E C O N O M I C S   B U L L E T I N

Extended producer responsibility in oligopoly

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Abstract

I investigate the optimal environmental tax under a policy based on extended producer responsibility (EPR) in oligopoly markets. I introduce the recycling market and explicitly consider how these policies affect the incentive for recycling. I derive the optimal tax rule, which depends on the weighted sum of the markup in the product market and the markdown in the recycling market. In contrast to the existing works that emphasize that the optimal tax rate is lower than the marginal external damage, I find that the optimal tax rate can be higher than the marginal external damage.

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1 Introduction

Goods must be disposed of after their consumption. Such disposing activities are not costless, but traditionally, (local) governments have been disposing of the post-consumer wastes at no charge to the consumer or producer. This means that the impact of the disposal cost (including environmental damage) on the economy is not internalized. It has been pointed out[1] that this externality yields excess production and insufficient recycling, resulting in excess waste disposal. Since the free public service of waste disposal is the starting point of this externality, the simplest way of internalization is to directly charge the consumers for the disposal cost of their consumption, that is, the Pigouvian tax.[2] However, it is often difficult to implement the sufficient charge level because of illegal disposal by consumers,[3] that is, the tax evasion by exploiting the difficulty in monitoring. The concept of extended producer responsibility (EPR) is proposed as a remedy for this post-consumer wastes problem. Recently, policymakers have been paying increasing attention to EPR.[4]

In this paper, I introduce a policy in which the producers are held liable for the disposal cost of their production. This policy transfers the financial responsibility of waste management from the local government to the producer, which is a primary function of EPR. In this policy, the maker of the disposed product is charged instead of consumer. Thus, the problem of monitoring consumers' illegal disposal can be avoided. Furthermore, in the absence of monitoring problems, this EPR policy and the direct charge on consumers (Pigouvian tax) are equivalent.

Since the makers of disposed products must be monitored, the EPR policy discussed here will be more suitable under a situation where the industry comprises some dominant makers, that is, the market structure in this industry is monopoly or oligopoly. Barnett (1980) and Misiolek (1980) research how market power modified the Pigouvian tax rule (the second-best Pigouvian tax under monopoly). However, they treat abatement activities only in emission functions and do not consider abatement *markets* such as recycling markets. Calcott and Walls (2000) incorporate recycling markets explicitly in their models with perfectly competitive firms.

I analyze the EPR policy as the second-best Pigouvian tax rule in an oligopoly model (including monopoly) with a recycling market. As a result, I have the following: First, the optimal Pigouvian tax rate is the marginal external damage plus the weighted sum of the markup in the product market and the markdown in the recycling market. Second, this optimal tax rate is higher than the second-best

[1] See, e.g., Porter (2002) and Fullerton and Wolverton (2000).

[2] In terms of ordinary environmental economics, wastes and recyclables correspond to emissions and abatements, respectively. Fullerton and Wolverton (2000) point out and summarize this correspondence excellently.

[3] Fullerton and Kinnaman (1995) analyze illegal disposal explicitly.

[4] OECD published a guidance manual about EPR for governments (OECD 2001). According to this manual, EPR is "a policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life."

Pigouvian tax rate which is induced without considering a recycling market. Moreover, it is possible for the optimal tax rate to exceed even the first-best Pigouvian tax rate, that is, the marginal external damage.

2 The model

Consider an industry where n symmetric firms supply homogeneous products and recycle some of the products. The firms produce the products at a constant marginal cost of $c \in \mathbb{R}_+$. The products are transacted in the product market and consumed by households. After consumption, the same amount of wastes as that of products are generated, and some part of the wastes can be recycled. The non-recycled consumed products are disposed of directly and generate some external damage (including both external disposal cost and environmental damage) with a constant marginal external damage of $d \in \mathbb{R}_{++}$. The recycled products are transacted in the recycling market and reproduced by producers with a marginal benefit of $b \in \mathbb{R}$.[5] The firms engage in Cournot competition in both the product market and the recycling market; that is, each firm i ($i \in \{1, \ldots, n\}$) chooses its supply of products x_i and demand for recycling r_i simultaneously.

