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Abstract

This paper shows that, in case of differentiated products mixed duopoly, environmental damage increases (decreases) with the level of privatization, if the level of privatization is less (more) than certain level. It also shows that partial privatization is optimal from the social welfare point of view. However, the social welfare maximizing level of privatization damages the environment most.

Keywords:

Privatization, mixed duopoly, environmental damage, environmental tax, social welfare

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1 Introduction

Partial privatization of state-owned enterprises has been a feature of government policy in many developing as well as developed countries since 1980's (Megginson and Netter, 2001; Maw, 2002). It has spread across several sectors such as iron and steel, chemicals, electricity, textile, mining, transport and printing. Nevertheless, these (partially) privatized firms compete with other private firms in product markets.

It is commonly observed that production process in most of the above mentioned industries emit pollutants, which damages the environment. The extent of such environmental damage is likely to depend on the intensity of product market competition, which is largely guided by the firms' objective functions. It implies that privatization can also generate environmental outcomes.

Determination of optimal environmental policy in the context of oligopolistic industries has received considerable attention in the literature. It helps us to understand a variety of issues: role of product differentiation and free entry (Canton et al., 2008; Fujiwara, 2009), consequences of asymmetric information (Antelo and Loureiro, 2009), implications of strategic managerial delegation (Pal, 2009; Barcena-Ruiz and Garzon, 2002) link between pollution taxes and financial decisions of firms (Damania, 2000), strategic choice of environmental policy in case of open economies (Conrad, 1993; Kennedy, 1994; Barrett, 1994; Ulph, 1996; Bhattacharya and Pal, 2010), so on so forth. But, the issue of privatization has not received much attention in this strand of literature. How does the environmental damage due to pollution vary with the level of privatization? Is there any

relation between the level of privatization and environmental taxes? What should be the optimal level of privatization when production process damages the environment? This paper attempts to answer these questions by considering a differentiated products mixed duopoly market structure.

We note that several studies have attempted to examine the implications of strategic interactions between public (partially privatized) and private firms to economic welfare (see, for example, deFraja and Delbono, 1989; Fershtman, 1990; Matsumura, 1998; Fujiwara, 2007; Saha, 2009; Pal, 2010). It is shown that partial privatization is socially optimal, unless products are perfect substitutes and firms have constant marginal costs of production. However, these studies ignore the consequences of privatization on environment.

Recently, Barcena-Ruiz and Garzon (2006) and Wang and Wang (2009) examine the effects of privatization on environmental outcomes, by comparing equilibrium outcomes under full privatization with that under full nationalization. Barcena-Ruiz and Garzon (2006) consider that products are perfect substitutes, whereas Wang and Wang (2009) allow for product differentiation. However, none of these two papers recognize the possibility of partial privatization and, thus, fails to analyse how the level of privatization affects environmental outcomes.

Considering a monopoly firm, Beladi and Chao (2006) show that, if the market demand function is not sufficiently convex, production decreases due to increase in level of privatization. Therefore, it is argued that privatization can result in better environment unless the market demand function is highly convex. But, they ignore the fact that firms undertake pollution abatement measures, which is likely to depend on environmental tax and, thus, on level of privatization. It implies that the results of Beladi and Chao (2006) may not hold true in a general setup that takes care of pollution abatement decisions of firms. Analysing the interaction between environmental policy and privatization in case international homogenous product duopoly, Ohori (2006) shows that privatization adversely affects environment, as it increases production, and partial privatization is socially optimum. The present paper differs from Ohori (2006) in three important dimensions: (a) unlike Ohori (2006), this paper considers asymmetric duopoly; (b) the framework of

this paper allows for product differentiation; and (c) while Ohori (2006) considers an open economy, this paper is restricted to a closed economy.

This paper shows that environmental damage first increases with the increase in level of privatization up to a point, thereafter it starts declining with the increase in level of privatization. This result is contrast to the findings of Beladi and Chao (2006) and Ohori (2006). The intuition behind this result is as follows. Increase in level of privatization leads to (a) decrease in total production of the industry and, thus, lower emission of pollutants (*direct effect*) and (b) lower environmental tax, which induces firms to produce more and abate less (*indirect effects*). Though the combined impact of direct and indirect effects of privatization on output is negative, the indirect effect of privatization on pollution abatement dominates the combined impact unless the level of privatization is greater than a critical level. This paper also shows that partial privatization is socially optimal. However, environmental damage due to production related pollution is highest at the the socially optimal level of privatization.

