Optimal Privatization Policy in Mixed Eco-Industry

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I. Introduction

1. Environmental Eco-Industry Issue
   - From “Kyoto Protocol (1997)” through “Paris Agreement (2015)”, the importance of the eco-industry has been increased, rapidly.

   - According to Environmental Business International (2012), the global market size of the eco-industry was approximately US$838 billion in 2010 and is expected to reach US$992 billion by 2017.

   - Many governments have recently recognized the importance of eco-industry and have enacted various policies to encourage the eco-industry.

- Pollution-reducing new technology
  - Denicolo (1999), Requate (2005) and Fisher et al. (2003) : the performance of taxes and tradable permits
  - Perino (2008) : green horizontal innovation
  - Perino (2010a) : the second-best policies for all combinations of emission intensity and marginal abatement costs

- Vertical Market Structure
  - Canton (2008), Canton et al. (2007, 2012), David and Sinclair-Desgagné (2005, 2010), David et al. (2011), Nimubona (2012) and Nimubona and Sinclair-Desgagné (2005, 2010) : Pigouvian tax depending not only on the market power of downstream, polluting firms but also on that of upstream, eco-industry.

2. Partial Privatization Issue

- Despite of the global trends in trade liberalization and privatization, state-owned enterprises (SOEs) are still highly concentrated in a few strategic sectors and, thus, they still control large portions of the world's resources.

- OECD report by Kowalski et al. (2013) : the 2000 largest public companies in the world, more than 10% are either SOEs or have significant government ownership; these government-associated companies’ sales are equivalent to approximately 6% of worldwide GDP

- De Fraja and Delbono (1989) examined two extreme case between privatization and nationalization while Matsumura (1998) introduced partial privatization approach.

- 2000s : Internationalization and Privatization Wave

  : Optimality of partial privatization with Non-Optimality of full nationalization

  - Ohori (2006) and Xu and Lee (2015) : in an international mixed duopoly
  - Naito and Ogawa (2009) and Kato (2013) : partial privatization improves the environment without any environmental policy instruments
  - Pal and Saha (2015) and Xu, et al. (2016) : the optimality of partial privatization under emission taxes

: Optimality of partial privatization with Non-Optimality of full privatization

- Lee et al. (2013) : the privatization and strategic trade policies between the two international mixed markets
- Yang, et al. (2014) and Wu et al. (2016) : a vertically related market where downstream industry or upstream industry is a mixed market

Neither full nationalization nor full privatization is optimal under moderate conditions in homogenous mixed oligopoly.

In this paper,

Incorporating the increasing attentions to environmental eco-industry and partial privatization issues,

we introduce

environmental damages as a negative externality and

mixed eco-industry where both private and public eco-firms exist.

