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Two-Part Tax for Polluting Oligopolists with Endogenous Entry*

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Ⅰ. Introduction

According to the Pigouvian rule, the optimal pollution tax should be equal to marginal social damage. Over the last few decades, however, theanalysis of optimal taxation for polluting firms has been extended,

* We appreciate for the helpful comments and suggestions provided by an anonymous referee in this journal and participants at the international conference of All China Economics (Hong Kong, 2009) and a micro-economics seminar at Korea University (Seoul, 2009).
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incorporating various imperfect market structures such as monopoly and oligopoly competitions with or without market entry (see for example, Buchanan (1969) and Barnett (1980) on monopoly; Levin (1985) and Simpson (1995) on oligopoly; Katsoulacos and Xepapadeas (1995) and Lee (1999) on endogenous market structure; and Canton *et al.* (2008) on a vertically related market structure). Requate (2007) summarizes important works on the theory of pollution tax under imperfect competition and shows that complete internalization of external damages under imperfect competition will impose additional social costs by further restricting the already suboptimal output of the firms. Thus, the second-best pollution tax should not be equal to marginal social damage, which does not follow Pigouvian rule—the trade-off in optimal taxation.

Most literature on these second-best instruments in the context of pollution tax has taken the single form of linear tax on the level of pollutant, output, or revenue. Yet, some of the literature consider a quadratic tax or an additional entrance fee to achieve the first-best outcome. For example, Shaffer (1995) suggests the use of a firm-specific ad valorem tax, and Xepapadeas (1997) shows how the use of an entrance fee can improve social welfare compared to a second-best pollution tax. Schott (2008) also proposes combined instruments of ad-valorem tax and entrance fee into the Pigouvian pollution tax. On the other hand, Lee and Kim (2000) construct an optional nonlinear pollution tax with asymmetric information, while Shaffer (1989) derives quadratic tax schedules that induce polluting firms to alter their output levels in a welfare-increasing direction under uncertainty. In principle, the exact number of combinations of some instruments is required to remedy different market failures, such as environmental policy for externality, competition policy for imperfect competition, and market structure policy for excessive (or insufficient) entry, as analyzed by Schott(2008).

In this paper, we propose a simple approach to find the first-best optimum by using multiple combinations of different instruments when there are many different market failures. We show that the ex post form of first-best policy combination is a simple Pigouvian tax rule, in which some distortionary effects of market failures might be cancelled out when the combination of efficient instruments are well-developed. This paper specifically considers the two-part tax—a combined form of output tax and entrance fee—for polluting oligopolists under endogenous entry where the market structure is determined through free entry or zero-profit conditions. In the presence of external damage that varies exogenously with aggregate output, we show that the simple combination of output tax and entrance fee produces the ex post Pigouvian rule, which achieves the first-best optimum for many different market failures.

Through an extensive discussion, when the estimation errors exist in the process of two-part tax, we also provide a detailed analysis of the impact of the regulation on social welfare and the incentives of interest groups such as regulated firms and environmentalist. We show that when the estimated slope of marginal damage is smaller than that of market demand, the regulator has an incentive to prefer over-estimation on regulatory information. But, this incentive is not compatible with the interest of regulated firms of under-estimation on market demand. We also show that when the estimated slope of marginal damage is larger than that of market demand, the regulator will dislike over-estimation on the slope of marginal damage if revenue matters in regulation. But, there might be a conflict of interest with environmentalists, but this can be resolved if the regulator can commit to recover external damage through financial support from government revenue. Therefore, if the regulator takes care of both welfare loss and revenue gain under the proposed two-part tax, not only over-estimation on the slope of external damage but also under-estimation on the slope of market demand should be taken into the policy consideration.

The rest of the paper is structured as follows. Section Ⅱ constructs the basic model. Section Ⅲ examines the optimal two-part tax for polluting oligopolists under endogenous entry. Section Ⅳ considers the possibility of information errors in estimating market demand and marginal damage functions and discusses some interesting findings on the impacts on social welfare and the incentives of interest groups. The final section provides a conclusion.

Ⅱ. The Basic Model

We consider the endogenous model of oligopolistic industry with n identical firms producing a homogeneous product, in which the output of the individual firm and the number of firms in the industry are both determined by profit-maximization and free entry/zero-profit conditions.[1)]

1) If the barriers to entry/exit are low, a large number of firms will enter into the market until equilibrium profits become zero. The issue of free entry related to the analysis of endogenous market structure was introduced by Mankiw and Whinston (1986) and was applied to environmental problems by Shaffer (1995), Katsoulacos and Xepapadeas (1995), and Lee (1999).

Each firm produces output q and is assumed to behave in the Cournot-Nash way in determining its profit-maximizing output level. The firm's cost function is given by $C(q)$, where $C'(q) > 0$ and $C''(q) \geq 0$.

