

Article

Farmers' Preferences for Recycling Pesticide Packaging Waste: An Implication of a Discrete Choice Experiment Method

Shengnan Huang ¹ and Ehsan Elahi ^{2,*}
¹ Institute of Agricultural Economics and Development, Chinese Academy of Agricultural Sciences, Beijing 100081, China

² School of Economics, Shandong University of Technology, Zibo 255049, China

* Correspondence: ehsanelahi@cau.edu.cn or ehsaneco@outlook.com

Abstract: Recycling pesticide packaging wastes (PPWs) is important for promoting green development in agriculture and improving the rural ecological environment. However, limited studies have focused on the subsidy, reward, and punishment policies for the recycling of pesticide packaging wastes. Therefore, to fill the research gap, the main aim of this study was to analyze farmers' preferences for different PPW recycling policies using a choice experiment method. Furthermore, the study identified farmers' heterogeneous preferences to provide a decision-making base for the governments to formulate PPWs recycling policies. We used a random parameter logit and latent class model to approach study objectives. A well-structured questionnaire was used to collect data from 256 vegetable growers from the Hebei province of China. The results found that more than 80% of farmers used less than 30 g (mL) of pesticides, and more than 60% of farmers deeply buried the PPWs. In the study area, farmers preferred subsidy incentive policies and found it hard to accept the higher capacity specifications of pesticide packaging and punitive measures. Moreover, it is confirmed that farmers' preferences for PPW recycling policies are heterogeneous, and 55.5% of farmers preferred incentive-type policies. Therefore, the government should establish a proper PPW recycling system with a subsidy-based incentive policy. Moreover, local agricultural officers should provide training to the farmers for recycling PPWs.

Keywords: recycling; pesticide packaging waste; policies; choice experiment; farmers



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1. Introduction

A good ecological environment is necessary for the survival of humans and other living organisms [1,2]. Although the Chinese government implemented rural revitalization strategies for the maintenance of the rural ecological environment [3], pollution caused by pesticide packaging wastes (PPWs) is poorly controlled, adversely affecting rural ecological environments. In 2019, according to a survey report of China, Chinese industry generated about 2.9~3.5 million PPWs each year, including 1.2~1.6 billion bottles and 1.6~1.9 billion bags, which is equal to 0.1~0.11 million tons [4].

In 2020, only 0.0287 million tons of PPWs were recycled, and 0.0227 million tons were processed. There are still a large number of PPWs that have not been properly recycled [4]. A study conducted in Anqiu County, Shandong Province of China, found that 47.14% of farmers discarded pesticides in empty containers in nearby fields, and 20.63% of farmers disposed of containers as garbage [5]. In 2019, another survey reported that only 0.30% of households adopted formal treatment methods for PPWs; 48.80% of households disposed of them in situ, and the remaining households disposed of the pesticide bottles with household garbage or sold them [6]. Furthermore, the PPWs are typically made of non-degradable materials such as plastics, aluminum foil, and glass, which can damage the soil structure [7–9]. The PPWs generally contain 2~5% of pesticide residues [10], which may be released into the surrounding environment by rainfall or irrigation [11], resulting in

irreversible contamination of the water and soil ecosystems [12–19], and even endangering human and animal safety when discarded in fields or ditches and rivers [20,21]. It is considered the most common agrochemical waste that poses a potential hazard to human health and the environment [22–27]. Therefore, it is imperative to establish appropriate PPW recycling and disposal systems to improve the rural ecological environment and promote rural revitalization holistically.

In 2017, to control the pollution of PPWs, the Chinese State Council released guidelines on promoting the green development of agriculture with innovative systems and mechanisms. It emphasized the establishment of a recycling and centralized treatment system for PPWs and required users to take responsibility for proper collection and producers and operators for recycling. In August 2020, China's Ministry of Agriculture and Rural Affairs and the Ministry of Ecology and Environment jointly issued the "Management Measures for Waste Pesticide Packages Recycling and Treatment", which clarified the corresponding recycling and disposal obligations and requirements for pesticide producers, operators, and users. Since there are plenty of pesticide producers, operators, and users of pesticides [28], it is difficult to enforce the responsibilities of each entity of PPWs [9]. Many studies have focused on PPW recycling. Some studies discussed the typical model of PPW recycling in various countries. For instance, following the polluter-pays principle, Australia has formed a "farmers pay and farmers return" recycling model. In contrast, Canada has formed an "enterprises pay, government purchase and farmers return" recycling model [29,30]. Although the administrative measures in China enforced that pesticide producers and operators should follow the principle of safe pesticide usage, no proper corresponding systems and models have been established in China. Most regions are still following the "government purchase services and farmers return" model.