We formulate

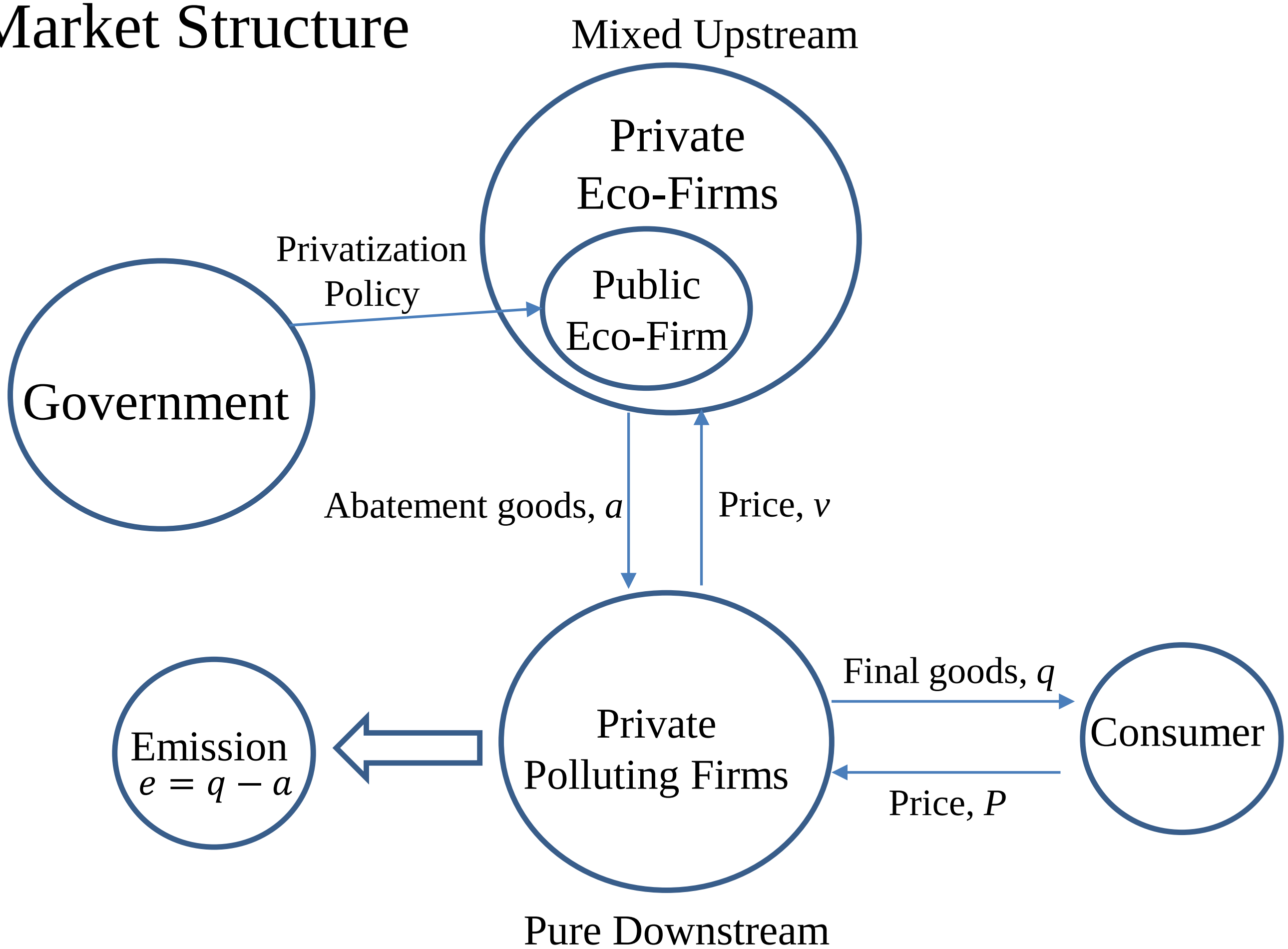
the vertically related market structure where downstream polluting industry and upstream eco-industry are inter-related.

We investigate and show

the optimal degree of privatization depending on the damage level.

II. Model

1. Vertical Market Structure



2. Timeline of game

<table>
<tr><th>Stage</th><th>Player</th><th>Instrument</th><th>Target</th><th></th></tr>
<tr><td>1st stage</td><td>Government</td><td>Degree of Privatization</td><td>Total Surplus</td><td rowspan="6">All games are solved by backward induction and the possible outcome is a subgame perfect equilibrium.</td></tr>
<tr><td>2nd stage</td><td>Polluting Firms</td><td>Emission Level</td><td>Own Profit</td></tr>
<tr><td rowspan="2">3rd stage</td><td>Public Eco-Firm</td><td rowspan="2">Cournot Competition in abatement goods market</td><td>Weighted sum of profit and total surplus</td></tr>
<tr><td>Private Eco-Firm</td><td>Own Profit</td></tr>
<tr><td>4th stage</td><td>Polluting Firms</td><td>Cournot Competition in final goods market</td><td>Own Profit</td></tr>
</table>