We assume that the producing output entails a positive effect on consumers' benefit and a negative effect on environmental pollution, which are assumed to vary with aggregate industry output, $Q = nq$. Consumers' benefit provides an inverse market demand function, $P = P(Q)$, where $P'(Q) < 0$, and environmental pollution causes an external damage function, $D = D(Q)$, where $D'(Q) > 0$, and $D''(Q) \geq 0$.

Social welfare is defined as the sum of consumers' and producers' surplus less environmental damages. Then, the regulator's problem is to choose the levels of outputs and the number of firms in order to maximize the following social welfare function:

$$\max_{n,q} W = \int_0^{nq} P(u)\,du - nC(q) - D(nq)$$

The first-order necessary conditions for the optimal allocation (q^*, n^*) are as follows:

$$\frac{\partial W}{\partial q} = nP(Q) - nC'(q) - nD'(Q) = 0 \tag{1}$$

$$\frac{\partial W}{\partial n} = qP(Q) - C(q) - qD'(Q) = 0. \tag{2}$$

These two socially optimal conditions can be rewritten as follows:

$$P(Q) - C'(q) - D'(Q) = 0 \tag{3}$$

$$P(Q) - C(q)/q - D'(Q) = 0. \tag{4}$$

Therefore, we can conclude that a socially optimal output is chosen at the minimum cost condition of $MC(q) = C(q)/q = AC(q)$ for each firm, and the socially optimal number of firms is determined at zero economic profit condition, $P(Q)q - C(q) = D'(Q)$, where private profits for each firm should equal its contribution to external damages.

Ⅲ. Two-Part Pollution Tax

In principle, the regulator who has perfect authority over industry resource allocations could assign the socially optimal output level of each firm and the socially optimal number of firms in (1) and (2). However, this is seldom the case in a market economy system since the regulator has limited authority.[2)]

In practice, the regulator may be able to secure the socially optimal allocation by employing an indirect instrument such as a pollution tax. One solution to induce firms to act in a socially optimal way is to impose a two-part tax consisting of an output tax and an entrance fee. We consider the sequential game situation where the regulator announces

2) The extent of agency discretion depends not only on the information but also on the allocation of residual rights of control over the industry between the agency and its political principal. For more further discussion on the issue of politics and incentives under incomplete information, see Laffont and Tirole (1993, p. 501). The issue of incomplete information will be examined in the next section.

the tax rate and the firms make their choices after observing the tax rule. Specifically, the regulator can set an output tax rate t per unit of output and fixed entrance fee S. Then, the firm's problem is :3)

$$\max_{q} \Pi = P(Q)q - C(q) - tq - S.$$

The first-order necessary conditions for symmetric Cournot-Nash equilibrium outputs are as follows :

$$\frac{\partial \Pi}{\partial q} = P(Q) + P'(Q)q - C'(q) - t = 0. \qquad (5)$$

Furthermore, under free entry equilibrium the number of firms is endogenously determined by the following zero-profit condition :

$$\Pi = P(Q)q - C(q) - tq - S = 0. \qquad (6)$$

By equating the social optimum conditions in (1) and (2) with the equilibrium conditions in (5) and (6), the regulator can achieve the social optimum in the industry equilibrium. The optimal two-part tax would be set as follows :

$$t = D'(Q) + P'(Q)q \qquad (7)$$

$$S = -P'(Q)q^2. \qquad (8)$$

3) Shaffer (1995), however, examines the potential for firms to distort the optimal outcome by behaving strategically toward the regulator. Specifically, if firms know the regulator's decision rule, they have an incentive to manipulate the information available to the regulator so as to increase their profit. The relevant issues of information and incentives will be discussed in the next section.

A few remarks are in order. First, the optimal output tax rate depends on the relative size between the positive effect of marginal damage and the negative effect of market power. Thus, as discussed by Shaffer(1995) and Lee(1999), the optimal output tax is the sum of marginal external cost and the deviation from price of the firm's marginal revenue. Therefore, the output tax rate may be either positive or negative, where a negative value for the output tax rate would correspond to a subsidy.

