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RURAL SOCIOLOGY

Estimating the effects of joining cooperatives on farmers' recycling behaviors of pesticide packaging waste: insights from apple farmers of China

Songqing Li[1,2] **Xuexi Huo**[1*]

[1]College of Economics and Management, Northwest A&F University, 712100, Yangling, China. E-mail: xuexihuo@nwsuaf.edu.cn. [*]Corresponding author.

[2]Business School, Guilin University of Electronic technology, Guilin, 541004, China.

ABSTRACT: The improper disposal of pesticide packaging wastes (PPW) has posed serious harm to the environment, including groundwater and soil pollution and even health concerns to the public. To address the environmental concerns and public health issues, there is a need to recycle the pesticides packaging waste (RPPW). Though small farmers in many developing countries have joined the cooperatives to reduce the production costs and increase the product premium, how these cooperatives improve farmers' RPPW behaviors is still sparse. The current study used data collected from 725 apple farmers in Shaanxi and Gansu provinces of China to explore the phenomenon empirically. Recycling decisions and degree are used to portray the farmers' RPPW behaviors. Firstly, the Logit model was used to analyze the effect of joining cooperatives on farmers' recycling decisions. Further, to address the sample selection bias, the present study employed the propensity score matching (PSM) method for empirical analysis concerning the effect of joining cooperatives on farmers' recycling degree. Results showed that joining cooperatives positively and significantly influences farmers' recycling decisions. If farmers join a cooperative, the probability of the recycling decisions and degree will increase by 20.30% and 27.50%, respectively. Moreover, it is also found that some other factors such as education level, environmental and public health risk perception, peer effect, and relationship network also significantly influence farmers' recycling decisions. Moreover, considering the differences in farmers' gender, age, and educational attainment, the study unveiled the heterogeneous effects of joining cooperatives on farmers' RPPW behaviors. The findings revealed that gender and age variables have noticeable masking effects while education level has a typical threshold effect. The overall findings provided insights for policymakers to emphasize the development of agricultural cooperatives, improve the risk and interest linkage mechanism, and build the RPPW system. These implications are also supportive for policymakers in other developing countries.

Key words: joining cooperatives, apple farmer, logit model, sample self-selection bias, PSM method.

Estimando os efeitos da adesão a cooperativas no comportamento de reciclagem de resíduos de embalagens de pesticidas dos agricultores: dados de produtores de maçã da China

RESUMO: O descarte inadequado de resíduos de embalagens de pesticidas (PPW) tem causado sérios danos ao meio ambiente, incluindo a poluição das águas subterrâneas e do solo e até mesmo problemas de saúde pública. Para abordar as preocupações ambientais e questões de saúde pública, há a necessidade de reciclar os resíduos de embalagens de pesticidas (RPPW). Embora pequenos agricultores, em muitos países em desenvolvimento, tenham se unido às cooperativas para reduzir os custos de produção e aumentar o prêmio do produto, ainda é escassa a forma como essas cooperativas melhoram os comportamentos de RPPW dos agricultores. O estudo atual usou dados coletados de 725 produtores de maçã nas províncias de Shaanxi e Gansu da China para explorar o fenômeno empiricamente. Decisões e grau de reciclagem são usados para retratar os comportamentos de RPPW dos agricultores. Primeiramente, o modelo Logit foi utilizado para analisar o efeito da adesão às cooperativas nas decisões de reciclagem dos agricultores. Além disso, para abordar o viés de seleção da amostra, o presente estudo empregou o método Propensity Score Matching (PSM) para análise empírica sobre o efeito da associação de cooperativas no grau de reciclagem dos agricultores. Os resultados mostraram que a adesão às cooperativas influencia positiva e significativamente as decisões de reciclagem dos agricultores. Se os agricultores aderirem a uma cooperativa, a probabilidade das decisões de reciclagem aumentará em 20,30%, e o grau de reciclagem aumentará em 27,50%. Além disso, também se constata que alguns outros fatores como nível de escolaridade, percepção de risco ambiental e de saúde pública, efeito de pares e rede de relacionamento também influenciam significativamente as decisões de reciclagem dos agricultores. Além disso, considerando as diferenças de gênero, idade e escolaridade dos agricultores, o estudo também revelou os efeitos heterogêneos da adesão às cooperativas sobre os comportamentos de RPPW dos agricultores. Os resultados revelaram que as variáveis de gênero e idade têm efeitos de mascaramento perceptíveis, enquanto o nível de escolaridade tem um efeito limiar típico. As descobertas gerais fornecem insights para os formuladores de políticas enfatizarem o desenvolvimento de cooperativas agrícolas, melhorar o mecanismo de vinculação de risco e interesse e construir o sistema RPPW. Essas implicações também são favoráveisaos formuladores de políticas em outros países em desenvolvimento.

Palavras-chave: cooperativismo associado, produtor de maçãs, modelo logit, viés de autosseleção da amostra, método PSM.

