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Antitrust Policy and Environmental Protection

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Abstract

We examine the effects of antitrust policy (the prohibition of a input price discrimination) when an emission tax is used for environmental protection. We show that antitrust policy reduces pollution emission and improves social welfare. Therefore, antitrust policy contributes to environmental protection.

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1 Introduction

The welfare effect of third-degree price discrimination has been intensively studied in the last century.[1] However, most studies have examined the relationship between total output and social welfare. We employ the standard model of input price discrimination proposed by Katz (1997) and DeGraba (1990) and examine the effects of a typical antitrust policy (the Robinson-Patman Act) on environmental protection.[2] The downstream market comprises Cournot duopoly firms that produce the final product for consumers. They use two intermediate inputs. One is a dirty input that is supplied in a competitive market; its use causes environmental pollution. The other is a clean input that is supplied by the monopolist; its use does not cause any environmental pollution. The two downstream firms have different production technologies and use the dirty input in different quantities. We refer to the firm that uses a lesser amount of the dirty input as an environmentally friendly firm. We refer to the other firm as an environmentally unfriendly firm. The difference in these firms' production technologies provides the monopolist with an incentive to price discriminate against them.

We assume that the pollution damage is serious, and the environmental protection agency (EPA) levies an emission tax on pollution emission. We then examine the effects of a specific antitrust policy (the prohibition of an input price discrimination) in two cases.[3] In the first case, EPA has to utilize the same tax rate regardless of the pricing regime. In the second case, EPA differentiates between the tax rates of two pricing regimes so as to maximize social welfare.

[1] See Schmalensee (1981), Varian (1985), and Schwartz (1990) for the reference.

[2] Yoshida (2000) and Valletti (2003) generalized the analysis of input price discrimination. More recently, Adachi (2002, 2005) examines the welfare consequence of third-degree price discrimination in the presence of consumption externalities. Galera and Zaratiegui (2005) generalizes the analysis to an oligopoly framework.

[3] In this paper, the application of antitrust policy implies the prohibition of an input price discrimination by a monopolist. The result presented in this paper may not be valid for different kinds of antitrust policies.

2 The Model

Two Cournot downstream firms produce a homogeneous final product and engage in quantity competition. Let q_i and q_j denote the quantities of the final product produced by firm i and firm j, respectively. The aggregate supply is indicated by $Q \equiv \sum q_i \equiv q_i + q_j$.

The downstream firms produce their products using two types of inputs: a clean input and a dirty input. The clean input is supplied by the upstream monopolist M, while the dirty input is supplied in a competitive market. The monopolist produces the clean input at a constant marginal cost c_M.

The downstream firms have Leontief-type technologies. The firm i requires one unit of the clean input and β_i units of the dirty input to produce one unit of the final product. Let e_i denote the amount of pollution emission by firm i. One unit of the dirty input leads to one unit of pollution emission, i.e., $e_i = \beta_i q_i$. We assume $\beta_i < \beta_j$. Thus, firm i uses a smaller amount of the dirty input than firm j to produce one unit of the final product. We refer to firm i and firm j as environmentally friendly and environmentally unfriendly firms, respectively. The aggregate emission is given by $E \equiv \sum e_i$.

The consumers' utility level, U, is assumed to be additively separable from the disutility arising from the environmental damage, $D(E) \equiv \varphi E$. Thus, $U = u(Q) + m - D(E)$, where $u(Q) \equiv aQ - \frac{1}{2}bQ^2$ and m is the numeraire consumption. Let p denote the price of the final product. From utility maximization by the consumers, it follows that $p = u'(Q)$. Thus, the downstream firms face the linear inverse demand function, $p(Q) \equiv a - bQ$.

EPA imposes an emission tax rate of τ. We normalize the price of the dirty input to 1. Then, the profit function of the downstream firm i is given by $\pi_i \equiv (p(Q) - r_i - \beta_i) q_i - \tau e_i$, where r_i is the price of the intermediate input. When price discrimination is prohibited by the antitrust law, $r_i = r_j = r$. The profit function of the monopolist is given by $\pi_M \equiv \sum (r_i - c_M) q_i$.

In the subsequent analysis, we consider the two-stage game. In Stage 1, the monopolist sets input prices. In Stage 2, the downstream firms decide their output levels. In order to find the subgame perfect equilibrium of this stage game, the usual backward induction is employed. Thus, we begin with solving the second-stage problem.

