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Policy Intervention Effect Research on Pesticide Packaging Waste Recycling: Evidence From Jiangsu, China

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Large quantities of pesticide packaging wastes have been thrown and abandoned in farmlands and surrounding environments, which is not only difficult to degrade but also posing a potential pollution threat to agricultural produce and the ecological environment due to the high concentration residues of pesticide. The Chinese government has formulated a series of policies and measures and established some recycling pilot provinces. However, the intervention effects of different kinds of policies on pesticide packaging waste recycling by farmers' and its mechanism were still unknown. This study took the pilot province Jiangsu Province as the example, by using the game theory and propensity score matching (PSM) model to analyze and compare the intervention effects of three kinds of pesticide packaging waste recycling policies, that is, punish, subsidy and reward, and mortgage return. The results showed that the three kinds of policies all positively affected farmers' recycling behaviors in the pilot area. The incentive effect of the punishment policy was the weakest, and the mortgage return policy was prominent with the recycling probability increasing 44.8% under a single policy. Based on these results, some policy suggestions were put forward as follows: improving farmers' cognition of environmental pollution caused by pesticide packaging waste and their awareness of environmental protection, establishing the necessary administrative punishment policy, increasing financial support and improving the standard of recycling subsidies, and vigorously promoting the mortgage return recovery policy in areas where conditions permit. So as to stimulate the willingness of pesticide users to recover independently, the government should reduce the cost of administrative law enforcement and contribute to the construction of rural ecological civilization.

Keywords: pesticide packaging waste recycling, policies intervention, farmers, game theory, PSM model

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1 INTRODUCTION

In the past few decades, pesticides have been widely used in agriculture in order to control pests and improve crop yields (Fernandes et al., 2020; Sharma et al., 2020), and it remains a key input factor for global food security at present (Maldani et al., 2017; Bagheri et al., 2018). Nonetheless, farmers tend to overuse pesticides to better control microbial diseases and pests (Bagheri et al., 2018), which is accompanied by the improper treatment of a large number of pesticide packaging waste. Pesticide packaging materials are generally made of polyester bottles and aluminum foil bags, with low economic value of reuse (Jones, 2014; Li and Huang, 2018). However, due to the difficulty of breaking down pesticide packaging waste, it is continuously accumulated in the farmland ecological environment for a long time, forming white pollution and affecting crop growth and agricultural machinery operation (Pasdar et al., 2017; Pirsaheb et al., 2017). Moreover, the high concentrated pesticides left in the packaging can directly enter waters and soils, posing potential hazards and threats to the production safety of agricultural products, rural ecological environment, and human health (Briassoulis et al., 2014; Eras et al., 2017; Marnasidis et al., 2018). A recent study has shown that about 83% of 317 topsoil samples contain 76 different types of pesticide residues from 11 EU countries (Silva et al., 2019). In addition, the Moroccan Poison Control Center reported that there were 1,451 cases of pesticide poisoning in 2015 (Badrane et al., 2018).

In order to minimize the potential harm of pesticide packaging waste, some countries have taken effective measures and established the system of waste pesticide packaging. For example, the non-profit organization for terminal treatment of pesticide packaging waste established in Brazil played an important role in the recycling and treatment of waste pesticide packages. Similar management schemes were established in some European countries, such as Belgium, France, and Germany (FAO/WHO, 2008). These schemes widely introduce the extension of producer responsibility, internalize external costs to pesticide producers, and improve the design of pesticide packaging, so as to increase the recycling efficiency of pesticide packaging waste (Park et al., 2018). The recycling of pesticide packaging waste is a pro-environmental behavior, which is inseparable from the extensive participation of farmers. Although some policies of pesticide packaging waste have been issued in some countries, the effect of farmers' recycling in most areas was still not ideal. According to the survey of the Rural Economic Research Center of the Ministry of Agriculture and Rural Affairs of the People's Republic of China, more than 62% of pesticide users in China habitually discard pesticide packaging waste in water or farmland and their surrounding areas (Wei and Jin, 2014).

In recent years, many studies have been carried out on farmers' behavior, attitude, and influencing factors in disposal of pesticide packaging waste (Garbounis and Komilis, 2021; Khadda et al., 2021; Li et al., 2021; Bondori et al., 2019; Li M. Y. et al., 2020). It was found that farmers in northern Greece and Mogan of Iran generally discard empty pesticide containers in farmlands, irrigation channels, and surrounding areas (Damalas et al., 2008; Bondori et al., 2019). Xu et al. (2021) found that the recycling price had the largest relative effect on control waste pesticide bottles based on a two-stage Heckman model in China. Zhao and Zhou, (2021) reported that the subsidy for pesticide packaging waste recycling should be normalized, and the way of incentive and supervision should be taken to improve the recycling enthusiasm of farmers, and Liu et al. (2021) believed that it was necessary to consider formulating differentiated compensation standards according to different pesticide packaging waste recycling schemes. Other researchers attributed the low recycling rate of pesticide packaging wastes to the poor quality of farmers themselves, poor awareness of pesticide risks, high proportion of non-agricultural employment, and inadequate rural recovery facilities (Zyoud et al., 2010; Sun, 2018; Wei and Du, 2018). Although most of the existing studies mainly focused on the influence factors of farmers' pro-environmental behavior (Botetzagias et al., 2015; Wang Y. D. et al., 2019; Thu et al., 2020; Zhou et al., 2020), few researchers had paid attention to the effect and mechanism of policy implementation on farmers' pesticide packaging waste recycling behavior.

The direct reason for the low recycling rate of farmers is lack of a behavioral driving force (Zhang et al., 2018; Li Z. M. et al., 2020; Meng et al., 2022). According to the theory of organizational behavior, to enhance the driving force of individual behavior, two kinds of means were generally taken: restraint and incentive, including law enforcement, external policy intervention, and improving market incentive (Hage et al., 2009; Li M. Y. et al., 2020; Pan et al., 2021). Agricultural waste pollution is a typical "external diseconomy" (Ellis and Fellner, 1943). The externality theory holds that an external diseconomy (negative externality) occurs in economic activities if a manufacturer causes losses that do not require payment to other manufacturers or society. At this time, market failure occurs, and the government needs to get involved for appropriate intervention (Abadie et al., 2016; Tang et al., 2021). The recycling of pesticide packaging waste is a beneficial social behavior, and recycling can produce positive externalities of the environment. However, because environmental resources are non-exclusive and non-competitive as public goods, pesticide users can directly benefit from the utilization of environmental resources without paying fees, so they generally make little or no contribution to environmental protection without external economic stimulus. The environmental damage caused by the utilization of environmental resources is finally transferred to the government, thus leading to the conflict between the choice of the government and the choice of farmers. If there are no any intervention measures, collective action will be in a dilemma. Li et al. (2019) believed that it was necessary for the government to take certain incentive or restraint policies to internalize the externality of environmental pollution. Among them, Pigou (1932) emphasized that the government should strengthen the direct regulation of the government by means of taxation and subsidies, which also provided a direct theoretical basis for the government to strengthen environmental regulation. According to the theory of institutional economics, institution is an important condition to restrict the behavior of subjects. In the case of market failure, the system can restrain and stimulate the subject's behavior through its coercive force and inducement, so as to form stable expectations and reduce transaction costs (Lu, 1996). In addition, existing studies have shown that government policies can effectively promote farmers to adopt the pro-environmental production mode by means of constraints, guidance, and incentives (Ma et al., 2009; Trujillo-Barrera et al., 2016; Brodhagen et al., 2017; Zhang et al., 2018), which laid a foundation for our study to explore how to apply policy measures to transform the externality of pesticide packaging waste recycling into internality.

