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Heterogeneous Risk Perceptions of Agricultural Producers on Pesticide Use and Pesticide Use Decision Analysis: Application of the Decomposed Theory of Planned Behaviour and Censored Quantile Regression

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This study uses the decomposed theory of planned behaviour, combined with a Bayesian learning framework to determine positive and negative risk perceptions using censored quantile regression. With this we will perform a pesticide use decision analysis of the usage of different pesticides. The result shows that agricultural producers have a higher chance of using pesticides with regulations permitted when these producers have higher positive or negative risk perceptions of pesticide use. Positive risk perceptions have an effect on the pesticide use of the agricultural producers regardless of high or low usage. However, the influence coefficient and significance increase when total usage increases. Negative risk perceptions have a significant negative effect on the pesticide use of agricultural producers with low total usage, but they do not significantly affect the pesticide use of agricultural producers with a high total usage.

Keywords: *Theory of Planned Behaviour, Risk Perceptions, Two-Stage Regression Approach, Censored Quantile Regression*

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I. Introduction

Pesticide usage is important in the modern agricultural production process, including seed disinfection, weed management, harmful insect control, soil disinfection and harmful germ and mould control. The proper application of pesticides not only reduces the production cost of pesticides, it also maintains a certain quality and yield of crop production (Freeman, 1993; Antle, Donald, and Crissman, 1998; Wilson, 2000). However, the excessive or improper use of pesticides negatively affects the environment, ecology and the food safety of agricultural products (Wilson, 2000; Pimentel, 2005). Therefore, pesticide usage is a risky investment for agricultural producers.

Previous studies on the effect of risk perception on the consumption decisions of health related risk-taking behaviour primarily focused on the perception of decision makers of the effect of the consumption decision on their own health. The majority of these studies indicated that an individual would not be inclined to buy or would reduce their consumption of these products if the individual had a deeper perception of the potentially negative risk of this behaviour (Rovira *et al*., 2000; Viscusi *et al*., 2000; Viscusi and Hersch, 2001; Lundborg and Lindgren, 2002). However, agricultural producers do not only have a negative risk perception of the application of pesticides, they also have a positive perception, namely, maintaining a certain quality and yield. Agricultural producers reduce their total pesticide usage because of the negative effects on health and environment, but they also increase their total pesticide usage because of the advantages these pesticides present. Briefly, pesticide usage results in both positive and negative behaviour incentives. Therefore, positive risk factors should be included when conducting a decision analysis of pesticide use; this was not considered in previous studies. Previous studies that investigate the effects of risk perceptions on the decision of health risk-taking behaviour also lacked a systematic theoretical foundation in that most of the choices on the decision-affecting variables were subjectively determined by the researchers. The present paper introduces the decomposed theory of planned behaviour (DTPB) in the field of psychological-related behaviours research (Taylor and Todd, 1995). The positive and negative risk perceptions of the decision makers on risk behaviour are also included to construct the theoretical basis for the selection of the agricultural producers. This inclusion will also determine the systematic integration decision influencing factors to explain the effects of the positive and negative risk perceptions of the pesticide usage decision of agricultural producers with different pesticide usage conditions.

In this study, research samples were taken from December 2005 to December 2007 from a survey of eight producers. The produce included Taiwan pears, grapes, oranges, bananas, papayas, wax apples, rice seedlings and brassicaceous vegetables. The samples had the characteristics of censored data. This paper adopted the censored quantile regression instead of a traditional regression equation to create the related empirical estimates and avoid obtaining biased empirical results.

The application of pesticides in agricultural production cannot be avoided in numerous areas because agricultural production is limited to the planting environment and peasant production habits. Therefore, pesticide use and management is a very important issue. The first step in pesticide use and management is to realise the behaviour pattern of the pesticide use of agricultural producers. This study aids in conceptualising how to strike a balance between agricultural production, environment protection and food safety. At the same time, management and control of agricultural producers pesticide use is one of the important measures to promote food safety, and understanding the factors affecting agricultural producer’s pesticide use decisions, help the government prevent agricultural producers form excessive use of pesticides or pesticide use wrong behavior. However, limited to the research survey data obtained was difficult. Because pesticide users would fear punishment, so the government to implement the survey, most users do not want to be investigated pesticides or pesticide use will not show the real situation. Therefore, past relevant research literature is very rare. This study wants to report closer to true agricultural producer's pesticide usage through survey data, and the results of this study may provide a pesticide use management and control planning reference for government or relevant parties.

This paper adopted the two-staged regression approach by empirically referring to Arias, Hallock, and Sosa-Escudero (2001) and Kan and Tsai (2004) to avoid an endogeneity problem caused by the failure to consider certain factors that influence the pesticide use decision and individual risk perception of agricultural producers. In addition, considering the amount of permitted pesticides used by the agricultural producers, this set of data had the limited characteristic (censor). Therefore, this paper utilises the Tobit model to estimate the mean amount of pesticide usage and the censored quantile regression to estimate the behaviour patterns of agricultural producers in different intervals of total pesticide use.

II. Conceptual Framework of Pesticide Use Decision of Agricultural Producers

2.1 Decomposed Theory of Planned Behaviour

Decomposed theory of planned behaviour (DTPB) was modified by Taylor and Todd (1995) from the theory of planned behaviour (TPB), which was developed by Ajzen (1991) based on social psychology. Ajzen believed that the adoption of specific operational decisions by a rational person was mainly affected by behaviour intention (BI), which refers to the overall probability or intention of an individual to take practical action. All of the other influencing factors are integrated after psychological evaluation, and the intention has a direct or indirect effect on behaviour. BI mainly consists of the attitude towards the behaviour, the subjective norm and the perceived behavioural control (note 1). However, catching the three oriented elements in this planned behaviour given the faith and intention in the original model as the theme is difficult for empirical operations of TPB (Shimp and Kavas, 1984). Taylor and Todd (1995) proposed DTPB as an answer to the problem by decomposing the three elements of TPB into several variables that can be practically observed. Therefore, the concept models raised by TPB could be implemented in empirical research.

2.2 Application of DTPB in the Pesticide Use Decision of Agricultural Producers

When DTPB is used to explain the pesticide use factors affecting the decisions made by agricultural producers with different degrees of pesticide usage, the meanings of the attitude towards the behaviour, subjective norm, perceived behavioural control and the corresponding pointer variables are presented in the following sub-sections.