2.1 Downstream Market

The second-stage game is characterized by Cournot duopoly with each firm incurring the marginal cost, $c_i \equiv r_i + \beta_i(1+\tau)$. We obtain the following equilibrium outputs under price discrimination:[4] $q_i^d = \frac{1}{3b}(a - 2r_i + r_j - (2\beta_i - \beta_j)(1+\tau))$ and $Q^d = \frac{2}{3b}\left(a - \overline{r} + \overline{\beta}\,(1+\tau)\right)$, where $\overline{r} \equiv \frac{1}{2}(r_i + r_j)$ is the average input price and $\overline{\beta} \equiv \frac{1}{2}\left(\beta_i + \beta_j\right)$ is the average pollution intensity of the two firms. If price discrimination is prohibited, i.e., $r_i = r_j = r$, then the equilibrium outputs become $q_i^u = \frac{1}{3b}(a - r - (2\beta_i - \beta_j)(1+\tau))$ and $Q^u = \frac{2}{3b}(a - r + \overline{\beta}(1+\tau))$. Furthermore, the second-stage Cournot-Nash equilibrium downstream profit and total emission level can be expressed as $\pi_i^x = b\,(q_i^x)^2$ and $E^x \equiv \sum \beta_i q_i^x$, respectively, for the pricing regime $x = d,\, u$.

2.2 Upstream Market

Under price discrimination, the monopolist maximizes its profit $\pi_M^d \equiv \sum (r_i - c_M)\, q_i^d$ with respect to r_i and r_j. This yields the discriminatory prices given by $r_i = \frac{1}{2}(a + c_M - \beta_i(1+\tau))$. Since $r_i - r_j = \frac{1}{2}(\beta_j - \beta_i)(1+\tau) > 0$, the environmentally friendly firm is charged a higher input price than the environmentally unfriendly firm. Firm i's marginal cost becomes $c_i^d = \frac{1}{2}(a + c_M + \beta_i(1+\tau))$.

The uniform pricing regime yields the profit function of the monopolist, given by $\pi_M^u \equiv \sum (r - c_M)\, q_i^u = (r - c_M)\, Q^u$. After substituting the aggregate input demand and then maximizing π_M^u through the choice of r, we obtain the optimal uniform price, $r = \frac{1}{2}(a + c_M - \overline{\beta}(1+\tau))$, which is the average of the optimal discriminatory prices, i.e., $r = \overline{r}$. Firm j's marginal cost becomes $c_i^u = \frac{1}{2}(a + c_M + \left(2\beta_i - \overline{\beta}\right)(1+\tau))$.

[4] The superscript d denotes the discriminatory pricing regime, while the superscript u denotes the uniform pricing regime.

The antitrust policy changes the pricing regime from price discrimination to uniform pricing. It doubles the cost difference between the two downstream firms, since $c_j^u - c_i^u = (\beta_j - \beta_i)(1+\tau) = 2(c_j^d - c_i^d) > 0$. Therefore, the antitrust policy strengthens the competitiveness of the environmentally friendly firm.

For an exogenously given emission tax, the equilibrium outcomes are summarized in the left column of Table 1. It follows that $q_i^d - q_j^d = \frac{1}{2b}(1+\tau)\left(\beta_j - \beta_i\right) > 0$. Thus, the discriminatory pricing does not reverse the marginal cost ranking.

We can show that $\partial(r_i - r_j)/\partial\tau = \frac{1}{2}(\beta_j - \beta_i) > 0$. The degree of the input price discrimination rises when the emission tax is increased. We also know that the tax increase relatively favors the environmentally friendly firm, $\partial(c_j^d - c_i^d)/\partial\tau = \frac{1}{2}(\beta_j - \beta_i) > 0$. Hence, we obtain $\partial(q_i^d - q_j^d)/\partial\tau = \frac{1}{2b}\left(\beta_j - \beta_i\right) > 0$. The tax increase widens the output difference between the two downstream firms.

The output difference under uniform pricing is $q_i^u - q_j^u = \frac{1}{b}(1+\tau)\left(\beta_j - \beta_i\right) > 0$; thus, $\partial(q_i^u - q_j^u)/\partial\tau = 2 \cdot \partial(q_i^d - q_j^d)/\partial\tau > 0$. This implies that the effect of the tax increase on the output difference is stronger under price discrimination.

Finally, we examine the effectiveness of the emission tax under both pricing regimes. By differentiating the total emission with respect to τ, we can compare the effectiveness of the emission taxation between the two pricing regimes as follows:

$$0 > -\frac{1}{3b}K = \frac{\partial E^d}{\partial\tau} > \frac{\partial E^u}{\partial\tau} = -\frac{1}{3b}(2K - \overline{\beta}^2),$$

where we define $K \equiv \beta_i^2 - \beta_i\beta_j + \beta_j^2 > 0$ and employ $2K - \overline{\beta}^2 > K \Leftrightarrow K - \overline{\beta}^2 = 3\left(\beta_j - \beta_i\right)^2/4 > 0$.

