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Original Research

Is it Possible for Government Intervention to Support Low-Carbon Transition in Agriculture through Agri-Environmental Protection? Evidence from the Waste Agricultural Film Recycling Pilot

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Abstract

With the escalating serious degradation of the agricultural environment and the rising carbon emissions in the agriculture sector, protecting the agricultural environment and advancing the low-carbon transformation of agriculture are essential priorities. This research develops a difference in differences model (DID model) based on panel data from Chinese provinces between 2011 and 2021 to evaluate the effectiveness and impact of government action in agricultural protection on reducing carbon emissions, using China's waste agricultural film recycling and utilization pilot project as a quasi-natural experiment. The study's conclusion that government involvement significantly reduced the amount and rate of agricultural film usage in the pilot areas proved the effectiveness of the pilot plan. In addition, the pilot regions' agricultural carbon emissions decreased significantly in quantity and rate as a result of the government's engagement, therefore advancing the low-carbon transformation of agriculture. Even after several robustness tests, the study's conclusions still hold up. Simultaneously, the study discovered that the efficacy and carbon reduction impact of the pilot strategy are moderated by the interaction between the government and the market. In order to gain experience for upcoming work on agricultural environmental protection and low-carbon agricultural transformation, the research makes policy recommendations.

Keywords: government intervention, agri-environmental protection, agricultural low-carbon transformation, recycling and utilization of abandoned agricultural films, difference-in-difference model

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Introduction

The recent increase in the world's population and the resulting need for food have posed serious obstacles to agriculture's production and efficiency. Agricultural film, fertilizer, and pesticides are continuously utilized in agricultural production in an effort to boost crop yields and enhance the productivity of farmed land. Among them, agricultural film can greatly increase agricultural products by regulating temperature and inhibiting water evaporation, which plays an important role in global food production and supply. However, the agricultural environment will suffer significant harm from agricultural film as well. Due to farmers' neglect of sustainable development, the recycling rate of this film is very low. Residual agricultural film in the soil is difficult to degrade, hindering the transfer of heat and water and resulting in reduced agricultural production. More seriously, the agricultural film remaining in the soil may also affect the safety of agricultural products.

The globe has responded positively to address issues related to agricultural environmental issues, including the usage of agricultural film. Agricultural environmental protection has a strong externality; individual farmers almost never communicate with the buyers of agricultural products, and the market can't punish the behavior that destroys the agricultural environment. On the contrary, farmers who use a lot of agricultural film, fertilizers, and pesticides in agricultural production can rely on production to obtain greater benefits. As a result, the market's regulatory function to safeguard the agricultural environment and prevent the excessive use of agricultural film has failed. As early as the 1990s, the European Union implemented the Common Agricultural Policy, in which the agri-environmental plan and cross-compliance were the main contents to deal with the agri-environmental problems. However, based on the case study of Italy, Bartolini et al. found that local farmers hardly complied with the provisions of this policy [1]. Similarly, Liu and Xu found that China's agricultural support and protection subsidy policy is beneficial to agricultural environmental protection in design, but in practice, it not only has a little positive impact on agricultural environmental protection but even has a negative impact [2].

In addition, one of the major contributors to carbon emissions in agricultural output is agricultural film [3]. The degradation methods of agricultural film mainly include photodegradation and biodegradation, because the realistic conditions of photodegradation on the intensity and exposure of ultraviolet rays are usually difficult to achieve, biodegradation is the more commonly used way. However, when the agricultural film is completely degraded by the organism, it will produce greenhouse gases and water. Therefore, reducing the amount of agricultural film used and increasing the rate at which it is recycled and used are crucial for protecting the environment of the soil, maintaining the standard of agricultural output, and pushing agriculture's transition to a low-carbon economy.

The globe came together to address the carbon emission issue in 2015, when the Paris Agreement was ratified at the Paris Climate Change Conference in response to the growing severity of the greenhouse effect. Nonetheless, the two main areas of focus for countries throughout the world are the creation of low-carbon cities and the conversion of industries into low-carbon sectors. Regarding this subject, the majority of the research now in publication is devoted to measuring and tracking the evolution of agricultural carbon emissions over time [4]. Although it is widely anticipated and agreed upon that the environmental impact of global agricultural carbon emissions will exceed the safe threshold based on the research findings of the body of existing literature, very few academics have addressed how to change the agricultural system to achieve its low-carbon transition. China strongly promotes the Paris Agreement and states that its objective is to achieve "2030 carbon peak, 2060 carbon neutrality". In light of this, China has made it a priority to advance the low-carbon transition and the high-quality growth of agriculture.

In 2016, the Chinese government mentioned in its Soil Pollution Prevention and Control Action Plan that six provinces, including Hebei, Liaoning, Shandong, Henan, Gansu, and Xinjiang, will fully recycle waste agricultural film by 2020. This pilot program aims to safeguard the soil ecosystem by increasing the rate at which agricultural film is recycled. However, one of the major contributors to agricultural carbon emissions is the use of agricultural film, and this pilot program is viewed as a critical step in advancing the low-carbon transformation of agriculture. Compared with market-based agricultural environmental protection policies, especially subsidies and incentives, direct government intervention is a "tangible hand", which achieves policy objectives through coercive force. This research uses the pilot program's extensive recycling of used agricultural film as a kind of artificial natural experiment. Based on the panel data of 30 inland provinces in China (excluding Tibet) from 2011 to 2021, a DID model is constructed to test its effectiveness and carbon reduction effect, so as to evaluate the role of government intervention in agricultural environmental protection in promoting the low-carbon transformation of agriculture.

The three items listed below comprise this study's marginal contribution. First off, this study adds to the body of knowledge on agriculture's low-carbon transition. The measurement and space-time evolution of agricultural carbon emissions have been the subject of much research by the academic community, which has given attention to this important issue. However, there is a dearth of discourse regarding strategies to encourage the low-carbon transformation of agriculture. This study investigates whether extensive recycling of waste agricultural film, based on China's pilot program, may facilitate the low-carbon transformation of agriculture. It complements existing research on the transformation of agricultural systems to achieve low-carbon agriculture.

Secondly, this study provides empirical evidence for the effectiveness of government intervention in agricultural environmental protection. There is growing evidence that market-based environmental policies have sustained incentive effects [5] and, in many cases, are more effective than government intervention. However, in agricultural environmental protection, the means of market incentive are not very effective and even have a negative effect. This study takes the pilot policy of comprehensive recycling of waste agricultural film in China as an example to provide empirical evidence for the effectiveness of government intervention in agricultural environmental protection.

Finally, this study provides suggestions for the formulation and improvement of government intervention policies in agricultural environmental protection. Based on the discussion of the effectiveness, carbon reduction effect, and boundary conditions of pilot policies for comprehensive recycling of waste agricultural film in China, this study puts forward specific policy recommendations. In the formulation and improvement of government intervention in environmental protection policies, China has made rich attempts, and the Chinese experience and enlightenment summarized in this study can also provide help for other countries in agricultural environmental protection.

Literature Review

Environmental Regulation in Agriculture

Studies on agricultural environmental protection measures, such as agricultural environmental protection measures, began very early in European and American countries [6, 7], according to the European Union's Common Agricultural Policy [1, 8]. In addition, Stupak et al. (2019), based on a case study in Germany, found that many farmers do not recognize official agricultural environmental management measures, and they are more inclined to achieve the goal of agricultural environmental protection through their own methods [9]. Bartkowski et al. found that agricultural environmental costs can effectively supplement agricultural environmental policies [10]. Bareille and Zavalloni, based on a case study of abandoned wetlands, found that decentralization can improve the efficiency of agricultural environmental payments [11].

In China, the relevant research on agricultural environmental protection measures was carried out late, and the research results mainly focused on agricultural insurance and financial subsidies. Zhong et al. found that under the conditions of low premiums and compensation for crop insurance, encouraging farmers to participate in crop insurance will not cause obvious damage to the agricultural environment [12]. Zhu et al. found that an agricultural environmental plan combining pension insurance and agricultural insurance could effectively promote farmers' efforts to protect agriculture and the soil environment [13]. Liu and Xu found that although the purpose of agricultural support and protection subsidy policy is to protect the environment, it has no positive impact on the agricultural environment in practice and even has a negative impact [2].

Whether it is China or other countries' agricultural environmental protection policies, the effect is relatively general, and some even have negative effects, especially China's subsidy policies. Take the use of agricultural film as an example. If the government encourages farmers to use higher-quality agricultural film through subsidies, it will not reduce the use of agricultural film but stimulate the expansion of high-quality agricultural film demand and ultimately run counter to the policy goal. Therefore, what kind of environmental protection policies can work is still worth studying.