For example, the Shanghai government is mainly responsible for PPW recycling, and farmers in Fengxian District can get a policy incentive of CNY 3 per kg [31,32]. At the same time, Heilongjiang has explored deposit and incentive recycling modes [5]. Regarding the end users of pesticides, the farmers are key partners in PPW recycling [32]. Especially, China has a large agricultural industry made up of small-scale farms that are addicted to the use of pesticides for the treatment of crops [33]; therefore, it is necessary to explore various strategies for PPW recycling.

In previous literature, the underlying driving factors of farmers' PPW recycling methods have been reported. It was found that environmental regulation remained effective in promoting farmers to adopt environmentally friendly production modes employing restraint, guidance, and incentive [7,34–36]. Similarly, reward and punishment policies are the primary factors to motivate the recycling behavior of PPWs. Compared with descriptive social norms and imperative social norms, economic incentives are more effective and have complementary effects on social norms [37]. Li et al. [38] collected data from 635 farmers in the Henan Province of China and found that the farmers' green disposal willingness and behavior of PPWs were affected by the perceived benefits and perceived risks. Farmers who were offered economic benefits were more likely to participate in pro-environmental activities [39,40]. Personal characteristics, particularly education level and knowledge, are also the main factors influencing farmers' production behavior [41]. These are mainly reflected by environmental cognition stimulating farmers' environmental protection intention [42–44].

However, limited studies have focused on the subsidy, reward, and punishment policies for the recycling of pesticide packaging wastes. Therefore, to fill the research gap, the main aim of the current study is to analyze farmers' preferences for different PPW recycling policies using a choice experiment method. Furthermore, the study identifies the farmers' heterogeneous preferences to provide a decision-making base for the governments for formulating PPW recycling policies.

2. Materials and Methods

2.1. Source of Data Collection

To estimate farmers' preferences for PPW recycling policies, in 2018, using a well-structured questionnaire, primary data was collected from vegetable growers of Zhangjiakou City, Hebei Province of China.

Pesticide applications were high in vegetables. In particular, the pesticide application for vegetables was 27.38 kg/hm², higher than the internationally recognized safe upper limit for pesticide use of 7.5 kg/hm². Therefore, we targeted the vegetable growers to collect data. Secondly, Zhangjiakou was a typical vegetable production area in the Huang-Huai-Hai and Bohai Rim-protected vegetable regions of the six advantaged regions for vegetable development in China. The vegetable planting area of Zhangjiakou was 103,127 hectares, with a total output of 5.7 million tons in 2018. Thus, the preferences of vegetable growers in Zhangjiakou can better reflect the policy expectation of PPWs in China.

In particular, we selected three towns from each county and randomly picked administrative villages. Afterward, a certain proportion of farmers were selected from each administrative village to conduct face-to-face interviews. A total of 260 farmers were targeted for data collection; however, enumerators were successful in conducting interviews with 256 farmers. The remaining farmers were not interested in participating in the survey. Therefore, the response rate during data collection was 98.46%.

2.2. Choice Experiment Method

The choice experiment is developed based on Lancaster's approach to consumer theory [45], and the framework of the behavior analysis of random utility theory [46]. The method can provide decision-makers (such as farmers) with alternative policy scenarios composed of different policy attributes for choosing, describing the discrete choice problem of decision-makers under the framework of utility maximization [47–49]. Furthermore, the choice experiment is an effective method for analyzing heterogeneous preferences [50].

