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An optimal deposit-refund system for mitigating hazardous packaging waste in Thailand's agricultural sector

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Abstract

This study utilized a Deposit-Refund System (DRS) with an optimal rate of deposit in order to increase the return rate of hazardous chemical packaging waste back into the system. Both survey and time series data were used to examine the willingness to pay (WTP) of Thai farmers and the marginal social cost of waste disposal (MSC) so that they would be used as an appropriate deposit rate. The findings indicate that using MSC at 0.30 USD/bottle as deposit rate would induce a higher return rate than using WTP at 0.15 USD/bottle. The distance between farmers' homes and hazardous chemical shops can also negatively affect the return rate. Thus, to reduce hazardous packaging waste in Thai agriculture, the government needs to impose a deposit rate at 0.30 USD/bottle (MSC) and strategically increase the number of returning points in order to boost the return rate for hazardous packaging waste.

Keywords: deposit-refund system, hazardous packaging waste, agriculture, pesticides, herbicides

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1. Introduction

The industrial and agricultural sectors are two major sources of hazardous waste in Thailand. While industrial waste is controlled by Thailand's Department of Industrial Works, in the agricultural sector there is no clear responsibility for hazardous waste. This may have caused an increase in the amount of hazardous waste from the agricultural sector by +5.73% in 2014, whereas the waste from industrial sector decreased by −23.23% in the same year [1]. As there is no specific regulation for handling hazardous waste from agricultural production, Thai farmers would use chemicals and throw away the packages, e.g. plastic and glass bottles. Consequently, they might get injured from the hazardous packaging wastes. The report of the Pollution Control Department, Thailand [2] states that from 2003 to 2010 the number of Thai residents who were injured or died due to agricultural hazardous waste were about 13,389 persons while the industrial hazardous waste caused injury or die for just 2,625 persons. This phenomenon should therefore be reconsidered as a severe problem in Thai agriculture. In addition, there were many kinds of hazardous chemicals used in Thai agricultural production in order to protect products at every stage, but the main hazardous chemicals used were herbicides, followed by pesticides. The uses of herbicide and pesticide substances accounted for more than 90% of all kinds of chemicals in the sector [1]. Hence, it is crucial to deploy some policies to manage the waste in the agricultural sector to prevent the number of people getting injured or dying due to hazardous wastes from agricultural production which is growing continuously.

To deal with this issue, it is necessary to employ a suitable economic instrument combined with a command and control policy as suggested by Tietenberg [3] and Oates and Baumol [4]. They claimed that using only a command and control policy may not achieve an economic efficiency because of the high long-term costs of monitoring. However, the economic instrument that is suitable for the case must meet the goals of environmental effectiveness, economic efficiency, equity, administrative cost-effectiveness, and acceptability [5]. There are five groups of economic instruments which could be considered in this case 1) Tax, Fee, and Charge 2) Tradable Permit System 3) Deposit-Refund System 4) Subsidy and 5) Green Procurement [6, 7]. These groups of economic instruments can be used for managing waste in different circumstances. For example, Tax, Fee, and Charge may change consumer behaviors of waste generation [8] but they may distort market price mechanisms as well. The Tradable Permit System could influence producers to invent green technologies but the cost of implementation is rather higher than other tools. The Deposit-Refund System could effectively reduce the amount of waste, especially packaging waste, but it may not work for some cases. The Subsidy tool would be better for encouraging consumers to reduce their waste but it needs a long period

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of promotion and may be ineffective with the society which has a high rate of population movement. The last tool, Green Procurement, was not found suitable for handling the waste problem as it focuses on the upstream process of production rather than the waste products [6].

Moreover, numerous studies have compared those economic tools which should be used for managing wastes in particular packaging wastes. For instance, Fullerton and Wolverton [9, 10] showed that with general equilibrium analysis, the Deposit-Refund System could be easier to implement than the Pigouvian tax and it could also create better waste contribution awareness at household level than the tax. This was confirmed by the study of Palmer and Walls [11]. They stated that if policy makers use the Deposit-Refund System with an equal rate among deposit rate, refund rate and marginal social cost, the social benefit would be larger than using just a tax or subsidy alone. Palmer and Sigman [12] and Walls [13] also compared the implementation costs across Tax, Subsidy, and Deposit-Refund System tools for waste management by using the Monte Carlo technique. Their key result was that the Deposit-Refund System could generate less implementation costs than others and it could decrease recyclable waste by 7.5%. Like Palmer and Sigman [12], Walls [13], and Oosterhuis et al. [14] investigated the effectiveness of a Deposit-Refund System compared to the tax. They found that the Deposit-Refund System could better decrease the amount of marine litter, as the revenue from tax may be used for other purposes and not only for waste management.