Second, the optimal entrance fee is positive, which works for controlling the number of firms in the market. Without entrance fee, the optimal tax in (7) provides the positive regulated profit of the firm at the socially optimal number of firms, i.e., $\widetilde{\Pi}(n^*) = P(n^*q)q - C(q) - D'(n^*q)q - P'(n^*q)q^2 = -P'(n^*q)q^2 > 0$ at equilibrium. It implies that more firms than the socially optimal number of firms have the incentive to enter the market under free entry. Therefore, positive entrance fee will reduce the equilibrium number of firms, which is determined at the zero profit condition.[4)]

Third, each firm should pay the ex post positive tax of $tq + S = D'(Q^*)q^*$ at Cournot equilibrium－the marginal damage of industry output－which is the exact level of the Pigouvian tax. This is so because the other market failures, except externality, such as distortionary effects of imperfect competition and excessive entry, will be cancelled out ex post in the optimal two-part pollution tax.[5)] Thus, as shown by Spulber

4) Notice that we have the following relation from the regulated profit under the two-part pollution tax : $\frac{\partial \Pi}{\partial n}(n^*) = P'q^2 - D''q^2 < 0$. Thus, as pointed out by Lee (1999), no more firms than the socially optimal number of firms will enter.

5) Mankiw and Whinston(1986) argue the social inefficiency of free entry when there exists imperfect competition. However, this paper shows that free entry with an

(1985), each firm in the industry is forced to compensate for the exact marginal damages per each unit of output, given the optimal number of firms—the Pigouvian rule.

Finally, the regulator can raise the positive revenues from the two-part tax:

$$R=(tq+S)n=D'(Q)Q. \tag{9}$$

Notice that this regulation is financially feasible from the standpoints of the regulator and firms;[6] that is, the regulated firms have zero profits, and the regulator has positive revenue at equilibrium. In addition, if external damages can be covered by the revenue, i.e., $R \geq D(Q)$ or $D'(Q) \geq D/Q$, the regulator does not need to construct the second-best Ramsey rule, in which the budget balance effect of regulation should be taken into policy consideration.[7]

entrance fee provides the first-best condition of zero profit, and output tax yields perfect competition; the tax effects are cancelled out at Cournot equilibrium. Therefore, in a competitive market with free entry, the Pigouvian tax equal to marginal external damages secures the socially optimal amount of output and the number of firms.

6) This implies that the tax effects on government revenue (from the viewpoint of the regulator) and the incentive of abatement technology (from the viewpoint of polluting firms) will differ. For example, different tax level will affect not only the amount of output production, which relates to output tax revenue, but also the abatement effort of the polluting firm. See Katsoulacos and Xepapadeas (1995) and Schott (2008).

7) If the financial feasibility matters, the budget balance effect of the regulator's decision should be taken into consideration, by raising (or lowering) the tax rate to reduce (or raise) output—the Ramsey rule. Oates (1995), Shaffer (1995), and Sugeta and Matsumoto (2005) provide important insight into revenues and efficiency of the pollution tax.

Ⅳ. Regulatory Effects of Information Errors

In practice, in calculating the optimal regulatory instruments in (7) and (8), the regulator must know some information about the slopes of external damage and market demand functions. However, economic agents, such as the regulator, regulated firms, and interest groups, may use incorrect estimates of the relevant parameters concerning the two-part pollution tax. Then, it is of significance to examine the effect of incorrect estimation on market performance.

In the following analysis, we relax the assumption of complete information and consider information errors in estimating the slopes of external damage and market demand functions. We assume that there is no informational asymmetry between the regulator and other interest groups, including firms and environmentalists.[8] In particular, we assume that the estimated slope of the market inverse function is $\widehat{P}\,'$ and the estimated slope of the damage function is $\widehat{D}\,'$. Then, the suggested optimal two-part pollution tax with output tax and entrance fee will be set as follows:

$$\hat{t} = \widehat{D}\,' + \widehat{P}\,'q \qquad (10)$$

8) It is also interesting to consider the case where the regulator has only partial knowledge of the needed parameters while the firms have more accurate information. Then, there will be a serious informational asymmetry between the regulator and regulated firm regarding implementation. Kim and Chang (1993) construct an incentive tax scheme under asymmetric information.

$$S = -\hat{P}'q^2. \tag{11}$$

Again, the entrance fee is positive, but the output tax rate is ambiguous; the total pollution tax $\hat{t}q + \hat{S} = \hat{D}'(Q)q$ is the estimated Pigouvian tax in equilibrium.

Then, the objective of the regulated firm is :

$$\max_q \hat{\Pi} = \hat{P}(Q)q - C(q) - \hat{t}q - \hat{S}.$$

The symmetric Cournot-Nash equilibrium outputs and profits with free entry will be determined at $(\hat{q}, \hat{n})$, which satisfy the following :

$$\hat{P}(\hat{n}\hat{q}) + \hat{P}'\hat{q} - C'(\hat{q}) - \hat{t} = 0 \tag{12}$$

$$\hat{P}(\hat{n}\hat{q}) - C(\hat{q}) - \hat{t}\hat{q} - \hat{S} = 0 \tag{13}$$

Putting (10) and (11) into (12) and (13) gives the following :

$$\hat{P}(\hat{Q}) - C(\hat{q}) - \hat{D}'(\hat{Q}) = 0 \tag{14}$$

$$\hat{P}(\hat{Q}) - \frac{C(\hat{q})}{\hat{q}} - \hat{D}'(\hat{Q}) = .0 \tag{15}$$

Then, we can conclude that the equilibrium output is equal to the socially optimal output, i.e., $\hat{q} = q^*$. This satisfies the minimum cost condition of $MC = AC$, but the equilibrium number of firms may differ from the socially optimal number of firms, i.e., $\hat{n} \neq n^*$, and thus total industry output may differ, i.e., $\hat{Q} \neq Q^* = n^* q^*$.

