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A Welfare Analysis on an Earmarked Deposit-Refund Recycling Policy

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Amongst the recycling policies that carry the property of extended producer responsibilities, deposit-refund (D-R) is recognized as an ideal policy as it can achieve a socially optimal outcome. In reality however, D-R often runs into a budget deficit. To correct for this void, we take the budget balance constraint into account in this paper, and re-examine the features of an earmarked D-R in recycling and output markets. Specifically, we investigate the circumstances under which a D-R runs into a budget deficit and examine the highest social welfare that an earmarked D-R can achieve. It is found that when recycling cost is relatively high, marginal environmental damage is mild, and the output market is competitive, the social welfare of an earmarked D-R is close to the social optimum. Under alternative conditions however, i.e., when recycling cost is low, marginal environmental damage is large, and output market is imperfect, it is more likely for a D-R to run into a financial deficit; this implies that the welfare of an earmarked D-R is less than the social optimum.

Keywords: *Recycling Policy, Deposit-Refund, Earmarking, Extended Producer Responsibility, Welfare Analysis*

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I. Introduction

In the last decade, waste management has gone beyond merely imposing duty on households; it has moved toward placing more responsibility on producers. In this so-called extended producer responsibility (EPR) emerging trend, producers are required to take financial or physical responsibility for the environmental impacts of their products (OECD, 1996). Various policy instruments consistent with EPR have been designed and analyzed.[1] In particular, deposit-refund (D-R) is recognized as an ideal mechanism as it can achieve a socially optimal outcome if the budget balance concern is ignored. However, in reality, D-R policies often run into budget deficits. We intend to correct for this void in this paper by re-examining the features of an earmarked D-R in recycling and output markets. Specifically, we investigate the circumstances when a D-R runs into a budget deficit and explore the highest social welfare that an earmarked D-R can achieve.

D-R is formulated as a recycling policy that is a combination of a tax/deposit on products due to their disposal cost and a subsidy/refund on recycling as a reward for the avoidance of disposal (Ino, 2011).[2] In the D-R mechanism, producers pay fees to the government and recyclers to express their responsibilities for their products. Recyclers receive fees and recycling subsidies from producers and the government. Within these financial incentives, the recycling activities are encouraged and the recycling market is stimulated.

Theoretically, D-R is applauded for its capacity to reduce resources use at the production stage while encouraging recycling at the disposal stage. When the tax and subsidy rates are appropriately determined, D-R can restore social efficiency in both production and recycling markets (Kinnaman and Fullerton, 2000; Walls and Palmer, 2001; Eichner, 2005). In practice, this policy has been applied to the waste recycling program in Taiwan, the used oil recycling program in both California and Western Canada and the lead-acid battery programs in several U.S. states (Walls, 2006).

Although D-R sounds promising, current analysis on D-R often neglects an important policy element, which is the concern of budget balance. This recycling mechanism requires a middle man, usually is the government, to collect the tax revenue from the output market and to transfer subsidies to the recycling market. If the middle man miscalculates the tax and subsidy rates or neglects the budget balance consideration, this policy may run into a budget deficit. It is more practical to incorporate a budget balance constraint into the analysis of D-R.

To compensate for this void, we investigate the features of an earmarked D-R recycling policy in this paper. By applying an analytical framework proposed by Eichner (2005), we discuss an earmarked D-R in an environment where producers in the same industry delegate their recycling responsibilities to a recycler by paying a waste disposal fee. The government charges a product tax on the producers and provides a recycling subsidy to the recycler. Under an earmarked D-R, the total subsidy cannot exceed to the tax revenues.

Based on this framework and the according analysis, we have several interesting findings. First, we confirm that when ignoring the budget balance consideration, D-R can restore efficiency. However, when taking a budget balance into account, the circumstances under which an earmarked D-R can achieve the social optimum is limited. Second, we find that when recycling technology is more efficient and recycling cost is low, the marginal environmental damage is large, and the output market is imperfect, implementing a D-R recycling policy may run into a budget deficit. Accordingly, the social welfare generated from an earmarked D-R is less than the social optimum.

This paper is organized as follows. Section 2 introduces the model and examines the social optimum for a D-R. Section 3 discusses the interactions between the producers and the recycler. Sections 4 and 5 examine the government's determinations on the optimal tax and subsidy rates with and without the budget constraint; and finally section 6 concludes this paper.

II. The Model Setting

Following the analytical framework proposed by Eichner (2005), we consider a closed economy with three major players: the government, the producers, and a recycling firm. Suppose there are given n producers in the output market producing a homogenous good Y without paying any production cost.[3] These producers compete within the output market in a Cournot fashion. The inverse output market demand function is $P = a - bY$, where a is the output market size, -b is the slope of the demand curve, $Y = \sum_{i=1}^{n} y_i$ is the total output and y_i is output of producer i. It is assumed that the market size is sufficiently large and each producer produces positive output.