China has been the largest pesticide user and consumer in the world over several decades, with nearly 1.3 million tons of pesticide consumption in 2020 (National Bureau of Statistics of China, 2021), and applies between 1.5 and 4.0 times more pesticides per hectare than the global average (Zhang et al., 2015). At the same time, China consumes more than 3.5 billion pesticide packaging materials every year. With the proposal of ecological civilization, the Chinese government pays more and more attention to the ecological environment, which is a prominent political issue related to the CPC's mission and a major social problem related to people's livelihood (Xi, 2019). Agricultural environmental pollution is related to the overall plan of ecological civilization (Zhang, 2019). With the maturity and deepening of scientific research on livestock and poultry manure, agricultural straw, and agricultural film, and the strict implementation of management policies, traditional agricultural non-point source pollution has been treated accordingly (Dai and Dong, 2014; Cao et al., 2020; Wang et al., 2020). Pesticide packaging waste is becoming the focus of agricultural and rural pollution control. China has issued a series of policies for recycling of pesticide packaging waste, and some provinces also have made some explorations in the recycling of pesticide packaging waste (Jin et al., 2018), especially the Soil Pollution Prevention and Control Law of the People's Republic of China, which was officially implemented on 1 January 2019, stipulates that producers, sellers, and users of agricultural inputs shall timely recycle the packaging waste and agricultural film of farming inputs such as pesticides and fertilizers, and hand over the pesticide packaging waste to particular institutions or organizations for bio-safety disposal. However, so far, China has not established a nationwide pesticide packaging waste recycling system, and there is a lack of unified management regulations or technical guidelines for the recycling of pesticide packaging waste (Wei and Du, 2018).

Jiangsu Province is an important agricultural production base in China, which is located in the middle and lower reaches of the Yangtze River and the transition zone between the north and the south. It has a mild climate, abundant rainfall, concentrated precipitation, significant plum rain, and abundant light and heat. Affected by the mid-latitude sea land facies transition zone and climate transition zone, as well as the westerly zone, subtropical zone, and low latitude easterly zone weather system, meteorological disasters occur frequently, with many types and a wide range of impact, including frequent and repeated diseases and insect pests. In addition, the scattered small-scale agricultural production mode still dominates, and the production scale of vegetables and fruit trees in facility agriculture is still small, mostly between 20 and 30 mu. The frequent occurrence of plant diseases and insect pests demands high requirements for the frequency application of pesticides; thus, the use intensity of pesticides is at a high level in the country, especially there is a large proportion of demand for small packaging pesticides. As one of the five pilot provinces in China, Jiangsu Province has created several intervention policies on pesticide packaging waste recycling, like punish, subsidy and reward, mortgage return, criticism and education, and inspection orders. However, few studies have determined the following questions: whether these policies played an effective role? Are there differences in intervention effects among different policies? Which policy is more feasible and practical? Hence, this study taking Jiangsu as an example, adopted the game theory and propensity score matching (PSM) model to empirically analyze the intervention effect differences and influencing factors of the three typical recovery policies of "punishment," "subsidy reward," and "mortgage return" through the field investigation of farmers in some recovery pilot and non-pilot areas. The results, on the one hand, provide an optimal path in screening, optimizing, and popularizing the recycling strategies of pesticide packaging waste for policy makers; on the other hand, they offer a reference for evaluation on the effect of policy implementation.

2 THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

2.1 Negative Externalities of Pesticide Packaging Waste

The negative externality of pesticide packaging waste is reflected in both the subject of recycling responsibility and other residents. When *Farmer A* willingly discards pesticide packaging waste, it results in water and soil pollution. A negative externality will damage agricultural product safety and human health and bring welfare loss to *Farmer B*. In other words, U_B (the utility of *Farmer B*) is a function of *Farmer B's* consumption (X_1, X_2, X_3. . .) and U_A (the behavioral utility of *Farmer A*). It is necessary to internalize the negative externality of pesticide packaging waste pollution caused by *Farmer A* through a punish or tax system.

$$U_B = g \cdot (X_1, X_2, X_3......, U_A).$$

On the contrary, pesticide packaging waste recycling is typical of positive externalities. Still, the beneficiaries of positive externalities are the recyclers themselves, the whole ecosystem, and all residents. The recyclers cannot obtain the revenue equivalent to the positive externalities. Therefore, it's a stretch to demand farmers to recycle pesticide packaging waste. In addition, farmers need to invest additional labor, material, and financial resources in recycling, which will result in a lack of internal motivation for farmers to recycle. Hence, compensation or other incentive systems enable farmers to obtain benefits equivalent to the positive externality of pesticide packaging waste recycling.

2.2 Analysis of Policy Theoretical Mechanism

At present, waste recycling management strategies mainly include incentive and property right exchange. Incentives are divided into positive incentives and negative incentives. Positive incentives are rewards and subsidies, etc., and negative incentives are punishment and education, etc. The advantages of punishment and return management measures are that the financial pressure of local governments is small, but punishment measures are easy to stimulate people's inner tendency to be exploited, resulting in negative emotional (Zorpas et al., 2018). In addition, if effective punishment is to be realized, considerable supervision force is required, the requirements for labor, financial, and resources are relatively high, and the actual implementation is difficult (Zorpas et al., 2017). The premise of the implementation of subsidy measures is that local finance has a certain basic strength. Subsidy measures can positively strengthen waste recycling, management and other behaviors, but subsidy measures need to formulate reasonable subsidy standards, and they need to be subsidized continuously and fairly, otherwise they cannot meet the return expectation of participants, or they cannot get timely subsidies after a certain recycling, which will lead to people's doubts about this system and lose the strengthening effect (Huang et al., 2013; Sun, 2020). The real right exchange is mainly realized by mortgage return. Part of the property (the property corresponding to the waste recycling value) is mortgaged as creditor's rights, and then the mortgagor exchanges the waste real right to return the creditor's rights. The advantage of mortgage return is to set a risk (if the waste cannot be recycled, the mortgaged property cannot be retrieved) to encourage the mortgagor to complete the recycling task on time and with quality, but the operation procedure is more complex.

Game theory, known as the "science of strategy" provides a useful tool to help scientists to understand how decision-makers (players) interact in an interdependent situation called the "game" (Eleftheriadou and Mylopoulos, 2008). In this theory, each player decides to optimize their own interests (returns), taking into account that the responses made by other players which may affect the actual results (Madani, 2010). Compared with quantitative simulation and optimal resource management model, the advantage of the game theory is to consider various details of the problem and estimate the possible solutions without quantitative information about benefits (Barati et al., 2021). The mixed strategy game theory is a theory that studies multi-person decision-making. It is not like the pure strategy game theory, and randomly selects a strategy with a certain probability distribution under the given information, which is closer to reality. In this game theory, Nash equilibrium is often used to analyze the outcome of the strategic interaction of several decision-makers (Limaei, 2010).

In this study, there was an interest conflict between farmers' pesticide packaging waste recycling behavior and government incentive behavior. Therefore, it is feasible to analyze farmers' and government's strategies in the behavior of pesticide packaging waste recycling based on game theory. This article did not take the mixed policy scenario into account to clearly compare the utility differences of the three policies. Under the three separate policy scenarios, it constructed the game analysis framework of a mixed strategy between the government and farmers. The game analysis assumed that the government and farmers could fully understand each other's strategic behavior and revenue function, that is, the information of both sides of the game was entirely open to each other.

2.2.1 Theoretical Mechanism of the Punish Policy

Punish policy required the government to impose a fine on farmers who, according to a certain standard, failed to recycle pesticide packaging waste. The punish policy's motivation was to increase the cost or expense of farmers who discard pesticide packaging waste at will, reduce farmers' revenue in disguise, and internalize negative externalities.

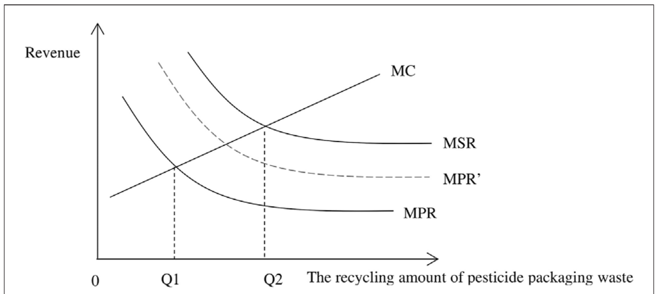

FIGURE 1 | Influence of the punish policy on the recycling level of pesticide packaging waste.