Finally, the regulator can get positive revenues; thus, the regulation will be financially feasible from the regulator's standpoint.

$$\widehat{R} = (\widehat{t}\ \widehat{q} + \widehat{S})\widehat{n} = \widehat{D}\ '\widehat{n}\ \widehat{q} = \widehat{D}\ '\widehat{Q} \tag{16}$$

For clarity, the specific forms of private cost, external damage, and market demand functions will be examined. In particular, we incorporate information errors in estimating the following three functions to examine the regulatory effects of information errors on social welfare and government revenues:

$$C(q) = \frac{c}{2}q^2 + f \text{ and } C'(q) = cq$$

$$\widehat{D}(Q) = \frac{d+\varepsilon_1}{2}Q^2 \text{ and } \widehat{D}'(Q) = (d+\varepsilon_1)Q$$

$$\widehat{P}(Q) = a-(b-\varepsilon_2)Q \text{ and } \widehat{P}'(Q) = -(b-\varepsilon_2),$$

where ε_1 represents over-estimated information error on the slope of marginal damage, and ε_2 represents over-estimated information error on the slope of market demand. Notice that these information errors have a negative value when these are under-estimated.

As we observed, a convenient feature of this formulation is that marginal cost and external damage functions are linear, and market demand function is also linear.[9] We assume that ε_i is sufficiently small, and

9) Koenig (1985) and Shaffer (1989) analyze similar quadratic functions and derive quadratic tax schedules that induce firms to alter their outputs in a welfare-increasing direction. However, their models treat uncertainty as shifting only the intercepts of the marginal damage and market demand functions, unlike our model.

a, b, c, d, and f are constant. We also assume that all parameters satisfy the interior solutions in the optimal solutions and equilibrium outcomes.

Now, the optimal regulatory instruments in (10) and (11) can be rewritten as:

$$\widehat{t} = (d+\varepsilon_1)Q-(b-\varepsilon_2)q \quad (17)$$

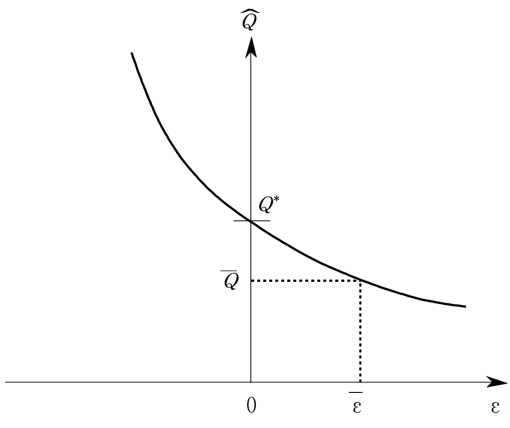
$$\widehat{S} = (b-\varepsilon_2)q^2. \quad (18)$$

Then, the profit-maximizing output and the number of firms in equilibrium will be determined at (14) and (15), in which

$$\widehat{\Pi} = (a-(b-\varepsilon_2)\widehat{Q})q-(\frac{c}{2}\widehat{q}^2+f)-\widehat{t}\ \widehat{q}-\widehat{S} = 0 \quad (19)$$

where $\widehat{q} = \sqrt{\frac{2f}{c}}$, $\widehat{n} = \frac{(a-\sqrt{2cf})\sqrt{c}}{((b-\varepsilon_2)+(d+\varepsilon_1))\sqrt{2f}}$, and $\widehat{Q} = \widehat{n}\ \widehat{q} = \frac{a-\sqrt{2cf}}{(b-\varepsilon_2)(d+\varepsilon_1)}$.

〈Figure 1〉 Information Errors and Output Changes



Notice that the equilibrium output is not affected by the information errors, i.e., $\widehat{q} = q^*$, but the equilibrium number of firms and industry output are affected by the information errors separately. In particular, industry output is negatively affected by ε_1, over-estimation on the slope of marginal damage, and positively affected by ε_2, over-estimation on the slope of market demand.

Let $\varepsilon = \varepsilon_1 - \varepsilon_2$ be the difference of information errors between the slopes of marginal damage and market demand. Then, from the second-order conditions, a comparative statics on the industry output gives $\frac{\partial \widehat{Q}}{\partial \varepsilon} < 0$ and $\frac{\partial^2 \widehat{Q}}{\partial \varepsilon^2} > 0$, which is depicted in <Figure 1>.