2.2.1 Attitude towards the Behaviour

Among the subjective belief perceptions on the attitude towards the use of pesticides, the most important is the perception of the effect this behaviour has on individual health. The application of pesticides affects the health of producers upon application and has a negative effect on the environment, ecology and food safety. TPB as an example reveals that the difference between the effects of pesticide usage in different degrees on health or the environment is a type of faith. The difference in the sizes is the evaluation of this faith. In the form, faith is a type of health and environment risk perception of decision makers.

Risk perception and risk commodity consumption decision-related theoretical tools are always applied in the economic field. The most important of these tools is the Bayesian learning framework proposed by Viscusi (1991), which reveals that risk perception is a series of learning processes. An old risk perception is modified to be a new posterior risk perception when an individual receives new information. For the special connotation, anterior beliefs (AB) are mainly affected by prior beliefs (PB), prior experience (PE) and information (IF). The conceptual equation can be expressed by Eq. (1) as below:

$$AB = \frac{aPB + bPE + cIF}{a + b + c} \tag{1}$$

where *a* refers to the coefficient corresponding to PB, *b* refers to the coefficient corresponding to PE, and *c* refers to the coefficient corresponding to IF. If the corresponding coefficients are treated in Eq. (2) as follows:

$$\dot{a} = \frac{a}{a + b + c}, \dot{b} = \frac{b}{a + b + c}, \dot{c} = \frac{c}{a + b + c} \tag{2}$$

then Eq. (3) can be obtained, which indicates that the consequent risk perception of decision makers is a function of past belief, personal experience and a new message. This measurement method can estimate all the influencing coefficients.

$$AB = \dot{a}PB + \dot{b}PE + \dot{c}IF \tag{3}$$

The studies that adopted the aforementioned analysis model revealed generally consistent findings on the reduction of the consumption or usage of risk products by a decision maker with higher negative health risk perceptions (Viscusi, 1991; Liu and Hsieh, 1995; Rovira *et al*., 2000; Viscusi *et al*., 2000; Lundborg and Lindgren, 2002). Unlike previous studies, a positive perception is also considered when pesticide usage maintains a certain quality and crop yield. Agricultural producers reduce total pesticide usage because of the negative effect pesticide usage has on health and the environment, but they also increase pesticide usage because of the advantages these pesticides provide. Pesticide usage has positive and negative behaviour incentives. Therefore, we should analyse positive risk factors when conducting a decision analysis on pesticide usage; this was not considered in previous studies.

This paper considers the positive and negative risk perception of agricultural producers on pesticide usage, which are mutually independent. Eq. (3) was used to construct the positive and negative risk perception equation. The effects of the pesticide use decision-making behaviour of agricultural producers were then analysed.

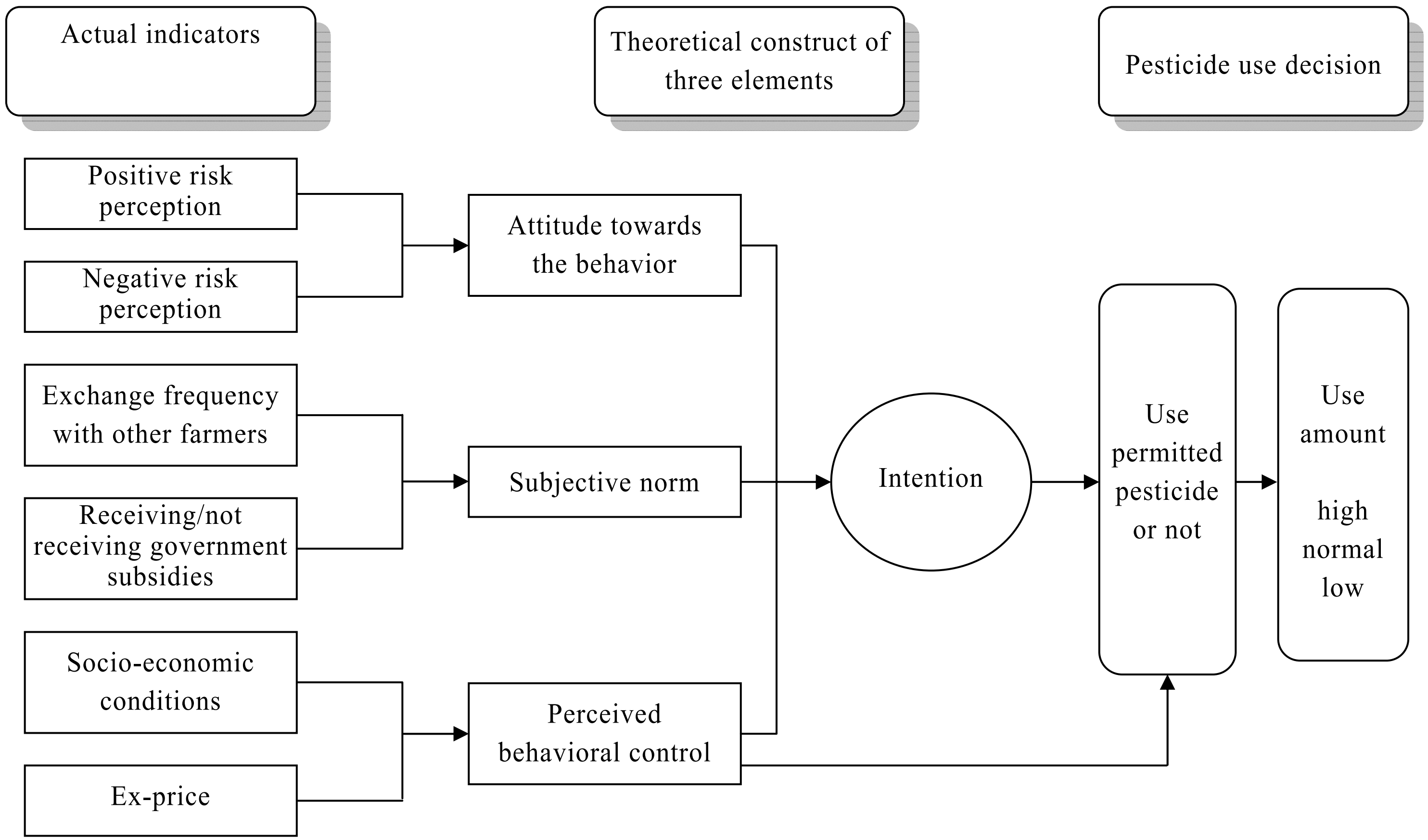
2.2.2 Subjective Norm

The subjective norm based on TPB refers to the BI induced by an interaction with another person. The BI of decision makers may be affected by other people's behaviours. Decision makers may change their decision because of pressure or simulation. Agricultural producers may change their original positive and negative risk perceptions on pesticide use because of interactions with other producers. More frequent interaction produces a higher effect.