Many of the studies mentioned above concluded that the Deposit-Refund System was the most effective tool for packaging waste management as it could reduce waste significantly and the cost of implementation was not remarkably high like others. These findings were confirmed by Walls [13], Fullerton and Wolverton [10], and Fullerton and Wolverton [15] who stated that, according to their theoretical and empirical analysis, the Deposit-Refund System was more suitable for packaging waste management than using virgin material tax, disposal fee, or recycled content standard. That is why many countries in the world implement a Deposit-Refund System as their main policy for container waste management as can be seen in Table 1 [6]. The table illustrates that the Deposit-Refund System was deployed mainly in order to manage containers of both alcoholic and non-alcoholic drinks. The rate of deposit was between 0.05 – 0.78 USD. These deposit rates were used for can and glass containers mainly. However, Kursah and Baabereyir [16] showed that the willingness to pay of people in Ghana for a deposit of sachet water plastic bag was just 0.013 USD (40% of the production cost per unit). It is true that the plastic bag is cheap. Thus, people tend to pay less for its deposit but this may lead to unredeemed deposit as well.

On the one hand, a Deposit-Refund System was a popular tool for packaging waste management in many countries and its effectiveness was affirmed by the study of Lavee [17]. He studied costs and benefits of implementing the Deposit-Refund System to handle beverage containers in Israel. The findings indicated that the benefits from the policy such as lower waste management cost were greater than the cost of the policy implementation by over 35%. On the other hand, the deposit-refund may not be suitable for every case, as claimed by Numata [18]. His findings showed that the deposit-refund may have negative impacts on some stakeholders and these impacts had not been taken into consideration; for instance, some consumers may not return their container waste to the sellers and leave their deposit. Consequently, the process of the Deposit-Refund System is not completed which in turn induces an inefficiency policy. The use of a Deposit-Refund System in the used oil industries in the USA was a good case in point as well. It was found that the cost-effectiveness ratio (the proportion between the transaction cost of implementing a Deposit-Refund System and the amount of waste being returned) was high due to an inconvenient waste return process. Thus, the transaction cost was getting high and became a barrier for the waste management to succeed [19].

On the whole, it is evident that a Deposit-Refund System was used in many countries due to its efficiency of getting waste back into the system. Most of them implemented the policy to manage consumer goods waste rather than hazardous waste even though hazardous waste would be more dangerous. In addition, due to the critical issue of hazardous packaging waste management in the Thai agricultural sector, an implementation of Deposit-Refund System policy seems to be viable. Hence, this study investigated the use of a Deposit-Refund System in Thai agricultural sector in order to get hazardous packaging waste back into the system while other previous studies would focus on drink containers and consumer goods waste mainly. In this paper, an optimal rate of deposit-refund was examined so that the system could achieve a high return rate of hazardous packaging waste in Thai agriculture by utilizing both survey data and time series data. These data were collected in Songkhla province which was selected as a representative province in Thailand.

Songkhla as a major province in the south of Thailand had been ranked as a top province producing waste in 2013. It used to account for 2.5 million tons of waste and people living in Songkhla could generate waste for 1.8 kilograms per person [1]. Even though the local governor attempted to reduce the enormous amount of waste, it seems not good enough as Songkhla was still in the top ten list of provinces generating waste in Thailand in 2018 [20]. In addition, the majority of people here are rubber and rice farmers

Table 1. The implementation of deposit refund systems in various countries.