The rest of the paper is organised as follows. The next section explains the model. It also contains the results of the analysis. Section 3 concludes.

2 The model

Let us consider an economy with an oligopolistic sector, consisting of two firms - firm 1 and firm 2, that produce a differentiated good and a competitive numeraire sector. Firm 1 is partially privatized and firm 2 is totally privately owned. The inverse demand function faced by firm i $(= 1, 2)$ is assumed to be linear such that the market price is given by $p_i = A - q_i - \gamma\, q_j$, i, j $= 1$, 2, $i \neq j$; where q_i (p_i) is the quantity (price) of the product of firm i and γ $(0 < \gamma < 1)$ is the product differentiation parameter.[1] Lower value of γ denotes higher degree of product differentiation, i.e., lower degree of substitutability

[1]The underlying utility function of the representative consumer is $U = Aq_1 + Aq_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2) + m$, where m is the quantity of the numeraire good. This specification of the representative consumer's utility function is similar to that of Singh and Vives (1984).

between products. We assume, for convenience, that both firms have identical marginal cost of production c, which is constant, and that there is no fixed cost of production.[2]

Production process in both firm 1 and firm 2 pollutes the environment. We assume, for simplicity, that production of each unit of output emits one unit of pollutant. However, each firm can reduce pollution by undertaking abatement measures. As in Ulph (1996), the cost of pollution abatement of firm i is given by $C_i = \frac{a_i^2}{2}$, where a_i (≥ 0) denotes the abatement level chosen by firm i. Thus, the emission level of each firm is $(q_i - a_i)$ and the total environmental damage due to pollution by the industry is as follows

$$ED = \frac{1}{2}d(q_1 - a_1 + q_2 - a_2)^2, \tag{1}$$

where d is the increment in marginal environmental damage due to pollution, which is assumed to be greater than $\frac{1}{6+2\gamma}$.[3]

The government imposes environmental tax t $(0 \leq t < A - c)$, on each firm, per unit of pollution emitted.[4] As a result, total tax revenue collected by the government is

$$T = t(q_1 - a_1 + q_2 - a_2). \tag{2}$$

The objective of the government is to maximize social welfare, which is given by

$$SW = CS + \pi_1 + \pi_2 + T - ED; \tag{3}$$

where

$$CS = \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2) \tag{4}$$

and

$$\pi_i = (p_i - c)q_i - t(q_i - a_i) - \frac{a_i^2}{2} \tag{5}$$

[2]Qualitative results of this paper go through, if we consider increasing marginal costs of production.

[3]This form of environmental damage function is widely considered in the literature (see, for example, Antelo and Loureiro (2009), Long and Soubeyran (2005) and Ulph (1996)).

$d > \frac{1}{6+2\gamma}$ ensures that the optimal environmental tax rate is positive, irrespective of the level of privatization

[4]Since emission subsidy is not politically viable, we restrict our focus to non-negative emission tax.

represent consumer surplus and profit, respectively, of firm i.

Other than deciding the rate of environmental tax t, the government also decides the level of privatization $\theta \in [0, 1]$ of firm 1. Following Matsumura (1998), the private sector owns a share θ of the partially privatized firm, firm 1. Clearly, higher value of θ denotes higher level of privatization and $\theta = 1$ ($\theta = 0$) corresponds to the case of full privatization (full nationalization) of firm 1.

We consider that a fully privatized firm maximizes its own profit, whereas a fully nationalised firm maximizes the sum of consumer surplus and producer surplus. The level of privatization (θ) determines the bargaining power of the private partner in bargaining over the payoff with the public sector.[5] Note that existing institutional factors of the economy play crucial roles in determining objective functions of fully nationalised firms as well as of partially privatised firms. Without any loss of generality, the objective function of firm 1 can be considered as the weighted average of its own profit and the sum of consumer surplus and producer surplus, $O_1 = \theta\pi_1 + (1-\theta)[CS + \pi_1 + \pi_2]$. [6] Thus, firm 1 chooses its output q_1 and pollution abatement level a_1 to maximize O_1, and firm 2 chooses its output q_2 and abatement level a_2 to maximize its own profit π_2. The stages of the game involved are as follows.

Stage 1: The government decides the level of privatization (θ).