3. Assumption

- Profit of Duopoly Polluting Industry having zero production cost

$$\pi_i = Pq_i - va_i \quad \text{for} \quad i = 1,2$$

- Linear Price of final goods : $P = A - Q$ where $Q = q_1 + q_2$
- Price of abatement goods : v
- Amount of abatement goods purchased by firm i : a_i

- Profit of Duopoly Eco Industry

$$\pi_e = va_e - \frac{{a_e}^2}{2} \quad \text{for} \quad e = p(public), r(private)$$

where a_e denotes the individual production of abatement goods

– Total surplus : Sum of the consumer surplus and producer surplus net of the environmental damages.

$$W = \int_0^Q P(u)\,\mathrm{d}u - \frac{{a_r}^2}{2} - \frac{{a_p}^2}{2} - d(e_1 + e_2)$$

with linear emission function, $e_i = q_i - a_i$ and linear environmental damage function, $d(E) = d \times E$ where $E = e_1 + e_2$

– Objective function of public eco-firm p :

$$T_p = \alpha\pi_p + (1-\alpha)W$$

where $\alpha \in [0,1]$ denotes the degree of privatization of public eco firm.

4. Analysis

– 4^{th} stage : Competition in final good market

Using the emission function, π_i can be re-written as

$$\pi_i = Pq_i - va_i \Longrightarrow \pi_i = (A - Q)q_i - v(q_i - e_i)$$

First order condition for profit maximization of firm i with respect to q_i

$$\frac{\partial \pi_i}{\partial q_i} = A - Q - q_i - v = 0 \quad \text{for} \quad i = 1,2$$

By solving simultaneously, we have equilibriums of the 4^{th} stage.

$$q_i = \frac{A - v}{3} \quad \text{and} \quad a_i = \frac{A - v - 3e_i}{3} \quad \text{for} \quad i = 1,2$$

– 3^{rd} stage : Competition in abatement goods market

As we assume the market clearing price of abatement goods, from the individual purchasing of abatement goods, we obtains the total demand of abatement goods as follows:

$$a_r + a_p = a_U = a_1 + a_2 = \frac{2A - 2v - 3(e_1 + e_2)}{3}$$

Solving above for *v*, we have following inverse demand function of abatement goods.

$$v(a_U) = \frac{2A - 3(e_i + e_j)}{2} - \frac{3}{2} a_U$$

– First order conditions of each eco firm are as follows:

$$\frac{\partial \pi_r}{\partial a_r} = v + \frac{\partial v}{\partial a_r} a_r - a_r = 0$$

$$\frac{\partial T_p}{\partial a_p} = \alpha \frac{\partial \pi_p}{\partial a_p} + (1 - \alpha) \frac{\partial W}{\partial a_p} = 0$$

From above F.O.Cs, we have following reaction functions of each eco-firm.

$$a_r(a_p) = \frac{2A - 3(e_1 + e_2) - 3a_p}{8}$$

$$a_p(a_r) = \frac{2(\alpha A + d(1-\alpha)) - 3\alpha(e_1 + e_2) - 3\alpha a_r}{2 + 6\alpha}$$

Solving simultaneously, we have equilibriums of the 3rd stage.

$$a_r = \frac{4A - 6d + 6(A + d)\alpha - 3(2 + 3\alpha)(e_1 + e_2)}{16 + 39\alpha}$$

$$a_p = \frac{2(5\alpha A + 8d(1 - \alpha)) - 15\alpha(e_1 + e_2)}{16 + 39\alpha}$$

$$a_U = \frac{2(2A(1 + 4\alpha) + 5d(1 - \alpha) - 3(1 + 4\alpha)(e_1 + e_2))}{16 + 39\alpha}$$

$$v = \frac{5\{(4A - 6(\alpha A - (1 - \alpha)d) - 3(2 + 3\alpha)(e_1 + e_2)\}}{32 + 78\alpha}$$