Country	System	Containers Covered	Deposit
Austria	Law to make deposit regulatory	PET bottles (non-refillables excluded)	\$0.4
Denmark	Packaging Law	Beer and soft drinks containers, Deposits on some wine and spirit bottles	\$0.27 – \$0.78
Netherlands	Agreement deposit	Soft drinks and water in one-way and refillable glass and PET containers	\$0.16 – \$0.72
Norway	Deposit on containers and tax dependent on return rate	Most drinks excluding milk, vegetable juices and water	\$0.16 – \$0.40
South Africa	Deposit return system	Approx. 75% beer, 45% soft drinks and some wine and spirits bottles	8 – 15% of product cost
Sweden	Law requires rate of 90% recycling of aluminium cans, or complete ban	Aluminium cans and PET	\$0.07 – \$0.56
Switzerland	Deposits required on all refillable drinks containers	All refillable drinks containers	\$0.16 – \$0.40
South Australia	Container Deposit Legislation- deposit required on almost all drinks containers	Most included except wine (unless in plastic bottle), milk, pure fruit juice	\$0.10 – \$0.05
USA-California	California Beverage Container Recycling and Litter Reduction Act	Non-refillable drinks containers, e.g. beer, spirits, carbonated, fruit drinks and some vegetable juices	\$0.05 – \$0.10
USA-Vermont	Beverage Container Law Deposit-return system	Beer, soft drinks, malt, soda and mineral water, mixed wine and liquor	0.05−0.15

Source: modified from Hogg et al. [6]

and supply their productions to many factories in the area. It is undeniable that rubber and rice productions need to use hazardous chemical such as herbicide and pesticide substances. The report of Pollution Control Department [1] also showed that there were many people getting injured or dying due to hazardous wastes from agricultural production in the province. That is why this study chose Songkhla province as proxy area of interest. However, it is the fact that the main hazardous chemicals used in Songkhla province were in a form of bottle due to the convenience of using and handling so this paper would investigate an optimal rate of deposit-refund as the first priority rather than the other forms of hazardous packaging.

Thus, the data obtained in the province were analyzed in order to discover an optimal deposit rate. As a result, the rate of injury and death due to toxicity of hazardous packaging waste in the Thai agricultural sector especially Songkhla province would decrease and ecological systems would be protected from toxic substances left over in the hazardous chemical packages used in agricultural production.

2. Methodology

To investigate a suitable deposit rate that could attract Thai farmers to return their hazardous packaging, the study needs to compare the returning probabilities between using the willingness to pay (WTP) expressed by the farmers and using marginal social cost (MSC) as suggested by Palmer and Walls [11]. They found that the optimal deposit rate should be equal to the marginal social cost of disposal as it could lead to a social optimum. However, their research would base on theoretical work and consumer goods mainly. For this reason, the methodology of examining the suitable deposit rate begins with exploring the two option rates of the deposit: 1) the willingness of Thai farmers to pay (WTP) and 2) the marginal social cost (MSC) of disposal. Consequently, the probabilities of hazardous packaging being returned under the two rates of deposit were computed and compared in order to reveal the best option for Thai farmers.

2.1 An analysis of WTP as a first candidate of an optimal deposit rate

To obtain WTP, a questionnaire was used as the main instrument. It was divided into three main parts. The first part was about general information of Thai farmers such as gender, age, and chemical use in production. The second was designed to ask about the farmers' WTP for the hazardous packaging deposit. The last part was devoted to evaluate the damages of hazardous packaging waste. The questionnaire was then proved for validity and reliability before collecting data. After that, four hundred respondents were interviewed by using both quota and accidental sampling techniques. Each respondent was face to face interviewed by the author at their home as each question needs to be clarified and ensured especially for getting the WTP and the environmental damages. This procedure was started in October 2018 and kept going until four hundred respondents were completely collected in March 2019. Regarding the part two in the questionnaire, before the price that farmers are willing to pay for deposit was asked, the impacts of hazardous chemical packaging waste were presented to the farmers first followed by the concept of a Deposit-Refund System which the government plans to implement in order to get hazardous packaging waste back into the system. After that, the farmers were then asked for an acceptable price of the packaging deposit. The answer was then filled in the questionnaire by the interviewer.

The part three in the questionnaire was designed to express damages of hazardous packaging waste. The damages were classified into two main sides: health damage and environmental damage. The former was measured by capturing the cost of illness caused by hazardous chemical which was left over its package including the cost of transportation from their home to a hospital. The latter was evaluated by using the contingent valuation method (CVM). The CVM is one of useful valuation techniques which could express the individuals' value for environmental goods under stated preferences. Survey questions were used to elicit preferences of respondents directly, by asking the individuals to state their preferences for the environmental goods [21]. As a result, the environmental value could be revealed through a pseudo market based on the story and questions in questionnaires which consists of three main parts: 1) a detailed description of the environmental goods 2) questions which are used to elicit the price for the goods and 3) questions about characteristics of respondents as they can be used to estimate a valuation function of the environmental goods.

