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An impact analysis of a Deposit-Refund System to mitigate hazardous packaging waste in Thai agricultural sector

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Abstract

Hazardous waste could harm human, animal, and ecology system and it has been a critical issue in Thailand for many years. One of the main sources of hazardous waste would come from the agricultural sector such as herbicide and pesticide chemical. In order to cope with these a Deposit-Refund System (DRS) may be a suitable policy to mitigate the waste especially hazardous packaging waste used in the sector. This theoretical work attempted to investigate impacts of the policy on the market including hazardous chemical and agricultural product prices. The findings showed that whenever DRS is imposed in the agricultural sector, the price of hazardous chemical products would increase by the total of the marginal administrative cost of hazardous packaging waste management and the marginal renting cost of keeping hazardous packaging wastes for return. In addition, the price of agricultural products would also increase by the value of administrative cost and renting area cost per unit of hazardous packaging waste. As a result, the policy maker needs to prepare for the rising prices together with the policy implementation.

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 & 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.

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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 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 & 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 between deposit rate, refund rate and marginal social cost, the social benefit would be larger than using just a tax or subsidy alone. Palmer, Sigman and Walls [12] and Walls [13] also compared the implementation costs across Tax, Subsidy, and Deposit-Refund System tools for recycle 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 reduce recycle waste by 7.5%. Like Palmer, Sigman and Walls [12], Walls [13], and Oosterhuis, Papyrakis and Boteler [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 recycle 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 0.02 – 0.78 US dollars.

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 [16]. He studied costs and benefits of implementing the Deposit-Refund System to handle beverage containers in Israel. The findings indicated that the average cost of the policy implementation was about \$0.038. In the meantime, the benefits from the policy such as lower waste management cost were greater than the cost of the policy implementation for over 35%. On the other hand, the deposit-refund may not be suitable for every case, as claimed by Numata [17]. 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 forfeit their deposit. Consequently, the process of the Deposit-Refund System is not completed which in turn induces a market failure. 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 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 [18].

Regarding the critical issue of hazardous packaging waste management in the Thai agricultural sector, an implementation of Deposit-Refund System policy seems to be viable. However, the statement by Numata [19] about the negative impact of the policy on market failure may need to be taken into account before imposing such policy in Thailand. For this reason, this paper was conducted to examine impacts of the Deposit-Refund System which would be imposed in the agricultural sector in Thailand soon.

2. Objectives

This paper attempted to investigate impacts of the Deposit-Refund System on both the hazardous chemical and agricultural product prices so that the policy maker could implement the policy efficiently. Hence, it would not create burdens on the chemical shops, farmer as well as consumers and become green economy in the future.

3. Methods and Results

To explore effects of DRS which have not been implemented yet in Thailand, the theoretical analysis was obtained. Various theories of producer and consumer were reconstructed by injecting the policy into their decision making of production and consumption, respectively. Thus, this section was divided into 2 parts as follows.

3.1 Hazardous chemical seller's decision making under a constraint of DRS

As the hazardous chemical retailers have to pay for the deposit rate which can be seen as packaging waste tax at this moment, the total revenue of the retailers is then deducted as shown in the equation (1).

$$TR = (p_x - tax)x \tag{1}$$

where TR is a total revenue of retailers, p_x is a hazardous chemical product price, *tax* is a deposit rate per unit of product, x is the number of hazardous chemical products being sold.

The cost of production (TC) consists of three parts: fixed cost (FC), variable cost (VC) and transaction cost (TX) which represent an opportunity cost of hazardous packaging waste management.

$$TC = FC + VC + TX \tag{2}$$

In addition, the fixed cost is determined as an exogenous variable

$$FC = FC^* \tag{3}$$

The variable cost is then constructed from both wage and packaging costs which could be subsidized by the refund from returning the hazardous packaging waste to the upstream seller.

$$VC = mvc \cdot x + (p_x - sub) \cdot k \tag{4}$$

where *mvc* is a marginal variable cost, x a number of selling hazardous chemical products, p_k is a hazardous packaging price, *sub* is a refund rate, and is a number of hazardous packaging waste which equal to a number of selling hazardous chemical products (x) so equation (4) could be rewritten to equation (5).

$$VC = mvc \cdot x + (p_k - sub) \cdot k \tag{5}$$

The transaction cost is a combination of an opportunity cost for returning the packaging waste, a transportation cost and the packaging waste administrative cost.

$$TX = \omega \cdot time_{trv} + c_d \cdot D + CA \tag{6}$$

where ω is a wage rate per hour, $time_{trv}$ is a number of hours spent on the transportation for returning the waste, c_d is the marginal cost of travelling to returning the waste, D is a distance from the site to a seller's shop, CA is an administrative cost for the hazardous waste management which could be calculated from an opportunity cost of administrative time to collect the waste (*mac*) and using space for keeping the waste until return (*mrc*). Hence, the TX could be rewritten as follows;

$$TX = \omega \cdot time_{trv} + c_d \cdot D + mac \cdot x + mrc \cdot x \tag{7}$$

Thus, the total cost for a hazardous chemical seller is reconstructed as follows,

$$\begin{aligned} TC &= FC^* + mvc \cdot x + (p_k - sub) \cdot x \\ &\quad + \omega \cdot time_{trv} + c_d \cdot D + mac \cdot x \\ &\quad + mrc \cdot x \end{aligned} \tag{8}$$

As the goal of the hazardous chemical seller is to maximize its profit, the profit function (π_1) is now constructed and derived with respect to x in order to express maximizing conditions as shown in equations (9) – (11).