After being consumed, good Y becomes waste and it is assumed that one unit of output generates one unit of waste.[4] According to the property of EPR, the producers delegate their waste recycling responsibilities to a recycling firm. After receiving a waste disposal fee u per output from the producers, the recycling firm is in charge of waste recycling and disposal. In this recycling market, α is denoted as the recycling rate, $\alpha \in [0,1]$; consequently, αY is the amount of waste being recycled, and $(1-\alpha)Y$ is the amount of waste being discharged. Supposing the total recycling cost for recycling αY is $N(Y,\alpha) = Y \cdot g\alpha^2 / 2$, where $g > 0$, this cost increases with the increasing amount of total waste Y, the recycling rate α, and the recycling technology parameter g. A lower value of g implies that the recycling technology is more efficient and recycling cost is lower. For wastes that are not recycled, we assume that each discharge will cause d amount of damage to the environment.

Even though the producers have delegated their recycling responsibilities to the recycling firm, the government still imposes an output tax t on the producers for their generation of a negative externality as their recycling rate is hardly 100 percent. To encourage more recycling activities, the government subsidizes the recycling firm by providing a subsidy s per unit of waste recycled. In this mechanism, the government acts as a middle man to connect the output and recycling markets through the tax and subsidy mechanism. If budget-balance is a concern for the government, then the total subsidy cannot exceed the total tax revenue. By determining the output tax and recycling subsidy rates, the government intends to pursue the maximum social welfare in this economy.

Given this model setting, we first examine the social optimum for the output and recycling markets. Define the social welfare as the sum of consumer surplus, profits of all producers and the profit of the recycling firm less the environmental damage, which can be represented in the following:

$$\underset{Y,\alpha}{Max} \quad W = \int_0^Y (a - bk)dk - \alpha YG(\alpha) - (1-\alpha)Yd \tag{1}$$

Taking the derivative of (1) with respect to Y and α, we obtain the following two first-order conditions:[5]

$$a - bY - \frac{g\alpha^2}{2} - (1-\alpha)d = 0 \tag{2}$$

$$-Yg\alpha + Yd = 0 \tag{3}$$

The social optimal output and recycling rate, denoted by α^* and Y^* respectively, can be obtained by solving (2) and (3) simultaneously, which are

$$Y^* = \frac{1}{b}\left(a + \frac{d^2}{2g} - d\right) \tag{4}$$

$$\alpha = \frac{d}{g} \tag{5}$$

It is easy to verify from (4) and (5) that $\partial Y^*/\partial g = -d^2/2bg^2 < 0$, $\partial \alpha^*/\partial g = -d/g^2 < 0$, $\partial \alpha^*/\partial d = 1/g > 0$ and $\partial Y^*/\partial d = 1/b[(d/g) - 1] < 0$.[6] These indicate that when the recycling technology becomes more efficient, (g is lower) and recycling becomes less expensive, both the social optimal output and recycling rate increase. Moreover, the impact of the marginal environmental damage from discharged wastes (d) on the social optimal output is negative while the impact on the recycling rate is positive. This is because when d rises, the environment suffers more damage from discharged waste. The social optimal output therefore should be lower but the recycling rate should be higher to mitigate the environmental damage.

With this social optimum result in mind, we next introduce the interactions between the producers, the recycling firm and the government. These three players in our model are interacted in a three-stage game structure. In the first stage, the government determines the optimal tax and subsidy rates (t and s) with an objective to maximize social welfare, where budget-balance may or may not be a concern. In the second stage, given the subsidy received from the government, the recycling firm determines the recycling rate (α) and the waste disposal fee charging on the producers (u). In the third stage, the producers compete within the output market in a Cournot fashion, given the tax rate and the waste disposal fee. We apply the backward induction method to solve this subgame.

III. Output and Recycling Markets

This section focuses on the interactions between the recycling firm and the producers. As there are n producers competing in a Cournot fashion within the output market, the profit function for the representing producer i is

$$\pi_i = [a - b(y_i + \sum y_{-i})]y_i - (t+u)y_i,\ i = 1, 2, \ldots, n \tag{6}$$

where $\sum y_{-i}$ is the total output produced by producers except i, t is the tax imposed by the government, and u is the delegation fee charged by the recycling firm.