Low-Carbon Transformation of Agriculture

In recent years, with the increasingly serious greenhouse effect, the shift of sectors, particularly agriculture, to low-carbon practices has drawn the attention of several researchers. Lopez et al. expanded the carbon emission index of agricultural products and evaluated the direct carbon emission of Spain as well as the virtual carbon emission generated by domestic imports and international transportation, and the results showed that the carbon emission was more than twice the usual carbon emission [14]. Hu et al. pointed out that agriculture is one of the primary causes of carbon emissions [15]. Research conducted using data from 62 economies along the "Belt and Road" revealed that shocks to China's agricultural product supply and demand had a notable effect on the agricultural carbon emissions of these nations. Ali et al. discovered that pesticides considerably raised agricultural carbon emissions and had a detrimental long-term effect on environmental quality based on data from Pakistan from 1973 to 2018 [16]. According to Mamun et al., agricultural GHG emission intensity is higher in developing nations, but as agricultural production rises, this emission intensity is quickly decreasing [17].

China is among the nations with the highest carbon emissions, and a large number of academics have studied the carbon emissions from its agriculture. Li et al. calculated the carbon emission, carbon sink, and temporal and spatial distribution of agriculture and animal husbandry on the Qinghai-Tibet Plateau through the ecological footprint method and proposed corresponding carbon reduction schemes based on this [4]. Based on the agricultural development data of Guangzhou, a causal association between agricultural flexibility, agricultural carbon emissions, and carbon sinks was discovered by Song and Yang [18]. Ma et al. found that the adoption of digital financial inclusion and enhanced inter-regional communication had a mediating role in the development of digital agriculture, which significantly reduced agricultural carbon emissions [19]. Based on data from China's 2011–2019 provincial panel, the conclusions were drawn. Wang et al. computed the carbon emissions of Chinese provinces from 2000 to 2021 based on data from six carbon emission sources: cultivated land, irrigation, fertilizer, pesticide, agricultural film, and diesel fuel [3]. They also looked at the effects of planting scale and technological advancements on agricultural carbon emission reduction. Jiang et al. discovered that agricultural insurance can lower agricultural carbon emissions by

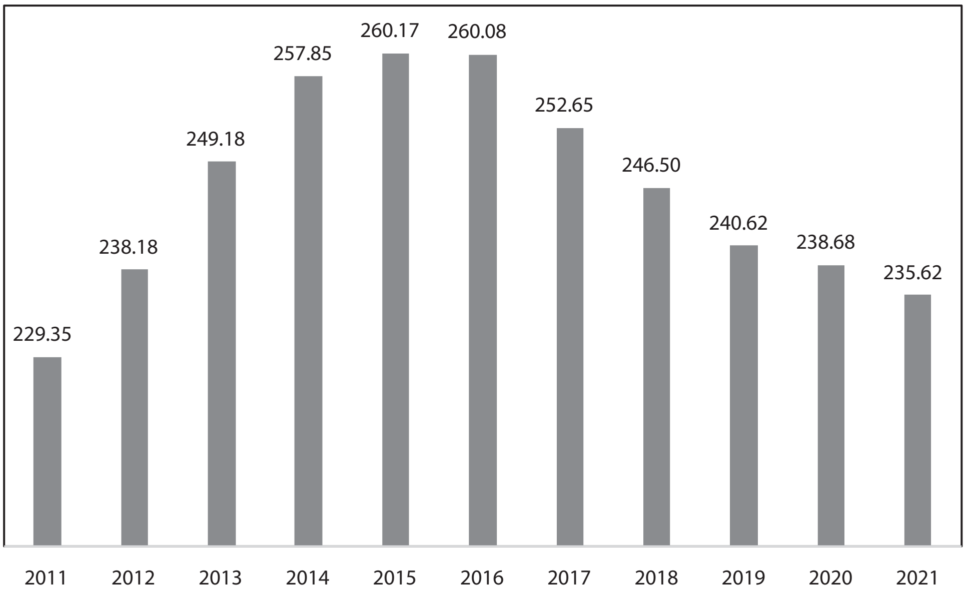

Fig. 1. Consumption of agricultural film in China (10,000 tons).
Data source: "China Rural Statistical Yearbook"

encouraging low-carbon technology innovation, based on provincial panel data between 2001 and 2019 [20]. Mu et al. found that policy-oriented agricultural insurance can promote agricultural carbon emissions by constructing a multistage dynamic DID model [21].

In the literature related to this, measuring agricultural carbon emissions and sinks is a common research outcome, as is the exploration of spatial and temporal distribution characteristics. In recent years, Chinese scholars have gradually carried out research on how to reduce agricultural carbon emissions, but it is not in-depth, and more research is needed to explore this topic.

Policy Background and Theoretical Mechanism

Policy Background

Due to the significant role of agricultural film in improving agricultural output value, it was first rapidly popularized in Japan, Europe, and the United States. In the 1970s, agricultural film technology entered China and was gradually promoted. Recently, China has become the world's largest agricultural film producer and consumer. Fig. 1 shows that China's usage of agricultural film rose by more than 300,000 tons between 2011 and 2015. In China, the usage of agricultural film has started to drastically decrease since 2017, but it is still rather significant. As can be observed, China has implemented obligatory steps and accomplished certain outcomes to lessen the harm that agricultural film usage causes to the environment.

In recent years, for the protection of the atmospheric and water environments, China has introduced many governance policies, which can be basically divided into government intervention type and market incentive type. Market incentive methods include, for instance, the creation of green financial innovation experimental zones, the carbon emission rights trading policy, and the sulfur dioxide emission rights trading policy. Government intervention takes the form of environmental protection tax collection, water pollution prevention and control action plans, and air pollution prevention and control action plans. To protect the agricultural and soil environment and reduce the use of agricultural film, China has also introduced a series of reform policies in recent years. The government made it clear in 2014 that residual film recycling and the promotion of high-quality agricultural film were essential. The government increased its involvement in agricultural environmental protection in 2015 by encouraging the use of thickened plastic film and changing agricultural film standards. In 2016, the government issued the Action Plan for the Prevention and Control of Soil Pollution, which, together with the Action Plan for the Prevention and Control of Air Pollution and the Action Plan for the Prevention and Control of Water Pollution, formed the three major action plans for environmental protection in China and kicked off a new round of work to protect agriculture and the soil environment in China.

The Action Plan for Soil Pollution Prevention and Control has put forward specific provisions for strengthening the recycling and utilization of waste film. First, the government will launch a pilot program in six provinces: Hebei, Liaoning, Shandong, Henan, Gansu, and Xinjiang, which will be distributed in different regions. Secondly, the government has put forward specific targets for pilot areas to achieve comprehensive recycling of waste agricultural film by 2020. Finally, the manufacturing of inferior agricultural film and its illicit sales will face severe consequences from the authorities and ensure that farmers use higher-quality agricultural film in production activities.

Theoretical Mechanism

The market, as the "invisible hand", and the government, as the "visible hand", are the two major means to optimize resource allocation and promote economic development. Nowadays, China's economy has developed rapidly, mostly due to the influence of the market system, and its efficiency advantage in resource allocation is obvious. However, the market mechanism has also failed in many areas, especially environmental protection [22]. Due to the externality of environmental protection, market players are usually reluctant to take the initiative to pay for it. Although the concept of green consumption is gradually gaining popularity, environmental information asymmetry still makes green production and sales a challenge [23]. In the agricultural market, consumers do not have direct contact with individual farmers, and they lack access to knowledge on the use of fertilizers, pesticides, and agricultural film during the production process. Therefore, the phenomenon of "bad money drives out good money" that cannot be regulated by the market mechanism has appeared in the agricultural product market, and because of their yield benefits, individual farmers that use a lot of agricultural films are now more competitive in the market.

For the recycling of waste agricultural film, the government's intervention in agricultural environmental protection is effective in the following three points: First, environmental protection and pollution control have externalities [24]. Protecting the soil environment will not bring benefits to farmers in the short term, so farmers will not take the initiative to recycle waste gas agricultural film. Through administrative intervention, the government can clarify the responsible person for environmental protection and governance and force farmers to recycle waste agricultural film. The "Soil Ten" policy clearly defines the principle of "who pollutes, who governs" and mandates that organizations or people that pollute soil have primary accountability for governance and rehabilitation. Farmers are the users and beneficiaries of agricultural film and should assume the responsibility of recycling waste agricultural film and protecting the agricultural environment.