Following random utility theory, the utility of farmer n obtains from alternative options i from a set of alternatives contained in the choice [51].

$$U_i = V_i(x_i, s) + \varepsilon_i \quad (1)$$

where U_i is the potential utility of options i , and $V_i(x_i, s)$ is the deterministic (observable) component that can be estimated by attributes x_i and farmer characteristics s . ε_i is an error term, which is assumed to be normally distributed at zero mean value and constant variance [52]. Usually, the deterministic component of utility V_i can be specified as:

$$V_i = ASC_i + \sum \beta_k x_k \quad (2)$$

$$V_i = ASC_i + \sum \beta_k x_k + \sum \gamma_m ASC_i \cdot s_m \quad (3)$$

where Equation (2) is also called the basic model. ASC_i is the alternative specific constant, which means the benchmark utility of "maintain the status quo" or "I choose neither", or the average utility of all other attributes that are not included in the model. $x_1, x_2, \dots, x_k$ are attributes found in the k th alternative, and $\beta_1, \beta_2, \dots, \beta_k$ are random parameters. To estimate the behavioral differences of farmers with different characteristics who choose "maintain the status quo" or "I will choose neither of them", we added the cross-terms of ASC_i and farmer characteristics $s_1, s_2, \dots, s_m$ that are shown in Equation (3). Therefore, Equation (3) is also known as the interaction model [49,53].

2.3. Experimental Design

The key to choosing experiments is to construct a more realistic and intuitive choice situation for farmers. It identified the attributes in the choice experiments and defined their levels to construct the choice set. We learned the typical patterns and practices of PPWs recycling through literature and the policy measures formulated and implemented in

various places to preliminarily determine the policy attributes and levels of PPW recycling. Combined with the pre-investigation, we finally selected packing capacity, subsidy, deposit, and penalty included in the choice experiment. Detailed information regarding the specific attributes and their levels are given in Table 1.

Table 1. The attributes and levels of PPWs recycling policies in the choice experiment.

Attributes	Descriptions	Levels
Packing capacity	Choices for different packing capacity	Large (>1 L); Medium ($0.2 < x < 1$ L); Small (<0.2 L)
Subsidy (CNY)	Subsidy for each returned PPW	None; 0.1; 0.2
Deposit (CNY)	Deposit for each PPW	None; 0.5; 1
Penalty (CNY)	Amounts of money if throw away PPW	None; 50; 100

Firstly, “packing capacity” refers to the pesticide packing volumes that farmers can select. Currently, most pesticide products sold in China have small packing capacities, such as 10 mL of Gaoqiao seed coating and Daoteng insecticide produced by Bayer [54]. In contrast, in developed countries such as Europe and the United States, most pesticide packing is in large volumes, such as 10 L. To minimize the number of PPWs from the source, this study selected the packing capacity as a recycling measure to analyze farmers’ acceptance of large-capacity packing pesticides and referred to practices of developed countries and Heilongjiang Province in China.

Secondly, “subsidy” refers to certain monetary incentive’s farmers can get when they return PPWs to specified recycling centers. As mentioned earlier, this attribute was chosen because China’s small-scale and decentralized agriculture makes it difficult to recycle PPWs. Most provinces in China have established monetary subsidy policies [31,32]. For example, Yuhang District in Zhejiang Province has formulated a PPW recycling subsidy system with CNY 0.2, CNY 0.5, and CNY 1.0 for 100 mL, 101~300 mL, and >300 mL, respectively [55]. Therefore, positive incentives such as appropriate subsidies or rewards are still required.

Thirdly, “deposit” refers to a certain security deposit charged for each pesticide packaging bag or bottle when farmers buy pesticides. The deposit will be returned when the PPWs return. This constraint policy mainly draws on the deposit system implemented by Baofeng County in Heilongjiang Province [5], which aims to cultivate a good habit of farmers recycling PPWs. Finally, “penalty” refers to the punishment that the local government will enact on the farmers by charging amounts of money if they are caught throwing away PPWs.

A complete choice experiment needs to include all possible combinations of the four attributes at three levels, and two alternatives to choose between would require the use of $(3^4)^2$ or 6561 choice sets. Since it is not practically feasible to work with 6561 choice sets, a fractional factorial design using the OPTEX procedure in SAS and D-optimal design that allowed for the estimation of all main and two-way interaction effects was used, and finally obtained nine choice scenarios. Meanwhile, it is not that every farmer will choose to participate in PPW recycling in actual production to make the choice scenarios more realistic. Therefore, the option of “I would choose neither of them” was added to each choice set to estimate situations for farmers who chose to give up or maintain the governance status and who did not like either of the two choice scenarios. A sample choice set is given in Table 2.