INTRODUCTION

Pesticides play an important role in increasing crop yields, agricultural output, and income and eventually improve family welfare by eradicating poverty (LI et al., 2022; MATHIS et al., 2022; ZAWISLAK et al., 2021). Recently, the changing patterns of climate change and the eruption

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of the COVID-19 pandemic have harmed the food supply and security, so in this regard, pesticide application is regarded as an essential factor leading to stabilizing food supply and security by halting the growing burden of pests and diseases (FERRARO & PAULA, 2022; GOH et al., 2021; MÖHRING et al., 2020). It is generally believed that pesticide packaging waste (PPW) hazardously pollutes the soil and groundwater, resulting in a decline in agricultural production and quality (BONDORI et al., 2019; JIN, 2016; LI, 2020a; ZHANG, 2019). The PPW mainly refers to the packaging materials and their direct contact with the pesticides discarded material after use in agricultural products such as bottles, cans, barrels, and bags made of plastic, glass, metal, paper, and other materials (LI & HUANG, 2018). In the case of China, it is reported that around 500,000 tons of pesticides are consumed every year. Pesticide packages reach up to 10 billion (FENG et al., 2020), which not only influences the ecosystem but also poses serious threats to food security and public health (GAO et al., 2019; LUO et al., 2015; MUBANGA & BWALYA UMAR, 2020; SHANG, 2021). In the case of farmers, they are regarded as both the producers and victims of pesticide packaging waste.They are implementers and beneficiaries of the RPPW (HUANG, 2021; LI & HUANG, 2018). Previous studies reported that farmers in developing countries heavily rely on discarding, burying, and incinerating pesticide packaging waste and their recycling proportion of pesticide packaging waste is relatively low (LI et al., 2018). Many factors may influence the farmers' RPPW behaviors as some scholars believe that recycling pesticide bottles and packaging plastics is a complicated process that requires high costs and ultimately influences the recycling rate (HU, 2015; LIN et al., 2018; LIU et al., 2021). Moreover, weak environmental awareness, low education level, low-risk perception, fewer laborers, insufficient subsidy, and a short recycling industry chain also influence the farmers' RPPW behaviors (JI et al., 2020; ZUO et al., 2018). Besides, the small-scale prevention methods of pest control in developing countries also negatively influence famers' RPPW behaviors (DAMALAS et al., 2008; WANG et al., 2016). In essence, the RPPW behavior of farmers has the typical public goods attributes, which inevitably generates moral hazards (CRAMER, 2022). Previous studies have unveiled that market incentives and government intervention have not been strengthened to make the effective policy of social governance at the grass-root level (NG et al., 2022; PUTNAM & BROWN, 2021). Hence, cultivating the third force to supplement and strengthen rural environmental governance is indispensable and invaluable.

It is also acknowledged that cooperatives in rural areas play an important role in facilitating small farmers to integrate and participate in the high-value and modern agricultural industry chain (AJATES, 2020; BIGGERI et al., 2018; MA et al., 2018a). Cooperatives have widely been viewed as an effective means to help farm households and their access to inputs at lower prices, boost market linkage and bargaining power, improve production skills, raise agro-food safety and quality standards, and shield against risks. The cooperatives are primarily based on values and principles of solidarity, equity, and social justice (GUZMAN et al., 2020). Previous studies have confirmed the social responsibility of cooperatives in regulating the environment or social governance by exerting collective action (RUOSTESAARI & TROBERG, 2016; ZHANG et al., 2021). Thus, the cooperatives help generate economic and social value simultaneously (GEZAHEGN et al., 2019; HOKEN & SU, 2018; LAI et al., 2021; OFORI et al., 2019; VERHOFSTADT & MAERTENS, 2015; XU & WU, 2018). It is also unveiled that joining cooperatives exert a positive and significant impact on farmers' technology adoption (MA et al., 2018b; MA & ABDULAI, 2019; MANDA et al., 2020; ZHANG et al., 2020), technological efficiency (OLAGUNJU et al., 2021), product quality (CAI et al., 2016; JI et al., 2019; WANG et al., 2019; WASSIE et al., 2019), agricultural and non-agricultural income (MA et al., 2021, 2022; MA & ABDULAI, 2017), and family welfare (MA & ABDULAI, 2016; SHUMETA & D'HAESEB, 2016).

Moreover,cooperatives play a crucial role in establishing the rule of law by reinforcing rural elites (FRANCESCONI & HEERINK, 2011). Specifically, cooperatives can strengthen social governance by enhancing collective actions, building relational networks, enhancing social pressure, and increasing group supervision (FONTE & CUCCO, 2017; GRADDY-LOVELACE, 2021; NIYAZMETOV et al., 2021). In the case of environmental governance, cooperatives also influence farmers' decisions to opt for eco-friendly behaviors (DIJK et al., 2015; SARKAR et al., 2022).