Second, the government can use policy tools to punish farmers who violate the recycling regulations for waste agricultural film. The legitimacy theory points out that the behavior of individuals and organizations must conform to the requirements of laws and regulations, social ethics, customs, and other requirements, and environmental legitimacy is the requirement for environmental protection behavior [25]. With the popularity of the green consumption concept, if farmers do not actively recycle waste agricultural film, it not only directly violates the relevant provisions of the "Soil Ten" policy, but also violates the expectations of consumers. In the case of government intervention, such behavior may directly face administrative fines. Even without fines, the loss of personal reputation would legitimize farmers' compliance. Just as the prospect theory suggests that people are much more sensitive to loss than to gain [26], and the deterrent of government intervention is much more attractive than economic incentives, farmers must actively recycle waste agricultural film.

Third, government intervention cannot create demand, but it can guide demand through policy tools [27]. After the waste agricultural film is recycled, it can be reprocessed to produce recycled particles and other building materials. However, in recent years, the market profit of recycled particles has declined sharply, and waste agricultural film is facing the situation of no recycling. The spontaneity, blindness, and lag of market regulation make processing factories and farmers reluctant to take part in the recycling of waste agricultural film. After the government intervention, the waste agricultural film recycling industry will receive policy support, especially financial support, resulting in processing plants being more confident in their business. With the prevalence of green consumption [28], processing plants will also usher in new development opportunities, thus forming a virtuous cycle. The increased demand for agricultural film recycling in processing plants will form a continuous economic incentive for farmers, who are willing to further increase their income through recycling agricultural film.

To sum up, government intervention in agricultural environmental protection can effectively alleviate the failure of market regulation. Under the guarantee of the government's mandatory force, the pilot policy of waste agricultural film recycling will be effectively implemented, and the use and utilization rate of agricultural film will be significantly reduced. Agricultural carbon emissions and emission rates will be greatly decreased as a result of the waste agricultural film recycling pilot program. This is because the use of agricultural film is also a major source of agricultural carbon emissions.

Research Design

Model Design

This study draws on the practice of Huang and Yi, regards the pilot of waste agricultural film recycling and utilization required by the government in the Action Plan for Soil Pollution Prevention and Control as a quasi-natural experiment, and adopts a DID model to test the effect of government intervention on agricultural environmental protection [5]. The specific model is as below:

$$Film_{i,t} / Carbon_{i,t} = \infty + \beta Treat_i \times Time_t + \gamma Controls_{i,t} + \delta + \mu + \varepsilon \quad (1)$$

Where i indicates the province and t indicates the year. Among the explained variables, *Film* is used to test the effectiveness of the pilot policy, and *Carbon* is used to test the impact of the pilot policy on the low-carbon transformation of agriculture. For specific measurements, refer to the 4.2 variable design. *Treat×Time* is an explanatory variable constructed by a DID model. *Controls* represent control variables that may affect the regional low-carbon transition. δ represents the individual fixed effect in the province dimension, and μ represents the time fixed effect in the year dimension. ε represents the interference term.

Variable Design

Explained Variables

Film: agricultural film, including plastic film for ground or near-ground covering, and plastic film for the production of plastic greenhouses and greenhouses, that is, shed film. In this study, *Ln(Film)* was obtained by logarithm of the amount of agricultural film used to test the impact of pilot policies on the total amount of agricultural film used. *Film_ratio* was obtained by dividing the amount of agricultural film used by pilot policies by the total agricultural output value to test the impact of pilot policies on utilization on the rate of agricultural film.

Carbon: agricultural carbon emissions. In this study, the carbon emissions produced directly or indirectly by six carbon source – chemical fertilizers, pesticides, agricultural film, diesel oil, irrigation, and plowing – were measured using the IPCC carbon emission coefficient method [3]. In this study, the logarithm of agricultural Carbon emissions was gained to obtain *Ln (Carbon)* to test the impact of pilot policies on total carbon emissions. *Carbon_ratio* was obtained by dividing agricultural carbon emissions by the total agricultural output value to test the impact of pilot policies on the agricultural carbon emission rate.

Explanatory Variables

Treat×Time: waste agricultural film recycling pilot. In this study, the pilot policy variables were constructed using a DID model. Among them, *Treat* is a virtual variable, and *Treat* is 1 when the province is the waste agricultural film recycling pilot; otherwise, it is 0. *Time* is a virtual variable, which is 1 when the waste agricultural film recycling pilot is implemented and 0 otherwise. The "Soil Pollution Prevention and Control Action Plan" should be clarified as having been issued in 2016, but specific provisions were implemented in 2017, so the implementation year of the waste agricultural film recycling pilot was determined to be 2017.

The interaction term *Treat×Time* represents the net difference between the provinces that pilot the recycling of waste agricultural film and those that do not, after implementation and before implementation.

Control Variables

This study chose a number of control factors that might have an impact on the usage of agricultural film

Table 1. Variable definition table.

Variable type	Variable symbol	Variable definition	Variable measure
Explained variable	Ln(Film)	Agricultural film usage (10,000 tons)	*Ln*(Agricultural film usage)
	Film_ratio	Agricultural film utilization rate (10,000 tons / 10 billion yuan)	Agricultural film use/ Gross agricultural product
	Ln(Carbon)	Agricultural carbon emissions (10,000 tons)	*Ln*(Agricultural carbon emissions)
	Carbon_ratio	Agricultural carbon emission rate (10,000 tons / 10 billion yuan)	Agricultural carbon emissions/ gross agricultural product
Explanatory variable	Treat×Time	Waste agricultural film recycling pilot	4.2.2 Explanatory Variables
Control variables	Agri_gdp	Total agricultural production value (10 billion yuan)	*Ln*(Gross agricultural product)
	Agri_per	The proportion of total agricultural product	Gross agricultural product/ Gross regional product
	Sow_area	Crop sown area (thousand hectares)	*Ln*(Planted area of crops)
	Irrigate_area	Effective irrigated area (thousand hectares)	*Ln*(Effective irrigated area)
	Fertilizer_pesticide	Application amount of chemical fertilizer and pesticide (10,000 tons)	*Ln*(Fertilizer and pesticide application rate)
	Machine_power	Total power of agricultural machinery (10,000 kW)	*Ln*(Total power of agricultural machinery)
	Diesel_fuel	Agricultural diesel consumption (10,000 tons)	*Ln*(Agricultural diesel use)

Table 2. Descriptive statistics.

Variable	Obs	Mean	Std.Dev.	Min	Max
Ln(Film)	330	1.753	0.921	-0.629	3.462
Film_ratio	330	0.496	0.293	0.109	1.697
Ln(Carbon)	330	5.284	1.043	2.457	6.766
Carbon_ratio	330	15.423	4.92	3.297	34.613
Treat×Time	330	0.091	0.288	0	1
Agri_gdp	330	2.604	1.03	0.023	4.184
Agri_per	330	0.096	0.057	0.003	0.297
Sow_area	330	8.176	1.164	4.484	9.62
Irrigate_area	330	7.286	1.049	4.694	8.729
Fertilizer_pesticide	330	4.812	1.149	1.589	6.574
Machine_power	330	7.685	1.121	4.543	9.499
Diesel_fuel	330	3.79	1.08	0.47	5.684

and agricultural carbon emissions in relation to the research findings of Wang et al., as indicated in Table 1 [3].

Samples and Data

With 330 observations overall, panel data from 30 Chinese provinces (except Hong Kong, Macao, Taiwan, and Tibet) between 2011 and 2021 was chosen as the starting research sample for this study. The China Statistical Yearbook and the China Rural Statistical Yearbook provided the data required for this investigation.

Empirical Analysis

Descriptive Statistics

The outcomes for the primary variables are displayed in Table 2. The mean value of Ln (Film) is 1.753, and the standard deviation is 0.921, which indicates that there is a certain gap in the use of agricultural film among provinces in China, but there is no excessive dispersion. The mean value of the *Film_ratio* is 0.496, and the standard deviation is 0.293. The data set and discretization are similar to *Ln(Film)*. The mean value of Ln(Carbon) is 5.284, and its standard deviation is 1.043, indicating a small difference among provinces. The mean value of the *Carbon_ratio* is 15.423 and its standard deviation is 4.92. The data set and discretization are similar to *Ln(Carbon)*. The mean value of *Treat×Time* was 0.091, indicating that the sample size of the pilot provinces with waste gas agricultural film recycling accounted for 9.1% after implementation. Statistical descriptions of other variables are shown in Table 2.

Validity Test

Dynamic Effect Test of Validity

This study first examines whether government intervention is effective in agricultural environmental protection, that is, whether government-forced recycling of waste agricultural film reduces the use and utilization rate of agricultural film in pilot provinces. The premise of this study's application of the DID model is the hypothesis that the pilot provinces and non-pilot provinces meet the parallel trend; that is, prior to the implementation of the pilot policy, the changing trend of agricultural film use and utilization in the pilot provinces and non-pilot provinces is the same. The model in this study was built as follows, and the dynamic effect test was conducted using the event study approach [29].

$$Film_{i,t} = \infty + \sum_{t=2011}^{2021} \beta Treat_i \times \mu + \gamma Controls_{i,t} + \delta + \mu + \varepsilon \quad (2)$$

In model (2), *Time* in the interaction term *Treat×Time* is replaced with a dummy variable μ for 2011-2021 to estimate the difference between pilot and non-pilot provinces in each year. Other variables are the same as those in model (1).