Stage 2: The government chooses the environmental tax rate (t)

Stage 3: Each firm simultaneously and independently decides the quantity (q_i) and the level of abatement (a_i).

[5]Alternatively, following Fershtman (1990), if we consider that the private partner and the public sector bargain over the quantity of output to be produced, where bargaining powers are determined by respective share holdings, qualitative results of this analysis go through. The reason is the formulations of Fershtman (1990) and Matsumura (1998) lead to comparable objective functions of the partially privatized firm (Kumar and Saha, 2008; Saha, 2009)

[6]Qualitative results of this analysis go through, if we consider the objective function of firm 1 as the (a) weighted average of its own profit and the sum of market specific consumer surplus and its own profit, as in Saha (2009); or (b) weighted average of its own profit and the sum of consumer surplus and its own profit, as in Wang and Wang (2009).

We solve this game by backward induction method. In stage 3, given the level of privatization and the rate of environmental tax, firms' optimum choice of outputs and abatement levels are as follows.

$$q_1 = \frac{(A-c-t)\ (2-\gamma)}{2\ (1+\theta)-\gamma^2},$$
$$q_2 = \frac{(A-c-t)\ (1-\gamma+\theta)}{2\ (1+\theta)-\gamma^2}, \tag{6}$$
$$\text{and} \quad a_1 = a_2 = t.$$

Clearly, both firms abate pollution up to the point where marginal abatement cost equals the environmental tax rate. Also, it is easy to check that the partially privatized firm produces more than the private firm, since the private firm is purely profit oriented whereas the partially privatized firm cares about total economic surplus also, i.e, the partially privatized firm is more output oriented than the private firm. Higher output orientation of the partially privatized firm makes it more sensitive to environmental tax: $\frac{\partial q_1}{\partial t} < \frac{\partial q_2}{\partial t} < 0$.[7] That is, increase in environmental tax rate leads to larger reduction in output of the partially privatized firm than that of the private firm. Firms' optimum choices in stage 3 also indicate that an increase in level of privatization leads to decrease (increase) in output of the partially privatized firm (private firm): $\frac{\partial q_1}{\partial \theta} < 0 < \frac{\partial q_2}{\partial \theta}$.[8] The intuition is higher level of privatization makes the partially privatized firm less aggressive in the product market, which results in shift of production from the partially privatized firm to the private firm. However, overall output of the industry decreases with the increase in level of privatization.[9]

Therefore, given the environmental tax rate, higher level of privatization leads to lower emission of pollutants and, thus, lower environmental damage. On the other hand, given the level of privatization, an increase in environmental tax rate leads to lower outputs as well as higher abatements, which also result in lower emission of pollutants and lower environmental damage. It indicates that level of privatization and environmental tax are substitutes in nature from environmental point of view.

Now, in stage 2 of the game, the government chooses the environmental tax rate to

[7] $\frac{\partial q_1}{\partial t} = -\frac{2-\gamma}{2-\gamma^2+2\,\theta} < -\frac{1+\theta-\gamma}{2-\gamma^2+2\,\theta} = \frac{\partial q_2}{\partial t}$, since $\theta \in (0,1)$ in case of partial privatization.

[8] $\frac{\partial q_1}{\partial \theta} = -\frac{2\,(A-c-t)\,(2-\gamma)}{(\gamma^2-2\,(1+\theta))^2} < 0 < \frac{\partial q_2}{\partial \theta} = \frac{\gamma\,(A-c-t)\,(2-\gamma)}{(\gamma^2-2\,(1+\theta))^2}$, since $0 < \gamma < 1$.

[9] $\frac{\partial (q_1+q_2)}{\partial \theta} = -\frac{(2-\gamma)^2\,(A-c-t)}{(\gamma^2-2\,(1+\theta))^2} < 0$.

maximize social welfare (SW), considering the level of privatization as given.[10] Substituting the optimum choices of q_i and a_i $(i = 1, 2)$, made by firms in stage 3, in the expression of social welfare and solving the problem $\underset{t}{Max}\ SW(t;\theta)$, we get

$$t = \frac{(A-c)\left[d\left(3-2\gamma+\theta\right)\left\{7-2\gamma\left(1+\gamma\right)+5\theta\right\}+\gamma\left(2+6\theta\right)-\gamma^2\left(1+\theta\right)-\theta\left(6+\theta\right)-1\right]}{13+2\gamma^3+2\gamma^4-2\gamma\left(1-\theta\right)+9\theta\left(2+\theta\right)-2\gamma^2\left(6+5\theta\right)+d\left\{7-2\gamma\left(1+\gamma\right)+5\theta\right\}^2} = t(\theta). \quad (7)$$