Based on the above discussion, no attention has been paid to exploring the role of joining cooperatives in influencing the farmers' RPPW behaviors. It is believed that joining cooperatives, in theory, can actively drive farmers to recycle pesticide packaging waste. Conversely, a lack of ecological knowledge has a significant inhibitory effect on farmers' eco-friendly behavior (BARNES et al., 2022; REZAEI et al., 2020). While on the other hand, pesticide residues directly and unfavorably influence agricultural output quality (LI et al., 2021a; SIRAJ, 2021). So in this regard, it is believed that the cooperatives can boost the cognizance of farmers regarding the hazardous impact of pesticide packaging and enable them to increase their enthusiasm regarding adopting RPPW behaviors through knowledge promotion training and peer information exchange. Moreover, the cooperatives' product quality certification and supervision also favorably influence farmers' behavior towards safe production. Hence, the farmers are inclined to the RPPW and obtain product premium. Thus, to explore the role of joining cooperatives on farmers' RPPW behaviors empirically, the current study uses the data of 725 apple farmers from Shaanxi and Gansu, China, and by using the logit model, the current study primarily analyzed the effect of joining cooperatives on the farmers' recycling decisions. Meanwhile, considering the sample "self-selection" bias of joining cooperatives, the study employs the propensity score matching (PSM) method to empirically analyze the net effect of joining cooperatives on the farmers' recycling degree. Additionally, the heterogeneity effects of some observable variables are also analyzed and discussed in the subsequent section.

The remaining structure of the study is organized as follows. The research methods are presented in section 2, and the results are reported and discussed in section 3 and 4. Section 5 concludes the study with practical implications.

MATERIAL AND METHODS

Data Sources & study participants

The data was collected from China's Shaanxi and Gansu provinces from July to August 2020 (Figure 1). The main reason for selecting these sampled areas is that, firstly, they are located in the Loess Plateau, where higher apple production occurs. Secondly, these sampled areas fall in the monsoon climatic zone, where seasonal pests and diseases occur severely, and pesticides are massively used in these areas, ultimately leading to massive pesticide packaging waste. Thirdly, these regions are underdeveloped areas, with a large scale of farmland transfer and accelerated development of cooperative organizations. Hence, these aspects make these regions well representative and typical areas to conduct the study.

Moreover, we employed stratified and random sampling methods to obtain the sampled data. In Gansu, the sampled counties selected for study are

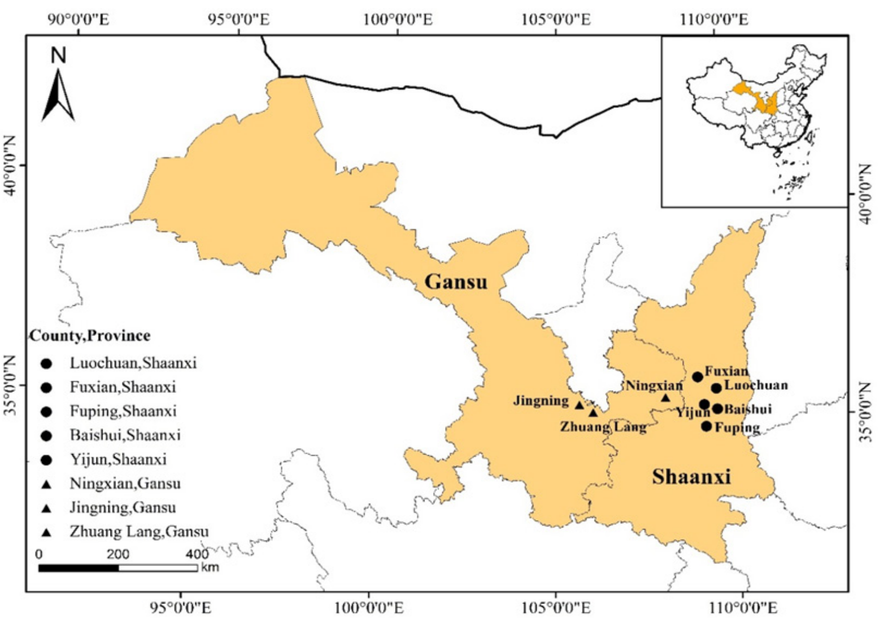

Figure 1 - Distribution of sample areas.

Jingning, Zhuanglang, and Ningxia, while in Shaanxi, Yijun, Baishui, Fuping, Luochuan, and Fuxian countries are selected. Around 2-4 towns from each sampled county are also randomly selected. Then 3-5 villages from each sampled town are also randomly selected in the next stage; lastly, 10-15 apple farmers are randomly chosen from each village. A total of 800 questionnaires were distributed, and after excluding invalid samples, only 725 valid samples were retained for empirical analysis with an efficiency of 91%. The sampled data showed 372 households in Shaanxi and 353 households in Gansu. Moreover, farmers' disposal behaviors of pesticide packaging waste are diverse; for instance, about 325 households discarded pesticide packaging waste, 385 households used trash bins to pitch, and 456 households handed it over to scrap buyers or pesticide distributors for the RPPW. Besides, these surveyed villages have recycling facilities or places for pesticide packaging waste.

Variables selection

Explained variable

The explained variable in the current study includes two variables, i.e., farmers' recycling decisions of pesticide packaging waste, and other is the farmer's recycling degree. The farmers' recycling decisions (after this referred to as "recycling decisions") is a discrete binary variable, i.e., If farmers give them to recycling scrap buyers or pesticide distributors for the RPPW, the value is 1; otherwise, the value is 0. After this, farmer's recycling degree (referred to as "recycling degree") is a continuous variable measured as the proportion of the number of pesticide bottles and plastic packaging recycled to the purchased amount.