2.2.3 Perceived Behavioural Control

The corresponding theory to perceived behavioural control includes internal and external factors in the behaviour control. Previous studies divided the main explanatory factors into two parts. One part was the difference in the personal characteristics and socio-economic background variables for resource accessibility such as gender and income (Conner *et al*., 1999; White, Altmann, and Nanchahal, 2002; Huchting, Lac, and LaBrie, 2008). The second part was the measurement of the quality of life, which is used to explain how emotional stress might change decision-making behaviour (Stewart, Chubon, and Weldon, 1989). Perceived behavioural control factors are important in the behavioural tendencies' moderator factor of decision makers. All questions on whether the decision makers will use pesticides and how much they will use are reinforced or limited by these factors.

In summary, we can obtain the conceptual framework on the pesticide use decision-making processes of agricultural producers based on the DTPB as shown in Figure 1.



Source: Modified from Ajzen (1991).

Figure 1. Pesticide Use Decision of Agricultural Producers under DTPB.

Table 1. Basic Data of Samples

Variables	Item	Items of Agricultural Products[1]								All samples
		Pear	Grape	Orange	Banana	Papaya	Wax apple	Rice seedings[2]	brassicaceous vegetable	
Age	Highest	68	65	66	62	56	64	60	64	68
	Lowest	32	38	46	40	40	35	34	42	32
	Average	55.3	50.2	56.9	53.5	48.9	52.5	48.6	54.4	51.6
Gender	Male	55	22	63	44	23	18	241	55	521
	Proportion	100%	100%	100%	97.8%	100%	94.7%	99.2%	91.7%	98.3%
	Female	0	0	0	1	0	1	2	5	9
	Proportion	0.0%	0.0%	0.0%	2.2%	0.0%	5.3%	0.8%	8.3%	1.7%
Education	Highest	4	5	3	5	4	5	5	3	5
	Lowest	1	1	1	1	1	1	1	1	1
	Average	2.77	3.08	2.42	2.55	3.16	2.78	3.25	2.62	2.94
Business scale	Biggest	4.5	2.5	5	1.5	1.8	2	50	0.5	
	Smallest	1	0.5	1	0.4	0.5	0.5	5	0.5	
	Average	2.75	1.12	2.69	0.98	1.6	1.17	18.6	0.29	
Medic-ation status	Followed	15	7	11	25	12	12	65	24	171
	Proportion	27.3%	31.8%	17.5%	55.6%	52.2%	63.2%	26.7%	40.0%	32.3%
	Un-followed	40	15	52	20	11	7	178	36	359
	Proportion	72.7%	68.2%	82.5%	44.4%	47.8%	36.8%	73.3%	60.0%	67.7%
Subsidies	Y	49	22	6	36	22	15	118	20	288
	Proportion	89.1%	100%	9.5%	80.0%	95.7%	78.9%	48.6%	33.3%	54.3%
	N	6	0	57	9	1	4	125	40	242
	Proportion	10.9%	0.0%	90.5%	20.0%	4.3%	21.1%	51.4%	66.7%	45.6%

Source: This study.

Note: 1. Number of samples: 55 for pears, 22 for grapes, 63 for oranges, 45 for bananas, 23 for papayas, 19 for wax apples, 243 for rice seedings, 60 for brassicaceous vegetables, respectively.

2. Scale of operation: 10k cartons per year for rice seedings and the remaining were Ha.

III. Data, Variables and Methods

3.1 Data

The empirical materials of this research were taken from an interview survey on the real pesticide usage of Taiwan agricultural producers for eight crops: pears, grapes, oranges, bananas, papayas, wax apples, rice seedings, and brassicaceous vegetables. The survey period was from December 2005 to December 2007. The contents covered include crop cultivation conditions, the pesticide usage conditions and the personal, social and economic data of agricultural producers. The total samples were 550. Twenty samples with incomplete data were removed from the total; thus, the actual number of samples was 530. The basic data of the samples are shown in Table 1.

3.2 Variables

The variables adopted in this paper include pesticide use, behaviour attitude, subjective norm, perceived behavioural control and other related variables based on the conceptual framework in Figure 1, which are explained in the following subsections respectively.

3.2.1 Total Pesticide Usage

There are two levels to pesticide usage decision making by agricultural producers. The first level is the decision to use or not to use pesticides regulations permit. The second level is the decision to use or not to use the amount regulations permit. Therefore, we observed whether the agricultural producers complied with the approval of the government agricultural department regarding the use of pesticides for specific insects or diseases when cultivating crops (note 2)

(1 = compliance; 0 = no compliance). If the agricultural producers used the pesticides approved by the government agricultural department, we observed whether the government-approved pesticide quantity was used (note 3).

3.2.2 Attitude towards the Behaviour

The corresponding variables in the attitude towards the behaviour adopted in this paper were the positive and negative health risk perceptions of pesticide usage of agricultural producers. We used the Health Knowledge Index (HKI) proposed by Kenkel (1991) and asked participants if they knew that pesticide use increases risks to health and the environment. The results obtained showed the individual negative risk perception (NK) level of the agricultural producers. The positive risk perception (PK) asks the participants if they knew that pesticide use maintains a certain quality and yield in crop production. Three problems were highlighted for negative risk perception, that is, the possible health risk caused by pesticides, increased risk to food safety and risk of increased environment pollution caused by chemicals. Only one problem was highlighted for positive risk perception, namely, maintenance of a certain quality and yield in crop production. This paper imitates Kan and Tsai (2004) for the treatment of the responses of participants, where the questions were answered using ordinal scales. The answers that participants could choose from included very possible, possible, unknown and impossible. The participants obtained three points if answer is very possible, two points for possible, one point for unknown, and zero for impossible.

