論文

Are Deposit-Refund Systems Superior to Other Externality Corrective Policies?: A Simple Partial Equilibrium Approach

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In a circumstance where one of three agents – households, firms, and professional garbage collector – can reduce pollution most efficiently, deposit-refund systems could be inferior to pure taxation policies because the former policies may give the agents an improper incentive to implement an externality-corrective activity, while the latter policies exclude such a possibility. The regulator should carefully select the policy target, as it can be crucial to this issue.

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Ⅰ. Introduction

Deposit-refund systems are regarded as one of desirable policy instruments to internalize or correct externality-related inefficiencies in the literature.[1] However, one issue is missed in the argument: who should practically carry out the externality mitigating activity? The purpose of this paper is to explicitly introduce this concern into the analysis. In that process, we set up a simple circumstance in which there is only one method to avoid the externality: to physically separate the externality receiver(s) from the externality-generating good by collecting it after consumption by the household as in the case of a littered beverage container. And that activity is performed by either households or firms or a professional garbage collector in practice. The focus is whether the choice of policy instruments influences the appropriateness of the resulting agent who collects the good. Our examination will show that the answer crucially depends on the target to whom policies are imposed. And not only deposit-refund syste ms but also traditional tax policies can be superior to other policies under certain circumstances.

The rest of the paper is organized as follows. Section Ⅱ introduces the fundamental structure of our model and shows main results. Section Ⅲ summarizes the essence of the results and mentions to the limitations of our argument.

Ⅱ. The Model

There exist many identical households and identical firms, which guarantees the competitiveness of a possible market. They uniformly consume and produce a common good. And the households' consumption of the good brings about a negative externality towards the third party agent(s). In order to avoid the effect, the third party agent(s) must be isolated from the good by someone. Suppose for example that the households consume a soft beverage which is

produced by the firms. And if the households litter its containers, their neighbor(s) suffers (suffer) from the bad view or smell generated by them.

Ⅱ-1. Social Optimality

Social optimality as a benchmark to evaluate the efficiency of the market trading as well as the appropriateness of government's policy-making is determined by maximizing the next social surplus or social welfare function with respect to three variables: the whole amount of the good produced and consumed in the economy, the amount of the good consumed by households and properly collected by any party to prevent the third party agent(s) from suffering from the resulting externality, and the amount of the good consumed by households but littered and left to generate the negative externality. That is,

$$Max._{x_i^c, x_i^{nc}} [B_i(x_i) - C_j^y(y_j) - min._{C^c}\{C_i^c(x_i^c), C_j^c(x_i^c), C_k^c(x_i^c)\} - D(x_i^{nc})]^2$$
$$s.t.\ \ x_i = y_j,\ x_i = x_i^c + x_i^{nc}\ ^3 \tag{1}$$

where $B_i(\cdot)$[4] is a representative household (=*i*)'s benefit from consuming the good, x_i in total, $C_j^y(\cdot)$ is a representative firm (=*j*)'s cost function to produce the good up to y_j, $C_l^c(\cdot)\ (l = i, j, k)$ is cost function to collect x_i^c, a part of x_i which is collected by agent l including k standing for another agent who is neither household nor firm like a garbage collection trader[5], and $D(\cdot)$ is damage function on the part of the negative externality receiving agent(s) in which x_i^{nc} denotes the residual non-collected amount of x_i apart from x_i^c. The third term of social welfare function implies that there are three alternative ways to collect the good consumed by household *i*: either he collects it for himself, or firm *j* does it in place of household *i*, or another agent does it professionally, and that one of the three cases is completely superior to other two in the sense that the agent can collect the good most cost-efficiently. The necessary conditions to maximize the function in equation (1) are

$$x_i^c;\ \ B_i' = C_j^{y\prime} + C_*^{c\prime} \tag{2a},$$
$$x_i^{nc};\ \ B_i' = C_j^{y\prime} + D' \tag{2b}$$