Core explanatory variables

Joining cooperatives is the core explanatory variable; if a farmer joins a cooperative, a value of 1 is assigned, and if not, a value of 0 is assigned. Hence, joining cooperatives is farmers' self-selection behaviors. According to the data, 409 apple farmers joined cooperatives, and 316 farmers did not join cooperatives.

Covariate variables

Following the previous studies such as DAMALAS et al. (2008) and SI et al. (2021a), farmers' characteristics (e.g. gender, age, and education level); family characteristics (e.g. proportion of fruit-land transfer-in, the scale of fruit cultivation, family income, and family labor); cognitive characteristics (e.g. risk preference, environmental risk perception, and public health risk perception); policy and social aspects (e.g. government propaganda, peer effect, and relationship network) are taken as covariates in the current study. The descriptive statistics of the variables are shown in table 1.

The independent sample T-test was used to compare the differences between those joining cooperatives and not joining cooperatives (see table 1). Results showed that the average values of famers' recycling decisions for those who joined and did not join cooperatives are 0.678 and 0.415, respectively. The difference is about 0.263 at the 5% significance level. Moreover, the average value of different groups of farmers' recycling degrees is approximately 0.526 and 0.311, respectively, and the difference is 0.215 at a 1% significance level.

Moreover, the summary statistics showed that the household heads are primarily male at around 47 years. Farmers who joined cooperatives have higher educational levels, the proportion of fruit-land transfer-in, the scale of fruit cultivation, family income, higher environmental risk perception, public health risk perception, peer effect, and relationship network. In contrast, farmers who did not join cooperatives have a higher risk preference. The difference is 1.406 at the 1% significance level.

Empirical estimations

Given that farmers' recycling decisions are discrete binary variables, the current study primarily used the Logit model to analyze the effect of joining cooperatives on farmers' recycling decisions. The Logit model formula is as follows:

$$Ln\left(\frac{p}{1-p}\right)=\beta_0+\sum_{i=1}^{n}\beta_i x_i+\mu$$
$$\frac{p}{1-p}=\exp\left(\beta_0+\sum_{i=1}^{n}\beta_i x_i\right) \quad (1)$$
$$p=F\left(\beta_0+\sum_{i=1}^{n}\beta_i x_i\right)=\frac{1}{1+\exp\left[-\left(\beta_0+\sum_{i=1}^{n}\beta_i x_i\right)\right]}$$

$$Prob(decision=1\,|\,joining,X)=\varphi(\alpha+\beta_1 joining+X\theta+\varepsilon) \quad (2)$$

In formula (1), where p represents the probability (0-1) of farmers' recycling decisions. B_0 is regression intercept (constant term). x_i is the influencing factor of farmers' recycling decisions, including *joining and X*. β_i is the regression coefficient of the *i-th* influencing factor. µ is random interference. In formula (2), the *decision* represents the farmers' recycling decisions. The X is the covariate variable. β_1 and θ are the regression coefficients estimated vectors of joining cooperatives and control variables, respectively. ε represents the independent and identically distributed random error term, and $\varphi(\cdot)$ is the logistic distribution's probability function.

Table 1 - Descriptive statistics of study variables.

Variables	Assignment	Joining cooperatives	Not joining cooperatives	Differences
Recycling decisions	Recycling=1, not recycling=0	0.678	0.415	0.263**
Recycling degree	The proportion of the number of pesticide bottles recycled to the quantity of pesticide purchased	0.526	0.311	0.215***
Gender	Male=1, female=0	0.805	0.724	0.081*
Age	Actual age (year)	47.569	47.939	-0.370
Education level	Education time (year)	7.959	6.014	1.945**
The proportion of fruit land transfer-in	Proportion of fruit land transfer-in area to total fruit land area	0.512	0.305	0.207***
The scale of fruit cultivation	Apple planted area (mu)	4.902	4.061	0.841**
Family income	Family income (ten thousand yuan)	12.105	8.422	3.683***
Family labor	Number of people over 16 years old (person)	3.409	3.615	-0.206
Risk preference	Risk aversion=1, risk neutrality=2, risk taking=3	1.087	2.493	-1.406***
Environmental risk perception	Perceived risk of harm to farmland and water (1 = completely impossible-5 = very likely)	3.615	2.292	1.323**
Public health risk perception	Perceived risk of harm to public health (1 = completely impossible-5 = very likely)	3.780	3.101	0.679**
Government propaganda	Propaganda times (times)	3.175	3.123	0.052
Peer effect	How much does farmers' RPPW behaviors affect you? (1 = completely impossible-5 = very likely)	4.104	3.572	0.532***
Relationship network	How many farmers do you interact with frequently? (people)	15.239	9.068	6.171***

Note: *, **, *** represent the significance level of 10%, 5%, and 1% respectively. 1 mu = 0.067 hectares and 1 yuan = 0.1568 USD.
Source: Field Survey (2019).