In addition, an ecology system which was devastated by hazardous packaging waste has to be valued by the farmer so the survey question was designed by following suggestions of Zainudin et al. [22]. They recommended that the first paragraph of the question should introduce environmental goods in general. The second should explain the details of goods that the respondents need to evaluate and the last part should come with the details of how the goods will be provided and the method that will be used to pay for the goods. Thus, the interviewer explained the damages of hazardous packaging waste on an ecology system by showing them the picture and asked the farmers to mitigate such damages by paying their money through the helping program of the municipality. The program will be introduced in a form of charging fee per bottle of hazardous chemical use as this method of paying would be accessible for all farmers. After they answered the most WTP for the fee as a free form, the iterative bidding technique was then used to negotiate what is the rate should be, like the study of Zainudin et al. [22]. This process was carried on until the respondent does not change their answer anymore. As a result, the ecology system damage was identified and filled in the questionnaire by the interviewer.

To sum up, it is obvious that the WTP as a candidate of an optimal deposit rate could be obtained from the answer in the part two of a questionnaire so that it would be utilized to calculate the probability of hazardous packaging waste being returned in section 2.3. The rest of survey data such as damage evaluation would then be used to compute the marginal externality cost of waste management in section 2.2.

2.2 An analysis of MSC as a second candidate of an optimal deposit rate

According to an analysis of MSC, Palmer and Walls [11] had claimed that the function of packaging waste disposal would be in a form of Cobb-Douglas because the disposal process could be seen as a production process. Thus, the hazardous packaging waste disposal function was formed as follows;

$$Z = A^{\alpha} K^{\beta} L^{1-\alpha-\beta} \tag{1}$$

where Z is the amount of hazardous packaging waste in a process of waste disposal. A is technological level. K is capital endowments. L is the amount of labour working in the process. α, β are coefficients and $0 < \alpha, \beta < 1$.

Moreover, the social cost of waste disposal (SC) is equal to the summation of the total cost (TC) and the externality cost of waste management (EC). The total cost consists of the fixed cost (FC) and the variable cost (VC). Hence, equations 2 and 3 were constructed.

$$SC = TC + EC \tag{2}$$

$$SC = FC + VC + EC \tag{3}$$

where FC is defined as an exogenous cost dependent on the product of capital endowments (K) and their returns (r). VC is defined as a product of wage (ω) and labours which is dependent on the hazardous packaging waste disposal function ($F(Z)$). EC is also dependent on the hazardous packaging waste disposal function ($EC(Z)$). Consequently, the social cost function was formed as follows;

$$SC = rK + \omega L(Z) + EC(Z) \tag{4}$$

The first order condition of this function with respect to the amount of packaging waste was then calculated. Thus, the marginal social cost (MSC) was revealed as shown in equation 5.

$$MSC = \omega ML_z + MEC_z \tag{5}$$

where ML_Z is the marginal labour cost with respect to waste and MEC_Z is the marginal externality cost with respect to waste.

The marginal labour cost of hazardous packaging waste here was indicated by regressing the labour cost data provided by the Songkhla municipal office [23]. First of all, an explicit form of the relation between labour costs and packaging wastes was identified by comparing across all 3 main forms: linear, log-linear, and double-log linear forms. As a result, the labour cost coefficient from the most explainable function could be extracted and used as a marginal labour cost of hazardous packaging waste. Moreover, the marginal externality cost could be computed by employing the data surveyed in Songkhla province as mentioned above. The damages induced by hazardous packaging waste were evaluated by using either market price technique or CVM technique. They were classified into two main types of damages, namely health and environmental damages. Both of these damages were then used as externality costs of hazardous packaging waste. The relation between externality costs and the amount of hazardous packaging waste was then revealed in order to extract the marginal effect of the waste. As the marginal labour and the marginal externality were indicated, the marginal social cost could be calculated as expressed in equation 5.