Punitive policies have positive external effects on the recycling of pesticide packaging waste. As shown in **Figure 1**, MPR and MSR represented the individual marginal income and social marginal income of pesticide packaging waste recycling, respectively, and MC represented the marginal cost. The horizontal axis represented the recycling amount of pesticide packaging waste. On the principle of maximizing personal income, farmers determined the recycling amount of waste as Q1 based on the principle of maximizing personal income. However, due to the existence of environmental benefits (i.e., the positive externality of recycling), the social marginal benefits were greater than the individual marginal benefits (MSR > MPR), and the equilibrium point of the recycling amount for maximizing social benefits is located in Q2, and Q1 is less than Q2. To reduce the penalty caused by not recycling packaging waste, farmers often increased the recycling amount. Thus, the curve below representing personal marginal income shifted from MPR to MPR' and gradually move closer to MSR, and the equilibrium amount of pesticide packaging waste recycled by farmers will return to the socially optimal level Q2.

Under the fining strategy implemented by the government, it was assumed that the government supervision cost was C_1 and the fine was F. If farmers do not recycle pesticide packaging waste, the reputation loss of being accused or complained was $-R_2$, and the probability of being supervised and fined was λ_1, farmers' revenue and cost of recycling waste was S_1 and C_2, respectively, and the probability of being wrongly fined due to other accidental reasons was λ_0. Under the government's not fining strategy, waste was discarded at will, and villagers were dissatisfied and complained, thus the loss of government reputation was $-R_1$. It was further assumed that the probability of government fining and not fining was q_1 and $1-q_1$, respectively, if the recycling probability of farmers was p_1 and the probability of not recycling was $1-p_1$. The game revenue matrix under complete information is given below:

When figuring out the Nash equilibrium of the mixed strategy, to maximize the utility, one party should have equal revenue regardless of the other party's strategy, that is:

When the government chooses the pure strategy of "fining," the expected utility of farmers is:

$$U_{f1}{}^{+} = p_1(-C_2 + S_1 - \lambda_0 F) + (1 - p_1)(-R_2 - \lambda_1 F). \quad (1)$$

When the government chooses the pure strategy of "not fining," the expected utility of farmers is:

$$U_{f1}{}^{-} = p_1(-C_2 + S_1) + (1 - p_1)(-R_2). \quad (2)$$

If $U^{+}_{f1} = U^{-}_{f1}$, the expected utility of farmers was not affected by the change of the government strategy. At this time, the equilibrium of farmers' recycling probability can be obtained as follows:

$$p_1{}^{*} = \frac{\lambda_1}{\lambda_1 - \lambda_0} = 1 + \frac{\lambda_0}{\lambda_1 - \lambda_0}. \quad (3)$$

The equilibrium of expected utility of farmers can be obtained by substitution of p_1*:

$$U_{f1}{}^{*} = \frac{\lambda_1 F(-C_2 + S_1) + \lambda_0 F{*}R_2}{\lambda_1 F - \lambda_0 F} = \frac{\lambda_1(-C_2 + S_1) + \lambda_0 R_2}{\lambda_1 - \lambda_0}. \quad (4)$$

Similarly, if the government expects utility $U^{+}_{g1} = U^{-}_{g1}$, it is not affected by the change of the farmers' strategy, that is, the equilibrium of the government fining probability is:

$$q_1(\lambda_0 \mathrm{F} - C_1) + (1 - q_1){*}0 = q_1(\lambda_1 \mathrm{F} - C_1) + (1 - q_1)(-R_1),$$
$$q_1{}^{*} = \frac{R_1}{(\lambda_1 - \lambda_0)F + R_1}. \quad (5)$$

The equilibrium of expected utility of the government can be obtained by substitution of q_1*:

$$U_{g1}{}^{*} = \frac{R_1\lambda_0 \mathrm{F} - R_1 C_1}{\lambda_1 F + R_1 - \lambda_0 F}. \quad (6)$$

When the recycling probability of farmers was p_1* and the probability of government fining was q_1*, the game between farmers and the government ceases to achieve a strategic equilibrium. In the mixed strategy game, one party's strategy choice was determined by the other party's strategy choice probability and revenue function. If the probability of government fining $q_1 > q_1$*, the revenue functions of farmers' recycling and not recycling are compared. If $S_1 + R_2 + (\lambda_1 - \lambda_0)\, F > C_2$, λ_0 can be regarded as infinitesimal, meaning, under the condition of farmers' pesticide packaging waste, when the sum of the revenue, reputation growth, and opportunity cost of being fined, recycling was more significant than the cost. Here, farmers' best choice was to recycle; otherwise, farmers should choose not to recycle. Therefore, when farmers do not recycle, the higher the probability of being punished by supervision (λ_1), the amount of fine (F), the recycling revenue (S_1), and the reputation growth (R_2) were, the lower the risk of being wrongly fined (λ_0) was when recycling, the smaller the value of (q_1*) was, the greater the possibility of the actual fining probability of the government being $q_1 > q_1$*, and more farmers tended to choose to recycle.

However, in some cases, the high cost of supervision (C_1) may result in the reduction of the government's punish. The possibility (λ_1) of being supervised and fined decreases when farmers do not recycle. Therefore, it is easy for farmers to have the fluke mind of "even if they discard the waste at will, they will not be found and punished." As a result, the opportunistic behavior of discarding waste into other people's fields will occur. Consequently, the intervention effect of the punish policy on recycling pesticide packaging waste is greatly weakened.

2.2.2 Theoretical Mechanism of the Subsidy and Reward Policy

It was assumed that the government subsidizes the farmers according to the quantity and specifications of pesticide packaging waste recycled by farmers. The essence of the subsidy was a "negative fine," so the subsidy and reward policy and punish policy had the exact intervention mechanism, which was equivalent to the direct upward movement of MPR (the individual marginal income curve) in **Figure 1**. When the government was under the subsidy strategy, the subsidy standard was S_2. As there are certain thresholds and requirements for subsidy distribution, the probability of farmers receiving subsidies after recycling was set at λ_2, and the probability of farmers without recycling receiving subsidies by speculation (such as recycling other packaging materials) was λ_{22}. The enthusiasm of farmers participating under the subsidy and reward policy measures was the opposite of the punish policy. Hence, its implementation cost (C_3) was lower than the supervision cost of the punish policy. While other behavior strategies were consistent with those of the punish policy. Assuming that the government does not subsidize the farmers, the reputation loss caused by farmers' failure to recycle packaging waste was R_1, the cost of farmers' recycling waste was C_2, the income was S_1, and the reputation loss of farmers who did not recycle the complaints was R_2.

It was assumed that the probability of the government adopting subsidy policy was q_2 and that of not adopting the subsidy policy was $1 - q_2$ and the probability of farmers recycling pesticide packaging waste was p_2 and that of not recycling was $1 - p_2$. The game revenue matrix under complete information is constructed, as follows, in **Tables 1**, **2**:

Nash equilibrium of the farmers' mixed strategy is:

$$p_2(-C_2 + S_1 + \lambda_2 S_2) + (1 - p_2)(-R_2 + \lambda_{22} S_2) =$$
$$p_2(-C_2 + S_1) + (1 - p_2)(-R_2) \quad (7)$$
$$p_2{}^{*} = \frac{\lambda_{22}}{\lambda_{22} - \lambda_2}.$$

The equilibrium of expected utility of farmers can be obtained by substitution of p_2*:

$$U_{f2}{}^{*} = \frac{\lambda_{22}(-C_2 + S_1) + \lambda_2 R_2}{\lambda_{22} - \lambda_2}. \quad (8)$$

Nash equilibrium of the mixed strategy of the government is:

$$q_2(-C_3 - \lambda_2 S_2) + (1 - q_2){*}0 = q_2(-C_3 - \lambda_{22} S_2) + (1 - q_2)(-R_1),$$
$$q_2{}^{*} = \frac{R_1}{R_1 + (\lambda_2 - \lambda_{22})S_2}. \quad (9)$$

The equilibrium of expected utility of the government can be obtained by substitution of q_2*:

TABLE 1 | Game revenue matrix between farmers and government under the intervention mechanism of punish.

