematic and quantitative analysis of the impact of a series of environmental policies issued by China since 2015 on the pollution emissions of the planting industry.

Materials and Methods

The present research used the survey data of farmers from the Rural Economic Research Center of the Ministry of Agriculture and the magic weapon database of Peking University. The control group and experimental group were constructed according to the "pollution emission intensity". Specifically, according to the provincial Bulletin of the First National Pollution Source Survey and the Bulletin of the Second National Pollution Source Survey, the emission intensity (emissions/planting equivalent) of various pollutants in each region was calculated and recorded as "Phase I emission intensity" and "Phase II emission intensity", respectively. Based on the idea of double difference, the pollutant emissions of the experimental group samples from 2006 to 2014 were calculated according to the intensity of the first pollutant emission, and the pollutant emissions from 2015 to 2020 were calculated according to the intensity of the second pollutant emission; The pollution emissions of the control group samples from 2006 to 2020 were calculated according to the emission intensity of the primary pollutant.

The "Implementation Opinions on Winning the Battle of Agricultural Non-point Source Pollution Prevention and Control" was officially proposed by the central government in 2015, and before that, there were no policy documents on agricultural non-point source pollution prevention and control issued by the country or provinces. After 2015, a series of intensive environmental policies have had a huge impact on the planting industry, and the government and planting entities have implemented emission reduction strategies. This study refers to the time-varying difference-in-difference (DID) method proposed by Beck *et al.* (2010). The model sets as follows.

$$lnPOLL_{it} = \beta_0 + \beta_1 P_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (1)$$

Here, $lnPOLL_{it}$ denotes the natural logarithm of the overall pollution intensity of the planting industry in province i in year t. The pollution emissions of different crop varieties were standardized based on the method proposed by Christian *et al.* (2004), and the coefficients were adjusted to obtain the overall pollution intensity of each province. P_{it} is a time dummy variable, with a value of 1 after the implementation of agricultural non-point source pollution environmental policies in 2015, and 0 otherwise. Z_{it} represents control variables, consisting of a series of variables namely quality characteristics include years of education and annual training hours; perception characteristics include perception of policy stringency and policy strict; management characteristics include sources of income, planting structure, and per capita GDP; regional included the proportion of agriculture, urbanization rate, and per capita arable land area and input characteristics included environmental protection investment and support for agriculture. ω_i Represents individual fixed effects, μ_t represents time fixed effects, and represents residual disturbances.

One can use the ESA event research method to design a mathematical model to analyze the time effect.

$$lnPOLL_{it} = \alpha_0 + \prod_{n\geq -2}^{5} \alpha_1 {P_{it}}^{n} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (2)$$

Formulas (3) - (5) can be introduced to analyze the heterogeneity of environmental protection policy effects from three aspects: the region ($region_i$), the distance from the provincial capital ($distance_i$), and the planting type ($cash_i$).

$$lnPOLL_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 region_i P_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (3)$$

$$lnPOLL_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 distance_i P_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (4)$$

$$lnPOLL_{it} = \beta_0 + \beta_1 P_{it} + \beta_2 cash_i P_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (5)$$

The environmental protection policy can effectively reduce the non-point source pollution emissions of the planting industry, but its impact mechanism needs to be further explored. The intermediary effect model is set up as follows:

$$M_{it} = \alpha_0 + \alpha_1 P_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (6)$$

$$lnPOLL_{it} = \delta_0 + \delta_1 P_{it} + \delta_2 M_{it} + \gamma Z_{it} + \omega_i + \mu_t + \varepsilon_{it} \quad (7)$$

Where M_{it} refers to intermediary variables, including environmental policy guidance mechanism, economic incentive mechanism and supervision mechanism. The guidance mechanism ($\ln GM_{inc\,it}$) is reflected by farmers' awareness of environmental pollution, the economic incentive mechanism ($\ln EM_{inc\,it}$) is reflected by environmental subsidies, and the supervision mechanism ($\ln SM_{inc\,it}$) is reflected by the efficiency of environmental protection case processing. The other variables have the same meaning as in formula (1).

Table 1 showed that all indicators except the level of supporting agriculture have passed the significance test. The correlation coefficient of the policy issuance was -0.345, indicating a negative impact on the overall pollution emission intensity.

Table 1. Correlation coefficient of the policy issuance.