It is straightforward to check that, for any given level of privatization, the optimum environmental tax rate is less than marginal environmental damage due to pollution, unless products are perfect substitutes $(\gamma = 1)$ and firm 1 is fully nationalized $(\theta = 0)$.[11] In other words, in case of differentiated products duopoly market structure, the optimal environmental tax rate is less than the standard Pigouvian environmental tax rate. This is true even if one of the firms is fully nationalized. In other words, the optimal environmental tax rate is less than the standard Pigouvian tax rate irrespective of the level of privatization, if products are differentiated. The underlying reason is, unlike as in case of monopoly, under differentiated products duopoly market structure full nationalization of one firm does not mitigate the problem of under production due to imperfect competition completely.

Moreover, it is easy to check that the optimum environmental tax rate (t) decreases at a decreasing rate due to increase in level of privatization (θ): $\frac{\partial t}{\partial \theta} < 0$, $\frac{\partial^2 t}{\partial \theta^2} > 0$. Therefore, it is evident that privatization has two effects on environmental damage: (a) privatization reduces environmental damage by reducing the overall industrial production (*direct effect*) and (b) it calls for lower environmental tax, to take account for the economic surplus, which in turn increases environmental damage by encouraging higher production and lower abatement by firms (*indirect effects*). If the indirect effects together dominates the direct effect, privatization will adversely affect the environment.

Now, for any given level of privatization, environmental damage due to pollution is $ED(\theta) = \frac{1}{2}d\{q_1(\theta) + q_2(\theta) - 2t(\theta)\}^2$, since $a_1(\theta) = a_2(\theta) = t(\theta)$; where $q_i(\theta)$ and $a_i(\theta)$ are

[10] Results of this paper are not sensitive to sequential decision making of the government.

[11] Given the level of privatization (θ), marginal environmental damage is $\frac{\partial ED}{\partial(q_1-a_1+q_2-a_2)} = \frac{(A-c)\,d\left(23+4\,\gamma^3-24\,\gamma\,(1+\theta)+\theta\,(34+7\,\theta)\right)}{13+2\,\gamma^3+2\,\gamma^4-2\,\gamma\,(1-\theta)+9\,\theta\,(2+\theta)-2\,\gamma^2\,(6+5\,\theta)+d\,(7-2\,\gamma\,(1+\gamma)+5\,\theta)^2}$.
$t - \frac{\partial ED}{\partial(q_1-a_1+q_2-a_2)} = -\frac{(A-c)\,(1+2\,d)\left((1-\gamma)^2+(6-(6-\gamma)\,\gamma)\,\theta+\theta^2\right)}{13+2\,\gamma^3+2\,\gamma^4-2\,\gamma\,(1-\theta)+9\,\theta\,(2+\theta)-2\,\gamma^2\,(6+5\,\theta)+d\,(7-2\,\gamma\,(1+\gamma)+5\,\theta)^2} < 0\ \forall\theta \in [0,1]$, since $0 < \gamma < 1$. $t = \frac{\partial ED}{\partial(q_1-a_1+q_2-a_2)}$ only if $\gamma = 1$ and $\theta = 0$.

obtained by substituting $t(\theta)$ in (6).[12] We observe that, if $\theta < \frac{1+\gamma-2\gamma^2}{9-7\gamma} = \theta^*$ ($0 < \theta^* < 1$, since $0 < \gamma < 1$), $\frac{\partial ED(\theta)}{\partial \theta} > 0$. Alternatively, if $\theta \geq \theta^*$, $\frac{\partial ED(\theta)}{\partial \theta} \leq 0$. That is, environmental damage due to pollution increases (decreases) with the increase in level of privatization, unless privatization is greater (less) than the critical level θ^*. Also, note that environmental damage is maximum at $\theta = \theta^*$.[13] The underlying reason is as follows. When the level of privatization is relatively less ($\theta < \theta^*$), increase in level of privatization decreases overall production, but environmental tax rate and, thus, pollution abatement by firms decreases more than proportionately to the decrease in overall production due to increase in level of privatization ($|\ \frac{\partial [2a(\theta)]}{\partial \theta}\ | > |\ \frac{\partial [q_1(\theta)+q_2(\theta)]}{\partial \theta}\ |$). As a result, higher level of privatization leads to higher pollution and higher environmental damage. The converse is true, if the level of privatization is more than a critical level. Alternatively, we can say that the indirect effect of privatization on environmental damage dominates its direct effect, unless the level of privatization is more than a critical level. These are interesting findings.