Table 2. A sample choice set.

Attributes	Alternative 1	Alternative 2	Alternative 3
Packing capacity	Large	Small	
Subsidy	CNY 0.5	None	I would choose
Deposit	None	CNY 0.1	neither of them
Penalty	None	CNY 100	

3. Analytical Framework

3.1. Random Parameters Logit Model

In terms of specific model sets, the common hypothesis models of choice experiments are mainly the multinomial logit model (MNL) and mixed logit model (MXL). Among these, the MXL relaxes the limitations of independent and identically distribution (IID) and independence of irrelevant alternatives (IIA), which can capture heterogeneity in farmer preferences. Besides, its estimated structure is better than MNL and can more closely simulate the real world [56]. As a type of MXL, the random parameter logit model (RPL) is the latest development of the discrete choice model and can get better-estimated results when the subjects have heterogeneous preferences [57]. Therefore, in this study, we used the RPL model to analyze farmer preferences for recycling measures of PPWs. The distribution function of the RPL model is not restricted to the normal distribution. Following Train [58], the probability that the n th farmer chooses option i can be written as:

$$P_{ni} = \int \frac{\exp(V_{ni})}{\sum_j \exp(V_{nj})} f(\beta|\theta) d\beta \quad (4)$$

where $f(\beta|\theta)$ is the probability density of β , β is a random variable that follows the distribution of $f(\beta|\theta)$, and θ is the true parameter describing the distribution.

3.2. Latent Class Model

To further analyze farmers' heterogeneous preferences for different recycling policies of PPWs, this study also built a latent class model (LCM) to classify farmers. The LCM is used because it is based on the response patterns of farmers in different scenarios. It is the different joint probabilities that allow for a more accurate, detailed analysis of farmers' preferences. LCM is formed by introducing the idea of factor analysis and structural equation model based on the principle of probability distribution and log-linear model [59], which improves the shortcoming of previous models in dealing with latent variables. The basic assumption of latent class analysis is that the probability distribution of various responses to each explicit variable can be explained by a small number of mutually exclusive latent categorical variables, and each category has a specific tendency to select responses to each explicit variable [60].

In Equation (4), if $f(\beta|\theta)$ is discrete, then this equation can be transformed into an LCM to determine the classes of different farmers to solve the drawbacks of artificial classification. N facility vegetable farmers can be divided into S latent class, and farmers with the same preference will fall into the same class. Then, the probability that n th farmer falls into the latent class s and chooses the i th policy measure combination:

$$P_{ni} = \sum_{s=1}^S \frac{\exp(\beta_s X_{ni})}{\sum_j \exp(\beta_s X_{nj})} R_{ns} \quad (5)$$

where β_s is the farmer parameters vector of the i th class, and R_{ns} is the probability that farmer n falls into the s th latent class, and can be expressed as:

$$R_{ns} = \frac{\exp(\mu_s z_n)}{\sum_S \exp(\mu_s z_n)} \quad (6)$$

where μ_s is the parameter vector of the facility vegetable farmers in the s th latent class, and z_n is a series of feature vectors that influence n th farmer to fall into a certain latent class.

4. Results and Discussion

4.1. Descriptive Statics

The basic characteristics of the sample are given in Table 3. In the study area, a major proportion of the sample was males (85%), 52 years of age and with 6 years of schooling. In terms of family characteristics, the average household population of the sample is 2.95. The

average non-farm and farm incomes were CNY 75,700 and CNY 74,100, respectively. The average farming experience was 6.77 years. Small-scale farmers were found in the study area because the average farm size was 0.404 ha.

Table 3. Summary statistics of basic variables.

Sample Characteristics	Mean	Standard Deviation	Minimum	Maximum
Gender (1 = Male; 0 = Female)	0.85	0.36	0	1
Age (Years)	51.68	9.60	22	78
Education (Years)	6.49	3.20	0	12
Household scale	2.95	1.05	1	6
Household income (CNY 10,000)	7.57	6.35	1	55
Household vegetable income (CNY 10,000)	7.41	6.28	1	55
Experience (Years)	6.77	2.18	1	12
Vegetable planting scale (hectare)	0.404	4.70	0.067	4

Farmers reported that the purchased pesticides were mainly small-capacity packing, and 92.1% of farmers purchased powder pesticides with less than 30 g packing capacity. In contrast, about 83% of farmers purchased water-based pesticides with less than 30 mL packing capacity (Figure 1).