In this study, Fig. 2 and Fig. 3 are the test results of the dynamic effects of the explained variables *Ln(Film)* and *Film_ratio*, respectively. The dynamic effect test is based on a base period of one year before the start of the pilot policy (2016) with a confidence interval of 95% [30]. Initially, prior to the pilot policy's 2017 adoption, all of the confidence intervals included zero, and the interaction term regression coefficients, β, varied above and below zero. This demonstrates that the use

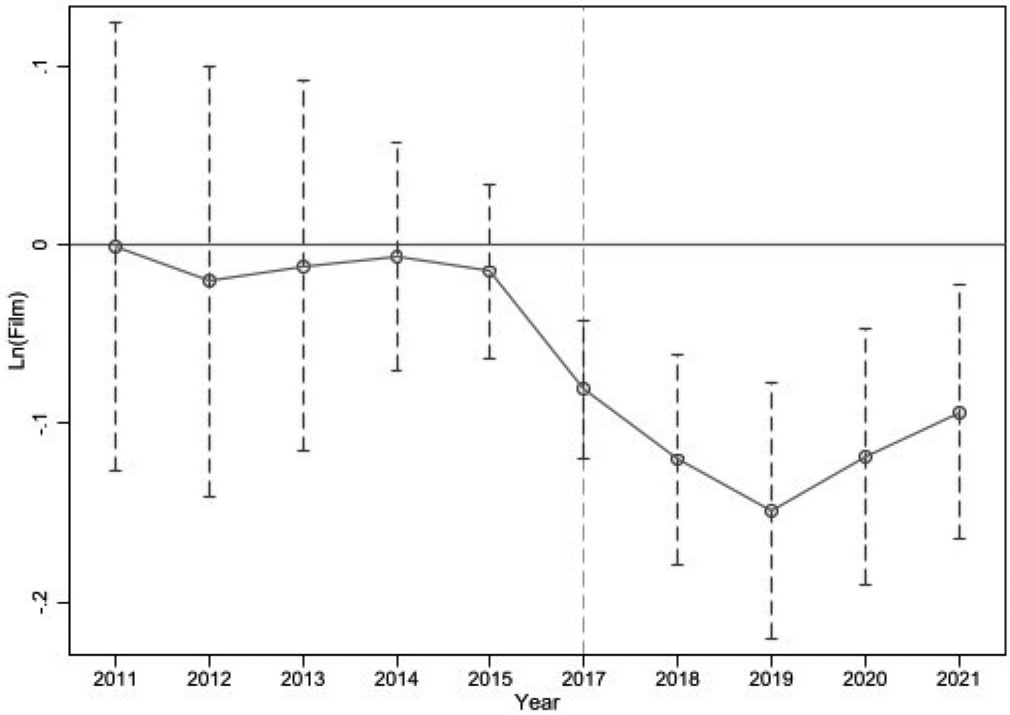

Fig. 2. Dynamic effect test of *Ln(Film)*.

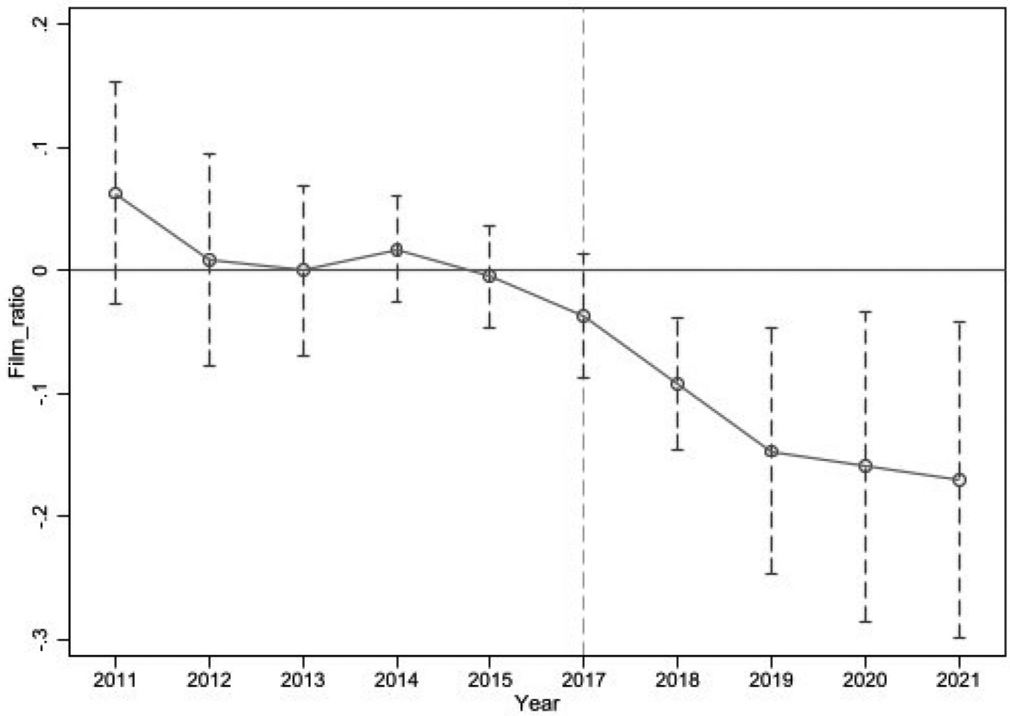

Fig. 3. Dynamic effect test of *Film_ratio*.

and utilization rate of agricultural film in pilot and non-pilot provinces changed in a consistent manner prior to the pilot policy's introduction. This research supports the parallel trend theory. Second, the regression coefficient β is considerably negative after the pilot policy was implemented (in 2017), suggesting that the government intervention has had an impact on lowering the usage and use of agricultural film in the pilot regions.

Table 3. Results of validity regression.

	(1)	(2)	(3)	(4)
	Ln (Film)	*Ln (Film)*	*Film_ratio*	*Film_ratio*
Treat×Time	-0.063**	-0.103***	-0.095***	-0.134***
	(0.025)	(0.017)	(0.023)	(0.021)
Agri_gdp		0.400***		-0.195***
		(0.058)		(0.032)
Agri_per		-2.863***		-1.360***
		(0.444)		(0.374)
Sow_area		0.007		-0.042
		(0.115)		(0.062)
Irrigate_area		0.022		0.105
		(0.114)		(0.067)
Fertilizer_pesticide		0.324***		0.141***
		(0.109)		(0.052)
Machine_power		-0.041		-0.028
		(0.033)		(0.021)
Diesel_fuel		0.084***		0.055***
		(0.024)		(0.014)
_cons	1.759***	-0.796	0.504***	0.052
	(0.006)	(0.484)	(0.004)	(0.311)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R^2	0.990	0.995	0.963	0.976

Note: The brackets indicate a robust standard error, while the values in ***, **, and * are significant at the levels of 0.01, 0.05, and 0.1, respectively.

Analysis of Regression Results of Validity

The regression analysis of the waste agricultural film recycling pilot policy's efficacy is presented in Table 3. The coefficient of the interaction term *Treat×Time* is significantly negative when the province-fixed effect and year-fixed effect are controlled, as indicated in columns (1) and (3). This suggests that government intervention significantly lowers the use and utilization rate of agricultural film in pilot provinces. As shown in columns (2) and (4), after adding some columns of control variables to the regression model, the coefficient of the interaction term *Treat×Time* is still considerably negative, indicating that the use and utilization rate of agricultural film in the pilot province is still significantly reduced when other conditions are controlled unchanged. In a word, government intervention is effective in agricultural environmental protection.

As for the control variables, the coefficients of *Agri_gdp, Agri_per, Fertilizer_pesticide, and Diesel_fuel* are also significant, indicating that these factors will affect the amount and utilization of agricultural film.