Further, to explore the effect of joining cooperatives on farmers' recycling degree, the current study also employed the propensity score matching (PSM) method. This method has several advantages: firstly, joining cooperatives is farmers' voluntariness, and the PSM method is appropriate to solve the issue of sampled "self-selection" bias (JUMPAH et al., 2020). Secondly, joining cooperatives is determined by farmers' difference in endowment characteristics between the treatment group (joining cooperatives), and control group (non-joining cooperatives), which leads to "selection bias." The PSM method can verify whether the recycling degree of the farmers who joined and did not join the cooperatives is consistent. Thirdly if farmers have joined cooperatives, the data that they have not joined cooperatives cannot be directly observed, so the PSM method can solve the "missing data" issue by constructing a counterfactual framework. Finally, some control variables are likely to affect farmers' decisions to join cooperatives and probably influence the RPPW behaviors. Thus, the PSM method can also solve the issue of endogeneity; finally, the research steps are as follows:

Firstly, the Logit model is used to estimate the probability fitting value of farmers joining cooperatives, and the propensity score value PS_m is:

$$PS_m = \Pr[L_m = 1 \mid X_m] = E[L_m = 0 \mid X_m] \quad (3)$$

Where $\Pr[L_m = 1 \mid X_m]$ is propensity matching score or probability of apple farmers' participating in cooperatives, L_m = 0 represents farmers not joining cooperatives, and X_m signifies the covariate variables.

Secondly, the PSM method matches the treatment group with the control group. This research selected three matching methods: K-nearest neighbor matching, caliper matching, and kernel matching. 1) K nearest neighbor matching is used to match the K nearest individuals in different groups. We set K to 4 and perform one-to-four matching to minimize the squared error of the mean. 2) Caliper matching refers to matching by limiting the absolute distance of the propensity score. We set the caliper to 0.020 to compare observations with a 2% difference in the propensity score. 3) Kernel matching means matching farmers joining cooperatives and non-joining by setting a propensity score broadband value of 0.060, weighting the propensity score value of the control group, and finally matching with farmers joining cooperatives and non-joining.

$$ATT = E(D_{1m}/L_m = 1) - E(D_{0m}/L_m = 1) = E(D_{1m} - D_{0m}/L_m = 1) \quad (4)$$

Where D_{1m} is the recycling degree of farmers joining cooperatives D_{0m} is the recycling degree of farmers who didn't join cooperatives. E ($D_{1m}/L_m = 1$) (can be directly observed and E ($D_{0m}/L_m = 1$) can't be directly observed, which is a counterfactual result. Consequently, the PSM method is used to explore the effect of joining cooperatives on farmers' recycling degree.

Finally, triple tests are employed. The first is the common support domain test, which evaluates whether the treatment and the control groups have a common support area and considerable overlap in the value range (WELDEAREGAY et al., 2021). The second is the balance test, which evaluates whether the treatment and control groups have significant differences in explanatory variables (core explanatory variables and covariate variables) to validate the matching quality (NGANGO & HONG, 2021). Finally, sensitivity analysis is also performed to verify the robustness of the model estimation results. The propensity score is estimated based on the observed variables and others, accounting for explicit bias instead of unobserved biases. Thus, the Rosenbaum bounds test is used to evaluate the sensitivity and reveal the effect of implicit bias on model estimation results (BECKER & CALIENDO, 2007).

RESULTS

Results of the effect of joining a cooperative on farmers' recycling decisions

The Logit model results to explore the effect of joining cooperatives on farmers' recycling decisions are illustrated in table 2. The results reported that joining cooperatives positively and significantly affects farmers' recycling decisions, with a marginal effect of 0.203 at the 5% significance level; that is if farmers join cooperatives, the probability of the recycling decisions will increase by 20.30%. The findings also revealed that other covariates influence the farmers' motivation to make recycling decisions. Specifically, if the education level is increased by one year, the probability of farmers' recycling decisions will increase by 1.4%. Likewise, if environmental and public health risk perception is increased by 1 unit, the possibility of farmers' recycling decisions will increase by 12.50% and 10.30%, respectively. Besides, if the intensity of peer effect and relationship network increases by 1 unit, the probability of farmers' recycling decisions will increase by 7.10% and 6.20%, respectively. However, some covariates also showed an inhibitory effect on farmers' recycling decisions. For instance, if the proportion of fruit-land transfer-in and the degree of risk preference increase by 1 unit, farmers' recycling decisions will decrease by 1.50% and 9.90%, respectively.

The study also performed a double-check analysis to ensure the quality of data matching. The first is the common support domain test to ensure the matching effect between control and treatment groups. The function density diagrams in figure 2 showed that the propensity score values after matching overlap; the overlapping area is the common support domain. Thus, the common support conditions are robust as most observations lie within the range, and negligible samples are lost. The second is the balance test. After samples are matched in table 3, the explanatory variables' standard deviation is less than 5%, and the deviation is reduced by 13.4%-13.8%, which signifies the reduction of overall bias. Before matching, the revised R2 value was 0.204, but after matching, the value dropped substantially to 0.117-0.126, and the p-values were all reported significant at the 5% level. Consequently, the PSM method substantially reduces the difference in explanatory variables between the treatment and control groups, and the quality of the samples is a good match.