Variable abbreviation	Description	Correlation coefficient	Mean value
$POLL_{it}$	2020 level	-	0.216
P_{it}	0=Non, 1=Proclaim	-0.345***	0.751
$Education_{it}$	Years	-0.165***	7.449
$Train_{it}$	Hours/Year	-0.325***	5.665
$Strengthe_{it}$	0=Weak, 1=Mean, 2=strong	-0.032***	1.124
$Strict_{it}$	0=Weak, 1=Mean, 2=strong	-0.043***	0.853
$Mode_{it}$	0=Employ, 1=Plant, 2=Breeding	0.007***	1.183
$Struc_{it}$	0=Grain, 1=Cash crop,	0.128***	0.645
$AGDP_{it}$	Yuan	-0.261***	72447.38
Arg_{it}	Gross agricultural product/GDP	0.146**	0.164
$City_{it}$	Urban population/total population	-0.094*	0.639
$Land_{it}$	Area (mu)	-0.192***	1.402
$Input_{it}$	million yuan	-0.121***	354.630
$Support_{it}$	Agricultural expenditure/gross agricultural product	0.043	0.003

Results and Discussion

The calculated results presented in Table 2 showed that the introduction of policy effect P_{it} in column (1) only led to a 1.5% reduction in the overall pollution emission intensity, which passed the test of 1% level. Columns (2) to (6) gradually control the quality characteristics (qc), perception characteristics (pc), operation characteristics (oc), regional characteristics (rc), and input characteristics (ic) on the basis of each column. The proportion of agricultural GDP and urbanization rate in the rc were not significant, while the other indicators passed statistical tests of 1, 5, or 10%, indicating high reliability of the estimated results. Most of the indicators passed the significance test, indicating that after the promulgation of the series of environmental protection policies, the treatment of non-point source pollution in the planting industry had a positive impact (Farooq *et al.* 2011).

Table 2. Benchmark regression results.

	Policy effect	Control qc	Control qc and pc	Control qc, pc and oc	Control qc, pc, oc and rc	Control qc, pc, oc, rc and ic
P_{it}	-0.015***	-0.014***	-0.013***	-0.013***	-0.012***	-0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
$Education_{it}$		-0.015***	-0.014***	-0.013***	-0.013***	-0.012***
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
$Train_{it}$		-0.095***	-0.094***	-0.092***	-0.091***	-0.090***
		(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
$Strengthe_{it}$			-0.007***	-0.006***	-0.006***	-0.005***
			(0.002)	(0.002)	(0.002)	(0.002)
$Strict_{it}$			-0.037***	-0.036***	-0.036***	-0.034***
			(0.004)	(0.004)	(0.004)	(0.004)
$Mode_{it}$				-0.088***	-0.087***	-0.085***
				(0.003)	(0.003)	(0.003)
$Struc_{it}$				-0.032*	-0.031**	-0.030**
				(0.010)	(0.010)	(0.010)
$AGDP_{it}$				-0.055***	-0.054***	-0.053***
				(0.006)	(0.006)	(0.006)
Arg_{it}					-0.005	-0.005
					(0.005)	(0.005)
$City_{it}$					-0.001	-0.001
					(0.003)	(0.003)
$Land_{it}$					-0.012***	-0.011***
					(0.005)	(0.005)
$Input_{it}$						-0.039**
						(0.008)
$Support_{it}$						-0.037***
						(0.007)
constant	12.437***	2.001***	1.743***	0.947***	0.916***	0.829***
	(0.003)	(0.020)	(0.029)	(0.049)	(0.073)	(0.086)
n	4348	4348	4348	4348	4348	4348
R^2	0.893	0.912	0.936	0.948	0.955	0.967
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes

According to the observation of time effect there is a negative impact on the pollutant emission intensity after the promulgation of environmental protection policies, and the impact will become larger and larger as time goes by (Fig. 1). It was observed that in the fifth year after the policy was issued, that is, the year with the longest implementation time limit in 2020, the slope of decline was maximum, and the effect of pollution control was more obvious.

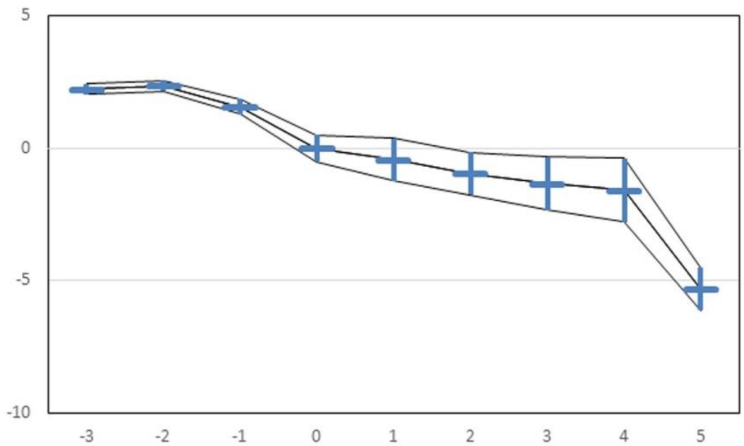

Fig. 1. Time impact of environmental policy.