– 2^{nd} stage : Commitments on emission

The profit of polluting firm and the first order condition are as follows:

$$\pi_i = \frac{\{2(5d(1-\alpha)+A(2+8\alpha))+5(2+3\alpha)e_j\}^2 - 5(2+3\alpha)(86+219\alpha)e_i^2}{4(16+39\alpha)^2}$$
$$+\frac{20e_i(A(2+3\alpha)(18+47\alpha)-2d(1-\alpha)(19+51\alpha)-(2+3\alpha)(19+51\alpha)e_j}{4(16+39\alpha)^2}$$

$$\frac{\partial \pi_i}{\partial e_i} = \frac{5\{(A(2+3\alpha)(18+47\alpha)-d(1-\alpha)(19+51\alpha)\}}{(16+39\alpha)^2}$$
$$-\frac{5\{(2+3\alpha)(19+51\alpha)e_j+(2+3\alpha)(86+219\alpha)e_i)\}}{2(16+39\alpha)^2} = 0,\ \text{for } i = 1,2 \text{ and } i \neq j$$

By solving simultaneously, we have equilibriums of the 2nd stage.

$$e_1 = e_2 = \frac{2A(2+3\alpha)(18+47\alpha) - 4d(1-\alpha)(19+51\alpha)}{(2+3\alpha)(124+321\alpha)}$$

$$q_1 = q_2 = \frac{2A(19+51\alpha) + 15d(1-\alpha)}{(124+321\alpha)}$$

$$a_1 = a_2 = \frac{A(4+22\alpha+24\alpha^2) + d(106+143\alpha-249\alpha^2)}{(2+3\alpha)(124+321\alpha)}$$

$$a_p = \frac{10\alpha A(2+3\alpha) + 8d(31+38\alpha-69\alpha^2)}{(2+3\alpha)(124+321\alpha)}$$

$$a_r = \frac{2\{A(2+3\alpha) - 9d(1-\alpha)\}}{124+321\alpha}$$

$$v = \frac{5\{A(2+3\alpha) - 9d(1-\alpha)\}}{124+321\alpha}$$

$$P = A - Q = \frac{3A(16+39\alpha) - 30d(1-\alpha)}{124+321\alpha}$$

– The upper boundary of damage level

q_i, a_i and a_p are always positive independently with damage level whereas e_i, a_r, v and P can be both positive or negative depending on the damage level.

$e_1 = e_2 \geq 0$ when $d \leq \bar{d}_e = \dfrac{A(2+3\alpha)(18+47\alpha)}{2(1-\alpha)(19+51\alpha)}$

$a_r \geq 0$ and $v \geq 0$ when $d \leq \bar{d}_v = \dfrac{A(2+3\alpha)}{9(1-\alpha)}$

$P \geq 0$ when $d \leq \bar{d}_P = \dfrac{A(16+39\alpha)}{10(1-\alpha)}$

Because $\bar{d}_P > \bar{d}_{e_i} > \bar{d}_v$, the upper bound of the damage level is $\bar{d}_v$

– 1^{st} stage : Decision on Privatization

$$W = \frac{1}{(2+3\alpha)^2(124+321\alpha)^2}\left\{4A^2(2+3\alpha)^2\{1632+\alpha(8541+11152\alpha)\right\}$$
$$+4d^2(1-\alpha)\{1124+\alpha(36068+3\alpha(45539+45897\alpha))\}$$
$$-2Ad(2+3\alpha)\{7416+\alpha(56682+3\alpha(131963+93189\alpha))\}$$

Assumption: The total surplus is monotonic or single-peaked over the degree of privatization when it takes a value between zero and unity.

If $\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=0} \leq 0$ then $\alpha^* = 0$ is optimal as corner solution.