3.2.3 Subjective Norm

Subjective norm describes the tendency of agricultural producers to use pesticides due to the pesticide usage of others or the external norms in their living environment. Two variables are included: communication frequency with other farmers or receipt of government subsidies. When the communication frequency with other farmers is high, the effect of the pesticide usage of other farmers on the tendency to use pesticide may be higher. If the agricultural producers receive government subsidies, the tendency to use pesticide is affected because these producers might be required to comply with the pesticide use regulations of the government. The communication frequency with other farmers is answered using ordinal scales. They are given 0-5 ordinal scale scores: “no exchange,” “few exchanges,” “one exchange every two or three months,” “two or three exchanges in one month,” “one exchange per week,” and “more than two exchanges per week.” The receipt of government subsidies is regarded as a dummy variable, which is recorded as one if the respondents have received government subsidies or zero if no subsidies have been received.

3.2.4 Perceived Behavioural Control

Perceived behavioural control shows the effects of some of the differences between the agricultural producers on pesticide use decisions. This paper utilises the socio-economic variables of agricultural producers and the previous crop prices as the perceived behavioural control variables. The socio-economic variables of agricultural producers include income, gender, education and years of work (note 4). Ex-price is the previous mean price of the cultivated crops of agricultural producers. In the process of the survey, the respondents were required to answer their annual incomes in an interval mode such as RMB 150,000 to RMB 200,000 or RMB 200,000 to RMB 250,000. The mean value was used as the annual income of these samples. Gender was a dummy variable, where male is recorded as 1 and female as 0. Education means the education years, which are recorded as 6 if the samples graduated from elementary school, 9 for junior high school, 12 for senior high school and 16 for college. For incompletion, 3 for elementary school, 7.5 for junior high school, 10.5 for senior high school and 14 for undergraduate. The previous crop price is the mean price of the crop that the agricultural producers cultivated in the most recent year in the agricultural statistic yearbook (Council of Agriculture, Executive Yuan, 2010).

3.2.5 Other Related Variables

This paper chooses some variables possibly related to the pesticide use decision of agricultural suppliers as instrument variables, including the acreage of agricultural producers and, if the cultivated crops were perennial, to avoid model identification. Acreage refers to the actual number of hectares. A dummy variable is used for whether the cultivated crops are perennial. It is recorded as 1 for perennial and o otherwise. All the variables used in this paper are shown in Table 2.

IV. Methods

This paper adopted the two-staged regression approach by empirically referring to Arias, Hallock, and Sosa-Escudero (2001) and Kan and Tsai (2004) to avoid an endogeneity problem caused by the failure to consider certain factors that influence the pesticide use decision and individual risk perception of agricultural producers. First, we made an estimation of the positive and negative risk perception variables. We then regarded the obtained positive and negative risk prediction values as the explanatory variables to be substituted into the pesticide use formula in Step 2.

The impact effect of the explanatory variables selected using DTPB and Bayesian learning framework on the total pesticide use of agricultural producers might also be different in different usage intervals. Only a mean margin effect of each explanatory variable could be obtained if the ordinary least squares (OLS) or Tobit model were used to make estimation. However, this would fail to capture the effect of each explanatory variable in different pesticide use intervals. Therefore, the Tobit model with responding censored data was used to assess the pesticide use decisions of agricultural producers in Step 2. The censored quantile regression model was used to estimate and analyse different pesticide use intervals at the same time.

Table 2.　Variable Codes and Introduction

Variable Category	Code	Description
Pesticide usage	CN	Whether the respondents used permitted pesticides or not (followed is recorded as 1; unfollowed is 0)
	TQ	Quantity of permitted pesticides used (standardisation process)
Attitude towards behaviour	PK	Whether the respondents knew that pesticide usage might cause crop production to maintain a certain quality and yield
	NK1	Whether the respondents knew that pesticide usage might increase health risks
	NK2	Whether the respondents knew that pesticide usage might increase risk to consumer food safety
	NK3	Whether the respondents knew that pesticide usage might increase the environment pollution caused by chemicals
Subjective norm	FO	Exchange frequency with other farmers
	GS	Whether the respondents received government subsides (Yes is recorded as 1; No is 0)
Perceived behavioural control	INC	Annual income of respondents
	SEX	Sex of respondents (Male is 1; female is 0)
	EDUY	Years of education of the respondents: 6 is elementary school, 9 is junior high school, 12 is senior high school, and 16 is college. Incompletion: 3 is elementary school, 7.5 is junior high school, 10.5 is senior high school, and 14 is college
	WY	Working years of the respondents in agriculture
	PL	Previous mean price of respondents' cultivated crops
Other related variables	AC	Acreage
	PC	Whether the crops cultivated by respondents are perennial (Yes is recorded as 1; 0 is no)

Source: This study.

4.1 Step One: Estimation of Positive and Negative Risk Perceptions

The positive and negative risk perception variables were converted from the respondents scale item. Given the ordinal index between the different fractions and the possible endogenous problems, we utilised the ordered probit model in Step 1 to transform the ordinal scales data of the positive and negative risk perception into continuous values with the same ordinal relationship. This is based on the method used by Kan and Tsai (2004).

We assumed the positive risk perception of individual i to be PK_i and the negative risk perception to be NK_{di}, where $d = s, c, e$; s refers to the risk perception of possible health problems caused by pesticide use of the respondents, c refers to the perception of possible food risk of consumers caused by pesticide use of the respondents and e refers to the perception of possible environment pollution caused by pesticide use of the respondents. PK_i and NK_{di} estimated by ordered probit model are as follows:

$$\begin{aligned} PK_i = j \qquad & if\ \lambda'_j < PK_j^* < \lambda'_{j+1} \quad j = 1,2,3,4 \\ & PK_i^* = \alpha' Z_i + \varepsilon'_i \\ & \lambda'_0 = -\infty \quad \lambda'_5 = \infty \\ & \varepsilon'_i \sim N(0,1) \end{aligned} \tag{4}$$

$$\begin{aligned} NK_{di} = j \qquad & if\ \lambda'_{dj} < NK_{dj}^* < \lambda'_{dj+1} \quad j = 1,2,3,4 \quad d = s,c,e \\ & NK_{di}^* = \alpha_d Z_i + \varepsilon_{di} \\ & \lambda_{d0} = -\infty \quad \lambda_{d5} = \infty \end{aligned} \tag{5}$$

In the ordered probit model of PK_i and NK_{di}, Z_i was the characteristic variable selected based on DTPB to explain personal behaviour; α', α_d refers to the coefficients of Z_i to be estimated; λ'_j and λ_{dj} refers to the cut-off values in the personal perception latent interval; and ε'_i and ε_{di} are the random error items. After estimating Eqs. (4) and (5), we obtain the personal potential positive and negative risk perception latent predicted values, namely, PK_i^* and NK_{di}^*. PK_i^* and NK_{di}^* are continuous numerical values with an ordinal relationship.