where the single prime signs mean first derivative of the relevant functions, and C_*^c stands for the solution of the third term of social welfare function. The whole amount of the good at the optimal level (x_i^*) is automatically determined in relation that $x_i^* = x_i^{c*} + x_i^{nc*}$ in which the asterisks imply the optimal values of the corresponding variables. The equations in (2) automatically brings

$$C_*^{c\prime} = D' \tag{3}.$$

Ⅱ-2. Market Economies Reinforced with Policy Instruments

Externality problems are not corrected or internalized in market economies except for under the Coasian circumstance. Thus, we explore behaviors of households[6] as well as firms in market economies with various types of policy instruments; pure taxation on the overall traded good or the non-collected portion of the good, pure subsidization to them, and deposit-refund system. Furthermore, we make up two alternative settings with regard to the policy target: household or firm.

A. Household-Targeted Policy Design

If the household is selected by the regulator as the target upon whom any policies are imposed, his net benefit maximization problems are set up as follows.

(i) Pure Taxation on the Overall Consumption of the Good

Under this policy, the household will determine the good consumption level so as to

$$Max._{x_i^c, x_i^{nc}} \{B_i(x_i) - px_i - tx_i - C_i^c(x_i^c)\} \qquad \text{s.t.} \quad x_i = x_i^c + x_i^{nc}$$

where p is a price of the good and t is a unit tax rate on the overall consumption of the good. Then, the necessary conditions are

$$x_i^c;\ B_i' = p + t + C_i^{c\prime} \qquad \text{and} \qquad x_i^{nc};\ B_i' = p + t \tag{4}$$

It is no doubt that the equations in (4) are incompatible with each other since $C_i^{c\prime} \neq 0$. Thus he naturally selects $x_i^* = x_i^{nc*}$ $(x_i^{c*} = 0)$ as a corner solution.

(ii) Pure Taxation on the Non-collected Portion of the Good

Under this policy, the household will choose the good consumption level in order to

$$Max._{x_i^c, x_i^{nc}} \{B_i(x_i) - px_i - \tau x_i^{nc} - C_i^c(x_i^c)\} \qquad \text{s.t.} \quad x_i = x_i^c + x_i^{nc}$$

where τ is a unit tax rate on the non-collected portion of the good. Then, the necessary conditions are

$$x_i^c;\ B_i' = p + C_i^{c\prime} \qquad \text{and} \qquad x_i^{nc};\ B_i' = p + \tau \tag{5}$$

It is obvious that two equations in (5) are compatible if $C_i^{c\prime} = \tau$. Then he will get $x_i^* = x_i^{c*} + x_i^{nc*}$.

(iii) Pure Subsidization to the Overall Consumption of the Good

Under this policy, the household will obtain the good consumption level so as to

$$Max._{x_i^c, x_i^{nc}} \{B_i(x_i) - px_i + sx_i - C_i^c(x_i^c)\} \qquad \text{s.t.} \quad x_i = x_i^c + x_i^{nc}$$

where s is a unit subsidy rate to the overall consumption of the good. Then, his consumption is attained by satisfying both

$$B_i' = p - s + C_i^{c\prime} \qquad \text{and} \qquad B_i' = p - s \tag{6}$$

It is clear that two equations in (6) are incompatible as long as $C_i^{c\prime} > 0$, so he will set $x_i^* = x_i^{nc*}$ $(x_i^{c*} = 0)$.

(iv) Pure Subsidization to the Collected Portion of the Good

Under this policy, the household will select the good consumption level in order to

$$Max._{x_i^c, x_i^{nc}} \{B_i(x_i) - px_i + \theta x_i^c - C_i^c(x_i^c)\} \qquad \text{s.t.} \quad x_i = x_i^c + x_i^{nc}$$

where θ is a unit subsidy rate to the collected portion of the good. Then, his necessary conditions are

$$x_i^c;\ B_i' = p + C_i^{c\prime} - \theta \qquad \text{and} \qquad x_i^{nc};\ B_i' = p \tag{7}$$

It is evident that two equations in (7) are compatible if $C_i^{c\prime} = \theta$. Then he will get $x_i^* = x_i^{c*} + x_i^{nc*}$.