Taking the derivative of (6) with respect to y_i and applying the symmetry property, we find that the optimal output for producer i is

$$y_i = y = \frac{(a-t-u)}{b(n+1)} \tag{7}$$

Intuitively, the output of producer i is decreasing with (i) an increasing tax rate (t), (ii) the delegation fee (u), and (iii) the number of producers (n). By summing over i from (7), we can obtain the total market output:

$$Y = ny = \frac{n(a-t-u)}{b(n+1)} \tag{8}$$

Next, we discuss the recycling firm's decision in determining the optimal recycling rate and the delegation fee charged to the producers. The recycling firm's profit function π^R is represented as:

$$\pi^R = uY - \frac{g\alpha^2}{2}Y + s\alpha Y \tag{9}$$

where uY is the total delegation fee received from the producers, $Yg\alpha^2/2$ is the total recycling cost, and s is the unit subsidy rate received from the government for recycling αY.

The first order conditions for the profit maximization problem are:

$$\frac{\partial \pi^R}{\partial u} = a - t - 2u + \frac{g\alpha^2}{2} - s\alpha = 0 \tag{10}$$

$$\frac{\partial \pi^R}{\partial \alpha} = -Yg\alpha + Ys = 0 \tag{11}$$

Solving (10) and (11) simultaneously, we obtain the recycling firm's optimal waste disposal fee and recycling rate as:

$$u^R = \frac{1}{2}\left[(a-t) - \frac{s^2}{2g}\right], \tag{12}$$

$$\alpha^R = \frac{s}{g}. \tag{13}$$

Note that the recycling rate is solely dependent on the government's subsidy. Without receiving the subsidy, i.e., $s = 0$, the recycling firm will not collect and disposal wastes, and the recycling rate will be zero. To ensure that the delegation fee is positive, the unit subsidy rate cannot be too high, i.e., $s < [2(a-t)g]^{1/2}$.

One can see from (12) that the impact of the recycling technology parameter (g) on the delegation fee (u^R) is positive while the impacts of the tax rate (t) and the subsidy rate (s) on u^R are negative. The reason for this is because when g increases, the recycling activities become more expensive, the recycling firm thus will increase its delegation fee. On the other hand, a higher subsidy rate lowers the firm's cost and a higher tax decreases the producers' demand for waste recycling, both will make the recycling firm set up a lower delegation fee.

Substituting the results of (12) and (13) into (8), we get the total output in this stage of equilibrium. The profit of the recycling firm can also be found as follows:

$$Y^R = \frac{n}{2b(n+1)}\left[a - t + \frac{s^2}{2g}\right],$$

$$\pi^R = \frac{n}{4b(n+1)}\left[a - t + \frac{s^2}{2g}\right]^2. \tag{14}$$

The impacts of exogenous parameters on the total output are the following:

$$\frac{\partial Y^R}{\partial g} = \frac{-ns^2}{4b(n+1)g^2} < 0, \quad \frac{\partial Y^R}{\partial s} = \frac{ns}{2bg(n+1)} > 0,$$

$$\frac{\partial Y^R}{\partial t} = -\frac{n}{2b(n+1)} < 0, \frac{\partial Y^R}{\partial n} = \frac{1}{2b(n+1)^2}\left[a - t + \frac{s^2}{2g}\right] > 0. \tag{15}$$

The intuition for these results is as follows. When recycling technology parameter g increases, the recycling firm will ask for a higher delegation fee, which discourages the producers' willingness to produce. Therefore, the total output decreases with g. Likewise, a higher rate tax also has an adverse effect on production. On the other hand, when the government's subsidy s increases, the recycling firm will lower the delegation fee, which reduces the total cost for the producers. Therefore, total production increases with s. Finally, the total production increases when the number of producers increases.

IV. A D-R without Budget Concern

We now move to the first stage of the game to discuss the government's determination of the tax and subsidy. In this section, we examine the government's decisions without considering the budget balance constraint. The government's maximizing social welfare goal can be expressed next.

$$\underset{s,t}{Max}\ W = CS + \sum_{i=1}^{n} \pi_i + \pi^R + tY - s\alpha Y - (1-\alpha)dY \tag{16}$$

The welfare function includes the following items: the consumer's surplus *CS*, profits from *n* producers $\sum_{i=1}^{n} \pi_i$, the recycling firm's profit π^R, the tax revenue *tY*, the total subsidy $s\alpha Y$; and the total environmental damage from the discharged waste $(1-\alpha)dY$.

Denote the government's optimal tax and subsidy as t^* and s^*, respectively. Substituting the results in (14) into (16) and taking the derivative of (16) with respect to *t* and *s*, we can obtain the equilibrium result of t^* and s^*, which are:

$$t^* = d - \frac{n+2}{n}\left(a + \frac{d^2}{2g} - d\right) < d,$$

$$s^* = d. \tag{17}$$

As there are two economic instruments (taxation and subsidies) to correct for the two distortions in the output and recycling markets, the economy can achieve the social optimum. That is, at the optimal t^* and s^*, the producers will produce at the social optimal output, and the recycling firm will recycle at the social optimal recycling rate, i.e., $\alpha^R = \alpha^*$ and $Y^R = Y^*$.