Proposition 1: *In case of differentiated products mixed duopoly, environmental damage can be non-monotone in level of privatization (θ). Increase in level of privatization adversely affects the environment, if $\theta < \frac{1+\gamma-2\gamma^2}{9-7\gamma} = \theta^*$ ($0 < \theta^* < 1$). Otherwise, if $\theta > \theta^*$, higher level of privatization leads to lower environmental damage. In other words, environmental damage is maximum at θ^* level of privatization.*

The above proposition is in contrast to Beladi and Chao (2006). Note that in case of monopoly firm, the direct effect of privatization on output has only one component, which is negative, since there is no rival firm. In addition, if the demand function is not highly convex, that negative direct effect outweighs the positive indirect effect of privatization on output via environmental tax when there is only one firm (Beladi and Chao, 2006). Clearly, if abatement measures undertaken by firm(s) is ignored, as in Beladi and Chao (2006), privatization will lead to better environment in case of linear or concave market

[12] $q_1(\theta) = \frac{(A-c)(1+2d)(-2+\gamma)(-7+2\gamma(1+\gamma)-5\theta)}{13+2\gamma^3+2\gamma^4+2\gamma(-1+\theta)+9\theta(2+\theta)-2\gamma^2(6+5\theta)+d(7-2\gamma(1+\gamma)+5\theta)^2}$ and
$q_2(\theta) = \frac{(A-c)(1+2d)(-7+2\gamma(1+\gamma)-5\theta)(-1+\gamma-\theta)}{13+2\gamma^3+2\gamma^4+2\gamma(-1+\theta)+9\theta(2+\theta)-2\gamma^2(6+5\theta)+d(7-2\gamma(1+\gamma)+5\theta)^2}$

[13] $\frac{\partial ED(\theta)}{\partial \theta} = 0 \Rightarrow \theta = \theta^*$, and $\frac{\partial^2 ED(\theta)}{\partial \theta^2}\ |_{\theta=\theta^*} < 0$.

demand functions. Nonetheless, 'firms do not undertake any pollution abatement measure, even when government imposes environmental tax' is a very strong assumption. Since it is optimal for firms to undertake abatement measure(s), there is an additional component of indirect effect of privatization on pollution emission, which is the effect of privatization on pollution abatement via its impact on environmental tax rate. This second order indirect effect plays a crucial role in determining the impact of privatization on environmental damage.

Next, we turn to stage 1 of the game, where the government decides the level of privatization to maximize social welfare, by correctly anticipating its impacts on optimal environmental tax rate and firms' behaviour. The problem of the government in stage 1 can be written as, $\underset{\theta}{Max}\, SW(\theta)$, where $SW(\theta)$ is obtained by substituting $t(\theta)$, $q_i(\theta)$ and $a_i(\theta)$ in the expression of SW. Solving this problem we get the social welfare maximizing level of privatization as follows.

$$\theta = \frac{1+\gamma-2\,\gamma^2}{9-7\,\gamma} = \theta_{pp}$$

Clearly, $0 < \theta_{pp} < 1$, since $0 < \gamma < 1$. It implies that partial privatization is socially optimal. This result is in line with the existing literature on privatization in case of differentiated products oligopoly (see, for example, Saha (2009) and Fujiwara (2007)). To illustrate it further, note that a fully nationalized firm sets the price at marginal cost. Privatization induces it to be less aggressive in the product market and to increase its price above the marginal cost. As a result, private firm's output increases at the expense of public firm's output leading to fall in total output. Thus, privatization adversely affects consumer surplus, but it leads to higher industry profit. Moreover, consumer surplus (industry profit) decreases (increases) at an increasing (decreasing) rate with the increase in level of privatization. Initially, if products are differentiated, gain due to increased industry profit is more than the loss due to lower consumers surplus. Therefore, in case of differentiated products mixed duopoly, partial privatization is optimal.[14] Environmental

[14]In case of homogeneous product mixed duopoly/oligopoly also partial privatization is socially optimal, provided that there is increasing marginal cost of production (see Matsumura (1998)).

pollution due to production, together with environmental tax and pollution abatement by firms, adds another dimension to it, as discussed before. We now summarize the equilibrium outcomes in Lemma 1.