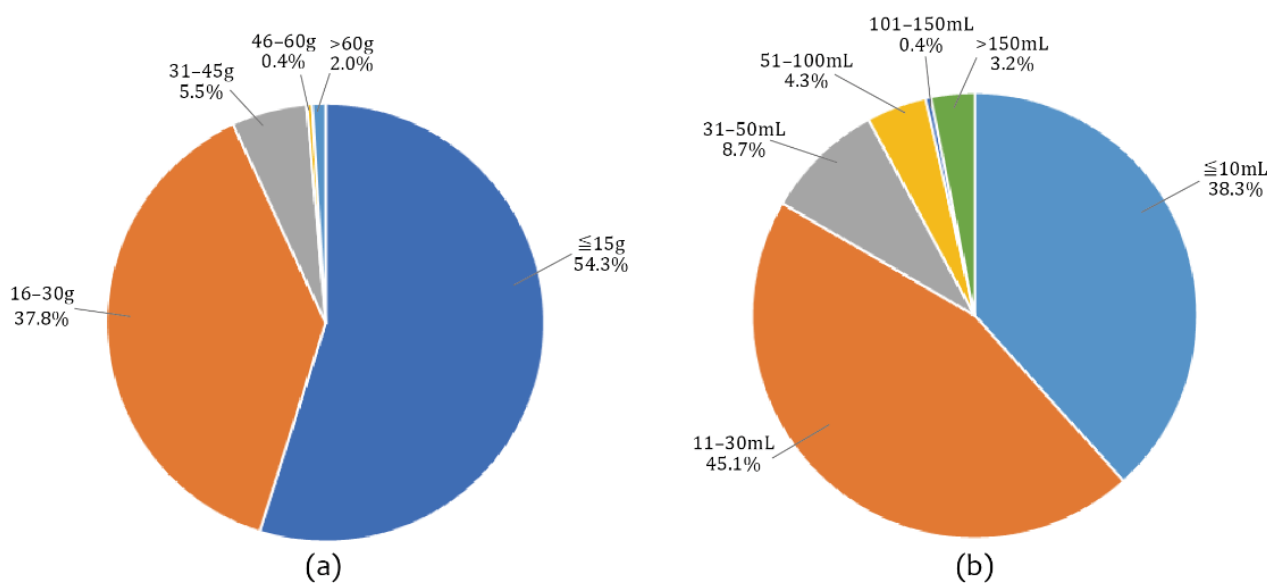


Figure 1. Pesticide packing capacity purchased by farmers. Panel (a) shows the powder pesticide packing capacity purchased by farmers. Panel (b) shows the water-based pesticide packing capacity purchased by farmers.

It was found that 62.50%, 68.36%, and 1.95% of the farmers' deeply buried pesticide packaging plastic bags, plastic bottles, and glass bottles, respectively (Figure 2). Whereas 23.83% and 16.20% of farmers burned the pesticide plastic bags and plastic bottles, respectively. Farmers have a certain awareness of PPW environmental pollution, and 44.92% of them believed that if they discard the PPWs, it will have a great influence on water and soil. However, 23.83% of respondents believed that discarding PPWs would have no or little impact on the environment. In the study area, farmers revealed that the local governments and the agricultural officers did not provide awareness and facilities to recycle PPWs.