2.3 The probability of hazardous packaging waste being returned

Due to Numata's study [24], DRS may lead to market inefficiency even though it is better than other economic tools. The reason for this is that the farmers would have a lack of incentive to return their hazardous packaging waste as their opportunity cost is higher than the deposit. Hence, this study took this concern into consideration by comparing the probabilities of return packaging waste between using WTP and MSC as a deposit rate. The probabilities were calculated by using a binomial logistic regression technique as the outcomes of farmer's decision can be only returned (1) and not returned (0). Thus, let $\Pr(y = 1)$ represents the probability of the waste being returned and $\Pr(y = 0)$ represents the probability of the waste not being returned. The explanation factors here were the farmer's revenue per day (REV), the number of household members that are not over 11 years old ($CHILD$), and the distance between their house and the hazardous chemical shop that kept their deposit ($DIST$). Regarding this relation, equation 6 was created.

$$\ln\left(\frac{\Pr(y=1)}{\Pr(y=0)}\right) = y_i = c+\beta_{1i}REV+\beta_{2i}CHILD+\beta_{3i}DIST \tag{6}$$

where y is a logarithm of the ratio between the probability that farmers return packaging waste and the probability that farmers do not return packaging waste. $\beta_1, \beta_2, \beta_3$ are coefficients of $REV, CHILD$ and $DIST$ factors, respectively. $i = 1$ represents the case of using WTP as a deposit rate and $i = 2$ represents the case of using MSC as a deposit rate.

3. Results and Discussion

The data used to indicate both WTP and MEC for this study were obtained from 400 farmers in Songkhla province, Thailand. In general, the proportion between male and female were not significantly different. They were 48 years old on average and had been educated to just primary school level. The main characteristics of samples looked similar to general information of Songkhla population shown in the Songkhla municipality annual report 2016 [23]. From this information, it is evident that the samples in this study could be good representatives of famers in Songkhla province. However, the samples were then interviewed in detail. The findings presented that most sample households consisted of four members including one less than 11 years old child. The farmers used at least one bottle of hazardous chemical per month in their production. Some of them would walk or ride a bicycle to buy hazardous chemicals but the majority of them preferred to take a motorcycle or car instead. The average distance from a farmer's house to a hazardous chemical shop was 5.7 kilometers, so the farmers would spend about 15 minutes for transportation. In addition, they evaluated damage values from the hazardous chemical as well. They expressed that the impact on their health and the environment were about 42.93 USD/bottle and 0.42 USD/bottle, respectively. Thus, the total damage value estimated by each farmer was about 43.35 USD/bottle as shown in Tables 2.

As the farmers were asked about the deposit rate, they would be willing to pay, many rates were indicated. However, the most favoured rate was 0.15 USD/bottle as this figure accounted for over 50% of the farmers (Table 3). The reason for this was that they tried to compare it with the price of used bottles in a waste market. Thus, this study would take the rate of deposit as 0.15 USD/bottle in the case of WTP rate. Consequently, the farmer had to choose between returning and not returning their packaging wastes under the case of using WTP as a deposit rate.

According to MSC described in equation 5, this study had to investigate the marginal labour cost with respect to waste (ML_Z) and the marginal externality cost with respect to waste (MEC_Z). To obtain ML_Z, the time series of labour expenditure paid for waste management in Songkhla were obtained [23]. The data were monthly collected from 2010 to 2016. They consisted of both fulltime and temporary labour cost which depended on the expected amount of waste in each month. Then, they were analyzed with a regression technique as follows.

First of all, the suitable form of the relation between the labour cost and the amount of waste had to be defined. From Table 4, it is clear that the simple linear form has nonstationary because the Dickey-Fuller unit-root test results show that we cannot reject the null hypothesis of nonstationary in the linear form of time series. In fact, a time series is stationary if its mean and variance are constant over time. Thus, the stationary in time series data is a crucial assumption in order to estimate parameters [25]. If this assumption is broken, the results of estimation would lead to other problems such as inconsistent of estimation, autocorrelation, and spurious correlation [26]. For this reason, the linear form should not be considered due to time series analysis ground rules. Hence, the comparison between the semi-log form and the double-log form indicated that the semi-log form performed better than the other in terms of either R^2 or AIC/BIC. It means that the semi-log function could explain the labour cost variable for 66.39% which was higher than the double-log form. In the meantime, AIC and BIC are criteria to choose a better model. The lower AIC/BIC represent the better model as it would close to the true model. For this study, the AIC/BIC values of the semi-log model were lower than the double-log model so the estimation of labour cost given by the semi-log model would be closer to the true value than the double-log. The test results also showed that there

Table 2. General information of Thai farmers in Songkhla province.