Assessment of the Carbon Reduction Effect

Dynamic Effect Test of the Carbon Reduction Effect

This study examines the influence of government involvement in waste gas agricultural film recycling on the low-carbon transformation of agriculture, specifically on agricultural carbon emissions and emission rates, after confirming the program's efficacy. Similar to 5.2.1, this research constructs the dynamic effect test model as follows and then determines if pilot provinces and non-pilot provinces satisfy the parallel trend hypothesis:

$$Carbon_{i,t} = \infty + \sum_{t=2011}^{2021} \beta Treat_i \times \mu + \gamma Controls_{i,t} + \delta + \mu + \varepsilon \quad (3)$$

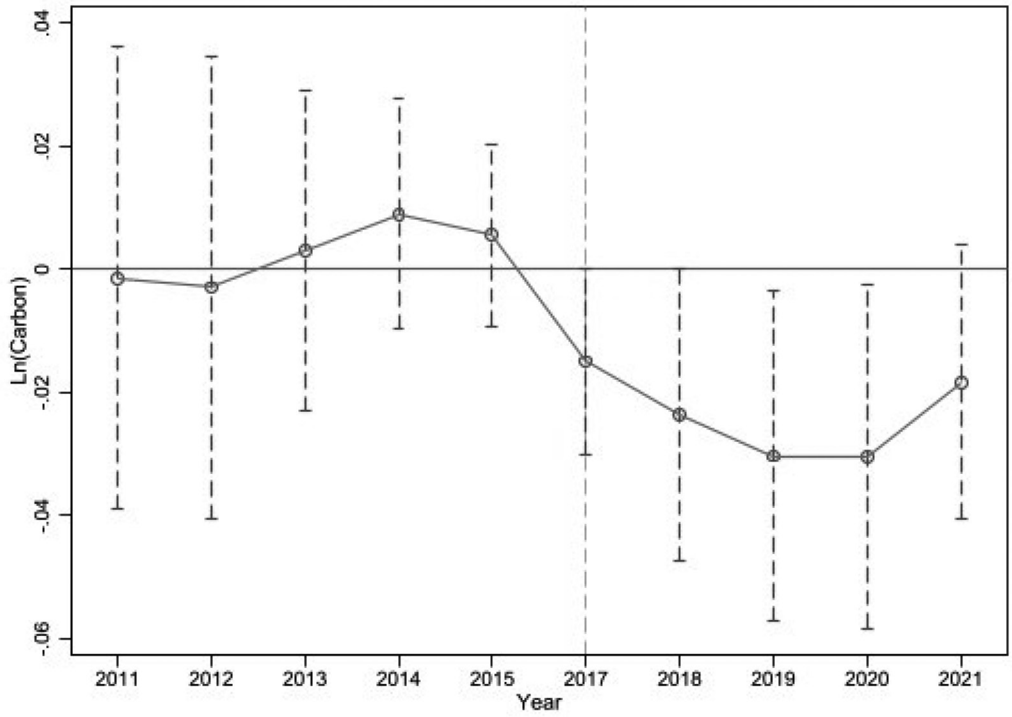

Fig. 4. Dynamic effect test of *Ln(Carbon).*

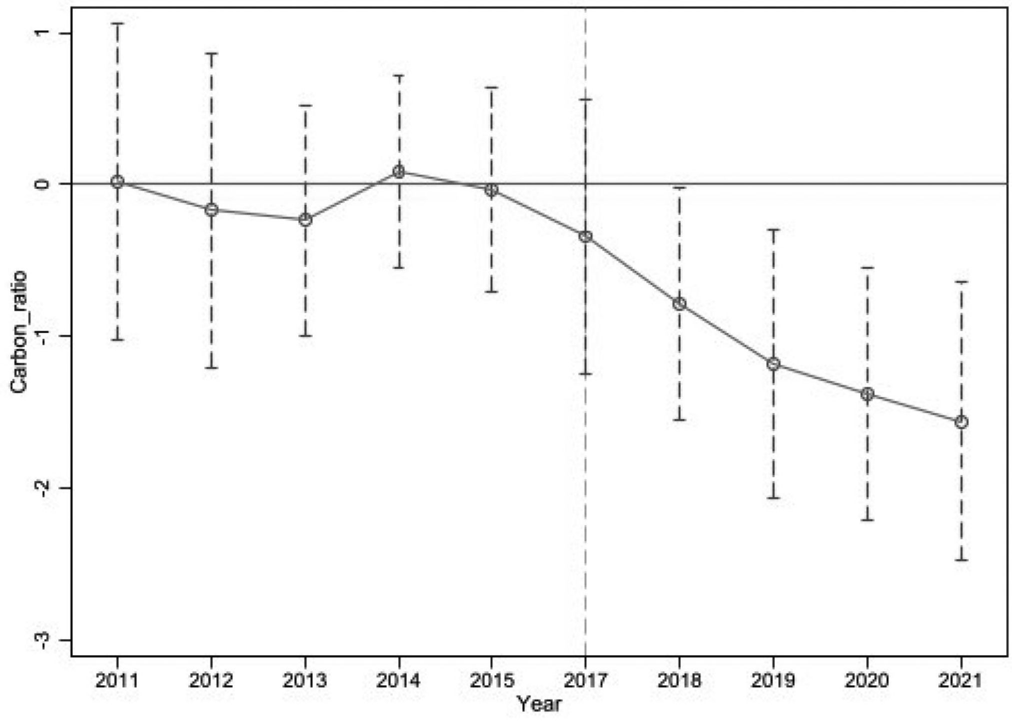

Fig. 5. Dynamic effect test of *Carbon_ratio.*

In model (3), other variables are the same as those in model (2), except that the explained variable is replaced with *Carbon.*

In this study, Fig. 4 and Fig. 5 are the test results of the dynamic effects of the explained variables *Ln(Carbon)* and *Carbon_ratio*, respectively. First, prior to the implementation of the pilot

Table 4. Regression results of carbon reduction effect.

	(1)	(2)	(3)	(4)
	Ln(Carbon)	*Carbon_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.026***	-1.003***	-0.003	-0.117
	(0.006)	(0.237)	(0.005)	(0.216)
Ln(Film)			0.223***	
			(0.024)	
Film_ratio				6.608***
				(0.898)
Agri_gdp	0.029*	-11.570***	-0.061***	-10.280***
	(0.016)	(0.936)	(0.014)	(0.918)
Agri_per	-0.038	-1.878	0.600***	7.110
	(0.118)	(4.525)	(0.108)	(4.849)
Sow_area	0.070*	2.224**	0.068**	2.499**
	(0.039)	(1.070)	(0.030)	(0.973)
Irrigate_area	-0.014	-1.828	-0.019	-2.519**
	(0.034)	(1.190)	(0.020)	(1.101)
Fertilizer_pesticide	0.636***	4.626***	0.564***	3.695***
	(0.059)	(1.139)	(0.043)	(1.012)
Machine_power	-0.010	1.521***	-0.000	1.708***
	(0.014)	(0.514)	(0.012)	(0.465)
Diesel_fuel	0.164***	2.375***	0.145***	2.012***
	(0.011)	(0.218)	(0.010)	(0.200)
_cons	1.117***	-2.129	1.295***	-2.474
	(0.160)	(6.944)	(0.102)	(6.738)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R^2	0.9996	0.974	0.9998	0.977

policy (2017), the interaction term regression coefficients β all fluctuated above and below 0, and the confidence intervals all contained 0. This study satisfies the parallel trend hypothesis. Second, following the pilot policy's adoption (in 2017), the regression coefficient β of the interaction term is significantly negative, indicating that government intervention has played an effective role in reducing agricultural carbon emission rates in the pilot provinces.

Regression Analysis of the Carbon Reduction Effect

The findings of the regression analysis of the waste agricultural film recycling pilot policy's impact on carbon reduction are shown in Table 4. The coefficient of the interaction term *Treat×Time* is strongly negative, as can be seen in columns (1) and (2), suggesting that government intervention significantly lowers agricultural carbon emissions and emission rates in pilot provinces. As for the control variables, the coefficients of *Agri_gdp, Sow_area, Fertilizer_pesticide, and Diesel_fuel* are also significant, indicating that these factors will affect agricultural carbon emissions and emission rates.

As shown in columns (3) and (4), after *Ln(Film)* and *Film_ratio* are taken as control variables, *Ln(Film)* and *Film_ratio* are significantly positive, indicating that the amount of agricultural film used and the use rate have a positive impact on the agricultural carbon emission rate, respectively. The coefficient of the interaction term *Treat×Time* is no longer significant, indicating that the mechanism of carbon reduction effect produced by the government intervention in agricultural environmental protection is to reduce the amount and utilization rate of agricultural film, which further proves the causal relationship of this study.

Further Analysis

Robustness Tests

Placebo Test

The conclusions of this study may be disturbed by potentially unobservable factors from province-year. To this end, this study used a placebo test to solve possible endogeneity problems [31]. Specifically, this study constructs a pseudo-experimental group through random sampling and interacts with the *Time* variable to form a new DID variable. If the results are not disturbed by potentially unobservable factors, the regression results of random sampling should not be significant.