(v) Deposit-Refund System

In general the deposit-refund system consists of a tax on the consumption of the good and a subsidy to the wide sense of environment-oriented activity. In our model, the latter activity corresponds to colleting the consumed good by the household. Under such a system, the household will choose the good consumption level in order to

$$Max._{x_i^c, x_i^{nc}} \{B_i(x_i) - (p + d)x_i + rx_i^c - C_i^c(x_i^c)\} \qquad s.t. \quad x_i = x_i^c + x_i^{nc}$$

where d is a unit deposit rate on the consumption of the good and r is the unit refund rate to the collected amount of the good. Then, his necessary conditions are

$$x_i^c;\ B_i' = p + d + C_i^{c\prime} - r \tag{8a}$$

$$x_i^{nc};\ B_i' = p + d \tag{8b}$$

It is obvious that two equations in (8) are compatible if $C_i^{c\prime} = r$. Then he will set $x_i^* = x_i^{c*} + x_i^{nc*}$.

On the other hand, the firm will choose the best production level by merely maximizing $\{py_j - C_j^y(y_j)\}$ to find that $p = C_j^{y\prime}$ is necessary to get y_j^*. That is, the production of this good is efficient.

(vi) Policy Setting

By comparing the socially optimal conditions in (2) and the above conditions in (4) through (8) which are privately optimal in the market setting with various policies, efficient policy instruments can be found. In that examination, the key point is who is the efficient good collector. If the household is the one under the household-targeted policy design, the pure taxation on the non-collected portion of the good and the deposit-refund system can induce him to engage

himself in the good collection activity.

Proposition 1a: *In the case that the household is the efficient good collector under the household-targeted regulation regime, as long as the relevant policy instruments are set ideally the pure taxation on the non-collected portion of the good and the deposit-refund system can induce the targeted agent to choose the socially optimal variables: overall consumption, collection, and non-collection of the good.*

If the household is not the efficient agent under this design, on the other hand, it is required to prevent the household from carrying out the good collection activity. It is the pure taxation on the overall consumption of the good that has such a function.

Proposition 1b: *In the case that the household is not the efficient good collector under the household-targeted regulation regime, only the pure taxation on the overall consumption of the good can induce the targeted agent to make an efficient decision in a form of corner solution: the household leaves all his consumption which is collected by another agent.*

B. Firm-Targeted Policy Design

If the firm is targeted by the regulator on whom any policies are imposed, his surplus maximization problems are set up as follows.

(i) Pure Taxation on the Overall Production of the Good

Under this policy, the firm will determine the good production level so as to

$$Max._{y_j^c, y_j^{nc}} \ \{py_j - C_j^y(y_j) - ty_j - C_j^c(y_j^c)\} \qquad s.t. \quad y_j = y_j^c + y_j^{nc}$$

where y_j^c is the good the firm collects after the household consumed it, y_j^{nc} is the residual portion of the good left alone, and t is a unit tax rate on the overall production of the good. Then, the necessary conditions to the above problem are

$$y_j^c;\ p = C_j^{y\prime} + t + C_j^{c\prime} \qquad \text{and} \qquad y_j^{nc};\ p = C_j^{y\prime} + t \tag{9}$$

It is apparent that the equations in (9) are not compatible as long as $C_j^{c\prime} > 0$. Therefore this firm certainly selects $y_j^* = y_j^{nc*}$ $(y_j^{c*} = 0)$ as a corner solution.