Variable	Mean	Std. Dev.	Min	Max
Age (years)	48.298	11.884	17	86
Household members (persons)	4.2625	1.629	1	12
Children below the age of 11 (persons)	0.645	0.892	0	4
Rubber production capability (kg./day)	35.353	88.548	3	1,536
Revenue (baht/day)	549.343	521.56	60	5,600
Round-trip distances from home to shop (km.)	5.799	10.404	0.2	100
Round-trip times from home to shop (minutes)	15.303	14.884	1	120
Health damage value (USD/bottle)	42.932	38.357	8.690	217.860
Environmental damage value (USD/bottle)	0.415	0.255	0.150	1.500
Total damage value (USD/bottle)	43.347	38.613	8.840	219.360

Table 3. The willingness to pay for the hazardous packaging deposit.

WTP (USD/bottle)	Freq.	%
0.030	15	3.75
0.060	14	3.5
0.090	24	6
0.120	19	4.75
0.150	218	54.5
0.180	36	9
0.210	14	3.5
0.240	18	4.5
0.300	38	9.5
More than 0.300	4	1
Total	400	100

was no issue about multicollinearity, autocorrelation, heteroskedasticity, as well as unit root.

Thus, the semi-log linear form was utilized in order to examine the marginal labour cost of waste disposal. As a result, the effect of waste on the labour cost was written as followed;

$$\ln(LabourCost) = 11.21 + 0.00012Waste \quad (7)$$

Then, equation 7 was transformed by using natural logarithm properties as $e \approx 2.71828183$ so equation 8 was constructed.

$$LabourCost = 73,865.42 + e^{0.00012Waste} \quad (8)$$

To obtain the marginal labour cost with respect to waste (ML_Z), it needs to calculate the derivatives of equation 8 with respect to waste as shown below;

$$ML_Z = 0.00012e^{0.00012Waste} \quad (9)$$

Equation 9 shows that the marginal labour cost with respect to waste (ML_Z) would depend on the product of 0.00012 and $e^{(0.00012waste)}$. Thus, ML_Z could be calculated and combined with the MEC_Z which was determined in the next section, in order to compute MSC at the end.

The next step was devoted to identify MEC_Z by exploring the damage value from surveyed data. However, as the linear regression technique under parametric analysis assumes that each disturbance (u_i) has normal distribution [25], the normality tests such as Skewness and kurtosis test and Shapiro-Wilk and Shapiro-Francia tests have been used to test the distribution of the disturbances resulted in damages and waste regression. The both normality test results showed that the p-values were 0.0000 which were less

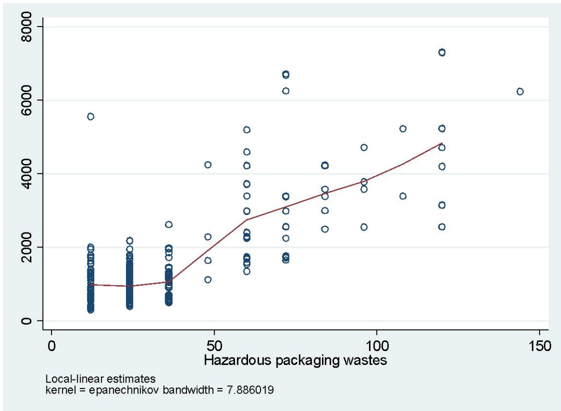

Figure 1: Relation of waste and damage cost with a nonparametric estimated plot.

than the significance level at 0.05. Thus, we can reject the hypothesis that the disturbance is normally distributed so the data cannot be analyzed with a parametric analysis [27, 28]. Hence, this study used a nonparametric analysis as a main technique to estimate an effect of waste on the total damage cost. The aim of the nonparametric estimation techniques is to estimate models with as fewest functional form and distribution assumptions as possible [29]. This study utilized kernel nonparametric regression as it is popular in literatures. This technique was introduced by Nadaraya [30] and Watson [31]. Then, there were many studies which extended the idea and enlarged the techniques of nonparametric analysis such as Ullah and Vinod [32] and Ullah [33]. Kernel nonparametric regression focuses on density estimation and/or distribution functions directly by smoothing the variables. It can be seen as an extension of Weighted Least Squares (WLS) which aim to minimize a weighted residual sum of squares. This is different from an Ordinary Least Squares (OLS) technique used in parametric analysis as OLS makes no distinction of where the data are located when estimating the conditional expectation. In contrast, kernel nonparametric regression will estimate the point of interest using data within a bandwidth instead [34].