Lemma 1 *Antitrust policy increases the effectiveness of the emission taxation.*

2.3 Optimal Emission Tax Rates

We now derive the optimal tax rates under both pricing regimes. The social welfare is $W \equiv u(Q) - pQ - D(E) + \pi_M + \sum \pi_i + \tau E$, where the first three terms constitute the consumer's surplus net of the environmental damage, the next two terms are the upstream and downstream profits, and the last term is the tax revenue. Substituting the above expressions into $u(Q)$, π_M, π_i and $D(E)$, we write the social welfare under the pricing regime $x = d$, u as

$$W^x = AQ^x - \frac{1}{2}b\left(Q^x\right)^2 - \sum \beta_i q_i^x - \varphi E^x,$$

where $A \equiv a - c_M > 0$. Differentiating W with respect to τ, we obtain the first-order condition for the optimal emission tax rate:

$$\frac{dW^x}{d\tau} = \left(A - bQ^x\right)\frac{dQ^x}{d\tau} - (1+\varphi)\frac{dE^x}{d\tau} = 0.$$

Substituting the comparative statics results under each regime, we obtain the optimal total outputs for the pricing regime $x = d$, u. We denote them as Q^{x*} in the right column of Table 1, together with the other optimal outcomes. Solving $Q^{x*} = Q^x$ for τ yields the optimal rate of emission tax for both regimes:

$$\tau^d = \frac{3K(1+\varphi) - 2A\overline{\beta}}{\overline{\beta}^2} - 1, \qquad \tau^u = \frac{3(2K - \overline{\beta}^2)(1+\varphi) - 2A\overline{\beta}}{\overline{\beta}^2} - 1.$$

When these optimal tax rates are utilized, both downstream firms produce positive output. The difference between these two optimal tax rates is $\tau^u - \tau^d = (K - \overline{\beta}^2)(1+\varphi)/(3\overline{\beta}^2) > 0$, since $K - \overline{\beta}^2 > 0$.

Lemma 2 *The optimal emission tax rate under price discrimination is lower than that under uniform pricing.*

We assume that the pollution damage is serious. Therefore, the parameters are restricted as follows:

Assumption 1: $3K(1+\varphi) > 2A\overline{\beta}$

This assumption implies that $1+\tau^u$ and $1+\tau^d$ are both positive. Since $\tau^u > \tau^d$, $1+\tau^d > 0$ is sufficient. However, we require the condition for $1+\tau^u > 0$ to prove that ΔE^* is negative.

3 Welfare Effect of the Antitrust Policy

3.1 First Case: EPA cannot set the tax rate.

EPA has to utilize the same tax rate regardless of the pricing regime. Using the equilibrium outcomes presented in the left column of Table 1, we can examine the welfare effect of the antitrust policy.

First, we find $\Delta Q \equiv Q^u - Q^d = 0$ and $\Delta E \equiv E^u - E^d = -\frac{1}{3b}(1+\tau)(K-\overline{\beta}^2) < 0$. The total output is unaffected by the regime change while total emission is reduced. However, the environmental condition is improved by the antitrust policy. If consumer welfare is given by the difference between consumer surplus and pollution damage, then antitrust policy improves it.

We now evaluate the welfare effect of the antitrust policy as follows: $\Delta W = -\sum \beta_i \Delta q_i - \varphi \Delta E$. When price discrimination is permitted, the monopolist charges the environmentally friendly firm a higher input price than it does the environmentally unfriendly firm. Antitrust policy shifts the production from the environmentally unfriendly firm to the environmentally friendly firm, while maintaining the aggregate output at the same level. This resolves the production inefficiency, which is captured by the term, $\sum \beta_i \Delta q_i < 0$. Furthermore, the antitrust policy reduces the total pollution emission and mitigates the pollution problem. Therefore, it also resolves the environmental inefficiency. From $E = \sum \beta_i q_i$, two welfare gains (production and environmental efficiencies) obtained by the antitrust policy amount to $\Delta W = \frac{1}{4b}(1+\varphi)(1+\tau)\left(\beta_j - \beta_i\right)^2 > 0$.

Proposition 1 *When an emission tax rate is exogenously determined, social welfare is improved by antitrust policy.*

3.2 Second Case: EPA optimizes the tax rate.

EPA now sets the emission tax rate. By substituting the optimal emission tax rates into the corresponding conditions, we obtain equilibrium outcomes as given in Table 1.