Results of the effect of joining a cooperative on farmers' recycling degree

Using PSM, the data is matched, and the results are shown in table 4. According to the results, it is apparent that the treatment group lost 17 samples and 392 samples participated in the matching; the control group lost 13 samples, and 303 samples participated in the matching, indicating that the treatment and the control groups have an excellent matching effect. The net effect of joining cooperatives on the recycling degree of apple farmers by employing three matching methods is reported in table 5. The model results showed that the recycling proportion of farmers who have not joined the cooperative is 9.3%-10.5%, with an average value of 9.70%. After joining cooperatives, the recycling proportion is raised to 36.20%-38.00%, with an average value of 37.20%. The net effects (difference) of ATT are 0.275, 0.281, and 0.268,

Table 2 - Estimated results based on the Logit model.

Variables	Farmers' recycling decisions
Join cooperatives	0.203** (0.088)
Gender	0.064 (0.050)
Age	-0.031 (0.019)
Education level	0.014** (0.006)
Proportion of fruit land transfer-in	-0.015** (0.007)
Fruit cultivation scale	0.021** (0.010)
Family income	0.072 (0.121)
Family labor	0.015 (0.011)
Risk preference	-0.099*** (0.035)
Environmental risk perception	0.125** (0.059)
Public health risk perception	0.103*** (0.033)
Government propaganda	0.026 (0.034)
Peer effect	0.071** (0.031)
Relationship network	0.062** (0.027)

Note: *, **, *** represent the significance level of 10%, 5%, and 1% respectively. Marginal effect is reported and standard errors are in parentheses.
Source: Authors' computation.

at 5%, 1%, and 1%, significance level, respectively. Consequently, comparatively for farmers who have not joined the cooperatives, if they join cooperatives, the recycling degree will increase by 27.50%, 28.10%, and 26.80%, with an average of 27.50%.

Moreover, it is argued that when the PSM method is used for model estimation, only observable factors are controlled, and there may be a hidden bias issue caused by omitting essential variables. So to further examine the robustness of the ATT value, the study further employed Rbounds Program to conduct a sensitivity analysis. According to the sensitivity analysis, if the gamma coefficient is still not significant when close to 2, the estimation conclusion is reliable (LIN et al., 1998). Results in table 6 show that the gamma value is close to 2. The unilateral significance level exceeded 0.1, indicating that even if there is implicit deviation, the impact of joining cooperatives on farmers' RPPW behaviors can't be changed. The ATT value is relatively robust to hidden bias.

Heterogeneity nalysis

This research further provided the heterogeneity analysis results concerning the effects of joining cooperatives on farmers' RPPW behaviors based on gender, different ages, and education levels (see table 7). In the case of gender, it is found that joining cooperatives positively and significantly influence female farmers' RPPW behaviors. If female farmers participate in the cooperatives, the probability of recycling decisions will increase by 5.6%, and the recycling degree will increase by 14.2%. Moreover, in the case of farmers' age, joining cooperatives plays an essential role in the RPPW behavior of farmers older than 60, i.e., if the farmers older than 60 join the cooperatives, the probability of recycling decisions will increase by 3.2%, and the recycling proportion will increase by 21.1%. Thus, the gender and age variables have noticeable masking effects compared to the benchmark regression. Besides, joining cooperatives has positively and significantly influenced the RPPW behaviors in the case of farmers having middle and high school education, i.e., if the farmer's education level is primary and they join cooperatives, the probability of recycling decisions will increase by 1.1%. The recycling degree will increase by 20.5%. Hence, education level has a typical threshold effect concerning joining cooperatives affecting farmers' RPPW behaviors.

DISCUSSION

Pesticide packaging waste (PPW) has become an essential part of agricultural solid waste and an essential source of non-point source pollution (BONDORI et al., 2019; LI et al., 2020b). The main factor leading to the non-point source pollution is the information asymmetry between farmers and the government at the grass-root level that makes farmers' morals hazardous under the weak supervision of the government (GAO et al., 2019; GEZAHEGN et al., 2019; GRADDY-LOVELACE, 2021). Though several incentive policies have been put forward, such as improving the subsidy (ZHANG, 2019), the marginal cost of farmers' RPPW behaviors is still not calculated. This research supported the findings of previous scholars regarding the dilemma of agricultural environmental governance

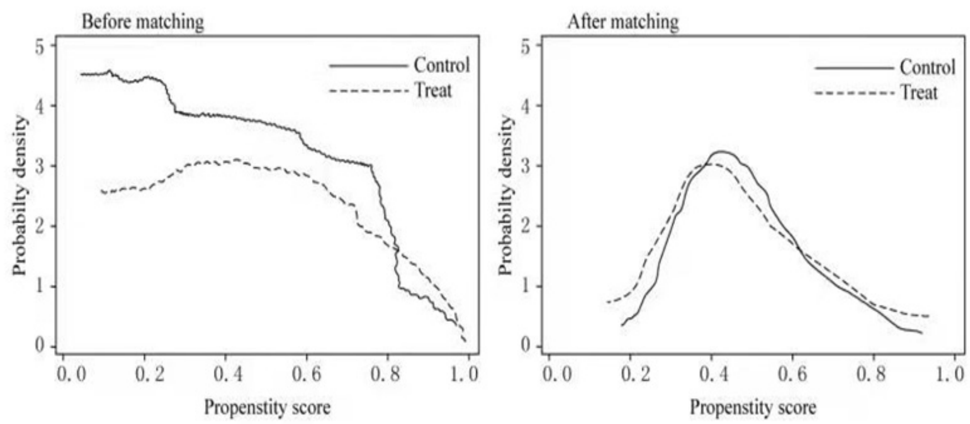

Figure 2 - Function density diagrams.