The efficiency of a D-R has been elaborated on Palmer and Walls (1997) and Walls and Palmer (2001); they have shown that under a perfect competition assumption, the government's optimal tax is equal to the subsidy rate and is identical to the Pigouvian tax. In their framework, the output market distortion does not exist. The government only needs to correct for the externality resulting from environmental damage. As a result, both the tax and subsidy rates can be set equal to the marginal environmental damage *d*.

In our model, we find that the optimal subsidy is identical to the marginal environmental damage but the optimal tax rate is less than *d*. The less-Pigouvian tax is due to the imperfect output market distortion. To correct for the output market distortion and to encourage production, the optimal tax rate is lower than the Pigouvian tax (Eichner, 2005). Note that when the number of producers increases, the output market distortion decreases. This will lead the optimal tax rate moving closer to the Pigouvian tax. This analysis tells that as long as the tax and subsidy are set appropriately, even under an imperfect output market, a D-R can also restore efficiency. We summary this result next.

Proposition 1:

Regardless the output market structure, a deposit-refund policy can restore social efficiency if the optimal output subsidy rates are set appropriately.

It is interesting to examine the impact of exogenous parameters on the optimal tax rate. Taking a derivative with respect to *g*, *d*, and *n* on (17) respectively, we find the following:[7]

$$\frac{dt^*}{dg} = \frac{(n+2)d^2}{2ng^2} > 0 \tag{18}$$

$$\frac{dt^*}{dd} = 1 + \frac{n+2}{n}\left(1 - \frac{d}{g}\right) > 0 \tag{19}$$

$$\frac{dt^*}{dn} = \frac{2}{n^2}\left(a + \frac{d^2}{2g} - d\right) > 0 \tag{20}$$

As shown above, the optimal tax is increasing with the recycling efficiency parameter (*g*), marginal environmental damage (*d*) and the number of producers (*n*). We write these results in the following proposition.

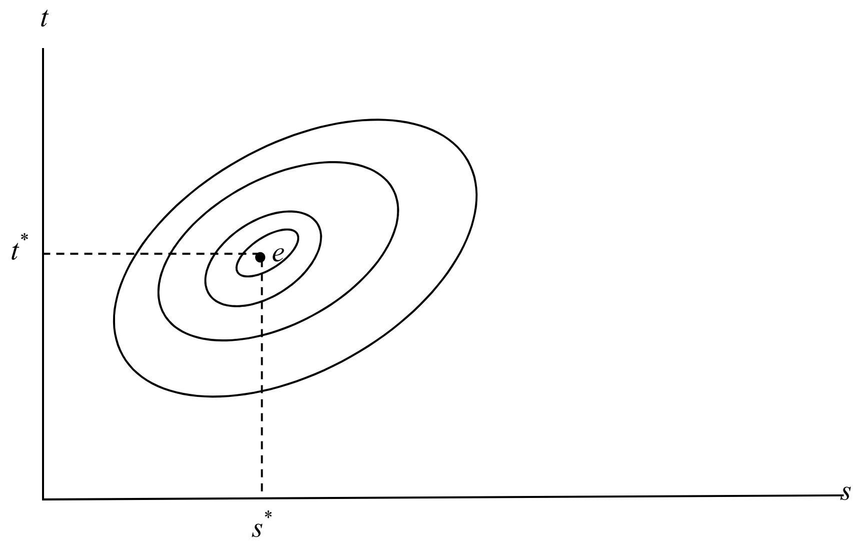
Proposition 2:

In a D-R policy, the optimal output tax increases when (i) recycling technology becomes less efficient and is more costly, (ii) the number of firms is higher and the output market is close to perfect competition, and (iii) the marginal environmental damage from discharged wastes becomes higher.

To elaborate the intuition of Proposition 2, we first examine the impact of *g* on *t*. From (4) and (14), one can easily observe that an increase in *g* decreases both Y^R and the social optimal output Y^*. However, the impact of an increasing *g* on the decrease of production is greater in Y^* than in Y^R, i.e., $\left|dY^*/dg\right| > \left|dY^R/dg\right|$.[8] That is to say, the output in a D-R deviates further away from the social optimum when *g* is large. As the difference between the producers' output and the social optimal output is enlarged with the increase of *g*, the government should set a higher tax to correct for this output distortion. Accordingly, $dt^*/dg > 0$.

The influence of marginal environmental damage *d* on the optimal tax is similar to the influence of *g* on *t*. Both Y^R and Y^* decrease with an increasing *d*. The magnitude of the difference between Y^R and Y^* is larger when *d* increases. Under this situation, the government needs to set a higher tax to lead the producers to produce at the social optimal output. As a result, $dt^*/dd > 0$. Finally, when the number of producers increases, the market becomes more competitive and the output distortion is less serious. Therefore, the government can set a higher tax so that $dt^*/dn > 0$.