		Government	
		Fining q_1	**Not fining $1 - q_1$**
Farmers	Recycling p_1	$-C_2 + S_1 - \lambda_0 F, \lambda_0 F - C_1$	$-C_2 + S_1, 0$
	Not recycling 1-p_1	$-R_2 - \lambda_1 F, \lambda_1 F - C_1$	$-R_2, -R_1$

TABLE 2 | Game revenue matrix between farmers and government under the intervention mechanism of subsidy and reward.

		Government	
		Subsidy and reward q_2	**Without subsidy and reward $1 - q_2$**
Farmers	Recycling p_2	$-C_2 + S_1 + \lambda_2 S_2, -C_3 - \lambda_2 S_2$	$-C_2 + S_1, 0$
	Not recycling 1-p_2	$-R_2 + \lambda_{22} S_2, -C_3 - \lambda_{22} S_2$	$-R_2, -R_1$

$$U_{g2}{}^{*} = \frac{-R_1 C_3 - R_1 \lambda_2 S_2}{R_1 - \lambda_{22} S_2 + \lambda_2 S_2}. \tag{10}$$

When the recycling probability of farmers was $p_2{}^*$ or $q_2{}^*$, the game between farmers and the government ceases to achieve a strategic equilibrium. When the probability of government subsidy was $q_2 > q_2{}^*$, the revenue functions of farmers who recycled and didn't recycle were compared. If $S_1 + R_2 + (\lambda_2 - \lambda_{22}) S_2 > C_2$, and λ_{22} was regarded as close to infinitesimal, it meant that the sum of revenue, reputation growth, and subsidy obtained by farmers' behavior of pesticide packaging waste recycling was more significant than the recycling cost, farmers' optimal choice was recycling. As shown in **Eq. 9**, when the farmers recycle packaging waste, the higher the λ_2 (the probability of obtaining the subsidy), S_2 (the subsidy standard of subsidies), S_1 (the income after recycling), and R_2 (reputation growth obtained by recycling) will be. When the farmers did not recycle packaging waste, the smaller the λ_{22} (the probability of obtaining speculative subsidies) would be, and thus, the smaller the $q_2{}^*$ would be. The greater the probability of actual government subsidies to be $q_2 > q_2{}^*$ was, the more the farmers tend to recycle.

In reality, due to the restriction of financial funds and the limited scope and intensity of subsidies, the government may reduce S_2 (the subsidy standard) or λ_2 (the probability of farmers receiving subsidies after recycling). When the expected amount of subsidies was not enough to compensate farmers for the labor cost, time cost, and transaction cost of recycling pesticide packaging waste, the influence of the subsidy and reward policy in stimulating farmers' recycling enthusiasm would be slightly insufficient.

2.2.3 Theoretical Mechanism of the Mortgage Return Policy

According to the aforementioned analysis, it can be seen that the punish or subsidy and reward system may fail, and some regions tried to replace it with the mortgage return policy. Mortgage return required the behavioral subject to pay a certain fee (i.e., deposit) in advance for the potential damage. If the potential damage does not occur, the payment will be returned. Precisely, under the guidance of the local government, pesticide packaging waste recycling points were set up in each agricultural material distribution store, and the mortgage amount can offset part of the pesticide price. The farmers pay it together when purchasing pesticides. When the farmers buy pesticides next time and return the previous pesticide packaging waste to the store, this part of the mortgage will be refunded. The incentive mechanism of such policies lies in the fact that the mortgage can be returned only when the farmers complete the specified recycling of pesticide packaging waste. Based on the standard calculation of 0.1 yuan/piece of bagged pesticide with the specification of ≦10 g/10 ml or bottled pesticide with the specification of ≦100 ml, assuming that farmers plant rice and wheat for two seasons, generally, the pesticide should be used in wheat at least three times per season (including two times of herbicides: one time for soil sealing, the other for stem and leaf treatment, and fungicide for one single time). Pesticide should be used in rice at least five to six times per season (including two times of herbicides: one time for soil sealing, the other of stem and leaf treatment, as well as three to four times of fungicides and pesticides). On average, about 90 bottles (bags) of pesticides and additives (pesticide additives include dissolution-aided, sedimentation-aided, penetration-aided, and other types) are used per hectare each time. Hence, farmers need to pay a mortgage of about 72–81 yuan/hm^2 every year, which means that if the packaging waste is not recycled, it can be regarded as a loss of 72–81 yuan/hm^2 of crops. If recycled, farmers need to pay extra labor costs for centralized placement and the carriage of packaging wastes after use, since the farmers return the last packaging waste at the same time when purchasing pesticides next time, there is no additional transportation cost. In addition, due to the wide-existed monopoly or oligopoly in the distribution market of agricultural materials in the villages, towns, and counties in

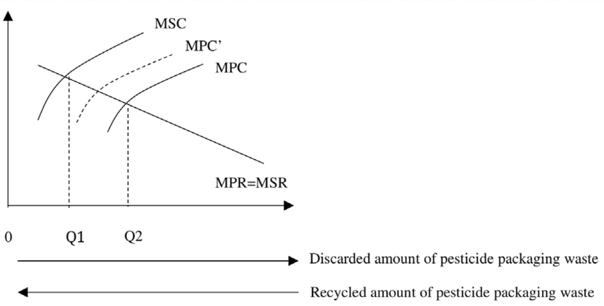

FIGURE 2 | Influence of the mortgage return policy on the recycling level of pesticide packaging waste.

China, the local government only needs to negotiate with a few monopoly dealers to implement the mortgage return policy. The local farmers can only buy pesticides at a price including a mortgage, which provides necessary conditions for the smooth implementation of the policy. Therefore, to control the possible impact of "market monopoly," including complete monopoly and oligopoly, on policy intervention effect, all sample areas selected in the empirical test below were supply markets monopolized by agricultural products.

As shown in **Figure 2**, the horizontal axis represented the discarded and recovered amount of pesticide packaging waste from left to right. MPC was the marginal private cost, meaning the cost of discarding (or recycling) waste. MSC was social marginal cost equal to marginal private cost plus environmental damage cost. When there was no mortgage, Q2 (the equilibrium point) of personal waste disposal was greater than Q1, meaning Q2 (the recycled amount) was less than Q1. To compensate for negative externalities, paying a mortgage was equivalent to the marginal private cost moving from MPC to MPC′. When the mortgage can compensate for the gap between marginal private and social marginal costs, the equilibrium point of discarded amount (recycled amount) moves from Q2 to Q1. Mortgage return gave farmers an obvious incentive to adopt recycling behavior because it can enable them to withdraw environmental costs again. Once the waste was discarded at will, the environmental cost must be paid in advance.

It was assumed that the probability of farmers recovering pesticide packaging waste to obtain the return of the mortgage was λ_3, the deposit standard was S_3, and the government implementation cost was C_4. The probability of receiving the return of the mortgage by speculation when not recycling the packaging waste was λ_{33}, with other conditions utterly consistent with the first two policies. Supposing that the probability of the government adopting the mortgage return policy was q_3, the probability of not adopting was q_3, farmers' recycling was p_3, and not recycling was 1-p_3. The game revenue matrix under complete information is shown in **Table 3**.