In the referred endogenous problem, some factors that might influence the pesticide use decision of agricultural producers and personal risk perception were not considered. All of the factors which are not considered are included in $\varepsilon'_{i\,and}\,\varepsilon_{di}$ in Eqs. (4) and (5). We utilised the positive and negative risk perception latent predicted values PK_i^* and NK_{di}^* estimated from Eqs. (4) and (5) in Step 1 as the explanatory variables to be substituted into the pesticide use estimation formula in Step 2. Then, ε'_i and ε_{di} were removed from the predicted values PK_i^* and NK_{di}^*. The influencing factors that cause endogenous problems were also deleted to resolve the endogenous problems.

When PK_i^* and NK_{di}^* are estimated in this step, model identification occurs in the measurement only if Z_i is used as an explanatory variable. This paper utilises instrumental variables to avoid the problem of model identification by referring to the practice of Kan and Tsai (2004) and Sprietsma and Waltenberg (2005). This paper also utilises the acreage of agricultural producers and whether or not the cultivated crops were perennial as instrumental variables. The acreage of the agricultural producers and whether or not the cultivated crops were perennial is not directly related to the risk perception of decision makers. However, the business operators with larger scale and longer operating time generally reflect a relatively more conservative attitude to risk (Macgill and Siu, 2004), which could explain the positive and negative risk perception latent of pesticide usage.

In summary, this paper utilises the ordered probit model to estimate the positive and negative risk latency of pesticide use using explanatory variables in three levels, namely, attitude towards the behaviour, subjective norm and perceived behavioural control, as well as two instrumental variables, namely, acreage and whether or not the crops were perennial. These are shown in Eqs. (6) and (7).

$$PK_i^* = \alpha_1^p FO_i + \alpha_2^p GS_i + \alpha_3^p INC_i + \alpha_4^p SEX_i + \alpha_5^p EDUY_i + \alpha_6^p WY_i + \alpha_7^p PL_i + \alpha_8^p AC_i + \alpha_9^p PC_i + \varepsilon_i^p \quad (6)$$

$$NK_{li}^* = \alpha_{l1}^n FO_i + \alpha_{l2}^n GS_i + \alpha_{l3}^n INC_i + \alpha_{l4}^n SEX_i + \alpha_{l5}^n EDUY_i + \alpha_{l6}^n WY_i + \alpha_{l7}^n PL_i + \alpha_{l8}^n AC_i + \alpha_{l9}^n PC_i + \varepsilon_{li}^n \qquad i = 1,2,3,4 \quad (7)$$

4.2 Step 2: Estimation of Pesticide Usage

The pesticide use decision of agricultural producers has two levels: use of permitted pesticides and quantity of permitted pesticides consumed. Firstly, we examine whether the agricultural producers made use of the permitted pesticides. The variables to be explained had a qualitative response characteristic, and the selection items were "Yes" or "No", which was limited and non-continuous data. Therefore, this paper utilises the binary logit model that is commonly used for the binary choice, as shown in Eq. (8):

$$CN_i = \beta_0 + \beta_1 \hat{P}K_i + \beta_{2l} \hat{N}K_{li} + \beta_3 FO_i + \beta_4 GS_i + \beta_5 INC_i + \beta_6 SEX_i + \beta_7 EDUY_i + \beta_8 WY_i + \beta_9 PL_i + \beta_{10} AC_i + \beta_{11} PC_i + e_i \quad (8)$$

In Eq. (8), $CN = 1$ indicates that the agricultural producers make use of the permitted pesticides, and $CN = 0$ indicates that the agricultural producers do not use the permitted pesticides. Maximum likelihood (ML) was used to estimate the parameters.

Secondly, we examine the amount of permitted pesticide used by the agricultural producers. This data had the limited characteristic (censor). Therefore, this paper utilises the Tobit model to estimate the mean amount of pesticide usage and the censored quantile regression to estimate the behaviour patterns of agricultural producers in different intervals of total pesticide use.

The Tobit estimation formula was used to estimate the mean amount of pesticide usage as shown in Eq. (9):

$$TQ_i = \gamma_0 + \gamma_1 \hat{P}K_i + \gamma_{2l} \hat{N}K_{li} + \gamma_3 FO_i + \gamma_4 GS_i + \gamma_5 INC_i + \gamma_6 SEX_i + \gamma_7 EDUY_i + \gamma_8 WY_i + \gamma_9 PL_i + \gamma_{10} AC_i + \gamma_{11} PC_i + \tau_i \quad (9)$$

which TQ refers to the pesticide use after standardisation.

This paper uses censored quantile regression to estimate the behaviours of agricultural producers with different total pesticide use. The general quantile regression could not be used to make estimation because the data had a censored characteristic. Otherwise, bias would occur (Powell, 1986; Chernozhukov and Hong, 2002; Koenker, 2005). As a solution, Powell (1986) developed quantile regression that responds to censor data. However, the quantile regression was too complicated and prevented the convergence of the result. Therefore, Chernozhukov and Hong (2002) modified Powell's method (Powell, 1986) and proposed the three-step censored quantile regression estimation procedure, which greatly reduces the difficulty of estimation and improves the non-convergence problem. Therefore, this paper adopted the three-step procedure to make a quantile regression estimation of the censored data.

The first step in the three-step censored quantile regression estimation procedure of Chernozhukov and Hong (2002) is the estimation of the probability of total pesticide use over the censored point of the individual agricultural producers using the probit probability model as below:

$$C_i = p(\delta X_i) + \omega_i \quad (10)$$

which C_i refers to the probability tendency of limited total pesticide use by individual agricultural producers, $p(.)$ refers to the normal distribution conversion function, δ refers to the estimation coefficient of an explanatory variable X_i, and ω_i refers to the random error item. After C_i was estimated, the sample group $S_0 = (i : p(\hat{\delta} X_i) > 1 - \theta + d)$ was selected. Here, θ refers to the component point of the censored samples, which accounts for the total samples, and d refers to the optional minimal positive number between 0 and θ.