A few remarks are in order. First, if ε is zero, including the case of no information error, $\varepsilon_1 = \varepsilon_2 = 0$, then the information errors are cancelled out in the equilibrium; that is, as far as over(under)-estimation on the slopes of two functions occurs with the same magnitude, the equilibrium output and number of firms are the same as the social optimum, i.e., $\widehat{Q} = Q^*$ when $\varepsilon = 0$.

Second, if ε is positive, as $|\varepsilon|$ increases, the number of firms decreases and thus total industry output decreases as well. If over-estimation on the slope of marginal damage is more exaggerative than over-estimation on the slope of market demand, total industry output in equilibrium will be lower than the social optimum.

Third, if ε is negative, as $|\varepsilon|$ increases, the number of firms increases and thus total industry output increases as well. If over-estimation on the slope of marginal damage is less exaggerative than over-estimation on the slope of market demand, total industry output in equilibrium will be higher than the social optimum.

Finally, as $|\varepsilon|$ increases, industry output decreases, but the impact of on the reduction rate of industry output is stronger when ε is negative.

Next, actual social welfare can be calculated as :

$$\widehat{W} = W(\widehat{Q}) = (a - \sqrt{2cf})\widehat{Q} - \frac{b+d}{2}\widehat{Q}^2. \tag{20}$$

Then, we have :

$$\frac{\partial \widehat{W}}{\partial \varepsilon} = (b+d)(Q^* - Q)\frac{\partial \widehat{Q}}{\partial \varepsilon} \quad \text{and}$$

$$\frac{\partial^2 \widehat{W}}{\partial \varepsilon^2} = (b+d)\left\{(Q^* - \widehat{Q})\frac{\partial^2 \widehat{Q}}{\partial \varepsilon^2} - \left(\frac{\partial \widehat{Q}}{\partial \varepsilon}\right)^2\right\}.$$

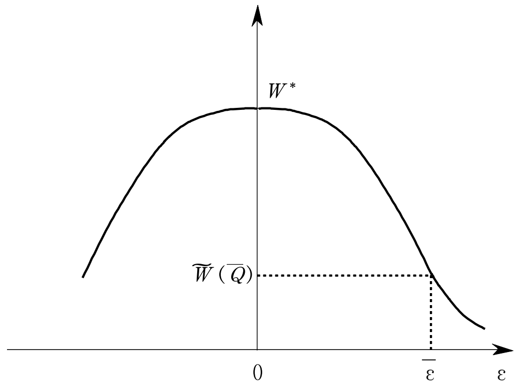
Then, from the comparative statics of industry output, we can conclude that the effects of information errors on social welfare depend on the difference of errors as follows. First, if ε is zero, industry output is the same as the social optimum, and thus social welfare will be maximized. In particular, the welfare level will be exactly equal to the case of no information error. Therefore, social welfare will be affected by relative information errors, not absolute information errors.

Second, if ε is non-zero, social welfare will be reduced, but its decreasing rate differs. In particular, we have the following signs :

$$\frac{\partial^2 \widehat{W}}{\partial \varepsilon^2} \lessgtr 0 \quad \text{if} \quad \widehat{Q} \gtrless \overline{Q} \equiv \frac{2}{3}Q^* (< Q^*)$$

As shown in <Figure 2>, if ε is positive, as $|\varepsilon|$ increases, social welfare decreases in a concave manner first and in a convex manner later after $\overline{\varepsilon}$. But, if ε is negative, as $|\varepsilon|$ increases, social welfare

〈Figure 2〉 Information Errors and Welfare Changes



decreases in a concave manner. Thus, when ε is negative and large, the impact of information errors on the reduction of welfare is stronger. Therefore, from the viewpoint of social welfare, over-estimation on the slope of market demand is more serious than over-estimation on the slope of marginal damage if $|\varepsilon|$ is large.

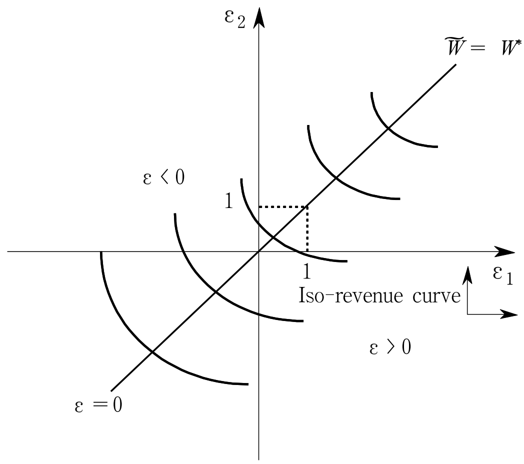
Next, we reexamine government revenue and the incentives for imposing this regulation. The regulator can raise the following (positive) revenues from the regulation:

$$\widehat{R} = (d+\varepsilon_1)\widehat{Q}^2. \tag{21}$$

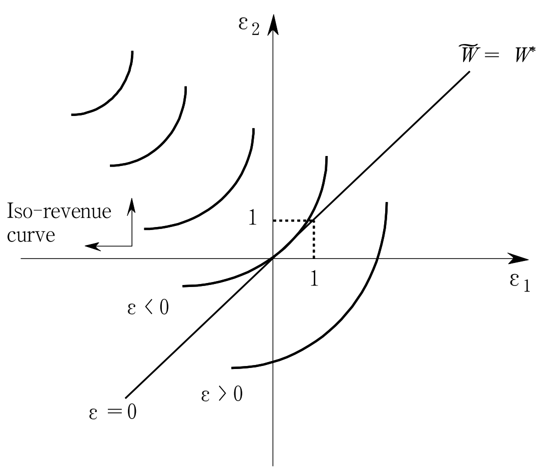
A few remarks are in order. First, the regulation is financially feasible from the viewpoint of society since actual external damages are covered by these revenues, i.e., $\widehat{R} \geq D(\widehat{Q}) = \frac{d}{2}\widehat{Q}^2$ unless ε_1 is negative and large.

Second, we have the following comparative statics:

〈Figure 3〉 Information Errors and Revenue Changes When ($b - \varepsilon_2 > d + \varepsilon_1$)



〈Figure 4〉 Information Errors and Revenue Changes When ($b - \varepsilon_2 < d + \varepsilon_1$)



$$\frac{\partial \widehat{R}}{\partial \varepsilon_1} = \frac{(b-\varepsilon_2)-(d+\varepsilon_1)}{(b-\varepsilon_2)+(d+\varepsilon_1)}\widehat{Q}^2 \quad \text{and}$$

$$\frac{\partial \widehat{R}}{\partial \varepsilon_2} = -2(d+\varepsilon_1)\widehat{Q}\frac{\partial \widehat{Q}}{\partial \varepsilon} > 0.$$

Thus, if $b-\varepsilon_2 > d+\varepsilon_1$, the revenue increases as the two information errors increase. When the estimated slope of marginal damage is smaller than that of market demand, the regulator has an incentive to collect over-estimation on regulatory information. In particular, since the welfare level is the same as far as ε is zero, the regulator will not care for the over-estimation. <Figure 3> shows that revenue increases to the north-east direction, while the locus of information errors, which are located on a 45 degree line, gives the same level of social welfare, i.e., $\widehat{Q} = Q$ when $\varepsilon = 0$.

However, if $b-\varepsilon_2 < d+\varepsilon_1$, the revenue increases as ε_1 decreases and ε_2 increases. When the estimated slope of marginal damage is larger than that of market demand, the regulator will reduce over-estimation on the slope of marginal damage if revenue matters in regulation. Put differently, the regulator has an incentive to accept over-estimation on the slope of market demand, but to reject over-estimation on the slope of marginal damage in order to raise higher revenue. <Figure 4> shows that revenue increases to the north-west direction, while social welfare decreases as ε becomes negative and large in absolute value; that is, as $|\varepsilon|$ moves to a large value, $\widehat{Q}$ increases, and thus social welfare decreases drastically. Therefore, the incentive to raise revenue is limited if the regulator considers the trade-off between welfare loss and revenue gain.

Finally, we will investigate market reactions from two interests groups－

environmentalists and regulated firms – under the proposed two-part pollution tax. First, if environmentalists take care of $\widehat{Q}$ so as to reduce external damage, they will always over-estimate ε_1. Thus, if $b-\varepsilon_2 < d+\varepsilon_1$, their interest conflicts with the interest of the regulator.[10] In addition, if they take care of the estimated damages, which is $\widehat{E}=\widehat{D}(\widehat{Q})=\frac{d+\varepsilon_1}{2}\widehat{Q}^2$, half of revenue in (21), their interest of minimizing estimated damages is always in conflict with the regulator's interest of maximizing revenue. However, if the regulator can commit to recover external damage through financial support from government revenue, this conflict of interests will be resolved.[11]

On the other hand, even though the regulated firms will maximize their estimated profit in (19), which will be zero under free entry equilibrium, they will collectively care about over-entry and consequent negative actual profit caused by information errors. In particular, they know that the actual industry profit $\widehat{F}=\widehat{n}\,(P(\widehat{Q})-C(\widehat{q})-\widehat{t}\,\widehat{q}-\widehat{S})=-\varepsilon_2\widehat{Q}^2$ will be non-negative only when ε_2 is negative, where $\frac{\partial \widehat{F}}{\partial \varepsilon_2}<0$. Hence, they will under-estimate the slope of market demand to reduce the number of entrants, which is not always compatible with the interest of the regulator. Thus, there might be unresolved conflicts between the regulator and the regulated firms.