In addition, as the major advantage of nonparametric regression is that it does not require Gauss-Markov assumptions including normal distribution assumption to be held, Kernel nonparametric regression was obtained to estimate the effect of waste on the total dam-

Table 4. Regression results from various forms of the relations between LabourCost and Waste.

Variable/Test method	Linear Coefficient (SE)	Semi-Log Coefficient (SE)	Double-Log Coefficient (SE)
Constant	-43486.2 (43344.67)	11.2049* (0.172884)	6.979237* (1.674714)
Waste	26.3429* (10.68732)	0.00012* (4.26E-05)	0.566783* (0.203354)
R^2	0.6815	0.6639	0.6634
Adj. R^2	0.6721	0.654	0.6535
AIC	1716.691	-48.66328	-48.55737
BIC	1723.479	-41.87524	-41.76933
DF Unit Root Test of LabourCost (H_0: no stationary)	0.1216	0.0328*	0.0328*
DF Unit Root Test of Waste (H_0: no stationary)	0.0000*	0.0000*	0.0000*
Durbin test for autocorrelation (H_0: no serial correlation)	0.7732	0.4957	0.4570
Breusch-Godfrey test (H_0: no serial correlation)	0.7669	0.4846	0.4458
B-P / C-W test for heteroskedasticity (H_0: Constant variance)	0.3988	0.9991	1.0000

*denotes significance at 1%

Table 5. Effect of wastes on damage cost estimated by nonparametric regression.

DamageCost	Estimate	Std.Err.	P > z
Mean of DamageCost	43.402	2.416	0.000
Effect of Wastes	0.287	0.136	0.035

Table 6. Binomial logistic regression results for the case of using WTP as a deposit rate.

WTP(0.15 USD/bottle)	Coef.	Std.Err.	z	P > z
Constant	2.464854	0.246657	9.99	0.000*
Revenue	0.000434	0.00012	3.60	0.000*
Children below the age of 11	-0.45861	0.160047	-2.87	0.004*
Distance	-0.46768	0.067162	-6.96	0.000*
Pseudo R^2 = 0.4058				

* significance at 1%

Table 7. Binomial logistic regression results for the case of using MSC as a deposit rate.

MSC(0.30 USD/bottle)	Coef.	Std.Err.	z	P > z
Constant	3.217235	0.408022	7.88	0.000*
Revenue	0.003271	0.000586	5.58	0.000*
Children below the age of 11	0.123533	0.309467	0.4	0.690
Distance	-0.34535	0.043636	-7.91	0.000*
Pseudo R^2 = 0.659				

* significance at 1%

Table 8. Predicted probabilities for hazardous packaging waste return using WTP and MSC, respectively.

Variable	Mean of probabilities	Std. Dev.	Min	Max
WTP (0.15 USD)	0.6650	0.323300	2.74E-19	1
MSC (0.30 USD)	0.8575	0.291541	3.26E-09	1

age cost here. The nonparametric regression results in Table 5 indicated that the effect of waste on the damage cost was 0.29 at a significance level of 0.05. It means that the damage cost (health and environmental impact costs) would increase 0.29 USD when the amount of waste increases for 1 bottle of hazardous packaging waste. This figure can be seen as a marginal externality cost (MEC_Z) of throwing 1 hazardous packaging waste out of the proper system. As a result, Figure 1 was then plotted to illustrate the estimated damage values upon hazardous waste by using nonparametric regression technique.