We use Figure 1 to illustrate the welfare of a D-R. The vertical and horizontal axes in Figure 1 represent the tax and subsidy rates respectively. The closed circles are iso-welfare curves. Each iso-welfare curve shows the combinations of *t* and *s* that can achieve the same social welfare level. Inner iso-welfare curves represent higher levels of social welfare. Point *e* on Figure 1 is the government's optimal decisions on tax and subsidy (t^*, s^*). At this point, the implementation of D-R can achieve the first-best outcome and its social welfare level is at $W^* = W(t^*, s^*)$.



Source: This study.

Figure 1. Social welfare and the government's optimal decision on (t^*, s^*)

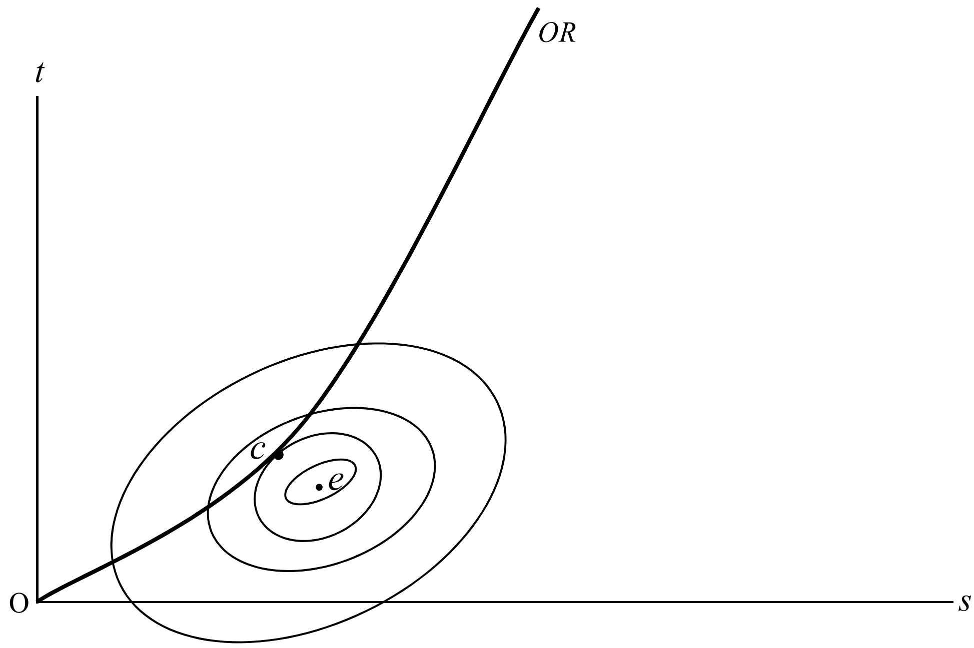
As is seen in Figure 1, without the consideration of a budget constraint, the implementation of D-R can always achieve the social optimum via the setting of the social optimal tax and subsidy rates. Nevertheless, such a D-R mechanism does not guarantee that a budget balance is satisfied. It is more practical to examine an earmarked D-R.

V. An Earmarked D-R

In this section, we examine an earmarked D-R. To begin with, we know that in an earmarked D-R, the decisions for the optimal tax and subsidy rates are intertwined because the budget constraint needs to satisfy: $tY \geq s\alpha Y$. Given that $\alpha = s/g$ from (13), the equivalent way to show this constraint is: $t \geq s(s/g) = s^2/g$. Substituting $t = s^2/g$ into (16), we can express the social welfare problem as the following.

$$\begin{aligned} \underset{s}{Max} \quad W &= CS + \sum_{i=1}^{n} \pi_i + \pi^R + [t - s\alpha - (1-\alpha)d]Y \\ &= \frac{3n^2 + 4n}{8b(n+1)^2}\left(a - \frac{s^2}{2g}\right)^2 - \frac{n[1-(s/g)]d}{2b(n+1)}\left(a - \frac{s^2}{2g}\right) \end{aligned} \tag{21}$$

The optimal subsidy and tax rates on an earmarked D-R cannot be obtained easily. However, we can identify the highest social welfare level that an earmarked D-R can achieve and explore the circumstances for an earmarked D-R to run into a financial deficit. The social welfare of an earmarked D-R is shown on Figure 2.



Source: This study.