In Step 2, the quantile regression function was regarded as $TQ_i = \upsilon_{\theta'} X_i + \rho_{\theta' i}$, which is sample group selected in Step 1. S_0 was made the quantile estimation for total pesticide use of agricultural producers as shown in Eq. (11):

$$\min_{\upsilon}\left[\sum_{i\in S_0|TQ_i\geq \upsilon X_i}\theta'\left|TQ_i-\upsilon X_i\right|+\sum_{i\in S_0|TQ_i<\upsilon X_i}\left(1-\theta'\right)\left|TQ_i-\upsilon X_i\right|\right] \tag{11}$$

Here, υ refers to an estimated coefficient, including $\hat{P}K_i^*$ and $\hat{N}K_i^*$ explanatory variable vectors, and θ' refers to the quantile point of the total pesticide use interval calculated based on S_0. After the estimation, sample group $S_1 = (i : \hat{\upsilon} X_i(\theta') > m_n)$ was selected in which m_n refers to a positive number near 0.

In Step 3, the quantile estimation was performed by substituting S_0 with S_1 as shown in Eq. (12) to obtain the non-biased explanatory variable coefficient υ'.

$$\min_{\upsilon}\left[\sum_{i\in S_1|TQ_i\geq \upsilon X_i}\theta''\left|TQ_i-\upsilon' X_i\right|+\sum_{i\in S_1|TQ_i<\upsilon X_i}\left(1-\theta''\right)\left|TQ_i-\upsilon' X_i\right|\right] \tag{12}$$

The empirical estimation formulas (13), (14), and (15), as conceptual counterpart for Eqs. (10), (11) and (12), were obtained as below:

$$\begin{aligned} C_i = p(&\delta_0 + \delta_1 \hat{P}K_i + \delta_{2l}\hat{N}K_{li} + \delta_3 FO_i + \delta_4 GS_i + \delta_5 INC_i + \delta_6 SEX_i \\ &+ \delta_7 EDUY_i + \delta_8 WY_i + \delta_9 PL_i + \delta_{10} AC_i + \delta_{11} PC_i) + \omega_i \end{aligned} \tag{13}$$

$$\begin{aligned} TQ_{i\in S_0} = &\upsilon_{\theta'0} + \upsilon_{\theta'1}\hat{P}K_i + \upsilon_{\theta'2l}\hat{N}K_{li} + \upsilon_{\theta'3}FO_i + \upsilon_{\theta'4}GS_i + \upsilon_{\theta'5}INC_i + \upsilon_{\theta'6}SEX_i \\ &+ \upsilon_{\theta'7}EDUY_i + \upsilon_{\theta'8}WY_i + \upsilon_{\theta'9}PL_i + \upsilon_{\theta'10}AC_i + \upsilon_{\theta'11}PC_i + \rho_{\theta' i} \end{aligned} \tag{14}$$

$$\begin{aligned} TQ_{i\in S_1} = &\upsilon'_{\theta''0} + \upsilon'_{\theta''1}\hat{P}K_i + \upsilon'_{\theta''2l}\hat{N}K_{li} + \upsilon'_{\theta''3}FO_i + \upsilon'_{\theta''4}GS_i + \upsilon'_{\theta''5}INC_i + \upsilon'_{\theta''6}SEX_i \\ &+ \upsilon'_{\theta''7}EDUY_i + \upsilon'_{\theta''8}WY_i + \upsilon'_{\theta''9}PL_i + \upsilon'_{\theta''10}AC_i + \upsilon'_{\theta''11}PC_i + \rho'_{\theta'' i} \end{aligned} \tag{15}$$

Here, $\rho_{\theta' i}$ and $\rho'_{\theta'' i}$ are random error items and θ' is the quantile point in the interval of pesticide usage based on the calculation of S_1. In the actual estimation, this paper utilises the bootstrap approach to make a repeated sampling of 500 times to avoid heteroscedasticity during the estimation.

V. Empirical Results

The estimation result of the positive and negative risk perception on pesticide usage of the agricultural producers is shown in Table 3. The result in Table 3 shows that income (*INC*) and education years (*EDUY*) were significant for all positive and negative risk perceptions whether or not government subsidies (*GS*) were received. This result indicates that agricultural producers who receive government subsidies and have higher income and education have more complete risk perception information for pesticide usage. Given the variables that produced these positive and negative risk perceptions, other explanatory variables of positive risk perception were not significant. This indicates that the effects of other characteristics of agricultural producers' perceptions regarding the maintenance of a certain quality and yield via pesticide usage made no obvious difference. For negative risk perception, income (*INC*), education years (*EDUY*) and higher acreage (*AC*) revealed a more obvious difference in negative risk perceptions for health, food safety for consumers and environmental chemical pollution caused by pesticide usage.

Step 2 estimates the factors that influence the permitted pesticide usage of agricultural producers' through the binary logit model and the factors that influence total pesticide use through the Tobit and censored quantile models. The results are shown in Table 4.

Table 3. Positive and Negative Risk Perception of Pesticide Usage of Agricultural Producers[1]

Variables	Positive Risk Perception		Negative Risk Perception					
	PK (pesticide usage may cause crop production to maintain a certain quality and yield)		NK_1 (pesticide usage may increase health risks)		NK_2 (pesticide usage may increase risk to consumer food safety)		NK_3 (pesticide usage may increase environment pollution caused by chemicals)	
	Coefficient	T-value	Coefficient	T-value	Coefficient	T-value	Coefficient	T-value
Constant	0.121***	9.746	0.068***	6.180	0.083***	5.381	0.052***	3.969
FO	0.034	1.285	0.017	0.787	0.026	1.443	0.011	0.891
GS	0.046*	1.804	0.049***	4.102	0.071***	3.236	0.035***	3.720
INC	0.039**	2.213	0.025**	2.034	0.020*	1.795	0.029**	2.142
SEX	0.006	1.179	0.016	0.989	0.037	1.374	0.024	1.498
EDUY	0.077*	1.826	0.041**	2.167	0.058***	3.310	0.040***	4.703
WY	0.018	1.390	0.031	1.482	-0.027	-0.917	0.015	1.319
PL	0.031	0.773	-0.019	-1.031	-0.024	-1.254	-0.009	-1.592
AC	0.009	0.822	0.022***	4.605	0.063***	4.571	0.036***	3.218
PC	0.022	0.531	0.065	1.190	0.049	1.008	0.053	0.810
Likelihood	−5,365.87		−4,673.50		-5,079.31		-4,950.54	
Adj/Pseudo R^2	0.059		0.037		0.032		0.039	

Source: This study.