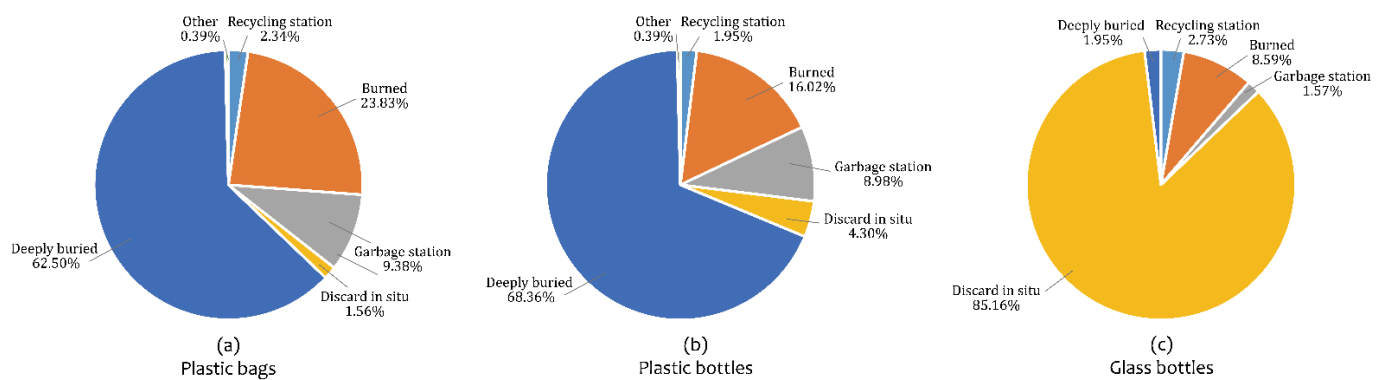


Figure 2. Disposal of PPWs. Panel (a–c) represents the disposal of plastic bags, plastic bottles, and glass bottles, respectively.

4.2. Estimation of Random Parameter Logit Model

The maximum simulated likelihood estimation method is used for the estimation of parameters, and the parameter estimation stability depends on the number of samples. Moreover, the maximum likelihood estimation method is generally used with Halton sequence simulation. Bhat [61] found that the simulation error of the RPL model is small. To improve the efficiency of estimation, this study uses NLOGIT 6.0 software to estimate the RPL model using the simulated likelihood method with 125 Halton draws. Results found that the basic model and the interaction model run well because the McFadden Pseudo R^2 is greater than 0.1, and the chi-square test is statistically significant at 1%. The results of the basic model and interaction model are shown in Table 4.

Table 4. Estimation of parameters of the basic model and interaction model.

Variables	Basic Model	Interaction Model
Coefficients		
ASC	−3.603 *** (0.201)	0.317 (1.417)
Packing capacity	−0.410 *** (0.068)	−0.354 *** (0.065)
Deposit	0.151 (0.093)	0.109 (0.096)
Subsidy	5.928 *** (0.929)	8.005 *** (0.996)
Penalty	−0.005 *** (0.002)	−0.005 *** (0.002)
Coefficients of standard deviation		
Packing capacity	0.908 *** (0.068)	1.144 *** (0.092)
Deposit	0.445 *** (0.144)	0.355 *** (0.165)
Subsidy	17.172 *** (1.388)	15.485 *** (1.099)
Penalty	0.041 *** (0.003)	0.043 *** (0.003)
Interaction term		
ASC × Gender	-	2.732 *** (0.866)
ASC × Age	-	−0.087 *** (0.018)

Table 4. Cont.

Variables	Basic Model	Interaction Model
ASC × Education	-	−0.119 ** (0.052)
ASC × Vegetable planting scale	-	−0.009 (0.049)
ASC × Cognition	-	−0.444 *** (0.129)
Log likelihood	−1486.036	−1449.498
McFadden Pseudo R ²	0.413	0.425

, and * represent the level of significance of parameters at 5%, and 1%, respectively. Standard errors are given in parentheses.

4.2.1. Impact of Alternative Specific Constant (ASC)

Results found that the parameter of ASC in the basic model is significantly negative. It means that most farmers were willing to make changes and tended to choose the corresponding combination of policy attributes for PPW recycling to improve the rural eco-environment.

4.2.2. Impact of Recycling Policy Attribute Variables

The given results in Table 5 depict that the subsidy incentive policy attribute is statistically significant and positive, which indicates that when the local government sets a large number of monetary incentive subsidy facilities, vegetable farmers are more willing to participate in PPW recycling. The result is in line with previous studies [57]. Li et al. [37] also found that under the influence of economic incentives, farmers' specialized recycling behavior of PPWs increased by 12.3%. The coefficients of pesticide packing capacity and penalty are significantly negative, which means that pesticide with a high packing capacity is not conducive to promoting farmers' participation in PPWs recycling. This is mainly because farmers are still in small-scale production, and the pesticides with small packing capacities are convenient to mix and use and avoid the preservation and storage of the remaining pesticides. The policy attribute variable of the deposit system is not statistically significant, which may be because farmers tend to have loss aversion and emphasize losses. The estimated results of the interaction model are consistent with the basic model. It indicates that the estimated results of the model are relatively robust.