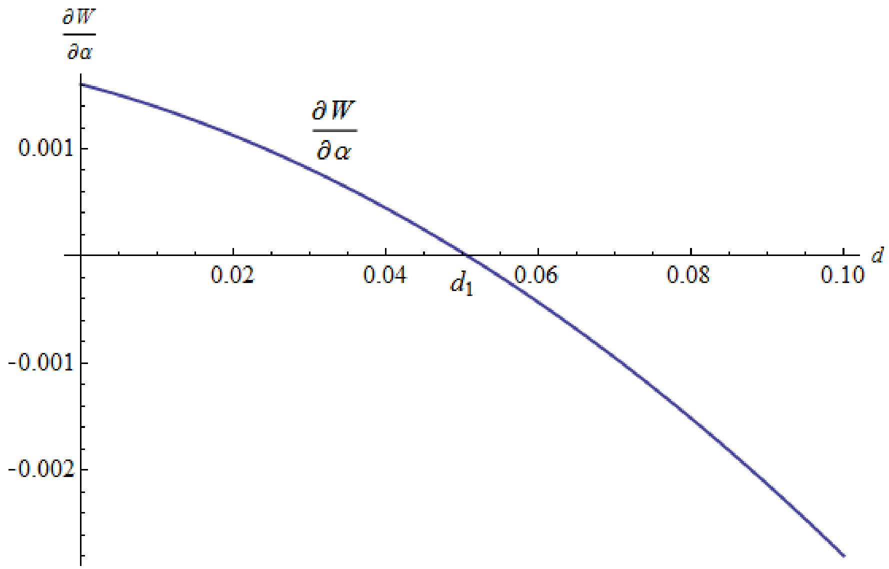
If $\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=1} \geq 0$ then $\alpha^* = 1$ is optimal as corner solution.

If $\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=0} > 0$ and $\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=1} < 0$ then α^* has an interior value between 0 and 1.

– Full Privatization Case

$$\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=1} = \frac{2(2830A^2 - 33197Ad - 443576d^2)}{3524845}$$

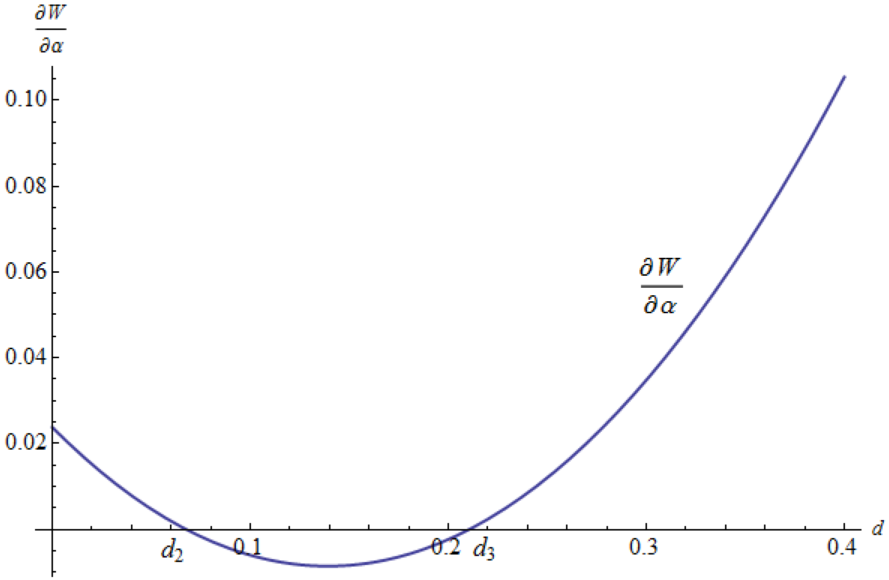
$$\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=1} > 0 \Leftrightarrow 0 < d < d_1 = \frac{A(\sqrt{773049} - 373)}{9968} (\approx 0.0507A)$$



– Full Nationalization Case

$$\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=0} = \frac{15(378A^2 - 7401Ad - 26611d^2)}{238328}$$

$$\left.\frac{\partial W}{\partial \alpha}\right|_{\alpha=0} < 0 \Leftrightarrow d_2 = \frac{6A}{89}(\approx 0.0674A) < d < d_3 = \frac{63A}{299}(\approx 0.2107A)$$