Lemma 1: *In equilibrium, level of privatization, environmental tax rate, environmental damage, tax revenues, social welfare, consumer surplus, profits and outputs are as follows.*

$$\theta_{pp} = \frac{1+\gamma-2\gamma^2}{9-7\gamma},$$
$$t_{pp} = \frac{(A-c)\ (\gamma+2\,d\ (7-6\,\gamma)-1)}{H},$$
$$ED_{pp} = \frac{2\,(A-c)^2\,d\,(8-7\,\gamma)^2}{H^2},$$
$$T_{pp} = \frac{2\,(A-c)^2\ (8-7\,\gamma)\ (\gamma+2\,d\ (7-6\,\gamma)-1)}{H^2},$$
$$SW_{pp} = \frac{(A-c)^2\ (-8+7\,\gamma)\ \left(-9+7\,\gamma^2+4\,d^2\ (-17+7\,\gamma\ (1+\gamma))+2\,d\ (-26+7\,\gamma\ (1+2\,\gamma))\right)}{(-9+7\,\gamma^2+2\,d\ (-17+7\,\gamma\ (1+\gamma)))^2},$$
$$CS_{pp} = \frac{(A-c)^2\,(1+2\,d)^2\ (53-\gamma\ (43+\gamma\ (43-35\,\gamma)))}{H^2},$$
$$\pi_{1,pp} = \frac{(A-c)^2}{2H^2}[19+\gamma\ (2-7\ (7-4\,\gamma)\ \gamma)+4\,d^2\ (67-2\,\gamma\ (40+7\ (1-2\,\gamma)\ \gamma))$$
$$+\,4\,d\ (1-\gamma)\,\{11+28(\gamma-\gamma^2)\}],$$
$$\pi_{2,pp} = \frac{(A-c)^2}{2H^2}[4\,d\ (43-44\,\gamma)\ (1-\gamma)+51\,(1-\gamma)^2+4\,d^2\ (99-2\ (92-43\,\gamma)\ \gamma)],$$
$$q_{1,pp} = \frac{(A-c)\ (1+2\,d)\ (9-7\,\gamma)}{H},$$
$$q_{2,pp} = \frac{5\ (A-c)\ (1+2\,d)\ (1-\gamma)}{H},\ \textit{where}\ H = 9-7\,\gamma^2+2\,d\ (17-7\,\gamma\ (1+\gamma))\,.$$

The subscript pp denotes partial privatization.

Note that, the government imposes environmental tax, if pollution damages the environment beyond a certain level. It is easy to check that, in the present scenario, the optimal environmental tax (t_{pp}) is positive, if the rate of marginal environmental damage (d) is sufficiently high: $t_{pp} > 0$, if $d > \frac{1-\gamma}{14-12\,\gamma}$, which is true by assumption.

From Lemma 1 and Proposition 1, we find that socially optimal level of privatization harms the environment most, since $\theta_{pp} = \theta^*$. If $\theta < \theta^*$, increase in privatization damages the environment more whereas economic welfare increases with privatization. The reverse

is true for $\theta > \theta^*$. Clearly, effects of privatization on economic welfare and environment are in opposite directions, where the former dominates the latter.

Proposition 2: *(a) Partial privatization is optimal from the social welfare point of view. (b) Socially optimal level of privatization damages the environment most.*

3 Conclusion

This paper analyses the impact of privatization on environment, where level of privatization is endogenously determined. Considering a differentiated products mixed duopoly market structure, it shows that environmental damage increases with the increase in level of privatization up to a point, thereafter increase in level of privatization reduces environmental damage. It also shows that partial privatization is socially optimal. However, socially optimal level of privatization damages the environment most.

Clearly, there is a conflict of interests between the 'green lobby' and the 'economic welfare lobby' as far as privatization is concerned. In the present analysis it is implicitly assumed that the strength of the 'green lobby' is limited in the sense that environmental damage does not receive higher importance than economic welfare in the government's objective function. Environmental awareness of citizens and institutional factors are likely to play crucial roles in determining the relative strengths of the parties involved. It seems to be useful to extend this paper to a more general framework that allows for endogenous determination of the government's objective function through bargaining between the 'green lobby' and the 'economic welfare lobby'. While this is beyond the scope of this paper, one may though suspect that the qualitative results of this paper would hold unless the strength of the 'green lobby' is sufficiently higher than that of 'economic welfare lobby'. It might also be interesting to extend the present analysis by considering consumption related pollution.