Table 5. Results of Latent Class Model.

Variables	Class 1 Policy Incentive Preferences	Class 2 Loss Aversion Preferences	Class 3 Institutional Constraints Preferences	Class 4 Small Packing Preferences
ASC	−6.044 *** (1.103)	−1.369 *** (0.433)	−6.321 *** (2.360)	−9.519 *** (3.665)
Packing capacity	−0.561 *** (0.058)	−0.342 ** (0.137)	0.442 *** (0.081)	−1.395 ** (0.693)
Deposit	−0.127 (0.107)	−1.182 *** (0.288)	0.498 *** (0.145)	−2.702 * (1.403)
Subsidy	9.174 *** (0.755)	3.087 * (1.645)	−3.596 *** (0.946)	−4.056 (5.137)
Penalty	0.013 *** (0.001)	−0.027 *** (0.005)	−0.006 *** (0.002)	−0.127 *** (0.040)
Age	0.048 * (0.028)	−0.003 (0.032)	0.023 (0.031)	-

Table 5. Cont.

Variables	Class 1 Policy Incentive Preferences	Class 2 Loss Aversion Preferences	Class 3 Institutional Constraints Preferences	Class 4 Small Packing Preferences
Education years	−0.019 (0.080)	−0.003 (0.032)	−0.052 (0.090)	-
Cognition	−0.131 (0.198)	−0.077 (0.219)	0.185 (0.229)	-
Class weight	55.5%	10.0%	23.2%	11.3%

*, **, and *** represent the level of significance of parameters at the 10%, 5%, and 1%, respectively. Standard errors are given in parentheses.

Regarding the size of coefficients of variables, it is confirmed that the subsidy policy is much higher than other policy attribute variables (Table 5), which indicates that the facility vegetable farmers prefer an economic incentive policy to participate in PPW recycling. The standard differences in packing capacity, deposit system, subsidy policy, and penalty are statistically significant. Moreover, the facility vegetable farmers have a greater heterogeneity in the preference of these four types of policy attribute variables and indicate that various farmers have a great difference in preferences of PPW recycling policies.

4.2.3. Interactions of Farmer's Characteristics with ASC

Results found that a parameter of the farmers' gender is statistically significant and positive (Table 5). It is revealed that female farmers pay more attention to production and the eco-environment, and they are more willing to participate in PPW recycling. The coefficients of farmers' age, education, and cognition of PPWs are statistically significant and negative. It means that when faced with the same combinations of recycling policy attributes, older farmers, with more educational years and higher awareness of environmental pollution, are more inclined to participate in PPW recycling. Since the income source of the older farmers is mainly agriculture, they are more likely to take part in PPW recycling. Moreover, farmers with higher education may improve their cognition of PPW recycling and find it easier to understand the adverse impact of random disposal of PPWs on the rural eco-environment. Therefore, they are more willing to participate in PPW recycling. The results are in line with Bondori et al. [42]; they found that educated farmers behaved positively on pesticide waste disposal. Similarly, Bagheri et al. [62] also found that well-educated farmers showed high safety behavior.

4.3. Estimation of the Latent Class Model

This study further analyzed the heterogeneity preferences of facility farmers for the PPW recycling policies using LCM. To test the suitability of the model, Akaike Information Criterion (AIC) or the Bayesian Information Criterion (BIC) were used to measure the model fitting effects. The BIC can effectively prevent the model from overfitting [62]. In this study, the BIC is used as the main basis for the classification of the LCM, and the results showed that when the facility vegetable farmers are divided into four categories, the BIC value is the smallest, which means that the model fitting effect is the best. This suggested that farmers can be divided into four different latent categories according to the utility of each policy attribute. Furthermore, we incorporated the educational years, vegetable planting scale, and farmers' cognition of PPWs as covariates into the LCM to further clarify the characteristics of farmers in each category. The estimation results of the LCM are given in Table 5. We defined each category by summarizing its characteristics of parameters.