This study was randomly sampled 500 times, and the coefficient values and P-values of the regression results were plotted as follows: Among them, the horizontal coordinate represented by the blue hollow point is the coefficient value of regression, and the vertical coordinate is the P-value. The kernel density curve of the coefficient distribution is the actual curve. The actual regression coefficient is indicated by the vertical dotted line on the X-axis (refer to columns (2) and (4) of Table 3, as well as columns (1) and (2) of Table 4), and the significance level of 0.1 is indicated by the horizontal dotted line on the Y-axis.

As shown in Fig. 6 to Fig. 9, most of the regression results of random sampling are 0, which is not significant. Moreover, the actual regression coefficient is a singular value. Therefore, this study's results are unaffected by perhaps unobservable influences.

PSM-DID Test

Due to China's wide variety of latitudes and longitudes, as well as its distinctly different terrain and soil properties, there are regional variations in the use of agricultural film. Shandong, which is named with the title "Hometown of Vegetables", Henan, which has a very large agricultural output, and Xinjiang and Gansu in the northwest region are the top four provinces in China's agricultural film industry. In order to eliminate the original differences between pilot provinces and non-pilot provinces, propensity score matching (PSM) is used to match pilot provinces with non-pilot provinces [32]. Specifically, this study took all control variables as covariates and calculated propensity scores using the nearest matching method on a scale of 1:4, with 116 observations after matching.

As shown in Table 5, the coefficient of the interaction term *Treat×Time* is significantly negative. This shows that after eliminating the regional differences between

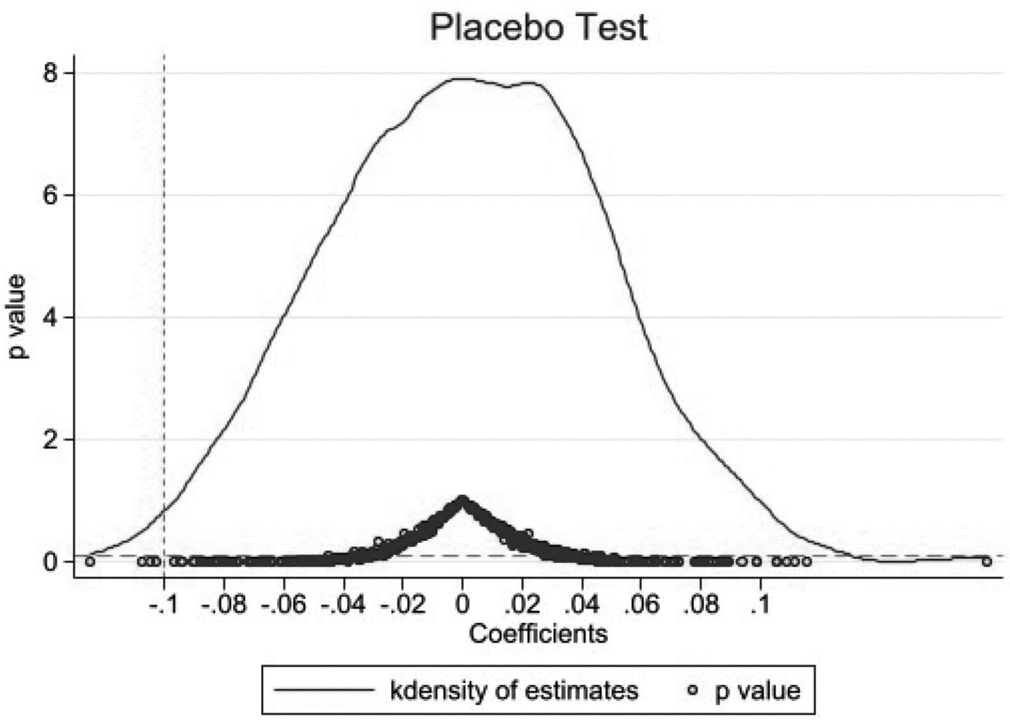

Fig. 6. Placebo test for *Ln(Film)*.

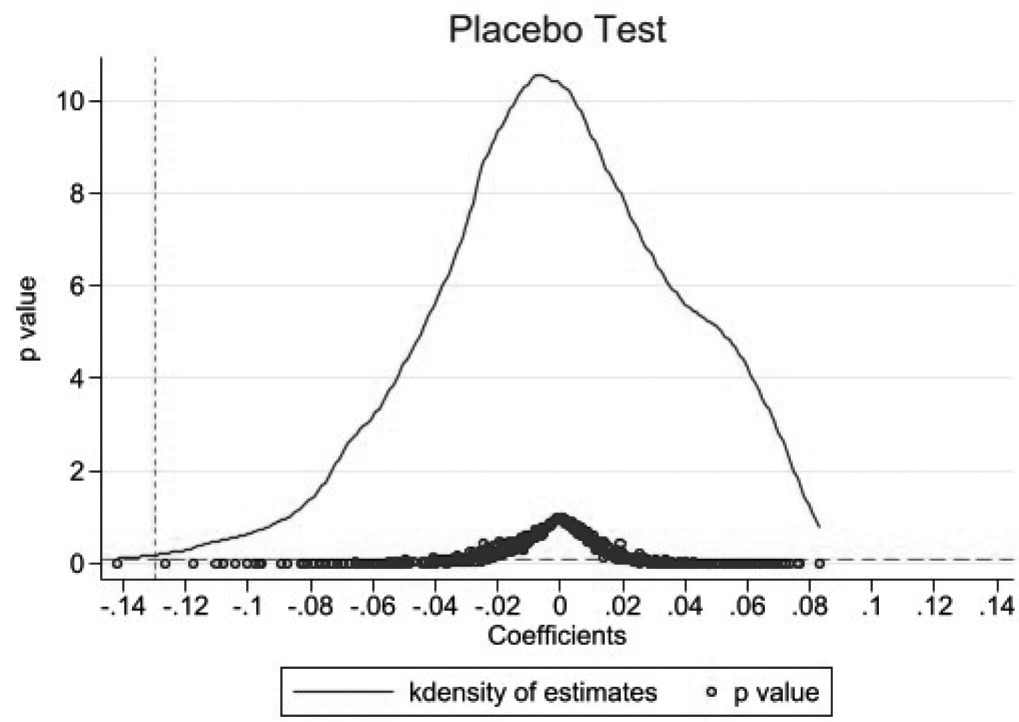

Fig. 7. Placebo test for *Film_ratio.*

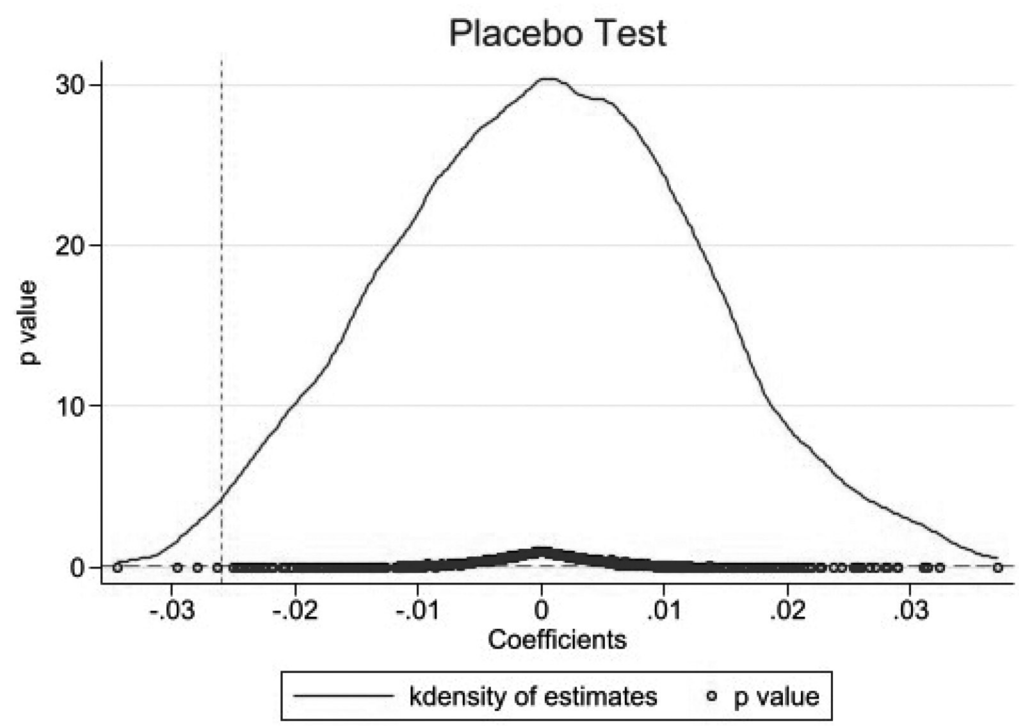

Fig. 8. Placebo test for *Ln(Carbon).*

pilot and non-pilot provinces, government intervention in agricultural environmental protection still has effectiveness and a carbon reduction effect, and the research conclusion is robust.