(ii) Pure Taxation on the Non-collected Portion of the Good

Under this policy, the firm will select the good production level in order to

$$Max._{y_j^c, y_j^{nc}} \{py_j - C_j^y(y_j) - \tau y_j^{nc} - C_j^c(y_j^c)\} \qquad s.t. \quad y_j = y_j^c + y_j^{nc}$$

where τ is a unit tax rate on y_j^{nc}. Then, the necessary conditions are

$$y_j^c;\ p = C_j^{y\prime} + C_j^{c\prime} \qquad \text{and} \qquad y_j^{nc};\ p = C_j^{y\prime} + \tau \tag{10}$$

It is obvious that two equations in (10) are compatible if $C_j^{c\prime} = \tau$. Then he will set up $y_j^* = y_j^{c*} + y_j^{nc*}$.

(iii) Pure Subsidization to the Overall Production of the Good

Under this policy, the firm will obtain the good production level so as to

$$Max._{y_j^c, y_j^{nc}} \{py_j - C_j^y(y_j) + sy_j - C_j^c(y_j^c)\} \qquad \text{s.t.} \quad y_j = y_j^c + y_j^{nc}$$

where s is a unit subsidy rate to the overall production of the good. Then, his production is achieved by satisfying both

$$p = C_j^{y\prime} - s + C_j^{c\prime} \qquad \text{and} \qquad p = C_j^{y\prime} - s \tag{11}$$

It is no doubt that two equations in (11) are incompatible so long as $C_j^{c\prime} > 0$, so he will set $y_j^* = y_j^{nc*}$ $(y_j^{c*} = 0)$ as a corner solution.

(iv) Pure Subsidization to the Collected Portion of the Good

Under this policy, the firm will choose the good production level in order to

$$Max._{y_j^c, y_j^{nc}} \{py_j - C_j^y(y_j) + \theta y_j^c - C_j^c(y_j^c)\} \quad \text{s.t.} \quad y_j = y_j^c + y_j^{nc}$$

where θ is a unit subsidy rate to the collected portion of the good. Then, his necessary conditions are

$$y_j^c;\ p = C_j^{y\prime} + C_j^{c\prime} - \theta \qquad \text{and} \qquad y_j^{nc};\ p = C_j^{y\prime} \tag{12}$$

It is evident that two equations in (12) are compatible if $C_j^{c\prime} = \theta$. Then he will select $\widetilde{y_j} = \widetilde{y_j^c} + \widetilde{y_j^{nc}}$ which deviates from the one determined by equations in (2).

(v) Deposit-Refund System

Under this system, the firm will choose the good production as well as collection levels so as to

$$Max._{y_j^c, y_j^{nc}} \{py_j - C_j^y(y_i) - dy_j + ry_j^c - C_j^c(y_j^c)\} \qquad \text{s.t.} \quad y_j = y_j^c + y_j^{nc}$$

where d is a unit deposit rate on the production of the good and r is the unit refund rate to the collected good. Then, his necessary conditions are

$$y_j^c; p = C_j^{y\prime} + d \tag{13a}$$

$$y_j^{nc}; p = C_j^{c\prime} + d + C_j^{c\prime} - r \tag{13b}$$

It is required that $C_j^{c\prime} = r$ in order for the two equations in (13) to hold. Then he will get $y_j^* = y_j^{c*} + y_j^{nc*}$.

Under this scheme, on the other hand, the household will choose the best consumption and emission levels by merely maximizing $\{B_i(x_i) - px_i\}$ to find that $p = B_i'$ is necessary to get x_i^*. This means that if the market equilibrium of this good transaction is efficient, the household will efficiently consume and leave the good entirely.

(vi) Policy Setting

By comparing the socially optimal conditions in (2) and the above conditions in (9) through (13) privately optimal in the market mechanism with various policies, efficient policy instruments can be found. The agent who is the efficient good collector is again the focus in this examination. If the firm is the one under the firm-targeted policy design, the pure taxation on the non-collected portion of the good and the deposit-refund system can encourage the firm to carry out the good collection activity.