Notes 1: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Effect of Heterogeneous Risk Perception on the Use of Permitted Pesticides and the Pesticide Use of Agricultural Producers[1]

Variables	Binary Logit Model[2]	Tobit Model[2]	Censored Quantile Model[2]				
			θ=0.05	θ=0.25	θ=0.50	θ=0.75	θ=0.95
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	0.0961***	36.8309***	7.2906*	11.9636*	26.4790***	43.2203**	58.7872***
	(5.0373)	(7.9936)	(1.7441)	(1.6680)	(5.5925)	(2.3842)	(11.1770)
PK	0.0472**	6.1416**	1.2890*	2.4132*	4.6740**	5.2006***	6.8027***
	(2.2520)	(2.1637)	(1.7362)	(1.7991)	(2.3352)	(3.1960)	(3.2535)
NK_1	0.0596***	-3.6020***	-1.9873***	-2.1613***	-3.5017***	-4.0322**	-3.0322*
	(4.5237)	(-3.5614)	(-5.2366)	(-3.9863)	(-3.0762)	(-2.4213)	(-1.6953)
NK_2	0.0168*	-1.4962*	-0.7875***	-0.8937**	-1.1756*	-1.5765*	-1.4548
	(1.7096)	(-1.8281)	(-2.9854)	(-2.4776)	(-1.8390)	(-1.6911)	(-1.6045)
NK_3	0.0383*	-1.1173**	-0.6554***	-0.8402***	-1.2237**	-1.2998*	-0.9566
	(1.7784)	(-2.0972)	(-3.6920)	(-3.1226)	(-2.4224)	(-1.8189)	(-1.6298)
FO	0.0079***	3.6810***	1.9082**	2.2035**	2.9105**	3.4505***	4.2028***
	(3.8960)	(3.3475)	(2.2663)	(2.4110)	(2.5612)	(3.3559)	(3.9440)
GS	0.0155***	-1.9521***	-1.3785**	-1.9970**	-2.4020**	-2.7920***	-2.0083***
	(6.4018)	(-3.0108)	(-2.5060)	(-2.5307)	(-2.6034)	(-2.9817)	(-3.3551)
INC	0.0330***	1.5726*	1.9726*	0.9946	1.3604*	2.2401*	2.1669
	(3.4522)	(1.8047)	(1.8047)	(1.3840)	(1.6531)	(1.7522)	(1.5657)
SEX	0.0029	0.6728	0.2950	0.4641	0.6281	0.6994	0.5577
	(0.7858)	(0.5960)	(0.6773)	(0.5026)	(0.7863)	(0.5693)	(0.6390)
EDUY	0.0237*	0.0639	-0.0519**	-0.0434**	0.0672*	0.0771	0.0544
	(1.6536)	(1.4397)	(-2.4526)	(-2.3002)	(1.6968)	(1.3665)	(1.1653)
WY	-0.0098**	0.1121*	0.0776	0.0905	0.1170	0.1268**	0.1376**
	(-2.2052)	(1.7204)	(1.1974)	(1.4627)	(1.5592)	(2.2165)	(2.3029)
PL	0.0017	0.0360*	0.0297	0.0226	0.0253*	0.0426*	0.0470*
	(0.9605)	(1.6833)	(0.9840)	(1.4828)	(1.6589)	(1.7593)	(1.8006)
AC	0.0473*	0.5357	0.4960	0.4631	0.5218	0.5992	0.5011
	(1.6697)	(1.3280)	(1.0935)	(1.5069)	(0.9580)	(1.4030)	(1.4968)
PC	-0.0115*	1.6451	0.8791	0.9688	1.3697	1.7769	1.8225
	(-1.7223)	(1.0012)	(1.2056)	(1.1495)	(0.8884)	(0.7664)	(0.9635)
Adj/Pseudo R^2	0.1037	0.1469	0.0241	0.0348	0.0697	0.1233	0.0962

Source: This study.

Note: 1. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

2. Explanatory variable for binary logit model is CN; explanatory variable for Tobit model and censored quantile model is TQ.

For the factors influencing the use permitted pesticides by agricultural producers, the coefficient of the positive risk perception (*PK*) of pesticide usage was positive, reaching 5% of significance. For the negative risk perception, the coefficient of perceptions that pesticide usage might increase self-health risk (NK_1), food safety of consumer risk (NK_2) and environmental chemical pollution risk (NK_3) was also positive. Here, the significant level of the self-health risk increase (NK_1) reached 1% and the remaining was 10%. In the subjective norm, the communication frequency with other farmers (*FO*), receipt of government subsidies (*GS*), income (*INC*), education years (*EDUY*) and working years in agriculture (*WY*) increased, showing statistical significance in the perceived behavioural control. The result showed that higher positive and negative risk perceptions of pesticide usage, frequent communication with other farmers, receipt of government subsidies, higher income, higher education and larger production area lead to a higher chance of using permitted and regulated pesticides. However, agricultural producers, who had engaged in agriculture for a longer time and had perennial cultivated crops, were less likely to use permitted and regulated pesticides.

In the factors that influence total pesticide use, the Tobit model estimates the trend in the variables relating to agricultural producers that use regulated and permitted pesticides. The estimation result showed that the coefficient of positive risk perception (*PK*) of pesticide usage in the behaviour attitude level was positive, reaching 5% of the significant level. For the negative risk perception, the coefficient of perceptions that pesticide usage might increase self-health risk (NK_1), food safety of consumer risk (NK_2) and environmental chemical pollution risk (NK_3) was negative. Here, the significant level of the self-health risk increase (NK_1) reached 1% and the remaining was 5% and 10%. Communication frequency with other farmers (*FO*) in the subjective norm and the increase of income (*INC*) and education years (*EDUY*) had positive effects on total pesticide use of agricultural producers. However, the agricultural producers with government subsidies (*GS*) and with longer working years (*WY*) had lower total pesticide use.

The censored quantile model estimated the use of permitted pesticides in different amounts by agricultural producers and the effect of each explanatory variable on the total pesticide used. The estimation result showed that the effects of all the explanatory variables were significantly different for agricultural producers with a lower total pesticide use ($\theta = 0.05$, 0.25) and a higher total pesticide use ($\theta = 0.75$, 0.95). Agricultural producers with a lower total pesticide use increased total pesticide use when they had a higher positive risk perception of pesticide usage (*PK*) and higher communication frequency with other farmers (*FO*). When the producers had a negative risk perception of pesticide usage (NK_i) and received government subsidies (*GS*), those agricultural producers with a lower total pesticide use further decreased their pesticide usage. However, agricultural producers with higher total pesticide use, positive risk perception (*PK*) and exchange frequency with other farmers (*FO*) had a positive result in total pesticide use, and the coefficient and significance were obviously increased. The effect of the receipt of government subsidies (*GS*) was also significant with a significant level increase to 1%. Notably, the negative risk perception of pesticide usage (*NKi*) did not significantly affect agricultural producers with higher total pesticide use. Increased risk to the health caused by pesticide usage (NK_1) was only 10% of the significant level. The effect of working years (*WY*) and the previous mean price of cultivated crop (*PL*) ranged from non-significant to significant and positive.