Table 3 showed the results of empirical analysis of heterogeneity variables $region_i$, $distance_i$ and $cash_i$. When the rural area is in the eastern region, the $region_i$ value is 1, otherwise it is 0. Result showed that the cultivation industry in the eastern region is more obviously controlled by the non-point source pollution brought by the environmental protection loan policy. When the distance between the rural area and the provincial capital city is less than or equal to 200 kilometers, the $distance_i$ value is 1, otherwise it is 0, and result showed that the rural area closer to the provincial capital has better environmental protection effect. The area of farmers planting cash crops was greater than or equal to 30%, $cash_i$ is 1, otherwise it is 0. Effects of the environmental protection policy of cash crop planting was more obvious than that of grain crop planting.

Table 3. Heterogeneity analysis of region, provincial capital distance and planting type.

Variable	(1)	(2)	(3)
P_{it}	-3.982*** (0.049)	-2.003** (0.038)	-1.497* (0.042)
$region_i P_{it}$	-8.365*** (0.072)		
$distance_i P_{it}$		-3.403*** (0.039)	
$cash_i P_{it}$			-2.648** (0.022)
Variable fixed	Yes	Yes	Yes
R^2	0.694	0.725	0.717
Individual fixed	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes

The parallel trend of this study can be tested by using formula (5), and the results are presented in Table 4. From Fig. 2, it could be seen that in the output graph diagnosis the linear trend model was not obvious, but the output graph of the observed average value meets the requirements of parallel trend test. In 2015, *The Implementation Opinions on Making a Good Fight against Agricultural Non-point Source Pollution* was issued, and the previous years' □□□□ was not significant, and the test effect of 10% level was met since 2015, and the subsequent years also met the significance level test of 5 or 10%, meeting the requirements of sample parallel trend test.

Table 4. Coefficient comparison of graphical diagnostic for parallel trends.

n	-3	-2	-1	0	1	2	3	4	5
$O\alpha_1$	2.843	1.338	1.115	0.047	-0.014	-1.293	0.228	0.574	0.431
$O\alpha_2$	0.264	0.052	-2.347	-2.857	-3.348	-3.895	-4.287	-4.889	-5.214
$L\alpha_1$	2.735	1.492	1.374	-0.271	-1.247	-0.748	-0.028	0.482	0.684
$L\alpha_2$	2.735	0.982	-0.594	-1.683	-2.952	-3.551	-4.387	-4.859	-5.114

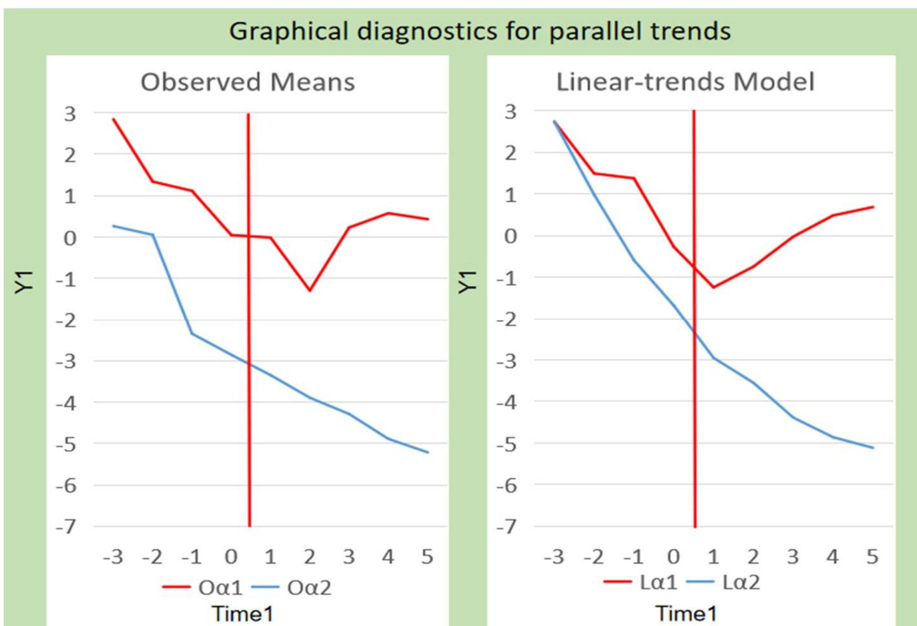

Fig. 2. Parallel trend inspection chart.