References

Antelo, M. and Loureiro, M. L. (2009). Asymmetric information, signaling and environmental taxes in oligopoly. *Ecological Economics*, 68(5):1430–1440.

Barcena-Ruiz, J. C. and Garzon, M. B. (2002). Environmental taxes and strategic delegation. *Spanish Economic Review*, 4(4):301–310.

Barcena-Ruiz, J. C. and Garzon, M. B. (2006). Mixed oligopoly and environmental policy. *Spanish Economic Review*, 8(2):139–160.

Barrett, S. (1994). Strategic environmental policy and international trade. *Journal of Public Economics*, 54(3):325–338.

Beladi, H. and Chao, C.-C. (2006). Does privatization improve the environment? *Economics Letters*, 93(3):343–347.

Bhattacharya, R. N. and Pal, R. (2010). Environmental standards as strategic outcomes: A simple model. *Resource and Energy Economics*, 32(3):408–420.

Canton, J., Stahn, H., and Soubeyran, A. (2008). Environmental Taxation and Vertical Cournot Oligopolies: How Eco-industries Matter. *Environmental and Resource Economics*, 40(3):369–382.

Conrad, K. (1993). Taxes and subsidies for pollution-intensive industries as trade policy. *Journal of Environmental Economics and Management*, 25(2):121–135.

Damania, R. (2000). Financial structure and the effectiveness of pollution control in an oligopolistic industry. *Resource and Energy Economics*, 22(1):21–36.

deFraja, G. and Delbono, F. (1989). Alternative strategies of a public enterprise in oligopoly. *Oxford Economic Papers*, 41(2):302–11.

Fershtman, C. (1990). The interdependence between ownership status and market structure: The case of privatization. *Economica*, 57(227):319–28.

Fujiwara, K. (2007). Partial privatization in a differentiated mixed oligopoly. *Journal of Economics*, 92(1):51–65.

Fujiwara, K. (2009). Environmental policies in a differentiated oligopoly revisited. *Resource and Energy Economics*, 31(3):239–247.

Kennedy, P. W. (1994). Equilibrium pollution taxes in open economies with imperfect competition. *Journal of Environmental Economics and Management*, 27(1):49–63.

Kumar, A. and Saha, B. (2008). Spatial competition in a mixed duopoly with one partially nationalized firm. *Journal of Comparative Economics*, 36(2):326–341.

Long, V. N. and Soubeyran, A. (2005). Selective penalization of polluters: an inf-convolution approach. *Economic Theory*, 25(2):421–454.

Matsumura, T. (1998). Partial privatization in mixed duopoly. *Journal of Public Economics*, 70(3):473–483.

Maw, J. (2002). Partial privatization in transition economies. *Economic Systems*, 26(3):271–282.

Megginson, W. L. and Netter, J. M. (2001). From state to market: A survey of empirical studies on privatization. *Journal of Economic Literature*, 39(2):321–389.

Ohori, S. (2006). Optimal environmental tax and level of privatization in an international duopoly. *Journal of Regulatory Economics*, 29(2):225–233.

Pal, R. (2009). *Delegation and Emission Tax in a Differentiated Oligopoly.* IGIDR-WP-2009-007, Indira Gandhi Institute of Development Research, India.

Pal, R. (2010). *How much should you own? Cross-ownership and privatization.* IGIDR-WP-2010-015, Indira Gandhi Institute of Development Research, India.

Saha, B. (2009). Mixed ownership in a mixed duopoly with differentiated products. *Journal of Economics*, 98(1):25–43.

Singh, N. and Vives, X. (1984). Price and quantity competition in a differentiatedduopoly. *Rand Journal of Economics*, 15:546–554.

Ulph, A. (1996). Environmental policy and international trade when governments and producers act strategically. *Journal of Environmental Economics and Management*, 30(3):265–281.

Wang, L. F. and Wang, J. (2009). Environmental taxes in a differentiated mixed duopoly. *Economic Systems*, 33(4):389–396.