The total demand for products X and the total supply of recycling R are derived from the following utility maximization problem of a representative household. Here, I assume the representative household is a price taker at P_x and P_r, which are the prices in the product market and the recycling market, respectively.

$$\max_{X,Y,R} U(X) + Y$$
$$\text{s.t.} \quad P_x X + Y + \tau(X - R) + C(R) = I + P_r R$$

where $U(X)+Y$ (Y is the numeraire) is the household's utility function that takes the quasi-linear form, which satisfies $U' > 0$ and $U'' < 0$; $C(R)$ is the recycling cost,[6] which satisfies $C' > 0$ and $C'' > 0$; and I is the given household's income. τ is the unit charge imposed on the household for its direct waste disposal $X - R$. I assume that all the outcomes (the amounts of products, recycling, and disposal) are interior solutions, that is, $X, R, X - R > 0$ in the equilibrium. From the first order conditions of the interior solutions, we obtain the inverse demand for products and the inverse supply of recycling:

$$P_x(X) = U'(X) - \tau, \qquad\qquad P_r(R) = C'(R) - \tau, \tag{1}$$

[5] b can be interpreted in various ways. If the firm sells its recycled materials in some other market, the market's price minus the reprocessing cost is the firm's benefit. If the firm uses recycled materials as inputs for its own products, b is the difference between the price of substitutable virgin inputs and the reprocessing cost.

[6] C is interpreted as the transaction cost in the collection process for recycling. Usually, intermediate traders or recyclers participate in the collection process for the consumed products. However, for simplicity, I suppose that the entire cost in this process is passed on to households. If all the markets for intermediate traders are competitive, this supposition is not essential.

which satisfies $P_x' < 0$ and $P_r' > 0$. Note that from these definitions of P_x and P_r, we have the relations $U'' = P_x'$ and $C'' = P_r'$. Further, I assume the second order and stability conditions of the Cournot games, that is, $P_x' + P_x''x < 0$ and $P_r' + P_r''r > 0$.[7]

3 The policy based on EPR

3.1 Equivalency

Suppose the unit liability (or the unit penalty) for non-recycled products is equal to ϕ. Then, firm i's profit maximization problem is

$$\max_{x_i, r_i} \left[P_x\Big(\sum_{k=1}^{n} x_k\Big) x_i - c x_i \right] + \left[b r_i - P_r\Big(\sum_{k=1}^{n} r_k\Big) r_i \right] - \phi(x_i - r_i). \tag{2}$$

I focus on the symmetric Nash equilibrium, that is, $x = x_1, \ldots, x_n$ and $r = r_1, \ldots, r_n$ in the equilibrium. Then, the first order conditions of the above problem are

$$P_x'(nx)x + P_x(nx) - c - \phi = 0, \qquad b + \phi - P_r(nr) - P_r'(nr)r = 0. \tag{3}$$

Using the definitions in (1) and the relations $U'' = P_x'$ and $C'' = P_r'$, we obtain

$$U''(nx)x + U'(nx) - c - (\phi + \tau) = 0, \quad b + (\phi + \tau) - C'(nr) - C''(nr)r = 0. \tag{4}$$

The following proposition states that the firm's liability for non-recycled products ϕ and the household's direct charge for waste disposal τ are perfectly substitutable.

Proposition 1 *For all policy combinations (ϕ, τ) such that $\phi + \tau$ has the same level, all the equilibrium outcomes (the amounts of products, recycling, and disposal) are the same.*

Proof. Suppose that $\underline{x}$ and $\bar{x}$ ($\underline{x} < \bar{x}$) are the equilibrium amounts of products for the same level of $\phi + \tau$. From (4), $\phi + \tau = U''(nx)x + U'(nx) - c$ must be satisfied for $x = \underline{x}, \bar{x}$. However, the right hand side is strictly decreasing in x since $U'''(nx)x + 2U''(nx) = P_x''(nx)x + 2P_x'(nx) < 0$. Thus, $U''(n\underline{x})\underline{x} + U'(n\underline{x}) - c > U''(n\bar{x})\bar{x} + U'(n\bar{x}) - c$, which is a contradiction. A similar proof can be applicable for recycling. As for the disposal, since the outcome is defined by $x - r$, the proof is clear from the result of the products and recycling. **Q.E.D.**

[7]These are the conditions that guarantee that the marginal revenue curves are steeper than the demand or supply curves.