As mentioned previously, Nash equilibrium of the farmers' mixed strategy is:

$$p_3(-C_2 - S_3 + \lambda_3 S_3 + S_1) + (1 - p_3)(-R_2 - S_3 + \lambda_{33} S_3) = p_3(-C_2 + S_1) + (1 - p_3)(-R_2),\ p_3^* = \frac{\lambda_{33}}{\lambda_{33} - \lambda_3}. \tag{11}$$

The equilibrium of expected utility of farmers can be obtained by substitution of p_3*:

$$U_{f3}^* = \frac{(\lambda_{33} - 1)(C_2\text{-}S_1) + R_2(1 - \lambda_3)}{\lambda_3 - \lambda_{33}}. \tag{12}$$

Nash equilibrium of the mixed strategy of the government is:

$$\begin{aligned} &q_3(-C_4 + S_3 - \lambda_3 S_3) + (1 - q_3)*0 \\ &= q_3(-C_4 + S_3 - \lambda_{33} S_3) + (1 - q_3)(-R_1), \\ &q_3^* = \frac{R_1}{R_1 + S_3(\lambda_3 - \lambda_{33})}. \end{aligned} \tag{13}$$

The equilibrium of expected utility of the government can be obtained by substitution of q_3*:

$$U_{g3}^* = \frac{-R_1 C_4 + R_1 S_3 - R_1 \lambda_3 S_3}{R_1 - \lambda_{33} S_3 + \lambda_3 S_3}. \tag{14}$$

p_3* and q_3* were the probability Nash equilibrium points for the government to implement the mortgage return policy and farmers to recycle pesticide packaging waste. When it was on the Nash equilibrium solution, the government and farmers stop the game and realize the mixed strategy Nash equilibrium solution. When $q_3 > q_3$*, the revenue functions of farmers recycling or not recycling are compared, and λ_{33} was regarded as close to infinitesimal, which meant that when the sum of the income, reputation growth, and mortgage amount obtained by farmers from recycling pesticide packaging waste was greater than the farmers' recycling cost, the farmers' best choice was recycling, otherwise not recycling. Therefore, the higher the S_3 (the mortgage amount), λ_3 (the probability that farmers got the mortgage return after recycling), S_1 (the income), and R_2 (reputation growth) after recycling were, the lower the λ_{33} (the probability of obtaining speculative deposit return when not recycling) and the value of q_3* were, and thus, the greater the

TABLE 3 | Game revenue matrix between farmers and government under the intervention mechanism of mortgage return.

		Government	
		Mortgage return q_3	**Non-mortgage return 1 – q_3**
Farmers	Recycling p_3	$-C_2 - S_3 + \lambda_3 S_3 + S_1$, $-C_4 + S_3 - \lambda_3 S_3$	$-C_2 + S_1$, 0
	Not recycling 1 – p_3	$-R_2 - S_3 + \lambda_{33} S_3$, $C_4 + S_3 - \lambda_{33} S_3$	$-R_2$, $-R_1$

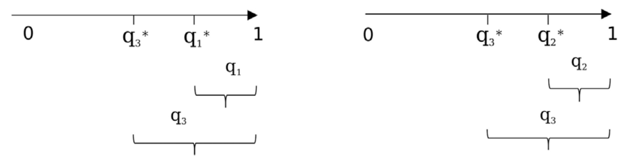

FIGURE 3 | Interval relationship of implementation probability of three policies which was greater than the equilibrium solution.

probability of the government adopting the mortgage return strategy to be $q_3 > q_3^*$, the more the farmers preferred to choose to recycle.

Compared with punish, subsidy, and reward policies, the mortgage return policy requires very low government supervision cost and public financial investment. Once effectively implemented, the reward mechanism can operate automatically. Therefore, for the cost of government supervision, $C_4 < C_1$, and $C_4 < C_3$, it can be inferred that the relationship among λ_1 (the probability of being fined for farmers who did not recycle), λ_2 (the probability of receiving subsidies after recycling), and λ_3 (the probability of receiving mortgage return after recycling) was as follows: $\lambda_2 > \lambda_1$ and $\lambda_3 > \lambda_1$. Therefore, from **Eqs 5**, **9**, and **13**, it can be found that $q_3^* < q_1^*$ and $q_3^* < q_2^*$.

According to the aforementioned mixed strategy equilibrium analysis, we assumed that the government chooses to implement three policies, respectively, and satisfies the conditions that $S_1 + R_2 + (\lambda_1 — \lambda_0) F > C_2$, $S_1 + R_2 + (\lambda_2 — \lambda_{22}) S_2 > C_2$, and $S_1 + R_2 + (\lambda_3 — \lambda_{33}) S_3 > C_2$. Then, when the probability of the government implementing the policy was greater than q^* (the equilibrium solution), farmers will choose to recycle. It can be seen from **Figure 3** that the value ranged satisfying $q_3 > q_3^*$ was the largest. In other words, under the mortgage return policy, farmers were most likely to choose to adopt the recycling strategy.

Based on the aforementioned analysis, the following hypotheses can be drawn:

H1: When the sum of the income, reputation, and fine/subsidy/mortgage amount of farmers who recycle pesticide packaging waste was greater than their recycling cost, the three policies can improve the probability of farmers' recycling of pesticide packaging waste.

H2: The intervention effect of the mortgage return policy on farmers' recycling of pesticide packaging waste was greater than that of the punish policy and subsidy and reward policy.

3 METHODOLOGY

3.1 PSM Model

The best way to evaluate whether a policy impacts farmers' recycling behavior is to compare the changes in farmers' recycling behavior with and without the intervention of the policy. However, the ideal random test data cannot be obtained, so it is necessary to construct a counterfactual causal state. Thus, the propensity score matching (PSM) was used to analyze whether the three policies of punish, reward, and mortgage can encourage farmers to recycle pesticide packaging waste (D'Agostino, 1998).

Therefore, we use the logit model to estimate farmers' probability under the three types of policy intervention. The model is as follows:

$$\mathrm{P}_{j_n}(X_m) = prob\left(\left(j_n = 1|X_m\right) = \frac{\exp\left(\beta X_m\right)}{1 + \exp\left(\beta X_m\right)} \quad (\mathrm{n} = 1, 2, 3), \tag{15}$$

where $\mathrm{P}_{j_n}(X_m)$ represented the probability of farmers being intervened by the n-type of the policy and j was the treatment variable. It should be made clear that the meaning of "farmers subject to policy intervention" meant that farmers were within the policy's coverage and had a perception and understanding of it. In other words, farmers who felt indifferent to the policy would not change their behavior whether they were in the policy pilot area or not. Therefore, it was inaccurate only to take "whether farmers were within the scope of policy implementation" as the treatment and identification variable of intervention effect, which echoed and corresponded with the hypothesis of "complete information of both sides of the game" in the aforementioned theoretical mechanism analysis. If the corresponding policies were implemented in the region and farmers perceive them, the value j_n was 1; otherwise, it was 0, and X_m was a covariate (matching variable). After obtaining the propensity score, the average intervention effect of three types of policies on whether farmers scientifically recycle pesticide packaging waste was obtained through appropriate matching methods:

$$ATT_n = E\left\{E\left[Y_{1i}\middle|\mathrm{j} = 1, \mathrm{P}_{j_n}(X_m)\right] - E\left[Y_{0i}\middle|\mathrm{j} = 0, \mathrm{P}_{j_n}(X_m)\right]\right\} \quad (\mathrm{n} = 1, 2, 3), \tag{16}$$

where Y_{1i} and Y_{0i} represented the behavior results of the same farmer in the treatment group and the control group, respectively.

3.2 Variable Selection

This article selected the ability of farmers to scientifically recycle pesticide packaging waste as the dependent variable. Considering that the way farmers deal with pesticide packaging waste, in reality, was not fixed, this article took the question "the treatment behavior of pesticide packaging after the last spraying" as the measurement standard, including 1) placing pesticide packaging in special recycling equipment or places, 2) taking pesticide packaging home, 3) tossing pesticide packaging to the roadside dump/garbage can/dustbin, and 4) throwing pesticide packaging to the field or ridge. Suppose the farmer chooses 1), and places it in the pesticide packaging waste recycling bin (bins). In that case, it was judged that the farmer had implemented the scientific recycling behavior. It was assumed that the farmer has not implemented the scientific recycling behavior in other cases.