Remove the Southern Provinces

The east, center, and west are home to the waste agricultural film recycling pilot provinces. However,

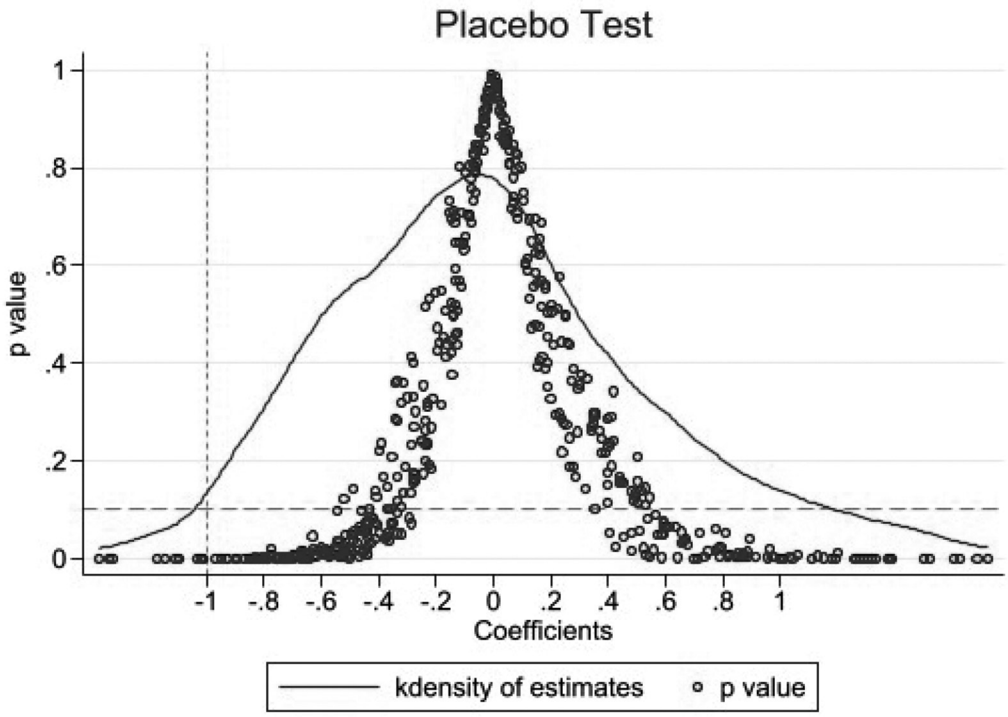

Fig. 9. Placebo test for *Carbon_ratio*.

Table 5. PSM-DID regression results.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.134***	-0.174***	-0.040***	-1.649***
	(0.039)	(0.036)	(0.010)	(0.402)
_cons	-4.791*	-2.689	0.327	-89.497***
	(2.529)	(1.792)	(0.572)	(31.913)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	116	116	116	116
R^2	0.995	0.982	0.9996	0.983

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard errors.

the pilot provinces are all in the north since the use of agricultural film is closely tied to heat preservation. The southern area was left out of this analysis in order to exclude any potential impact of the differences between north and south on the regression estimation findings. The term "northern provinces" refers to the areas of Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Heilongjiang, Jilin, Liaoning, Shandong, Henan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang located north of the Qinling-Huaihe River line. Forty percent of the northern provinces are comprised of the pilot provinces.

As shown in Table 6, the coefficient of the interaction term *Treat×Time* is significantly negative. This shows that government intervention in agricultural environmental protection still has effectiveness and a carbon reduction effect after eliminating regional differences, and the research conclusion is robust.

Control the Impact of Other Policies

Other policies may also influence the use of agricultural films and the carbon emissions from agriculture, thereby

Table 6. Excluded the regression results of the southern provinces.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.138***	-0.143***	-0.047***	-1.436***
	(0.022)	(0.022)	(0.006)	(0.269)
_cons	-0.396	-0.014	1.159***	-17.936**
	(0.559)	(0.401)	(0.151)	(7.523)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	165	165	165	165
R^2	0.998	0.974	0.9998	0.981

Note: The brackets indicate a robust standard error, while the values in ***, **, and * are significant at the levels of 0.01, 0.05, and 0.1, respectively.

Table 7. Regression results of controlling the impact of other policies.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.111***	-0.137***	-0.027***	-1.018***
	(0.018)	(0.021)	(0.006)	(0.236)
SMPP	-0.021	-0.000	-0.007	-0.265
	(0.019)	(0.013)	(0.006)	(0.196)
CET	-0.100***	-0.027*	-0.024***	-0.330
	(0.021)	(0.015)	(0.007)	(0.223)
_cons	-0.162	0.223	1.270***	0.023
	(0.506)	(0.334)	(0.170)	(7.112)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R^2	0.996	0.976	0.9996	0.974

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard errors.

potentially confounding the results of this analysis. To address this, the present study controls for the impact of these policies within the model.

First, one of the experimental projects in the Action Plan for Soil Pollution Prevention and Control involves recycling waste agricultural film. The prevention and management of mineral contamination is another crucial pilot project included in the Soil Contamination Management Action Plan. Mineral contamination has been rigorously prohibited since 2017 in the following provinces: Inner Mongolia, Jiangxi, Henan, Hubei, Hunan, Guangdong, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, and Xinjiang. This pilot may interfere with the results of this study because the timing of the two pilots is consistent and the pilot provinces are duplicated. Moreover, the purpose of strictly preventing mineral pollution is to improve the soil environment, which may also affect the use of agricultural film and agricultural carbon emissions in the process. To control the influence of soil mineral pollution prevention on the results, the variable SMPP [33], which evaluates the policy effect, was also constructed by using the DID model and taken as the control variable.

Secondly, policies aimed at controlling carbon emissions are likely to have an effect on agricultural carbon emissions. Among all carbon reduction initiatives in China, the carbon emissions trading pilot is the most representative and successful. In 2013, China initiated trading in seven carbon emissions trading markets, including those in Beijing, Tianjin, Shanghai, Chongqing, Hubei, Guangdong, and Shenzhen. By 2016, Fujian had also launched its carbon trading market. Consequently, this study employs a multi-period DID model to incorporate the policy variable for the carbon emissions trading pilot (CET) and includes it as a control variable.

As shown in Table 7, the coefficient of the interaction term *Treat×Time* is significantly negative. Moreover, while *SMPP* has no significant impact on agricultural film use or agricultural carbon emissions, CET exhibits a notable and significant impact. This shows that after controlling mineral pollution prevention and carbon emissions trading, government intervention in agricultural environmental protection still has effectiveness and a carbon reduction effect, and the research conclusion is robust.

Control the Impact of Farmer Characteristics

Farmers are direct participants in agricultural activities, and their characteristics may influence their agricultural production activities, thereby affecting the use of agricultural films and agricultural carbon emissions. This paper primarily controls for the impact of farmers' income and consumption levels, which affect their production conditions and motivation. Specifically, this study takes the logarithm of farmers' per capita disposable income and consumption and incorporates it into the regression model.

Table 8. Regression results of control the impact of farmer characteristics.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.083***	-0.132***	-0.018***	-0.965***
	(0.014)	(0.021)	(0.005)	(0.256)
Income	1.557***	0.210	0.499***	2.014
	(0.300)	(0.239)	(0.096)	(3.731)
Consume	-0.354***	-0.028	-0.212***	-1.313
	(0.102)	(0.070)	(0.038)	(1.353)
_cons	-12.954***	-1.775	-1.826*	-9.637
	(3.045)	(2.333)	(1.029)	(38.897)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R^2	0.996	0.976	0.999	0.974

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard error

Table 9. Regression results of hysteresis effect.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.098***	-0.136***	-0.019**	-0.944***
	(0.018)	(0.021)	(0.009)	(0.342)
_cons	-0.426	0.309	1.077***	-3.151
	(0.499)	(0.335)	(0.339)	(8.792)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	300	300	300	300
R^2	0.996	0.974	0.999	0.945

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard error

Table 10. Regression results of cluster analysis.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time	-0.103***	-0.134***	-0.026**	-1.003**
	(0.029)	(0.035)	(0.011)	(0.421)
_cons	-0.796	0.052	1.117***	-2.129
	(0.564)	(0.483)	(0.237)	(12.270)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R^2	0.995	0.976	0.9996	0.974

Note: At the significance levels of 0.01, 0.05, and 0.1, respectively, ***, **, and *, and robust standard errors from clustering to province level are in brackets.

Table 11. Regression results of a replacement measure.