Hence, each firm's equilibrium output of products and input of recycling are given by the functions of $\phi + \tau$, that is, $x^*(\phi + \tau)$ and $r^*(\phi + \tau)$, respectively. Totally differentiating (3), we obtain

$$\frac{\partial x^*}{\partial(\phi + \tau)} = \frac{1}{n(P'_x + P''_x x) + P'_x} < 0, \qquad \frac{\partial r^*}{\partial(\phi + \tau)} = \frac{1}{n(P'_r + P''_r r) + P'_r} > 0. \tag{5}$$

Therefore, the firm's liability for non-recycled products ϕ, as well as the household's direct charge for waste disposal τ, has two effects on the equilibrium waste disposal $x^* - r^*$. In the product market, firms become aware that they must bear the liability for each additional unit of their production. This reduces the supply of products and contributes to the reduction of waste disposal. This is called the "output reduction effect." In the recycling market, firms can avoid the liability for each additional unit of their recycling. This increases the demand for recycling. Thus, recycling is encouraged, which results in smaller amounts of waste. This is referred to as the "input substitution effect.[8]"

3.2 Second-best policy

The social planner maximizes the equilibrium social welfare:

$$\max_{\phi+\tau} W^* = [U(nx^*) - ncx^*] + [nbr^* - C(nr^*)] - d(nx^* - nr^*). \tag{6}$$

The first order condition of this problem is[9]

$$\frac{\partial W^*}{\partial x}\frac{\partial x^*}{\partial(\phi + \tau)} + \frac{\partial W^*}{\partial r}\frac{\partial r^*}{\partial(\phi + \tau)} = 0. \tag{7}$$

By substituting (4) and using the relations $U'' = P'_x$ and $C'' = P'_r$, we obtain

$$\frac{\partial W^*}{\partial x} = nU' - n(c + d) = n(\phi + \tau - d) - nP'_x x, \tag{8}$$

$$\frac{\partial W^*}{\partial r} = n(b + d) - nC' = nP'_r r - n(\phi + \tau - d). \tag{9}$$

Let S_x (S_r) denote the share of the output reduction effect (the input substitution effect) in the total marginal reduction of waste disposal; that is,

$$S_x = \left| \frac{\partial x^*}{\partial(\phi + \tau)} \Big/ \frac{\partial(x^* - r^*)}{\partial(\phi + \tau)} \right|, \qquad S_r = \left| \frac{\partial r^*}{\partial(\phi + \tau)} \Big/ \frac{\partial(x^* - r^*)}{\partial(\phi + \tau)} \right|. \tag{10}$$

Note that by definition, $S_x, S_r \in (0, 1)$ and $S_x + S_r = 1$. Let η_x and η_r be the price elasticities of the product's demand $P_x/P'_x nx^*$ and the recycling supply $P_r/P'_r nr^*$, respectively. Note that $\eta_x < 0$ and $\eta_r > 0$. By rearranging (7) using these notations, we arrive at the following second-best policy.

[8] Walls (2004) introduced these terms into the economics of waste and recycling.

[9] I assume that the second order condition is satisfied.

Proposition 2 *The optimal policy combination of ϕ and τ satisfies that*

$$\phi + \tau = d + \left[\frac{P_x}{n\eta_x} S_x + \frac{P_r}{n\eta_r} S_r \right].$$

One unit of waste reduction eliminates the external damage d, but S_x parts of waste reduction follow the output reduction effect and S_r parts accompany the input substitution effect. Unit reduction of output expands the welfare loss in the product market, which is a markup resulting from the monopoly power $P_x/n\eta_x$.[10] Thus, the optimal policy level is reduced by $(P_x/n\eta_x)S_x$ from the first-best level d. On the other hand, unit recycling encouragement eliminates the welfare loss in the recycling market, which is a markdown resulting from the monopsony power $P_r/n\eta_r$.[11] Thus, the optimal policy level must be modified upward by $(P_r/n\eta_r)S_r$. As a result, the second-best level is adjusted by the weighted sum of the markup in the product market and the markdown in the recycling market, $(P_x/n\eta_x)S_x + (P_r/n\eta_r)S_r$.

If I suppose that the recycling market is absent from our model, that is, $S_x = 1$ and $S_r = 0$, our second-best policy level turns out to be $\phi+\tau = d+P_x/(n\eta_x)$; when $n = 1$, this is consistent with the second-best Pigouvian tax rule under a monopoly introduced by Misiolek (1980).[12] In this case, the second-best Pigouvian tax rate is always less than the marginal external damage. However, as mentioned above, the monopsony power in recycling drives the optimal policy level in the other direction. Hence, it is important to address the question: Which extent the policy level should be increased to?