The change in total output is $\Delta Q^* = -(1+\varphi)(K - \overline{\beta}^2)/(b\overline{\beta}) < 0$. Therefore, the total output is reduced by the antitrust policy.

The change in total emission is

$$\Delta E^* = \frac{1}{3b\overline{\beta}^2}(K - \overline{\beta}^2)\left(2A\overline{\beta} - 3(3K - \overline{\beta}^2)(1+\varphi)\right)$$

Assumption 1 requires $2A\overline{\beta} < 3K(1+\varphi)$. From $3K - \overline{\beta}^2 > K$, it follows that $\Delta E^* < 0$.

The change in social welfare is

$$\Delta W^* = \frac{1}{6b\overline{\beta}^2}(1+\varphi)(K - \overline{\beta}^2)\left(3(3K - \overline{\beta}^2)(1+\varphi) - 4A\overline{\beta}\right)$$

Assumption 1 requires $4A\overline{\beta}$ to be under $6K(1+\varphi)$. From $3K - \overline{\beta}^2 > 2K$, it follows that $\Delta W^* > 0$. This implies that antitrust policy improves social welfare.

Proposition 2 *When an emission tax rate is optimally chosen, social welfare is increased by antitrust policy.*

4 Conclusion

This note has examined the effect of antitrust policy when an emission tax is used for environmental protection. We consider two cases. In the first case, it is assumed that the same emission tax rate is applied regardless of the pricing regime. In the second case, it is assumed that the emission tax rate is optimized depending on the pricing regime. In both cases, we show that antitrust policy (the prohibition of an input price discrimination) reduces the total emission and improves social welfare. Furthermore, it enhances the effectiveness of the pollution taxation. The joint use of pollution taxation and antitrust policy is favorable for environmental protection.

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Table 1. Equilibrium Outcomes

Case 1 EPA cannot set the tax rate.	Case 2 EPA optimizes the tax rate.
Input Prices	
$r_i - c_M = \frac{A-(1+\tau)\beta_i}{2}$;	$r_i^* - c_M = \frac{A\overline{\beta}\left(\overline{\beta}+2\beta_i\right)-3\beta_i K(1+\varphi)}{2\overline{\beta}^2}$;
$r - c_M = \frac{A-(1+\tau)\overline{\beta}}{2}$	$r^* - c_M = \frac{3\left(A\overline{\beta}-\left(2K-\overline{\beta}\right)(1+\varphi)\right)}{2\overline{\beta}}$
Individual Outputs	
$q_i^d = \frac{A-(1+\tau)\left(2\beta_i-\beta_j\right)}{6b}$;	$q_i^{d*} = \frac{A\overline{\beta}\left(2\left(2\beta_i-\beta_j\right)+\overline{\beta}\right)-3K\left(2\beta_i-\beta_j\right)(1+\varphi)}{6b\overline{\beta}^2}$;
$q_i^u = \frac{A-(1+\tau)\left(2\left(2\beta_i-\beta_j\right)-\overline{\beta}\right)}{6b}$	$q_i^{u*} = \frac{A\overline{\beta}\left(4\left(2\beta_i-\beta_j\right)-\overline{\beta}\right)-3\left(2K-\overline{\beta}^2\right)\left(2\left(2\beta_i-\beta_j\right)-\overline{\beta}\right)(1+\varphi)}{6b\overline{\beta}^2}$
Total Output	
$Q^d = \frac{A-(1+\tau)\overline{\beta}}{3b}$;	$Q^{d*} = \frac{A\overline{\beta}-K(1+\varphi)}{b\overline{\beta}}$;
$Q^u = \frac{A-(1+\tau)\overline{\beta}}{3b}$	$Q^{u*} = \frac{A\overline{\beta}-\left(2K-\overline{\beta}^2\right)(1+\varphi)}{b\overline{\beta}}$
Total Emission	
$E^d = \frac{A\overline{\beta}-(1+\tau)K}{3b}$;	$E^{d*} = \frac{A\overline{\beta}\left(2K+\overline{\beta}^2\right)-3K^2(1+\varphi)}{3b\overline{\beta}^2}$;
$E^u = \frac{A\overline{\beta}-(1+\tau)\left(2K-\overline{\beta}^2\right)}{3b}$	$E^{u*} = \frac{A\overline{\beta}\left(4K-\overline{\beta}^2\right)-3\left(2K-\overline{\beta}^2\right)^2(1+\varphi)}{3b\overline{\beta}^2}$

Note. $A \equiv a - c_M > 0$, $K \equiv \beta - \beta_i\beta_j + \beta_j^2 > 0$ and $K - \overline{\beta}^2 = 3\left(\beta_i - \beta_j\right)^2/4 > 0$.