Proposition 2a: *In the case that the firm is the efficient good collector, under the firm-targeted regulation regime as long as the relevant policy instruments are set efficiently, the pure taxation on the non-collected portion of the good and the deposit-refund system can induce the targeted agent to select the socially optimal variables: overall consumption, collection, and non-collection of the good.*

If the firm is not the efficient one under this design, on the other hand, it is verified to prevent the firm from collecting the good. It is the pure taxation on the overall production of the good that plays the role.

Proposition 2b: *In the case that the firm is not the efficient good collector, under the firm-targeted regulation regime, only the pure taxation on the overall production of the good can let the targeted agent to make a right decision in a form of corner solution: the firm produces the proper amount of the good, but does not engage himself in collecting the good.*

Ⅲ. Concluding Remarks

In this paper, we investigate the incentive effectiveness of environmental policies in the sense of whether agents are induced to choose socially optimal values with respect to overall production or consumption, collection, and littering of a good. It is demonstrated in Tables 1and 2 that if the policy-targeted agent coincides with the efficient good collector, both pure taxation on the non-collected good and deposit-refund system should be adopted, while an agent other than the policy-targeted one is the efficient good collector, only pure taxation on the overall production or consumption of the

good should be recommended. This implies that such a kind of pure taxation prevents the targeted agent from carrying out the inefficient collecting activity.

The above results may be vulnerable to some criticisms. First, agents, especially households, have only two alternatives to treat the consumed good, that is, collecting or littering (not collecting) in our model. However other methods can be found in reality involving recycling in Fullerton and Kinnaman (1995). Second, our model building is based on a partial equilibrium setting instead of general equilibrium one utilized in Fullerton and Wolverton (2000). Third, the professional garbage collector in our model is not given the ability to make a decision for himself. Introducing these respects into the analysis will make the results more robust.

TABLE 1a: Household-Targeted Policy Evaluation when the Household is Efficient Good Collector

	(i)	(ii)	(iii)	(iv)	(v)
x_i^c	No	Yes	No	No	Yes
x_i^{nc}	No	Yes	No	No	Yes
x_i	Yes	Yes	No	No	Yes

TABLE 1b: Household-Targeted Policy Evaluation when the Household is Not Efficient Good Collector

	(i)	(ii)	(iii)	(iv)	(v)
x_i^c	Yes	No	No	No	No
x_i^{nc}	Yes	No	No	No	No
x_i	Yes	No	No	No	No

TABLE 2a: Firm-Targeted Policy Evaluation when the Firm is Efficient Good Collector

	(i)	(ii)	(iii)	(iv)	(v)
y_i^c	No	Yes	No	No	Yes
y_i^{nc}	No	Yes	No	No	Yes
y_i	Yes	Yes	No	No	Yes

TABLE 2b: Firm-Targeted Policy Evaluation when the Firm is Not Efficient Good Collector

	(i)	(ii)	(iii)	(iv)	(v)
y_i^c	Yes	No	No	No	No
y_i^{nc}	Yes	No	No	No	No
y_i	Yes	No	No	No	No

"Yes" means that the socially optimal value is attainable through the Policy Implementation.
"No" means that the socially optimal value is not attainable through the Policy Implementation.

NOTES

1) Numata (2014) reviews the literature about deposit-refund systems with regard to their theory and practice.
2) In this social welfare formulation, we pick up one household's and one firm's objective functions as the representative agents. Summing up all agents' functions, however, would bring about no essential changes to the results below.
3) Such a formulation of the good is sometimes called "mass balance" in the literature including Fullerton and Kinnaman (1995).
4) It is assumed throughout the paper that all the functions are "well-behaved" so as to guarantee the existence of

interior solutions.

5) The collection trader is assumed to be subject to the regulator, so it makes no decision.

6) There are lots of articles which deal with households' decision-making problems. Palmer and Walla (1997) and Ino (2011) are typical examples.

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