III. Findings and Remarks

1. Proposition 1
   – Suppose that the total surplus is either monotonic or single-peaked over the degree of privatization when it takes a value between zero and unity. Then, the optimal privatization policy crucially depends on the level of damage as follows:

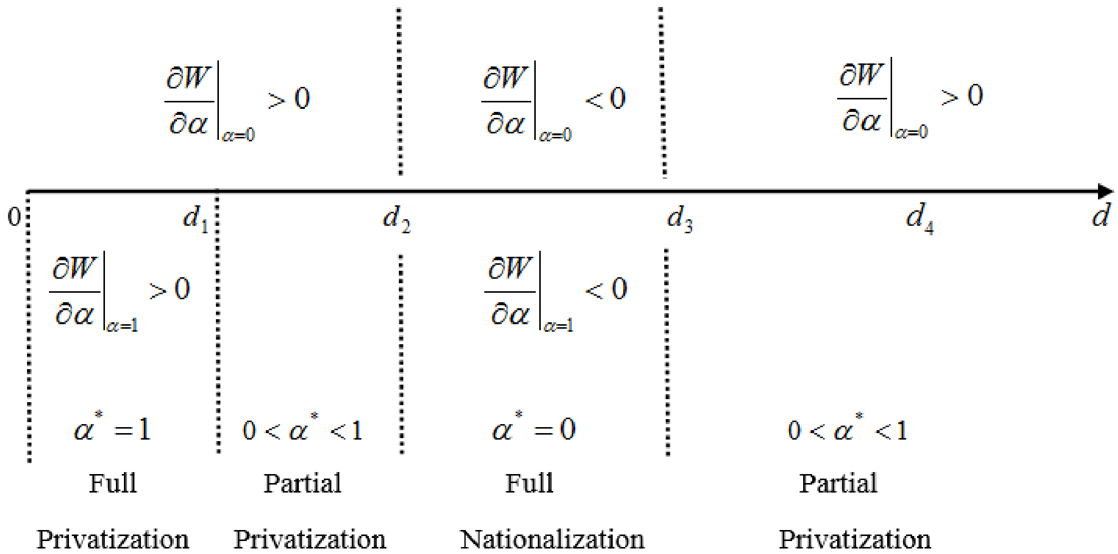
(i) If the damage is small (i.e., $0 \le d \le d_1$), then full privatization is optimal.

(ii) If the damage is medium (i.e., $d_1 < d < d_2$), then partial privatization is optimal.

(iii) If the damage is large (i.e., $d_2 \le d \le d_3$), then full nationalization is optimal.

(iv) If the damage is too large (i.e., $d > d_3$), then partial privatization is again optimal.

1. Proposition 1
   – Optimal privatization policy depending on the damage level



<Fig.1 Signs of the partial derivatives of W w.r.t. α ($\partial W / \partial \alpha$) as function of damage level>

2. Implicit subsidies for public eco-firm

– Profit of public eco-firm

$$\pi_p = \frac{2(5A\alpha(2+3\alpha)+4d(1-\alpha)(31+69\alpha))(10A(1+\alpha)(2+3\alpha)-d(1-\alpha)(214+441\alpha))}{(2+3\alpha)^2(124+321\alpha)^2}$$

$$\pi_p \frac{>}{<} 0 \Leftrightarrow d \frac{<}{>} d_{\pi_p=0} = \frac{10A(1+\alpha)(2+3\alpha)}{(1-\alpha)(214+441\alpha)} \qquad d_{\pi_p=0} > d_2$$

$$\pi_p\Big|_{\alpha=0} = \frac{d}{124}(10A-107d) \frac{>}{<} 0 \Leftrightarrow d \frac{<}{>} \frac{10A}{107} \approx 0.0934A = \tilde{d}_{\pi_p}$$

If $d_2 < d < \frac{10A}{107}$ then the profit of public firm is positive.

If $\frac{10A}{107} < d < d_3$ then the profit of public firm is negative meaning needed government subsidies.