	(1)	(2)
	Film_ratio	*Carbon_ratio*
Treat×Time	-0.022***	-0.089*
	(0.006)	(0.053)
_cons	2.632***	41.048***
	(0.237)	(2.535)
Controls	Yes	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
Obs	330	330
R2	0.983	0.992

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and robust standard errors from clustering to province level are in brackets.

As shown in Table 8, the coefficient of the interaction term Treat×Time is significantly negative. Moreover, *Income* and *Consume* variables have a significant impact on agricultural film use and agricultural carbon emissions.

Hysteresis Effect

To further prove causality, this study delayed the interaction term *Treat×Time* and all control variables by one phase to examine the effects of *Treat×Time* and control variables in the T-1 phase on the use of agricultural film and agricultural carbon emissions in the T phase. As shown in Table 9, the coefficient of *Treat×Time* is significantly negative, and the research conclusion is robust.

Cluster Analysis

To further ensure the robustness of the regression model, the robust criteria are mistakenly clustered in the province dimension. As shown in Table 10, the coefficient of the interaction term *Treat×Time* is significantly negative, and the research conclusion is robust.

Replace Measures

To further ensure the robustness of variable measurement, the denominators of the two variables *Film_ratio* and *Carbon_ratio* were replaced from the total agricultural output value (10 billion yuan) to the sown area of crops (thousands of hectares). At the same time, in order to facilitate the coefficient display, the *Film_ratio* and *Carbon_ratio* of the new measure are multiplied by 100. As shown in Table 11, the coefficient of *Treat×Time* is relatively negative, and the research conclusion is robust.

Moderating Effect Analysis

In recent years, the process of marketization has made outstanding contributions to China's economic development. But there are specific areas where the market has failed.

In the agricultural product market, the final consumer and individual farmers do not have a direct buying and selling relationship, and it is difficult to make individual farmers pay for their environmental damage behavior. On the contrary, the extensive use of agricultural film has increased crop production in a short time, and the phenomenon of "bad money driving out good money" has gradually prevailed, and agricultural environmental protection needs government intervention to guarantee the compulsory force.

Different from previous research results, this study believes that government intervention is more effective in agricultural environmental protection. Therefore, the relationship between government and market has a regulating effect on the effectiveness and carbon reduction effect of government intervention in agricultural environmental protection. The stronger the government's ability to intervene, the better the effectiveness and carbon reduction effect of the pilot policy. This refers to the research results of Gang et al. and uses the relationship between Government and Market, a subdivision item in its marketization process index, to test [34]. The larger the *Market*, the lower the level of government intervention.

To test the moderating effect of *Market*, this study interacted with Treat×Time, Treat, and Time, respectively, and constructed the following models for the regression test:

$$Film_{i,t} / Carbon_{i,t} = \infty + \beta Treat_i \times Time_t \times Market_{i,t} + \theta Treat_i \times Time_t + \sigma Treat_i \times Market_{i,t} + \varphi Time_i \times Market_{i,t} + \beta Market_{i,t} + \gamma Controls_{i,t} + \delta + \mu + \varepsilon \quad (4)$$

As shown in Table 12, the coefficient of the interaction item *Treat×Time×Market* in columns (1) and (3) is not significant, while the coefficient of the interaction item *Treat×Time×Market* in columns (2) and (4) is significantly positive, indicating that the quantitative effectiveness and carbon reduction effect of the pilot policy are not significantly different in different government-market relationships. However, in terms of efficiency, a more coercive government has the advantage. The regulating effect of the relationship between government and market further shows that government intervention is more effective in agricultural environmental protection and can effectively alleviate market failure.

Heterogeneity Analysis

The primary function of agricultural film is to enhance ground temperature and maintain soil moisture, among others. Its usage is largely aimed at coping with variable weather conditions. A region's dependency on agricultural

Table 12. Regression results of moderating effect analysis.

	(1)	(2)	(3)	(4)
	Ln(Film)	*Film_ratio*	*Ln(Carbon)*	*Carbon_ratio*
Treat×Time×Market	0.001	0.068***	0.002	0.656***
	(0.013)	(0.013)	(0.005)	(0.152)
Treat×Time	-0.126	-0.546***	-0.044	-5.129***
	(0.086)	(0.086)	(0.033)	(1.035)
Time×Market	-0.027***	-0.014***	-0.009***	-0.357***
	(0.008)	(0.005)	(0.003)	(0.104)
Treat×Market	0.014	0.019	0.003	0.092
	(0.009)	(0.011)	(0.004)	(0.104)
Market	0.011**	-0.001	0.005***	0.115**
	(0.006)	(0.003)	(0.002)	(0.056)
_cons	-0.601	0.200	1.153***	-0.061
	(0.473)	(0.309)	(0.141)	(6.247)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	330	330	330	330
R2	0.996	0.980	0.9996	0.976

Note: Robust standard errors from clustering to the provincial level are in brackets. ***, **, and * are significant at the levels of 0.01, 0.05, and 0.1, respectively.

Table 13. Regression results of heterogeneity analysis 1.

	Ln(Film)		Film_ratio	
	Few	*Many*	*Few*	*Many*
Treat×Time	-0.095***	-0.106***	-0.086***	-0.154***
	(0.030)	(0.020)	(0.027)	(0.025)
_cons	0.772	-5.584***	1.378***	0.094
	(0.743)	(0.879)	(0.423)	(1.227)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	169	161	169	161
R^2	0.996	0.993	0.971	0.982

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard error

Table 14. Regression results of heterogeneity analysis 2.

	Ln(Carbon)		*Carbon_ratio*	
	Few	Many	Few	Many
Treat×Time	-0.022***	-0.025***	-0.345	-1.192***
	(0.009)	(0.006)	(0.384)	(0.179)
_cons	1.236***	-0.471*	2.214	-34.668***
	(0.199)	(0.259)	(11.487)	(10.541)
Controls	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Obs	169	161	169	161
R^2	0.9997	0.999	0.970	0.989

Note: ***, **, and * are significant at the level of 0.01, 0.05, and 0.1 respectively, and the brackets are robust standard error

film decreases as its ability to monitor and adapt to meteorological changes improves. Therefore, this study classifies samples into two groups based on the median number of agricultural meteorological observation stations in the region for the current year: those with fewer and those with more observation stations. As demonstrated in Table 13, the effects of the policy are more pronounced in samples with a greater number of observation stations, regardless of whether the measurement is Ln(Film), Film_ratio, Ln(Carbon), or Carbon_ratio. This suggests that enhancing meteorological observation and response capabilities can further reduce dependency on agricultural film and decrease agricultural carbon emissions.

Conclusions and Suggestions

With the extensive use of agricultural film, the agricultural environment has been seriously polluted, and agricultural carbon emissions have also increased significantly, further aggravating the greenhouse effect. In 2016, China issued a Soil Pollution Prevention and Control Action Plan, which calls for the pilot recycling of waste agricultural film in six provinces. Based on Chinese provincial panel data from 2011 to 2021, this study constructs a DID model to explore the effectiveness and carbon reduction effects of this pilot policy. The study found that, through government intervention, this pilot program effectively decreased the amount of agricultural film used and utilized in the trial region. Additionally, the pilot program has greatly lowered the emission rates and carbon emissions from agriculture in the pilot zones. The aforementioned research findings remain true following a number of robustness tests, including the PSM-DID Test and Placebo Test, the exclusion of southern provinces, and the control of intervention in the prevention and control of mineral contamination. Lastly, this study discovered that the efficacy and testing impact of the pilot program are moderated by the interaction between the market and the government.

The following policy suggestions are presented by this study in light of the aforementioned research findings: First of all, the experience of recycling waste agricultural film will be promoted, and government intervention measures will be actively used to protect the agricultural environment. In China, the government's intervention in agricultural environmental protection has a remarkable effect and can effectively mitigate market failures. In the future, countries can introduce similar pilot policies to change the unfavorable status quo of agricultural environmental protection through government intervention. Secondly, bolstering the monitoring of carbon sinks and emissions from agriculture and giving the problem of agricultural carbon emissions active consideration. One significant source of carbon emissions is agriculture. In order to mitigate the greenhouse impact, agricultural carbon emissions must be given more attention by all nations. Not only should agricultural film be used, but there is an urgent need to investigate ways to reduce agricultural carbon emissions by addressing issues with arable land, irrigation, fertilizers, pesticides, and motor fuel. Finally, the relationship between the market and the government should be coordinated. Markets determine the allocation of resources, but governments should intervene when markets fail. The government can formulate laws and regulations, action plans, etc., require farmers to strictly protect the agricultural environment, support the development and growth of green industries such as agricultural film recycling, and form a virtuous cycle.

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Conflict of Interest

The authors declare no conflict of interest.

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