In the first category, the estimation coefficient of the subsidy policy is relatively large, meaning that farmers in this category are more willing to accept monetary incentives for PPW recycling, which can be called "policy incentive preferences". This type of farmer accounted for the largest proportion (55.5%). It reveals that the farmers prefer subsidy policies of the RPL model. In addition, the coefficient of punishment measures is signifi-

cantly positive, which indicates that this type of farmer can take incentive-based policies combined with appropriate punishment.

In the second category, the estimated coefficients of deposit and punishment policies are significantly negative, and the coefficient of subsidy policy is relatively large. The farmers in this category are more willing to accept monetary incentives but have more obvious capital loss aversion, which can be called “loss aversion preferences”. PPW recycling policies such as deposit and punishment will significantly reduce farmers’ utilization levels, and an appropriate monetary incentive policy can enhance the enthusiasm of these farmers’ participation. This type of farmer accounts for 10.0%.

In the third category, the estimated coefficients of packing capacity and deposit are significantly positive, and the estimation coefficient of the subsidy policy is significantly negative. These kinds of farmer are more willing to accept the adjustment of pesticide packing capacities. They can take in deposit constraints but do not recognize subsidy incentive policies and can be called “institutional constraints preferences”. This type of farmer accounts for 23.2%.

In the fourth category, the estimated coefficient of the packing capacity is significantly negative. This implies that an increase in the pesticide packing capacities will significantly lower the utility level of this type of farmer, and they prefer pesticides with current small packing capacities. It is called the “small packing preferences”, and its proportion is 11.3%. The policies and measures adopted in this study are all unattractive to this type of farmer to participate in PPW recycling.

5. Conclusions and Policy Implications

The adoption of recycling strategies is imperative to promote green agriculture. Farmers are the end-users of empty pesticide containers. Therefore, the estimation of farmers’ preferences for recycling policies is important for designing strategies and action plans to reduce pollution, natural resources contamination, and pesticide poisoning in agricultural regions. In the current study, the data from 256 vegetable growers were collected from Zhangjiakou, Hebei Province of China, and the study estimated the heterogeneous preferences of farmers for PPW recycling policies. About 86% of farmers reported that the local government had not provided awareness on PPW recycling, and about 98% of farmers do not have any facility for recycling pesticide bottles in their villages and towns. Farmers in the study area are willing to participate in PPW recycling strategies and have heterogeneous preferences for PPW recycling policies.

Female farmers were more active in participating in PPW recycling, which may be because women usually have better personal hygiene and living habits than men, even though they do not know how to dispose of pesticide containers correctly. Furthermore, it was found that farmers with higher education are more willing to take part in PPW recycling. Farmers preferred incentive-based policies like monetary subsidies, while it is more difficult to accept the expansion of pesticide packing capacity and punishment policies. Similarly, more than half of farmers preferred the incentive policies (55.5%) and can accept the punishment policies like a penalty. This result is consistent with existing studies. The economic compensation exerted a synergistic effect on regulation stipulations, and mandatory social norms and economic incentives have complementary effects. It can promote the recycling probability of agricultural specialization by 6.03% [37]. In the study area, 23.2% of farmers would prefer to expand the packing capacity of pesticides and implement the deposit systems. There are those who think that institutional constraint policies are more useful and that the single monetary incentive policy is a temporary solution and cannot be sustainable. There are 10.0% of farmers who are loss averse and can improve their participation to a great extent with an adequate amount of monetary incentive policies.

The local government should provide facilities for recycling PPWs on farms and trainings to improve farmers’ awareness regarding the safe disposal of PPWs in China and other developing countries. In agricultural-producing countries, the instructions to recycle

pesticide bottles should be written in English and local languages. Most importantly, the local governments of agricultural-producing countries should strengthen the early guiding role of subsidy incentive policies and encourage farmers to participate in PPW recycling actively.

Although the study found interesting results, it has a few limitations. For example, farmers in various regions may have different preferences for PPW recycling. The recycling policies can be refined further, such as the material of pesticide packaging (whether it can be recycled or not), washing of containers, and construction of recycling stations. Therefore, in the future, the research should expand by surveying different regions in China and further explore the recycling modes, such as the location of the recycling stations and clarify farmers' heterogeneous preferences in different regions.

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