and reveals that the previous policies confronted challenges to internalizing the negative externality of agricultural and environmental pollution (BURTON, 2014; CRAMER, 2022; KOONDHAR et al., 2021; ZADJALI et al., 2013). Hence, this research contributed to the literature in three folds; firstly, the study expanded the theoretical connotation of farmers' behaviors and characterized farmers' RPPW behaviors from the aspects of recycling decisions and degree. Secondly, unlike previous research, the current study integrated cooperative participation into the analytical framework of farmers' RPPW behaviors and empirically explored the effects of joining the cooperatives on the farmers' recycling decisions and degree by using the Logit model and PSM method, respectively. The overall findings confirmed the significant effect of joining cooperatives on farmers' RPPW behaviors. Analogous to the studies of previous researchers, it reflects that the product quality control, risk-sharing, and benefit mechanism between the cooperatives and farmers are the driving forces to operate the cooperatives effectively (GARCIA, 2021; LI et al., 2020a; MANDA et al., 2020). Moreover, farmers are more enthused about getting the cooperative's unified technical guidance and planting management skills (MANDA et al., 2020; OLAGUNJU et al., 2021) and actively implement RPPW behavior, which can effectively reduce pesticide residues from the soil and water and ultimately improve product quality (JI et al., 2019; KUMAR et al., 2018). Likewise, consistent with the study of MA et al. (2018b), CAI et al. (2019), and SARKAR et al. (2022)'s studies, our study also confirmed the role of cooperatives in improving the farmers' eco-friendly technologies adoption. The RPPW has specific public goods properties and positive environmental externalization. The cooperatives can strengthen the agricultural activities and regulate the local environmental concerns (GRADDY-LOVELACE, 2021), boost collective actions at the rural level (SOUZA NOGUEIRA et al., 2018), reshape social norms (HAO et al., 2018), and finally motivate farmers to implement RPPW behaviors consciously. Finally, the cooperatives can

Table 3 - Results of the balance test.

Matching method	Standardization deviation (%)	Reduced deviation (%)	Pseudo-R^2	P-value
Before matching	18.7		0.204	0.002
K-nearest neighbor matching	4.9	13.8	0.126	0.017
Caliper matching	5.3	13.4	0.117	0.014
kernel matching	5.1	13.6	0.125	0.019

Source: Authors' computation.

Table 4 - Results of matching data.

	Unmatched sample	Matched sample	Total
Control group	13	303	316
Treatment group	17	392	409
Total	30	695	725

Source: Authors' computation.

strengthen the members' network, peer effect, and group supervision, which affects the safe production behaviors of farmers (SI et al., 2021b; YU et al., 2021; ZHANG et al., 2020). Parallel to the study of ZUO et al. (2018), and OFORI et al. (2019), if the farmers don't select the RPPW, they will suffer moral condemnation and social pressure from other farmers.

Further, given some observable variables' nonlinearity impact, the effects of joining cooperatives on farmers' RPPW behaviors are also explored. Results inferred that female farmers who joined cooperatives took the lead in agricultural pro-environmental behaviors and were more inclined to adopt RPPW. The results contradict the findings of REZAEI et al. (2020), DOHMWIRTH & LIU (2020), and SU et al. (2021)'s studies; the results further infer that RPPW can be sold or exchanged for a small payment, which is generally sensitive and acceptable to women in developing countries. Meanwhile, the causal relationship between age and farmers' green production behavior in the previous literature is mainly an inverted U-shaped or negative relationship (ABATE et al., 2014; HAO et al., 2018; JI et al., 2019). However, our research confirmed the motivation and initiative of farmers older than 60 who joined cooperatives to implement RPPW behaviors, which may be closely related to the elderly farmers' lower-income and stronger desire to improve family welfare. Besides, consistent with the studies of WANG et al. (2016) and PENGH et al. (2018), it is also reported that education level boosts farmers' innovative awareness, environmental literacy, and information ability, which significantly influence farmers' RPPW behaviors. Hence, these observable variables have significant heterogeneous effects in joining cooperatives and affecting their RPPW behaviors.

Additionally, it is also reported that some covariates such as environmental and public health risk perception, peer effect, and relationship network play a key role in farmers' recycling decisions. Consistent with the views of LI et al. (2021b), PAN et al. (2020), and SU et al. (2021), who believed that the public goods attributes of environmental and health determine the inefficiency of farmers' participation and governance. Meanwhile, within the framework of planned behavior theory, environmental and health risk perceptions are the most fundamental endogenous forces that influence farmers' decisions-making. Although the cost-benefit comparison concerning the RPPW was not considered in previous studies (BONDORI et al., 2019; LI et al., 2020a), the relationship between network and peer effect is beneficial to boosting farmers' bounded rational decisions to avoid environmental and health damages. Moreover, contrary to JIA & LU (2018) and SI et al.

Table 5 - Estimation results of the ATT.