Since some farmers are insensitive to the outside information, being informed of the policy does not mean that all farmers can

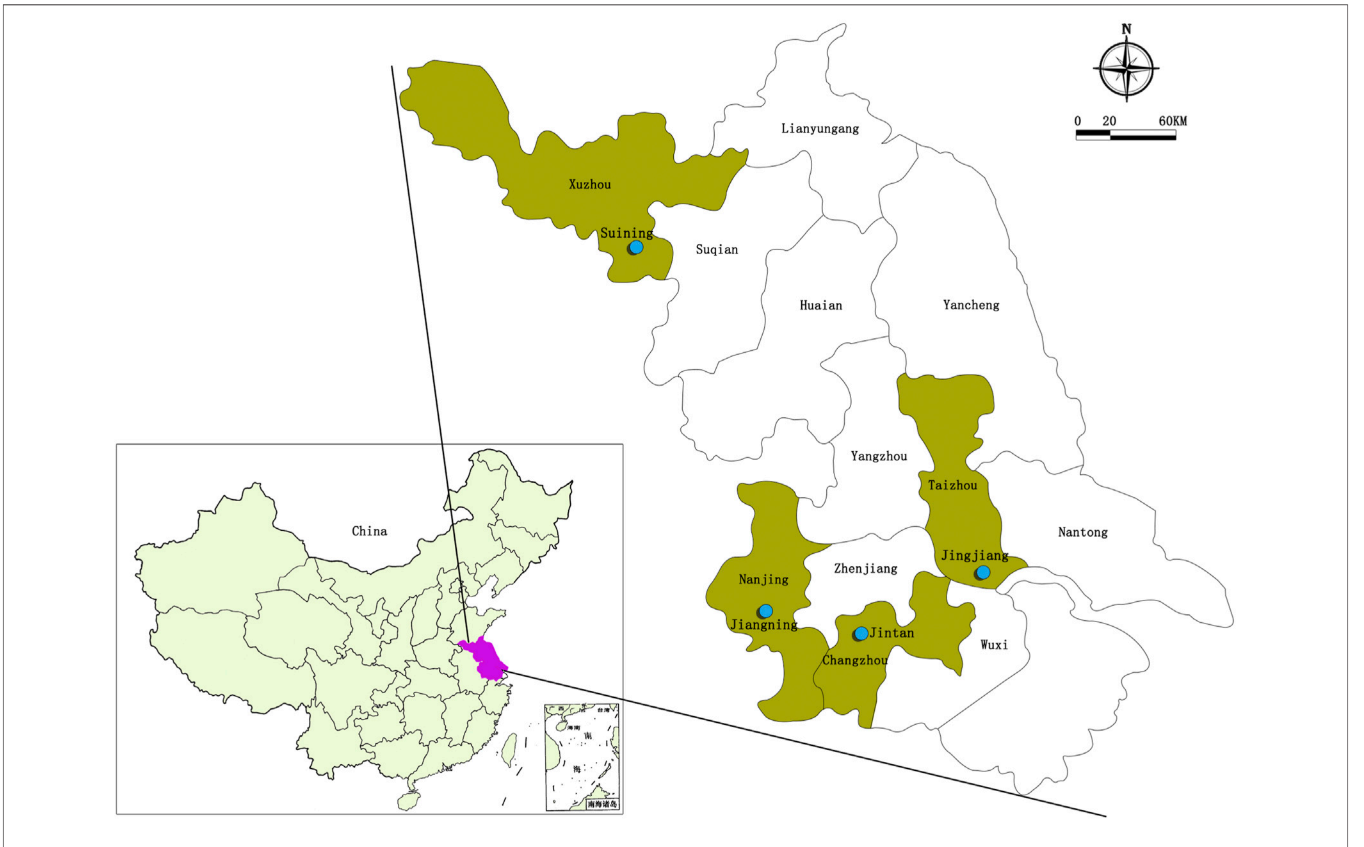

FIGURE 4 | Map of four pilot cities selected in this study.

recognize the existence and content of the policy and make conscious or behavioral responses. Therefore, "whether farmers are informed of the punish policy and have a perception of the policy," "whether farmers are informed of the subsidy and reward policy and have a perception of the policy," and "whether farmers are informed of the mortgage return policy and have a perception of the policy" were taken as three treatment variables: j_1, j_2, and j_3.

According to the treatment variables, the selection of covariates needed to take two factors into account: first, the farmers' knowledge of the policy, that is, the administrative area where the farmers were located, according to the actual investigation, generally promotes the pilot policy in towns; the second was whether farmers perceive and understand the policy, which was related to the individual characteristics of farmers, including the age, gender, education level, planting area, the proportion of agricultural income in household agricultural income, and the cognition of hazard caused by pesticide packaging waste. In addition, due to only four female respondents in the sample whose proportion was too small, the gender factor was not considered temporarily.

3.3 Data Source

The data used in this study were obtained from the survey of farmers in major grain-producing counties (cities and districts) in northern, central, and southern Jiangsu Province from August to September 2019. The questionnaire included the essential characteristics of farmers, such as production characteristics, recycling behavior of pesticide packaging waste, and cognition of agricultural non-point source pollution. According to the geographical distribution of the administrative regions of Jiangsu Province and the pilot situation of pesticide packaging waste recycling, four cities (Jingjiang City, Jintan District of Changzhou City, Jiangning District of Nanjing City, and Suining Country of Xuzhou City) were selected as the research areas, and the pilot and non-pilot towns with similar production conditions were chosen from each county (city, district) (**Figure 4**). The distribution of specific sample points is shown in **Table 4**. According to the actual scale distribution, 20–40 farmers were selected from each town. A total of 585 effective samples were taken, of which 65 were provided with pesticides by the flight prevention organization. After the operation, the packaging waste was taken away without the need for farmers to recycle. The remaining farmers were self-defended and autonomous, or organizations did not provide medicine, and these farmers needed to purchase and recycle pesticides by themselves. To control the influence of the degree of competition in the sales market of agricultural materials on the policy effect, this study selected the areas where the agricultural materials sale in villages and towns were of monopoly or oligopoly, and the final sample consisted of 452 households.

TABLE 4 | Distribution of samples.

Area	County (city, district)	Towns for research	The type of intervention policies	Available sample
Southern Jiangsu	Jiangning District of Nanjing City	Lukou Town	Punish	31
		Hengxi Town	Subsidy	19
		Chunhua Town	None	28
		Hushu Town	None	23
	Jintan District of Changzhou City	Zhulin Town	Subsidy	17
		Xuebu Town	None	27
		Zhiqian Town	None	25
Central Jiangsu	Jingjiang City	Xieqiao Town	Subsidy	24
		Shengci Town	Subsidy	20
		Xilai Town	Subsidy	21
		Xinqiao Town	None	22
		Gushan Town	None	20
Northern Jiangsu	Suining Country of Xuzhou City	Gaozuo Town	Punish	33
		Suihe Town	Punish	28
		Qing'an Town	Mortgage return	32
		Guanshan Town	None	25
		Lingcheng Town	None	29
		Taoyuan Town	None	28

3.4 Descriptive Statistics of the Sample

3.4.1 Sample Area and Policy Description

The recycling of pesticide packaging waste was in the early stage at present, and only some pilot counties and towns had implemented relevant policies. In the sample, the areas implementing the punish policy were mainly distributed in Lukou Town (Jiangning), Gaozuo Town (Suining), and Suihe Town (Suining). A total of 92 households have been investigated. In Suihe Town (Suining), farmers were fined according to the polluted area. Once the pesticide packaging waste was found and discarded in the field, the land managers would be fined 450 yuan/hm^2, and the others would be fined according to the number of packaging waste items, ranging from 0.1 to 0.5 yuan per bottle. The regions implementing the subsidy and reward policy were distributed in Xieqiao Town (Jingjiang), Shengci Town (Jingjiang), Xilai Town (Jingjiang), Zhulin Town (Jintan), and Hengxi Town (Jiangning), where there were 101 effective samples. The waste recycling policy was promoted with the zero difference distribution of pesticides. Waste pesticide bottles and pesticide bags from the zero difference distribution were subsidized by 0.3 yuan and 0.1 yuan, respectively. The mortgage return policy was implemented in Qing'an Town (Suining), with 32 valid samples. The government had set up recycling equipment at fixed agricultural materials sales points, with the agricultural materials dealers collecting the mortgage. The charging standard for bags with ≦10 g/10 ml or bottles with a specification of ≤100 ml was 0.1 yuan/bottle (bag), which gradually increases according to the mortgage standard of different packaging specification levels. The mortgage will be returned to farmers after waste recycling. The local governments of villages and towns where the remaining 227 households live only conducted criticism and education or did not implement any recycling policy.