Regarding ML_Z and MEC_Z mentioned above, the marginal social cost of waste disposal was computed by replacing both values in equation 5 with an average wage at 306 USD/month [34] so that MSC was about 0.30 USD/bottle. Thus, this study would take this rate as a deposit rate for the case of using MSC. Up to here, both rates of deposit were defined already. The case of using WTP, the deposit rate was 0.15 USD/bottle and in the case of using MSC, the deposit rate was 0.30 USD/bottle. It is important to note that the rate of 0.15 USD/bottle was close to the rate used in Europe countries such as Netherlands, Norway and Switzerland but this rate may not be suitable for hazardous packaging waste. As such rate was set for consumer good waste deposit mainly, the countries do not need to take impacts on human health and environment into consideration before setting the deposit rate. This would be a different point of looking at hazardous packaging waste which could impact on both human and environment. For this reason, the suitable rate should induce a higher rate of waste being returned. Hence, these two rates were used to estimate the probabilities of return hazardous packaging wastes for both scenarios. A binomial logistic regression was employed as a main tool to illustrate the factors influencing the probability of return and predict the probability of return as well.

Tables 6 and 7 present the effects of three main factors: revenue, numbers of children below the age of 11, and distance from home to hazardous chemical shop in the cases of using WTP and MSC as a deposit rate, respectively. It is evident that all main factors could affect the probability of return in the case of using WTP. In fact, the distance and the number of children would have negative impacts on the probability as the cost of return would get higher than the deposit rate when farmers have to go further and spend more time in order to get a deposit back from the shop. In contrast, if their revenue gets higher, they would tend to return more. This would be interpreted that the revenue could increase farmers' ability to return hazardous packaging waste as they could afford for the cost of transportation and administrative activities. As in the case of using WTP, if the government imposes MSC as a deposit rate, distance and revenue would have a major impact on probability of return with the same direction. But the number of children could not impact on the probability in this case.

Both scenarios affirm that the distance between the farmer's house and the hazardous chemical shop play an important role for the returning probability of Thai farmers. Consequently, the returning probabilities of each farmer for both cases of deposit rates: WTP and MSC were computed by using estimated results in Table 6 for the case of WTP and Table 7 for the case of MSC. Thus, Table 8 was therefore created to present the predicted probabilities of hazardous packaging waste return under the two scenarios. The figures show that using MSC (0.30 USD/bottle) as a deposit rate could increase the returning probability to 86%, averagely while using WTP (0.15 USD/bottle) could create the probability of just 67%, averagely. For this reason, the government should use the MSC as a deposit rate when it is going to impose the Deposit-Refund System in the Thai agricultural sector, reducing unredeemed deposits by establishing an optimal deposit rate. The farmers would tend to return their hazardous packaging waste, and subsequently, the number of injuries and deaths related to hazardous packaging waste would decrease substantially.

4. Conclusions

It is clear that the Deposit-Refund System (DRS) is an efficient economic tool to cope with waste, especially beverage container and packaging waste, as many counties in the world have shown. However, it appears to be a rare case of applying DRS in the agricultural sector. This study aimed to study a suitable DRS in order to reduce hazardous chemical packaging waste in Thai agriculture, as Thai farmers continue to use the chemicals in their production but do not take responsibility for their waste. Thus, there is a risk of Thai people being injured or dying due to such hazardous waste. The deposit rate is still the key issue for the case as it may lead to an inefficient policy due to a high non-return rate [18]. This study utilized two different rates of deposit: the willingness to pay for a packaging deposit (WTP) and the marginal social cost (MSC) suggested by Palmer and Walls [11]. The findings indicated that using MSC as a deposit rate could better incentivize Thai farmers to return their waste than using WTP as expressed by Thai farmers. This was relevant to the study of Siritorn and Permpoonwiwat [35]. They found that WTP for a waste collection service could not lead to an optimal price as people tend to express it lower than the true one due to extra living cost awareness. That's why the probability of retuning waste in the case of using WTP as a deposit rate was lower than using MSC, remarkably. Apart from the fact that MSC as a deposit rate could draw the hazardous packaging waste back into the system better than using WTP as a deposit, the distance between farmers' homes and agricultural chemical shops also has significantly a negative impact on the returning rate as well.

For these reasons, the government of Thailand should consider DRS as a main policy of managing hazardous packaging waste especially in the agricultural sector. The policy implementation is also one of important parts. The government should set the rate of deposit to be equal to MSC rate (0.30 USD/bottle) and increase the number of returning points in order to reduce the opportunity cost of Thai farmers. As a result, the number of people getting injured or dying due to hazardous wastes from agricultural production would be reduced soon.

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