Proposition 3 *Under the optimal policy combination, (i) when $P''_x \geq 0$ and $P''_r \geq 0$, we always have $(P_x/n\eta_x)S_x + (P_r/n\eta_r)S_r < 0$; (ii) otherwise, we can have $(P_x/n\eta_x)S_x + (P_r/n\eta_r)S_r > 0$.*

Proof. First note that $(P_x/n\eta_x)S_x + (P_r/n\eta_r)S_r = M/|\partial(x^* - r^*)/\partial(\phi + \tau)| \lesseqgtr 0$ if and only if

$$M \equiv P'_x x^* \left| \frac{\partial x^*}{\partial(\phi+\tau)} \right| + P'_r r^* \left| \frac{\partial r^*}{\partial(\phi+\tau)} \right| \lesseqgtr 0.$$

(i) The following manipulation suffices:

$$\begin{aligned} M &= \frac{P'_x x^*}{|nP''_x x^* + (n+1)P'_x|} + \frac{P'_r r^*}{|nP''_r r^* + (n+1)P'_r|} \quad \text{(by substituting (5))}, \\ &\leq \frac{P'_x x^*}{|(n+1)P'_x|} + \frac{P'_r r^*}{|(n+1)P'_r|} \quad \text{(since } P''_x, P''_r \geq 0 \text{ and } P'_x < 0, P'_r > 0), \\ &= \frac{r^* - x^*}{n+1} < 0 \quad \text{(since } x^* > r^* \text{ by the assumption of positive disposal)}. \end{aligned}$$

[10] By an appropriate manipulation, we can show that $P_x - (c + \phi) = |P_x/n\eta_x|$.

[11] Similarly, we can show that $(b + \phi) - P_r = |P_r/n\eta_r|$.

[12] Barnett (1980) considers a more general situation including abatement activities. For oligopoly, see Xepapadeas (1997) Chap.5. However, in their model, abatement activities are treated in emission functions, not in markets. Thus, their analyses are essentially the same with regard to the conclusion that the second-best Pigouvian tax rate is lower than the marginal external damage.

(ii) The following example suffices. Suppose $n = 1$, $P_x(x) = 2 - x$, $P_r(r) = \sqrt{r}$, $b = c = 0$ and $d = 29/30$. Then, $x^* = (2 - (\phi + \tau))/2$ and $r^* = (2(\phi + \tau)/3)^2$. Under the optimal policy, $x^* = 1/2$, $r^* = 4/9$, and $\phi + \tau = 1$. (See Figures 1 and 2 for illustrations of the optimal case.) Therefore, I have $M = 5/108 > 0$ and $\phi + \tau > d$. **Q.E.D.**

Note that the case of Proposition (i) includes the linear and the log linear demand (supply). Thus, as far as the demand (supply) elasticity is estimated in the linear or the log linear model, the optimal policy level is still less than the marginal external damage. In this case, the optimal policy level is closer to the first-best level than in the case where the monopsony recycling market is not considered. However, more generally, this level can be increased further. Proposition (ii) indicates that if the firms also have market power in the abatement markets, the Pigouvian tax rate can exceed the marginal external damage.

3.3 Monitoring problem

As for waste reduction, ϕ and τ produce the same two effects. However, the two policies are different when we consider the monitoring problem. When the consumers are charged, we must monitor who discharged the wastes. However, this is often difficult because it is possible for consumers to evade their charge by disposing of their wastes illegally. On the other hand, when the producers are charged (or penalized), the disposal cost for one firm's product is always charged on this firm regardless of who has consumed it. Thus, we can implement this policy merely by monitoring which firm's production the disposed wastes are. In particular, in an oligopoly industry, the products will not be anonymous.[13] Therefore, when the monitoring problem is considered, EPR not only works as well as, but can also be superior to the household's direct charge for waste disposal.

Note that our analysis does not exclude the case that ϕ and τ are mixed. In reality, it is observed that local governments charge consumers for waste disposal services. However, the monitoring problem usually prevents the governments from implementing the sufficient charge level for the disposal cost. The EPR policy can also be used to fill the gap between the optimal and practical levels of charge on consumers.

4 Concluding remarks

Using an oligopoly model incorporating the recycling market, I have discussed how the optimal EPR policy modifies the Pigouvian tax rule. I find that the optimal Pigouvian tax level is modified by the weighted sum of the markup in the product market and the markdown in the recycling market and that it is possible for this tax level to exceed the marginal external damage.

[13]This is more plausible if the products exhibit some product differentiation, However, in this paper, I have not focus on this aspect for simplicity.