3.4.2 Description of Farmers' Characteristics

According to the treatment variable setting mentioned previously, among the three groups of policy intervention, the farmers in the "mortgage return" group had the highest perception of the policy, over 90%. This was followed by the "subsidy and reward" group, with farmers' perception reaching 66.49%. The "punish" group was the lowest, with only 45.70% of the farmers who were aware of the local implementation of the punish policy. Compared with areas without policies, the four groups of farmers had no significant differences in education level, number of the family agricultural labor force, participation in production organizations, and other characteristics (**Table 5**). Due to the high level of non-agricultural employment in Lukou Town, Jiangning, the proportion of farmers' agricultural income and land management scale in the punish group was significantly lower than those in other countries' groups. Generally, for pesticides with a large standard dosage used per hectare, manufacturers often produce large barrels of 1, 2, 5, and 10 L, and other specifications for large-scale households or farms. Theoretically, the higher the scale level is, the higher the proportion of large-scale packaged pesticides is and the lower the difficulty of recycling is. However, in reality, considering the matches between the pesticide dosage per hectare, the dispensing dilution ratio, and the capacity of various common dispensing barrels. A variety of small packaging pesticides designed by the manufacturer enable farmers to pour a package (bottle) of pesticides to exactly match a barrel of water for dilution, without the need to use measuring cups (barrels) for dispensing, which was convenient and time-saving. Therefore, in addition to small-scale peasants, medium-sized farmers with self-defense and autonomy tended to choose small packaging pesticides. According to the

TABLE 5 | Basic characteristics of farmers in different policy application areas.

	Punish	Subsidy or reward	Mortgage return	None
Proportion of samples (%)	20.35	22.34	7.08	50.22
The proportion of farmers who clearly perceive the policy (%)	45.70	66.39	90.61	–
The average level of education (year)	8.23	8.46	8.63	8.02
Average household agricultural labor force (person)	2.06	2.23	2.53	2.10
The proportion of average agricultural income to total household income (%)	57.14	81.12	96.40	93.44
Average management area of farmlands (hm^2)	11.01	17.84	13.74	14.25
The proportion of farmers with more than 5.33 hm^2 and adopting efficient plant protection machinery socialization service (%)	47.83	55.44	50.00	61.67

TABLE 6 | Farmers' awareness and recycling behavior of pesticide packaging waste in areas with different policy application areas.

	Punish	Subsidy or reward	Mortgage return	None
Understanding of relevant recycling provisions of the *Soil Pollution Prevention and Control Law of the People's Republic of China* (%)				
I do not know	14.13	6.93	6.25	21.10
I know, but I'm not sure	82.61	68.32	75.00	78.02
I know them well and am very clear about the subject of recycling responsibility	3.26	25.74	18.75	0.88
Awareness of environmental hazards caused by pesticide packaging waste (%)				
Pesticide packaging waste residues are toxic and harmful to the environment	59.78	78.22	84.38	65.20
Harmful, but has little impact	35.87	17.82	12.50	23.30
Harmless	4.38	3.96	3.13	10.62
Treatment of pesticide packaging waste after the last spraying (%)				
Place it in specialized recycling equipment or places	18.48	44.55	68.75	8.41
Take it home and sell it to waste collectors	4.35	29.70	9.38	32.59
Throw it to the roadside dump/garbage can/dustbin	61.96	16.83	18.75	21.10
Throw it to the field or ridge of field	14.24	9.90	3.13	37.89

survey, farmers with a business scale of more than 5.33 hm^2 and adopting efficient plant protection machinery socialization services have a significantly higher probability of using large packaging pesticides than other farmers. As shown in **Table 5**, although the average household size of each group reaches about 13.33 hm^2, only about half of the farmers had a demand of large packaging pesticides.

3.4.3 Farmers' Cognitive Results After Policy Intervention

From the perspective of farmers' cognition and recycling behavior of pesticide packaging waste, the performance of the subsidy and reward group and mortgage return group was significantly better than the other two groups (**Table 6**). The proportion of farmers in all three groups of punish, subsidy and reward, and mortgage return, who had known or known well about the relevant management regulations in the Soil Pollution Prevention and Control Law of the People's Republic of China, has reached more than 78%. Of which, 25.74% of farmers in the subsidy and reward group had known the subject of recycling responsibility, while 21.1% of farmers in the non-policy intervention group did not know at all. Similarly, the subsidy and reward group and mortgage return group also had a higher awareness of the harm caused by pesticide packaging waste to the environment, and there were 78.22–84.38% of farmers who believed that the residual pesticides of pesticide packaging waste were serious to the environment, respectively. According to the regulations, the proportion of farmers in the mortgage return group was the highest, and 68.75% of farmers recycled pesticide packaging waste to special equipment or places. The proportion of the subsidy and reward group and punish group was 44.55–18.48%, respectively, while only 8.41% of farmers in areas without policy implementation participate in recycling.

4 RESULTS AND DISCUSSION

4.1 Matching Balance Test

According to the setting of treatment variables, the samples were divided into the punish treatment group–punish control group, reward treatment group–reward control group, and mortgage treatment group–mortgage control group for propensity score matching, respectively. Due to the limited sample size, the matching method of one-to-one effectively returning to the nearest neighborhood was used for sample matching. The smaller the standardized deviation after matching is, the better the matching effect is. Generally, whether the absolute value of standardized deviation is less than 20% will be checked. In the balance test results, the absolute value of standardized deviation after variable matching was less than 20%, and the matching effect was relatively good. The matching results are shown in **Table 7**.

TABLE 7 | Matching balance test.

Variable		Matched % bias		
		Punish control group	Subsidy control group	Mortgage control group
Regional variables	Whether it belongs to Lukou Town, Gaozuo Town, or Suihe Town	−0.3		
	Whether it belongs to Xieqiao Town, Shengci Town, Xilai Town, Hengxi Town, or Zhulin Town		0.1	
	Whether it belongs to Qing'an Town			0.0
Individual variables	Level of education	1.4	−18.2	8.8
	Age	−3.2	16.7	−2.2
	Pollution awareness of packaging waste	10.0	−3.0	−2.8
	Planting scale	8.1	4.0	−9.1
	Number of the household agricultural labor force	−13.6	4.9	−11.3
	The proportion of average agricultural income to total income	−16.1	−11.4	3.2

TABLE 8 | Average intervention effect of three policies calculated based on the one-to-one nearest-neighbor matching method.

	Intervention group	Control group	ATT value	T value
Punish policy	0.195	0.171	0.024*	1.67
Subsidy and reward policy	0.429	0.102	0.327**	2.38
Mortgage return policy	0.758	0.310	0.448***	3.36

*Note: * indicates* $p < 0.1$, *** indicates* $p < 0.05$, *and **** indicates* $p < 0.01$.