Figure 2. Social welfare and earmarked deposit-refund

The axes on Figure 2 are the same as in Figure 1. And again, the closed circles are iso-welfare curves. The OR line is the budget constraint, i.e., $t = s\alpha = s^2/g$. This OR line has several properties: (1) it goes through the origin point O; (2) its slope is positive; (3) it is increasing with s;[9] and (4) its location is affected by exogenous parameters g; when g increases, the OR line will pivot around the origin point clockwise.

We denote the highest social welfare that an earmarked D-R can achieve as $\tilde{W}$. It is obvious that the area above the OR line implies that the combinations of (t, s) will lead the D-R to have a financial surplus, and area below the OR line will lead to a financial deficit. If the socially optimal outcome (t^*, s^*) lies above the OR line, then the earmarked D-R can achieve the first-best outcome and the budget balance plays no role in the model, thus we get $\tilde{W} = W^*$. If the social optimal outcome (t^*, s^*) lies below the OR line, an implementation of D-R will run into a financial deficit, and it cannot reach the social optimum. The highest social welfare that an earmarked D-R can achieve is at the tangent of OR line and iso-welfare curve, which is point c on Figure 2. As the social welfare level at c is less than e, i.e., $\tilde{W} < W^*$, point c apparently is the second-best outcome.

Through the above illustration, we answer our first research question, which is:

The social welfare level that an earmarked D-R can achieve is dependent on where the social optimum lies. If the social optimum outcome lies above the OR line, the government can simply set the D-R tax and subsidy at point e. The implementation of an earmarked D-R can achieve the highest social welfare level, i.e., the first-best outcome. If the social optimum lies below the OR line, then the highest social welfare level that an earmarked D-R can reach is only at the second-best outcome.

The next interesting research issue is to explore the circumstances under which an earmarked D-R runs into a financial deficit. To show this, we examine whether the net budget surplus (NBS) of a D-R, defined as $(t^* - \alpha^* s^*)Y^*$, is improving or getting worse as exogenous parameters (g, d, and n) change.

We first examine the impact of recycling technology parameter g on the NBS. Recall that the social optimal tax t increases with g, as is seen in (18). Also, given (5), we know that the unit subsidy expenditure $s\alpha$ is decreasing when g increases, as α is decreasing with g. These two effects together imply that when g increases, the government's finances will be improved, and the OR line in Figure 2 will pivot around the origin point clockwise. In this circumstance, the budget constraint is more likely to be fulfilled. In other words, the OR line is more likely to lie below the social optimal point. As a result, an earmarked D-R is more likely to reach the first-best outcome.

Adversely, when g decreases, the tax will decrease and the subsidy expenditure $s\alpha$ will increase, which may cause NBS become negative. An earmarked D-R is more likely to reach to the second-best outcome only.

Secondly, we analyze the influence of output market structure on the NBS. As is seen in (20), the social optimal tax increases with n. This result is due to the fact that the imperfect market distortion becomes smaller when n increases. Therefore, the optimal tax can be set higher. From (13) and (17), we also have known that the number of producers has no impact on $s\alpha$. These findings indicate that NBS is higher when n increases. On the other hand, when n is small, it is more likely that NBS may become negative.

The impact of g and n on NBS can be summarized next.

Proposition 3:

Other things being equal, an earmarked D-R is more likely to achieve the second-best outcome only when (i) recycling technology is efficient and recycling cost is low, or (ii) when the number of producers is small.

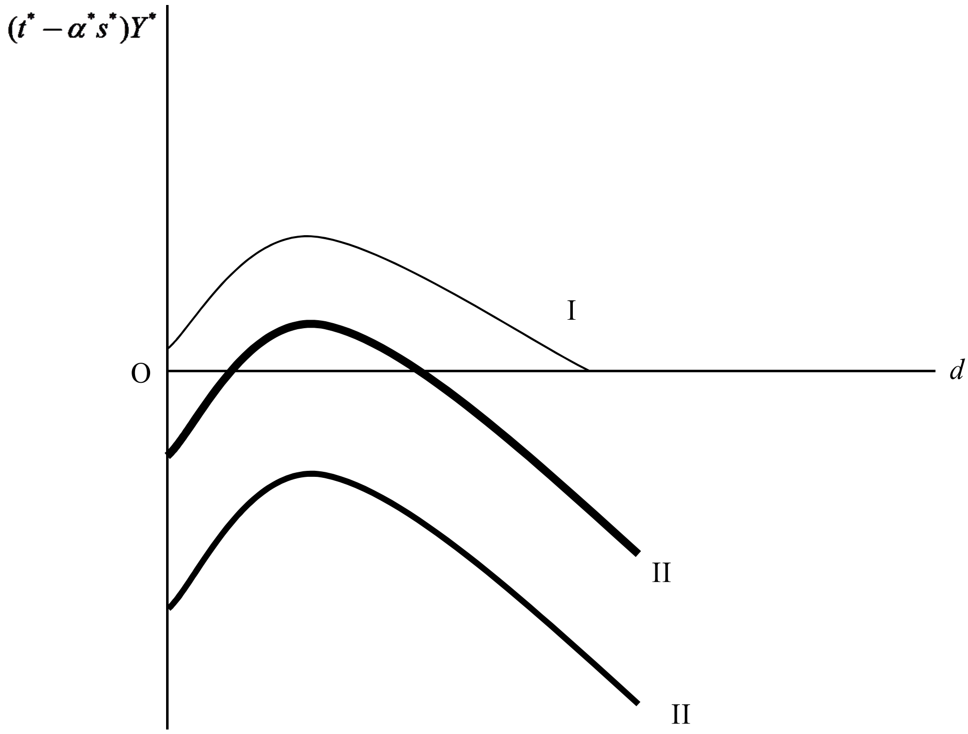
Finally, we examine the effect of environmental damage d on NBS. From (19) and (13), we know both t and α increases with d. Therefore, whether the value of NBS is increasing or decreasing depends on the relative magnitude of $\partial t/\partial d$ and $\partial(s\alpha)/\partial d$, which can be express as:

$$\frac{\partial[(t^* - s^*\alpha^*)Y^*]}{\partial d} = \left[\frac{\partial t^*}{\partial d} - \frac{\partial(s^*\alpha^*)}{\partial d}\right]Y^* + (t^* - s^*\alpha^*)\frac{\partial Y^*}{\partial d}$$

$$= \frac{1}{b}\left(\frac{2(n+2)}{n}+1\right)\left(1-\frac{d}{g}\right)\left[a+\frac{d^2}{2g}-d\right] - \frac{d}{bg}\left[a-3d+\frac{3d^2}{2g}+g\right] \qquad (22)$$

The sign of (22) is ambiguous. We show the relationship between the NBS and *d* in Figure 3.

The vertical and horizontal axes in Figure 3 are the levels of NBS and *d* respectively. As one can see, the NBS is concave in *d* and their relationship is an inversed U curve.[10] The three NBS curves in Figure 3 indicate the relationship between NBS and *d* given a number of producers (*n*). When *n* increases, the curve shifts upward. Curve I shows that given an infinite *n*, the NBS is positive no matter what *d* is.; Curve III shows that, given a small *n*, the NBS is always negative no matter what *d* is; and Curve II shows that, given a mild number of *n*, the NBS can be either positive or negative, depending on the level of *d*.



Source: This study.

Figure 3. The relationship between net budget surplus and marginal environmental damage with a varying number of firms

Figure 3 tells us that when n is extremely large, an earmarked D-R is more likely to achieve the first-best outcome as the NBS is positive. However, when n is extremely small, an earmarked D-R is more likely to achieve the second-best outcome as the NBS is negative. An interesting result occurs in the case when n is mild, as is seen on Curve II. One can see that the NBS is negative when d is extremely small; but when d becomes extremely large, the NBS decreases and becomes negative again. This finding is summarized in the following proposition:

Proposition 4:

When the number of firms is extremely large (small), an earmarked D-R is more likely to achieve the first-best (second-best) outcome. When the number of firms is mild, an earmarked D-R may achieve the second-best outcome if the marginal environmental damage is extremely high or small.

The explanation for Proposition 4 is as follows. When d is extremely small, the environmental externality is negligible. Given that the output market is imperfect, the social optimal tax may become negative due to the imperfect output market distortion. That is, instead of taxing, the government may have to subsidize on the producers. The NBS thus is negative and there is no doubt that an earmarked D-R can achieve to the second-best outcome only. As the marginal environmental damage increases, the government needs to correct both the output market distortion and the environmental externality. Both the social optimal tax t^* and the unit recycling subsidy expenditure $\alpha^* s^*$ become positive. If d is not too high, the NBS may be positive. However, if d is too high, the environmental externality problem becomes very serious; the government has to increase the recycling subsidy expenditure, which may cause NBS become negative. As a result, an earmarked D-R can only achieve the second-best outcome.

VI. Conclusion

In this paper, we do a social welfare analysis on an earmarked D-R. We ask two questions in this paper: what is the highest social welfare level that an earmarked D-R can achieve, and what are the circumstances for it to achieve the first-best outcome. By asking these questions, we explore the conditions for a D-R to run into deficit and thus are able to provide policy insights for the implementation of this recycling policy.

It is well known that adding a budget constraint on a public policy usually cannot achieve the first-best outcome; our analysis verifies this faithful finding. We show that the social welfare level that an earmarked D-R can achieve is dependent on where the social optimum lies. When the social optimum outcome has already satisfied the budget constraint, the highest social welfare level generated from an earmarked D-R is identical to the one in a D-R without budget concern. However, if the social optimum outcome cannot satisfy the budget constraint, then the highest social welfare level that an earmarked D-R can achieve is always less than the one generated from a D-R without budget concern.