Therefore, to obtain higher welfare, the regulator should take care of

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10) Similarly, if environmentalists care for actual damage when they know that information errors exist, the actual damage $D(\widehat{Q})$ will be reduced when they over-estimate ε_1.

11) Notice that regulator can still get positive revenue even after supporting external damage for environmentalist. The financial issue of double dividend effect of the Pigouvian tax can be found in Lee and Kim(2000).

external damage not to over-estimate in the case of under-estimation on market demand, while it should control market demand not to under-estimate in the case of over-estimation on external damage. Some of interest results with numerical example is provided in Appendix.

Ⅴ. Concluding Remarks

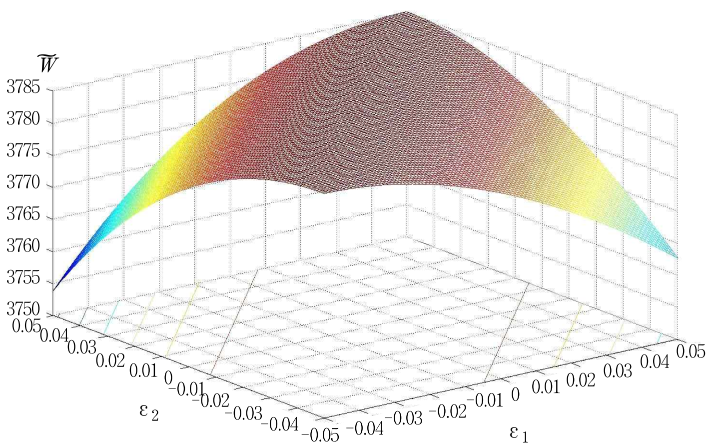
This paper has constructed the two-part tax—a combined form of output tax and entrance fee—for polluting oligopolists with free entry and shown that it produces the ex post Pigouvian rule. We have also analyzed how social welfare and government revenue are affected by the information errors of estimating the slopes of a demand curve and a marginal environmental damage, and examined the conflict of government and the incentive of the interest groups in the process of regulation. In particular, we have shown that if the regulator takes care of both welfare loss and revenue gain under the proposed two-part tax, not only over-estimation on the slope of external damage but also under-estimation on the slope of market demand should be taken into the policy consideration.

However, the provided analysis used the specific functional forms of linear demand and quadratic environmental damage to get the detailed simulation results. For the future research, we need to generalize the model to examine the role of information errors and investigate the information sharing problem under asymmetric information between regulator and the regulated firms.

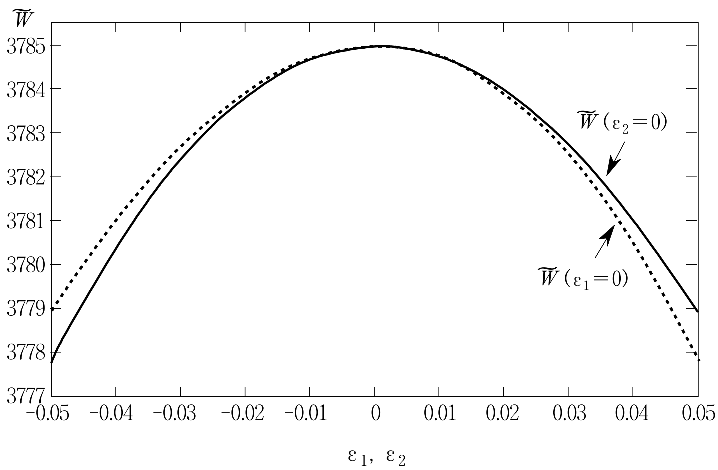
〈Appendix〉 Numerical Example

We will provide simulation results to examine the above comparative analysis. The initial value is a=100, b=0.7, c=1.1, d=0.5, f=10, and the information errors varied from -0.05 to 0.05. Then, the social optimum is calculated as $q^*=4.264$ and $n^*=18$. <Figure 5> and <Figure 6> provide the changes of welfare and show that welfare is more sensitive to ε_2 when there is over-estimation, while welfare is more sensitive to ε_1 when there is under-estimation. Finally, <Figure 7> and <Figure 8> provide the changes in government revenues. In particular, <Figure 7> shows that revenue increases as the two information errors increase, while <Figure 8> shows that revenue increases as ε_1 decreases and ε_2 increases.