4.2 Intervention Effects of Different Policies on Farmers' Behavior of Pesticide Packaging Waste Recycling

As shown in **Table 8**, the average intervention effects of the three policies were measured by the one-to-one nearest-neighbor matching method. The results showed that the three kinds of policies all had a significant positive impact on the recycling behavior of pesticide packaging waste of farmers who had a perception of policies, which supported Hypothesis 1. This result indicated that farmers gradually realize the harm of pesticide packaging waste, not only the harm of pesticide residues, but also the long-term consequences caused by improper treatment of packaging waste, so they took a positive attitude toward the recycling of pesticide packaging waste. In terms of the degree of impact, the punish policy had a significant impact only at the level of 10%, where the intervention effect was the weakest, the subsidy and reward policy had a considerable impact on the level of 5%. Under the intervention of a single subsidy and reward policy, the probability of farmers recycling pesticide packaging waste increased by 32.7% compared with the one without intervention. The mortgage return policy significantly impacted on the 1% level, where the intervention effect was the best. Under a single policy, the recovery probability of farmers can be increased by 44.8%. Based on these results, Hypothesis 2 was supported.

4.3 Discussion

In terms of empirical researches, many scholars have established various models supplemented by a variety of methods to evaluate the effect of pro-environmental policies, such as Heckman selection model and Poisson model (Song et al., 2020), Driving Force-Pressure-State-Impact-Response model with the entropy method (Qu and Liu, 2017), and Structural equation modeling with the theory of planned behavior (Sarma, 2022). In fact, to accurately evaluate the effect of a policy, the most accurate method is to select a period of time before (t0) and after (t1) the occurrence of the policy, and observe the changes of the experimental group and the control group at the same time. However, due to many studies that were often conducted after policies have been occurred, the data of t0 period were not obtained, and in reality, it is impossible to select two groups of almost homogeneous samples for the coverage and non-coverage of the policy. Therefore, the PSM method is usually used to manually construct a more reasonable treatment group and control group to improve the accuracy of estimation (Wen et al., 2022). In this study, PSM was used to analyze whether the three policies of punishment, reward, and mortgage can promote farmers to recycle pesticide packaging waste, which is reasonable.

From the perspective of public economics, pesticide packaging waste recycling is a typical public activity with positive externalities, and its governance process needs the extensive participation of farmers (Bouma et al., 2008; Lu et al., 2022). However, farmers need extra time and energy to participate in the recycling of pesticide packaging waste, and the benefits brought by recycling, such as beautifying the environment, and reducing pollution, are not exclusive. Therefore, it is necessary to formulate relevant regulatory and compensation policies to transform externality into internality (Xie et al., 2017). In addition, it is difficult for the government to supervise, which is easy to produce "free riding." Therefore, relevant government departments need to issue reward and punishment policies to forcibly restrict farmers' behavior from the outside (Al Zadjali et al., 2013; Brodhagen et al., 2017; Pan et al., 2021), which was consistent with the view of this study. Moreover, Zhao and Zhou, (2021) found that social trust can promote the implementation efficiency of reward and punishment policies.

In this study, the effect of mortgage return policy was better than subsidy and reward. Some researchers indicated that economic compensation had significant positive influence on farmers' pro-environmental behavior (Wang B. et al., 2019; Li et al., 2021; Was et al., 2021). However, since the promotion of the economic subsidy and reward policy on recycling of pesticide packaging waste by farmers' is regulated by many factors, such as recycling price, awareness of pesticide residue risk, social norms, and social trust, multiple factors are needed to work together to optimize the effect of economic subsidies (Trujillo-Barrera et al., 2016; Sharafi et al., 2018; Xu et al., 2021). While the mortgage return policy required farmers to pay environmental costs in advance, in order to obtain the maximum individual marginal cost, farmers always have strong endogenous driving force, thus leading to the fact that the probability of pesticide packaging waste recycling was the highest. The mortgage return policy is often adopted in the waste recycling and recycling industry, such as the recycling of plastic bottles and batteries. By implementing the mortgage return system, the holders of contaminated products can be stimulated to reclaim the mortgage without randomly discarding the potentially polluted waste products into the environmental medium, so as to effectively promote the safe placement and recycling of products (Linderhof et al., 2019; Roca et al., 2022). Thus, this practice of bringing the environmental pollution caused by farmers' behavior into the environmental protection cost in advance also provides a new idea for the formulation and implementation of pro-environmental behavior policies.

Although the intervention effects of different policies regarding pesticide packaging waste recycling in this study were determined, there are still some limitations, which are worthy of further discussion. First, the heterogeneity of farmers, including income difference, education level, environmental awareness, and a series of factors, may lead to their different environmental awareness and then affect their behavioral response to the recycling policy. Second, because the policy implementation is still in the pilot stage, there are few sample areas for this study, which may influence the accuracy of the effect of policy intervention. Therefore, the follow-up research needs to explore further the differences of policies on the intervention mechanisms of distinct subjects and scientifically investigate the differences of policy effects caused by farmers' heterogeneity, to improve the accuracy of policy formulation and implementation.

5 MAIN CONCLUSION AND POLICY IMPLICATION

5.1 Main Conclusion

In this study, 452 farmers in Jiangsu Province were taken as the research sample, and based on the game theory and PSM model, this article empirically analyzed and compared the intervention effects of different policies on farmers' behavior of pesticide packaging waste recycling. The results showed that: 1) the three kinds of approaches of punish, subsidy and reward, and mortgage return all could significantly influence pesticide packaging waste recycling by farmers in the pilot area; 2) different intervention policies had obvious differences on the recycling behavior of pesticide packaging waste of farmers, and among them, the effect of mortgage return policy was the most prominent, with the probability of farmers recycling pesticide packaging waste being 44.8% higher than those without intervention; 3) the intervention of the mortgage return policy was equivalent to charging farmers "the fine under the condition of non-recycling" in advance. The "fine" can only be returned when farmers' recycling behavior occurs, effectively stimulating the enthusiasm for active recycling to reduce interest losses. Thus, it was an incentive system with low government supervision costs and financial pressure and can operate automatically, while the intervention effects of the punish policy and subsidy and reward policy were relatively weak due to high implementation cost, lack of a critical law enforcement system, excessive local financial pressure, and other reasons.

5.2 Policy Implication

Based on the aforementioned analysis and conclusion, putting the uneven quality of farmers into consideration, this study indicated that in areas with more pesticide packaging wastes, the first trial experience of Jiangsu Province can be used for reference. This included establishing supporting policies for implementing the *Soil Pollution Prevention and Control Law of the People's Republic of China*, implementing active intervention, and improving the effectiveness of the rule of law. Therefore, the following suggestions were put forward:

First, improve the administrative supporting rules and regulations related to the recycling of pesticide packaging waste, bring the recycling of pesticide packaging waste into the administrative law enforcement system, and strengthen the guidance and restraint of informal systems such as social norms.

Second, the government can increase financial support, improve the standard of recycling subsidies, strengthen first-line level management and the allocation of human and material resources in areas with strong local financial strength, implement recycling, and improve the effectiveness of law implementation.

Third, the mortgage return recovery system should be actively promoted in areas with a high monopoly in the pesticide distribution market, which can not only improve the recovery efficiency but also reduce the government supervision cost and financial pressure.

Fourth, strengthen the publicity and popularization of government policies and comprehensively improve farmers' attention, perception, and understanding of relevant recycling policy mechanisms, thus continuously and effectively promoting farmers' recycling of pesticide packaging waste.

Finally, we can implement the real name system of pesticide procurement, establish a pesticide packaging waste recovery and treatment and traceability system coordinated by producers, operators, and users, and comprehensively promote the recovery and treatment of pesticide packaging waste.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

NH: data curation, initial version writing, and writing—review and editing; QZ: investigation, methodology, and data analysis; CL: investigation and formal analysis; HS: conceptualization and supervision.

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