$$\begin{aligned} \pi_1 &= [(p_x - tax) \cdot x] - [FC^* + mvc \cdot x \\ &\quad + (p_k - sub) \cdot x + \omega \cdot time_{trv} + c_d \cdot D \\ &\quad + mac \cdot x + mrc \cdot x] \end{aligned} \tag{9}$$

$$\begin{aligned} Max[\pi_1 &= p_x \cdot x - tax \cdot x - FC^* - mvc \cdot x \\ &\quad - p_k \cdot x + sub \cdot x - \omega \cdot time_{trv} \\ &\quad - c_d \cdot D - mac \cdot x - mrc \cdot x] \end{aligned} \tag{10}$$

$$(p_x - p_k) + (sub - tax) - (mvc + mac + mrc) = 0 \tag{11}$$

However, in the case that the policy maker imposes DRS with an equal rate between deposit and refund ($tax = sub$), equation (11) is then transformed into equation (12).

$$p_x = p_k + (mvc + mac + mrc) \tag{12}$$

Regarding the competitive market equilibrium, the marginal cost of production must be equal to the price of product at the maximum profit level. Equation (12) needs to be modified by setting $p_x = mc = mvc + p_k$. Equation (13) is now revealed and illustrates the conditions of the market after the DRS is imposed.

$$p_x = mc(mac + mrc) \tag{13}$$

Equation (13) indicates that whenever the government imposes a Deposit-Refund System policy in the Thai agricultural sector, the price of hazardous chemical products would increase. The price increase is equal to the total of the marginal administrative cost of hazardous packaging waste management and the marginal renting cost of keeping hazardous packaging wastes for return.

3.2 Farmer's decision making to use hazardous chemicals under DRS

The total revenue of farmers who use hazardous chemical products in their production depends on the value of product selling and also the value of hazardous packaging waste refunds as shown in equation (14).

$$TR = p_y \cdot y + sub \cdot x_y \tag{14}$$

where p_y is a product price, y is a number of selling products, *sub* is a refund rate which can be seen as a subsidy for returning hazardous packaging wastes,

x_y is a number of hazardous packaging wastes which depend on y.

The total cost (TC) of agricultural production is a combination of fixed cost (FC), variable cost (VC), and transaction cost (TX) induced by DRS.

$$TC = FC + VC + TX \tag{15}$$

where FC is an exogenous variable.

$$FC = FC^* \tag{16}$$

VC is a summation of the product of a marginal variable cost (mvc) and outputs (y), and the product of deposit rate (tax) and a number of packaging waste (k).

$$VC = mvc \cdot y + tax \cdot k \tag{17}$$

However, the number of packaging waste here is set to be equal to the number of hazardous packaging wastes used in the production so equation (17) has to change to equation (18).

$$VC = mvc \cdot y + tax \cdot x_y \tag{18}$$

Tx reflects four opportunity costs: 1) returning time loss that is calculated by multiplying wage (ω) and a period of time spent on the returning process ($time_{trv}$), 2) transportation loss that is captured by multiplying a marginal cost of travel (c_d) and a distance of travel (D), 3) administrative loss which is computed by multiplying a marginal cost of packaging waste management (mac) and a number of packaging waste (x_y), and 4) renting area loss that is calculated by multiplying a marginal cost of renting area used to keeping packaging waste before return (mrc) and a number of packaging waste (x_y).

$$TX = \omega \cdot time_{trv} + c_d \cdot D + mac \cdot x_y + mrc \cdot x_y \tag{19}$$

Consequently, the total cost of farmers' production is transformed into equation (20).

$$\begin{aligned} TC &= FC^* + mvc \cdot y + tax \cdot x_y + \omega \cdot time_{trv} \\ &\quad + c_d \cdot D + mac \cdot x_y + mrc \cdot x_y \end{aligned} \tag{20}$$

Then, the farmer would like to maximize its profit subject to a number of outputs as shown in equations (21) – (23).

$$\begin{aligned} \pi_2 &= [p_y \cdot y + sub.x_y] - [FC^* + mvc \cdot y \\ &\quad + tax \cdot x_y + \omega \cdot time_{trv} + c_d \cdot D \\ &\quad + mac \cdot x_y + mrc \cdot x_y] \end{aligned} \tag{21}$$

$$\begin{aligned} Max[\pi_2 &= p_y \cdot y + sub \cdot x_y - FC^* - mvc \cdot y \\ &\quad - tax \cdot x_y - \omega \cdot time_{trv} - c_d \cdot D \\ &\quad - mac \cdot x_y - mrc \cdot x_y] \end{aligned} \tag{22}$$

$$p_y - mvc + (sub - tax - mac - mrc) \cdot mx_y = 0 \tag{23}$$

In the case of imposing deposit rate and return rate equally, the tax variable must be equal to the sub variable in equation (23). Thus, it is transformed into equation (24).

$$p_y = mvc + (mac + mrc) \cdot mx_y \tag{24}$$

Moreover, at the market equilibrium, the marginal variable cost here is the same as the marginal cost of production so equation (24) is rewritten to be equation (25).

$$p_y = mc + (mac + mrc).mx_y \tag{25}$$

Equation (25) could be interpreted that when DRS is imposed on the Thai agricultural sector, the price of agricultural products would increase. The incremental price is equal to the value of administrative cost and renting area cost per unit of hazardous packaging waste.

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. For this reason, the government may impose DRS in the agricultural sector in the near future. We found that whenever DRS is imposed in the agricultural sector, the price of hazardous chemical products would increase by the total of the marginal administrative cost of hazardous packaging waste management and the marginal renting cost of keeping hazardous packaging wastes for return. In the meantime, the price of agricultural products would also increase by the value of administrative cost and renting area cost per unit of hazardous packaging waste. These incremental prices of both hazardous chemical products and agricultural products would be rather reallocated between the producers and consumers due to the market mechanism. Hence, the policy maker needs to prepare for the rising prices together with the policy implementation in order to make a sustainable economy.

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