3. Kick-out of private eco-firm

$$a_r = \frac{2\{A(2+3\alpha) - 9d(1-\alpha)\}}{124+321\alpha}$$

$$\pi_r = \frac{8\left(9d(-1+\alpha) + A(2+3\alpha)\right)^2}{(124+321\alpha)^2}$$

$$v = \frac{5\{A(2+3\alpha) - 9d(1-\alpha)\}}{124+321\alpha}$$

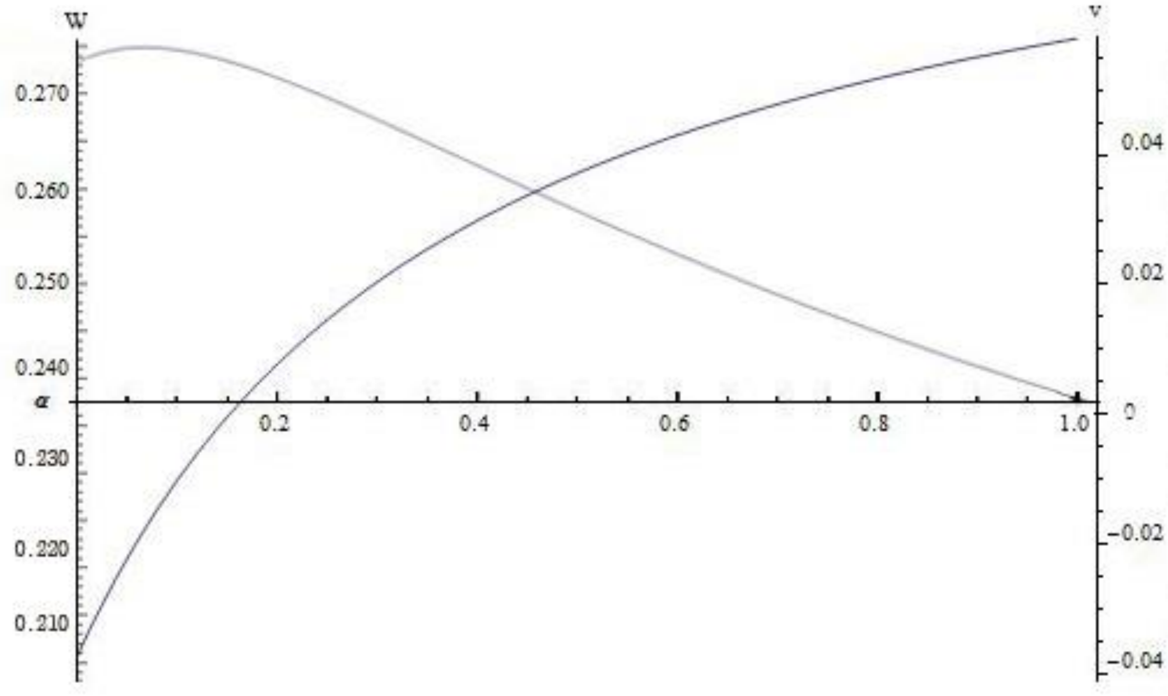
- The price of abatement goods has negative slope and positive intercept depending on the damage level and the sign of abatement goods' price depends on the damage level.

$$v\Big|_{d=0} = \frac{A(2+3\alpha)}{124+321\alpha} > 0 \qquad \frac{\partial v}{\partial d} = -\frac{45(1-\alpha)}{124+321\alpha} < 0 \qquad v(\alpha^*) \underset{<}{\overset{>}{-}} 0 \Leftrightarrow d \underset{>}{\overset{<}{-}} \tilde{d}_v = \frac{A(2+3\alpha)}{9(1-\alpha)}$$