These results are further interpreted. From the average trend, the positive and negative risk perceptions of pesticide usage of the agricultural producers affect their total pesticide use. However, the quantile result shows that positive risk perception affects the pesticide usage of the agricultural producers with higher or lower use amounts, and the coefficient and significance of the effect increases with the increase of total use. Negative risk perception had a significantly negative effect on the total pesticide use of agricultural producers with lower total use. However, the effect on agricultural producers with a higher total use was relatively insignificant.

The positive risk perception represents a perception that pesticide usage maintains a certain quality and yield for crops. Therefore, the effect of positive risk perception could be regarded as focus on production benefit. Agricultural producers with a higher total use had a higher effect on the coefficient and significance of positive risk perception. This result indicates that agricultural producers with higher total pesticide use are interest oriented. The effect of the receipt of government subsides (*GS*) and the previous mean price of the cultivated crop (*PL*) on the agricultural producers with higher total use also has a higher significance. If the negative risk perception of pesticide usage is higher, the pesticide usage of agricultural producers recedes. However, no obvious effect on the food safety of consumer risk perception and environment pollution risk perception was found for agricultural producers with a higher total use, except for health risk perception. For agricultural producers with a higher total use, the importance of production benefit was higher than that of the possible risk caused by pesticide usage, especially outside their own risk. These characteristics were also more obvious in those with longer working years.

The application of non-approved pesticides and its excessive usage increases agricultural production, consumption and environment risk. Agricultural producers using higher amount of pesticides paid more attention to production interests than to the negative risk of pesticide usage. These characteristics, namely, frequent exchange with other farmers and longer working years, could help the government agricultural department to create related policies to support the correct, safe and effective use of pesticides by agricultural producers.

VI. Conclusions

This paper utilises DTPB to investigate the pesticide use decision of agricultural producers. The result showed that agricultural producers would have a higher chance of using regulated and permitted pesticides when these producers had higher positive and negative risk perception of pesticide usage, communicated with other farmers more frequently, had governmental subsidies, had higher income, higher education and a larger production area. When the agricultural producers engaged in agricultural work for more years and cultivated perennial crops, the probability of using permitted pesticides was reduced. In the factors that influence total pesticide use, positive risk perception had an effect on agricultural producers with a higher or lower total use. The impact coefficient and significance also increased with an increase in total use. The negative risk perception had a significantly negative effect on total pesticide use of the agricultural producers with lower total use. However, the effect on agricultural producers with higher total use was relatively insignificant.

Positive risk perception represents the perception that pesticide usage maintains a certain quality and yield for crops. Therefore, the effect of positive risk perception could be regarded as a focus on production benefit. For the agricultural producers with a higher pesticide usage, regardless of government subsidies receipt, the previous annual mean price of the cultivated crop and the number of working years had a significant effect on their usage decision.

Management and control of agricultural producers pesticide use is one of the important measures to promote food security, and understanding the factors affecting agricultural producer’s pesticide use decisions, help the government prevent agricultural producers form excessive use of pesticides or pesticide use wrong behavior. The survey data of this study is through the conduction of the pesticide manufacturers it is, however, restricted only to the year of 2005-2007 survey data. If the government could have implemented the survey regularly and routinely we will have made deep observation from such relatively comprehensive and longer period of agricultural producers’ behaviors. Such expectation is beyond our control. Pesticide users’ fear of punishment by government is even a time consuming issue to resolve.

This study expects to report closer to true agricultural producer’s pesticide usage through survey data, and the results of this study provide some agricultural producers’ characteristics should be noted in the creation of related policies that support the correct, safe and effective use of pesticides to maintain environmental and ecological sustainability and safe agricultural food hygiene, this may helpful for pesticide use management and control planning reference for government or relevant parties.

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Endnotes

1. “Attitude towards the behavior” refers to the personal evaluation and feeling for a specific matter and outcome, which is the group of beliefs and perceptions of an individual. These beliefs and perceptions may be accumulated from actual life experience or intellectual learning. “Subjective norm” refers to the behavior tendency cultured in the interaction between the person and others. “Perceived behavioral control” refers to the internal and external resource limitation and promotion factors a person faces when a desire to engage in a particular behavior exists.
2. In this paper, specific insect pests or diseases were selected. Scab, black spot, scale insects and aphid were chosen for the pear; Lu disease for grapes; scab, anthrax, scale insects, aphid, thrip and anoplophora chinensis for orange; black spot, scale insects, aphid and snout beetle for banana; fruit disease, anthrax, scale insects and aphid for papaya; epidemic disease, anthrax, thrip and scale insects for wax apple; seedling blight for rice seedings; downy mildew, aphid, asparagus caterpillar and silverleaf whitefly for brassicaceous vegetables.
3. We adopted a standardisation process. For example, the standardized usage coefficient was 100 when the use amount approved by the agricultural department and the use amount of the agricultural producers were both 10 L/Ha, but it was 150 if the use amount of the agricultural producers was 15 L/Ha.
4. The original socio-economic variables included age, which was removed to avoid collinearity because of its high relation to working time.

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農業生產者對農藥使用的異質風險認知與農藥使用量決策分析—解構式計畫行爲理論與受限分量迴歸的應用

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本文應用解構式計畫行為理論，並結合貝式學習架構（Bayesian learning framework），以受限分量迴歸進行正、負向風險認知，對不同農藥使用程度的農業生產者之農藥使用量決策分析。結果顯示，當對農藥使用的正、負向風險認知程度越高，農業生產者會有越高的機率使用法令規定許可的農藥。其中正向風險認知，雖然不管對高、低使用量的農業生產者之農藥使用量都會造成影響，但隨著使用量的增加，影響的係數與顯著性也隨之增加。而負向風險認知，則是對低使用量的農業生產者的農藥使用量有顯著的負向影響，但對高使用量的農業生產者，影響卻不顯著。

關鍵詞：解構式計畫行為理論、風險認知、二階段估計法、受限分量迴歸

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