Year 2012 and 2011 are taken as the implementation time points of a series of environmental policies to conduct a placebo test. The test results are shown in columns (1) and (2) of Table 5. Results showed that when 2012 and 2011 are the implementation time points of the policy, the policy variable P_{it} is further used as $Treat_i * Post_t$said. *Treat$_i$* is a dummy variable. When the value is 1, it is the Treat group, and when the value is 0, it is the control group; $Post_t$ is a time dummy variable. When the observed value occurs in 2015 and after a series of environmental policies are issued, the value is 1, otherwise the value is 0. The estimated coefficient is not significant, which means that there is no significant difference between the control group and the experimental group in the change trend of pollution emissions from the planting industry. The environmental tax variable, and the statistical results are significant (Column 5 of Table 5). Excluding the indicators before the promulgation of the environmental protection policy in 2015, the statistical results are significant. Excluding the indicators after the promulgation of the environmental protection tax law in 2019, the statistical results are still significant, as shown in column 6 of Table 5.

Table 5. Placebo test data.

	Policy time point in 2012	Policy time point in 2011	Robust standard error of clustering	Standard error of Bootstrap method	Add control variable	Partial samples
$Treat_i * Post_t$	-0.062	-0.053	-0.072***	-0.072***	-0.038***	-0.029***
	(0.072)	(0.052)	(0.011)	(0.015)	(0.472)	(0.596)
Constant	-0.128	-0.128	0.384	0.384	-0.681***	-0.705***
					(0.188)	(0.194)
Variable fixed	Yes	Yes	Yes	Yes	Yes	Yes
N	4348	4348	4348	4348	Yes	Yes
R^2	0.442	0.442	0.147	0.147	Yes	Yes

The intermediary effect of environmental policy guidance mechanism was 0.417, accounting for 7.8% (Table 6). The guiding mechanism can reduce the pollution emissions from the planting industry by improving farmers' awareness of environmental pollution. The government should strengthen environmental protection publicity and education, publicize the harm of planting pollution to the environment and human health to farmers, and make farmers realize the seriousness and necessity of pollution and take measures to reduce pollution. The intermediary effect of the economic incentive mechanism was 0.252, accounting for 4.8%, which passed the significance test at the level of 1%. The government encourages farmers who meet the environmental protection requirements to take environmental protection measures to reduce the pollution emissions of the planting industry by formulating subsidy policies and giving them certain subsidies or tax credits. The intermediary effect of the supervision mechanism was 0.185, accounting for 3.9%, which passed the significance test at the level of 5 or 1%. If the government or relevant institutions have a high efficiency in handling cases, that is, they can quickly find problems and deal with them, it will form a deterrent effect on farmers and reduce the occurrence of their violations.

Based on the panel data from 2006 to 2020, the impact of environmental protection policies on reducing non-point source pollution emissions from planting industry was studied. The main conclusions are as follows: (1) Environmental policies can inhibit and reduce the pollution emissions from the planting industry, and the longer the environmental policies are issued, the better the effect. (2) Results of heterogeneity analysis show that the environmental policies of the eastern region, the economic crop planting area, and the rural areas closer to the provincial capital have more obvious effects on reducing the non-point source pollution of the planting industry. (3) Environmental policies have a positive impact on the treatment of non-point source pollution in the planting industry through the guidance mechanism, economic incentive mechanism and supervision mechanism.

Table 6. Mediation effect of influence mechanism.

Variable	$\ln FI_{inc\ it}$	$\ln GM_{inc\ it}$	$\ln FI_{inc\ it}$	$\ln EM_{inc\ it}$	$\ln FI_{inc\ it}$	$\ln SM_{inc\ it}$	$\ln FI_{inc\ it}$
P_{it}	-0.024 (0.013)	-0.019 (0.007)	-0.022*** (0.011)	-0.023*** (0.007)	-0.018*** (0.012)	-0.021*** (0.011)	-0.019** (0.008)
$\ln GM_{inc\ it}$			-0.014*** (0.016)				
$\ln EM_{inc\ it}$					-0.017*** (0.013)		
$\ln SM_{inc\ it}$							-0.008*** (0.012)
Constant	- 0.942*** (0.122)	-0.925*** (0.117)	-0.874*** (0.084)	-0.846*** (0.081)	-0.819*** (0.075)	-0.803*** (0.068)	-0.799*** (0.062)
Sobel test		Z=6.34, p=0.000 0.417		Z=7.83, p=0.000 0.252		Z=5.26, p=0.000 0.185	
Variable fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4348	4348	4348	4348	4348	4348	4348
R^2	0.547	0.569	0.424	0.758	0.441	0.458	0.406
Proportion of indirect effects		0.078		0.048		0.039	

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