$$\tilde{d}_v - d_3 = \frac{A(31+1464\alpha)}{2691(1-\alpha)} > 0$$

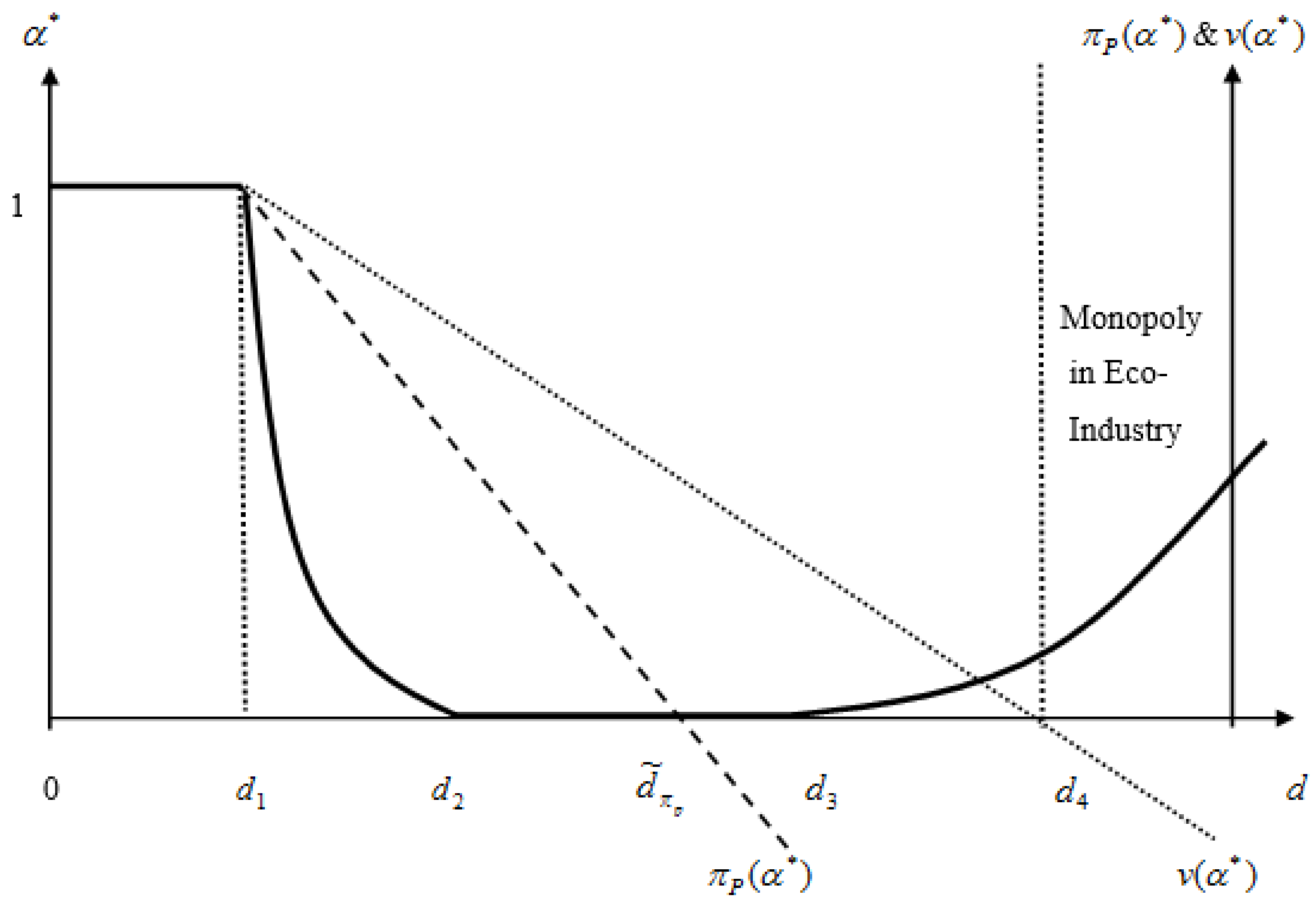
- Proposition 2 : With the optimal partial degree of privatization, the private eco-firm will be kicked out when $d > d_4 = 2A/9$

- Simulation



$d_4 < d$

IV. Conclusion



Thank you for listening.

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ありがとうございます。

Welcome any comments to “newhuman@hanmail.net”