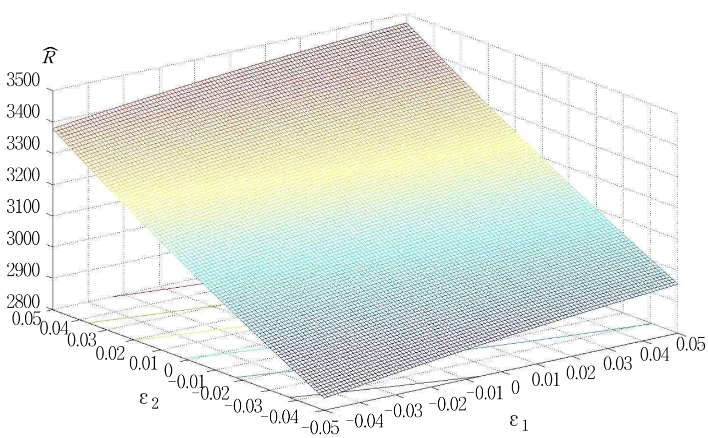
〈Figure 5〉 Simulation Result 1 : Information Errors and Welfare Changes



〈Figure 6〉 Simulation Result 2 : Information Errors and Welfare Changes

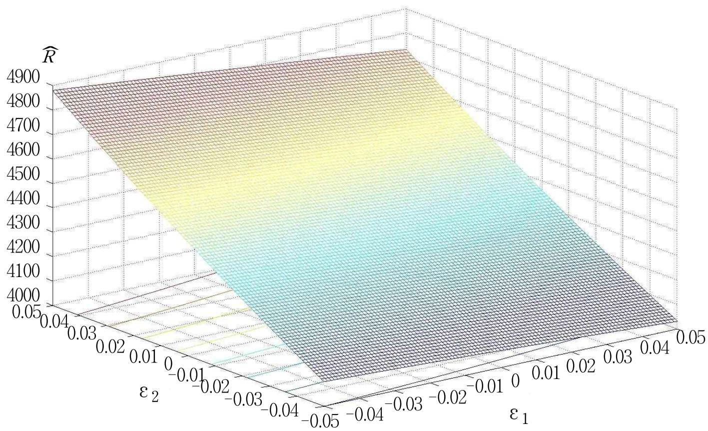


〈Figure 7〉 Simulation Result 3 : Information Errors and Revenue
$(b-\varepsilon_2 > d+\varepsilon_1)$



〈Figure 8〉 Simulation Result 4 : Information Errors and Revenue

$(b - \varepsilon_2 < d + \varepsilon_1)$



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요　　약

내생적 시장진입 구조에서 오염배출 과점기업에 대한 이부 환경세

박철희 · 이상호

본 연구는 오염을 배출하고 있는 과점기업들이 시장 진입을 내생적으로 결정할 때 정부가 부과할 수 있는 산출세와 진입세로 구성된 이부 환경세를 설계하고 있다. 특히, 시장 산출량에 따라 비례적으로 오염의 외부성이 발생하는 경우 이부 환경세는 후생을 극대화하는 사회적 최적 수준을 달성할 수 있다는 것을 보였다. 또한 논의의 확장으로 규제 과정에서 추정오차가 존재하는 경우 이부 환경세가 사회후생과 정부조세에 미치는 영향에 대해서도 분석하고 있다. 구체적으로, 사회적 이익집단들이 각자 자신들의 이익에 따라 서로 다른 정보를 제공하는 경우 이부 환경세가 시장 산출량, 정부조세, 그리고 사회 후생에 미치는 영향을 정태적으로 비교 분석해 보았다. 결과적으로, 정부가 사회 후생의 손실분과 정부의 조세 수입 모두를 고려한다면, 오염 함수의 기울기에 대한 과대 추정뿐만 아니라 수요 함수의 기울기에 대한 과소 추정에 대해 유의해야 한다.

주제어 : 이부 환경세, 오염배출 과점기업, 내생적 시장진입, 추정 오차

Two-Part Tax for Polluting Oligopolists with Endogenous Entry

Chul-Hi Park and Sang-Ho Lee

This paper constructs the two-part tax — a combined form of output tax and entrance fee — for polluting oligopolists under endogenous entry. In the presence of external damage that varies exogenously with aggregate output, we show that the two-part tax produces the ex post Pigouvian rule and thus achieves the first-best optimum. We also examine a detailed analysis of the impact of the two-part tax on social welfare and government revenues. Finally, when estimation errors exist in the process of regulation, we identify the incentive conflicts between interest groups and analyze the effects of estimation errors on determining optimal tax. In particular, we show that if the regulator takes care of both welfare loss and revenue gain under the proposed two-part tax, not only over-estimation on the slope of external damage but also under-estimation on the slope of market demand should be taken into the policy consideration.

Keywords : two-part tax, polluting oligopolist, endogenous entry, estimation errors