In this paper, I have restricted attention to the downstream policies, which are essentially taxes on waste disposal. Theoretically, an upstream deposit-refund policy, which is also regarded as an EPR-suitable policy, has been discussed as an ideal policy to internalize the disposal cost and avoid the monitoring problem.[14] Thus, it is worth deriving the optimal deposit-refund policy in oligopoly and comparing it with the downstream policies. The deposit-refund policy has two policy instruments that can separately cope with the two market failures resulting from monopoly power: tax in the product market and subsidy in the recycling market. Therefore, even if we do not consider the monitoring problem, the upstream policy will be superior to the downstream policies with respect to efficiency. However, even so, our downstream-EPR policy has some advantages. First, this policy provides an incentive to firms to urge the home reduction of wastes[15] by focusing on aspects such as long-term usage or reusability. Second, the administration cost of this policy can be lower than that of the deposit-refund policy.[16] A formal analysis of these points remains for future research.

[14] See, e.g. Dinan (1993), Palmer and Walls (1997) and Fullerton and Wolverton (2000). These papers analyze the deposit-refund system under perfect competition.

[15] Choe and Fraser (1999) discuss that the deposit-refund policy fails to encourage the home reduction of wastes.

[16] For example, our downstream-EPR policy is feasible for local governments, while the deposit-refund policy is difficult to implement since some product and recycling markets can be in other jurisdictions.

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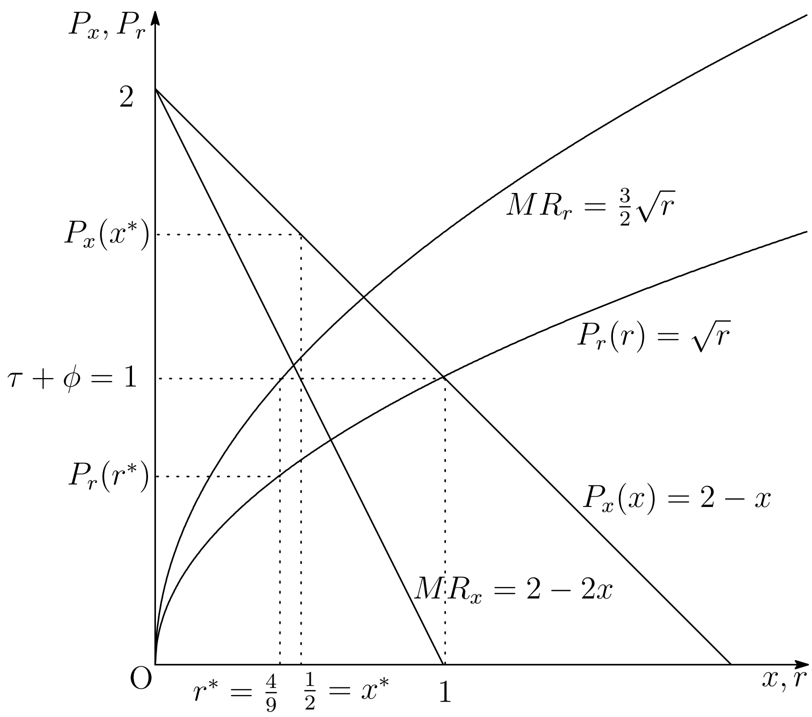

Figure 1: Optimal case of the example. MR_x is the marginal revenue curve of products. MR_r is the marginal revenue curve of recycling.

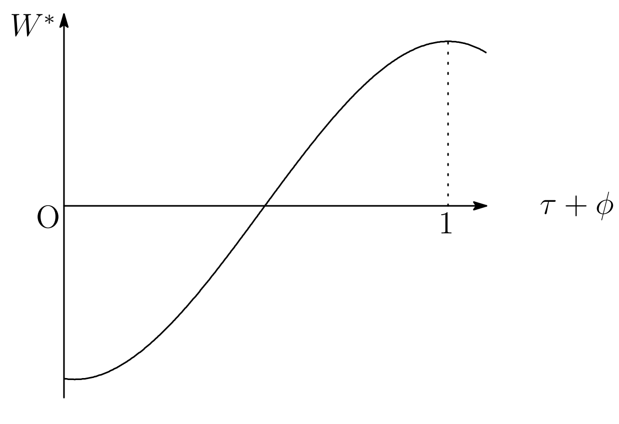

Figure 2: Equilibrium welfare of the example.