Matching method	Recycling degree	Treatment group	Control group	ATT	S. E.
K-nearest neighbor matching	Recycling proportion	0.380	0.105	0.275**	0.125
Caliper matching	Recycling proportion	0.362	0.094	0.268***	0.096
kernel matching	Recycling proportion	0.374	0.093	0.281**	0.110
Mean	Recycling proportion	0.372	0.097	0.275	

Note: *, **, *** represent the significance level of 10%, 5%, and 1% respectively.
Source: Authors' computation.

Table 6 - Sensitivity level of the ATT.

Dependent variable	Gamma	Sig+	Sig-	T-hat+	T-hat-	CI+	CI-
Recycling proportion	1	0.000	0.000	1.386	1.386	0.912	2.047
	1.46	0.001	0.000	0.692	2.538	0.307	3.454
	2	0.075	0.000	0.288	3.490	-0.111	4.082

Note: Gamma represents the participation ratio caused by unobserved factors; Sig^+ and Sig^- mean the upper and lower bounds of significance level, respectively; T-hat+ and T-hat represent the upper and lower bounds of Hodges Lehmann point estimation, respectively; CI+ and CI- represent the upper bound (0.95) and lower bound (0.95) of the confidence interval, respectively.

(2021c)'s studies, our study confirmed the negative effect of the proportion of fruit-land transfer-in on farmers' RPPW behaviors. The intertemporal nature of farmers' eco-friendly behavior and the asymmetry of the farmland transfer period inhibit farmers' recycling decisions. Besides, supported by previous literature, it is believed that farmers in developing countries are risk-averse (AZIZ et al., 2020; CLAY, 2018; KOONDHAR et al., 2021). If farmers have a higher risk preference, they will discard, bury, and incinerate pesticide packaging waste.

This study has some shortcomings, such as other factors influencing farmers' RPPW behaviors, are behavioral habits, rural culture, and recycling income. Moreover, missing variables may also cause endogenous issues that lead to estimation bias. Furthermore, the survey areas are located in areas of heavy production of apples. Farmers are more dependent on the apple industry and have a vital role in environmental protection awareness. Farmers' recycling degree may be evaluated. Of course, these shortcomings may provide exciting avenues for future researchers.

CONCLUSION AND POLICY RECOMMENDATION

With the rapid development of large-scale and specialized agricultural production and the

Table 7 - Results of heterogeneity analysis.

Variables	Recycling decisions	Recycling degree
---Gender---		
Male	0.036 (0.027)	0.091 (0.107)
Female	0.056^{**} (0.022)	0.142^{*} (0.077)
---Age---		
<40 years	-0.014 (0.009)	0.085 (0.102)
40-60	0.016 (0.011)	0.105 (0.076)
>60 years	0.032^{**} (0.015)	0.211^{***} (0.073)
---Education level---		
<7 years (primary school)	0.012 (0.008)	0.085 (0.106)
7-13 (middle and high school)	0.011^{**} (0.005)	0.205^{*} (0.107)

Note: *, **, *** represent the significance level of 10%, 5%, and 1% respectively. Marginal effect is reported and standard errors are in parentheses.
Source: Authors' computation.

increase of plant diseases and insect pests caused by climate change, pesticide packaging waste has become a new source of agricultural non-point source pollution. Hence, how to effectively supplement government supervision and financial incentive policies and explore the role of social organizations in driving farmers' RPPW behaviors and strengthening rural environmental governance remained empirically tested.

Based on the data of 725 apple farmers from Shaanxi and Gansu, the study employed the Logit model and PSM method to explore the effects of joining cooperatives on farmers' RPPW behaviors. The results showed that joining cooperatives positively and significantly influences farmers' recycling behavior. Education level, environmental and public health risk perception, peer effect, and relationship network also stimulate the farmers' recycling decisions. Furthermore, based on group heterogeneities analysis, it is found that the gender and age variables have noticeable masking effects concerning joining cooperatives, and their effect on farmers' RPPW behaviors and education level has a typical threshold effect. Finally, with the diversified development of the environmental governance system, this research holds that cooperative organizations have become a valuable addition to supplement the government's environmental governance and play an essential role in inducing farmers' eco-friendly behaviors such as the RPPW.

Followed by the research conclusions, the study put forth the following recommendations such as (1) the government should actively cultivate the development of agricultural cooperatives, guide the standardized operation of cooperatives, improve the subsidy mechanism for the cooperatives, highlight the essential role of cooperatives in the RPPW, and increase farmers' recycling proportion. (2) Moreover, the government should encourage small farmers to join cooperatives, improve the interest linkage mechanism, reduce agricultural production costs, and increase agricultural production. Meanwhile, ecological education and training are also required to improve farmers' environmental risks and stimulate farmers' enthusiasm and initiative to participate in the RPPW. (3) Furthermore, the government should build a recycling system for pesticide packaging waste, explore a paid recycling model, and improve the efficiency of the RPPW. In last, the government should encourage companies to develop biodegradable pesticide packaging to reduce the source of pesticide packaging waste.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest concerning this article's research, authorship, and publication.

AUTHOR'S CONTRIBUTIONS

All authors contributed equally to the conception and writing of this manuscript. The authors have critically revised the manuscript and approved the final version.

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