We also find that with other things being equal, when recycling technology is less efficient, recycling cost is high and the number of producers is large, the net budget surplus of D-R is more likely to be positive. Under the opposed circumstances, i.e., the recycling technology is efficient and recycling cost is low, the number of producers is small, and the marginal environmental damage is large, the net budget surplus of D-R is more likely to be negative, which indicates that an earmarked D-R can only achieve the second-best outcome. These results indicate that policymakers can implement an earmarked D-R without the loss of social welfare when the recycling cost is high, output market is in a perfect competition, and the damage from unrecycled products is relatively mild.

Recently in the Taiwanese local media, it has been shown that several recycling funds including steel, glass, and cartons, are having financial deficit problems. In part, this is due to the fact that several illegal underground firms are not incorporated into the system, which implies that the number of firms is less than the recycling funds estimated. In addition, we speculate that such deficit problems may also due to the fact that the recycling technology for these products are more efficient as these materials are relatively easy to collect and thus their recycling costs are relatively low. As argued, an under-estimated number of firms and a more efficient recycling technology both tend to lead a negative net budget balance. This news may provide evidences that our theoretical results are robust.

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Endnotes

1. These policies include deposit-refund, minimum recycled content requirements, product taxes, advanced disposal fees, materials restrictions, and materials regulations (Walls, 2006).
2. Note that D-R has many different names. Kinnaman and Fullerton (2000) name it as "two-part tariffs" or "deposit-refund". Walls (2006) labels it as the "advance recycling fees combined with a recycling subsidy". Walls and Palmer (2001) call it as "a combination of output tax and recycling subsidy program".
3. We make this simplification because the focus of this paper is not on the producers' competitive behaviour but rather on their responses in bearing the recycling responsibilities.
4. This assumption is to satisfy the material balance requirement that is first described in Walls and Palmer (2001). As an example, one can think of the PVC bottle market. One PVC bottle generates one bottle of waste if it is not recycled.
5. The second-order condition is satisfied as $\partial^2 W \big/ \partial Y^2 = -b < 0$, $\partial^2 W \big/ \partial\alpha^2 = -Yg < 0$, and $(\partial^2 W / \partial Y^2)(\partial^2 W / \partial\alpha^2) - (\partial^2 W / \partial Y \partial\alpha)(\partial^2 W / \partial\alpha\partial Y) = bYg > 0$.
6. As $\alpha \in [0,1]$, we have d/g≤ 1.
7. From footnote 4, we know that (d/g) −1 ≤ 0. Moreover, as the social optimal output is positive we can also find that [a + (d2/2g) − d] > 0 based on Equation (4).
8. From (4) and (14), one can prove that |∂Y*/∂g| = d2/2bg2 > |∂YR/∂g| = nd2/4b(n+1)g2.
9. Since dt /ds = 2s/g > 0 and d2t /ds2 = 2/g > 0, the slope of OR line is positive and increases with an increasing s.
10. The NBS in d is concave because $\partial^2[(t^* - s^*\alpha^*)Y^*] \big/ \partial d^2 = [2(n+2)/n+1]\,(a + d^2/(2g) - d)$ $-[2(n+2)+1](1-d/g)/b - (a - 6d + 2d^2/g + g)/\left(bg\right) < 0$. Furthermore, because $\partial[(t^* - s^*\alpha^*)Y^*]/\partial d\,|_{d=0} = [2(n+2)/n+1]a/b > 0$ and $\partial[(t^* - s^*\alpha^*)Y^*]/\partial d\,|_{d=g} = -(a - g/2)/b < 0$, we prove that the NBS in d is an inverse-U curve.

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專款專用押退保證金回收政策的福利分析

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在所有符合生者者責任制度延伸的回收政策裡，押退保證金制度被公認為是一個有效率的制度。然而，在實際應用中，由於繳費的生產者與收費的回收業者對象不一致，此制度常面臨預算短缺的現象。本研究旨在探討一個專款專用的押退保證金回收制度，目的在檢驗此政策在哪些狀況之下較易產生預算短缺的問題。本研究發現，當回收成本相對高、環境邊際損害溫和以及產品市場越趨近於完全競爭時，專款專用的押退保證金制度的資源配置接近社會最適。這意味著在相反的情況之下，此回收政策較容易產生預算短缺的現象，亦即當回收成本相對較低、環境邊際損害大以及產品市場為不完全競爭時，實施專款專用押退保證金制度的社會福利會低於社會最適。

關鍵詞：回收政策、押退保證金、專款專用、生產者延伸責任制度、福利分析

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