Impact of costly endogenous communication on the efficiency of the Average Pigouvian Tax (APT): An experimental study

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Introduction

Plan

1. General framework
2. Purpose of the study
3. Theoretical model
4. Experimental design
5. Results
1. General framework

- Nonpoint source pollution (NPSP)
  - Many sources of emissions
  - Inability to observe the individual emissions
  - Aggregate concentration of pollution is measurable
• Example of NPSP from agricultural sources

1. General framework
2. Purpose of the study
3. Theoretical model
4. Experimental design
5. Results
• Challenges

- Total cost of removing nitrates represents 15 to 20% of the cost of water (France)
- Estimation of the cost water pollution: 20 billion euros (Europe)
- 1972 Clean water Act (US. Environmental Protection Agency)
1. General framework

• Possibilities to regulate NPSP

2. Purpose of the study

3. Theoretical model

4. Experimental design

5. Results

- Ambient tax (Segreson, 1988)

- Pesticides

- Field 1

- Field 2

- Field 3

- Emissions

- Ambient pollution
• Variants of ambient taxes

- Tax/Subsidy
- Tax only or pure tax
- Fixed fine

Large income transfers $\rightarrow$ Political feasibility

- Average Pigouvian Tax (APT) (Suter et al, 2008)

$\rightarrow$ Low taxation

$\rightarrow$ Necessity of cooperation

APT + nonbinding costless communication ("cheap talk") $\rightarrow$ high levels of efficiency.
2. Purpose of the study

- To improve the practical significance of the APT
- To contribute to the experimental economic literature on social dilemma games

Communication in the field:
- costs (minimal resources, time etc.) born by at least some group members
- groups themselves often establish the rules that govern their interaction in social dilemmas

The efficiency of the APT
- Endogenous costly communication
- Exogenous costly communication
3. Theoretical model

N identical firms

The emissions and profit functions are respectively denoted by \( x \)
and \( \pi(x) \); \( \pi_x \geq 0 \) and \( \pi_x' < 0 \)

Ambient pollution: \( X = (x_1, \ldots, x_n) \)

Total damages, \( D(X) = \partial \sum_{i=1}^{n} x_i \); \( \partial > 0 \)

Social welfare: \( W(X) \)

\[
W(X) = \sum_{i=1}^{n} \{\pi(x_i)\} - \left[ \partial \left( \sum_{i=1}^{n} x_i \right) \right]
\]

FOC: \( \pi'_x(x^*) = \partial \quad (1) \)

Ambient tax to internalize social damages
3. Theoretical model

Profit function of a firm:

\[
\pi_{to}(x, X) = \begin{cases} 
\pi(x) & \text{if } X \leq nx^* \\
\pi(x) - t(X - nx^*) & \text{if } X > nx^* 
\end{cases}
\]

FOC:

\[
\pi'_{to}(x^*) = t \quad (2)
\]

\[
(1) = (2) \implies t = \partial
\]

Any strategy such that \( x \neq x^* \) is strictly dominated.

Each firm bears the full social marginal cost.

Social optimum is not implemented as a nash equilibrium.

\[
Max \left\{ n \left[ \pi(x) - \frac{t}{n}(X - nx^*) \right] \right\} \implies \pi'(x^c) = t
\]
4. Experimental design

4.1. Practical procedures
LEES (Laboratory of experimental economics)
160 under-graduate students of different majors
4.1. Practical procedures

- Subjects play the role of polluting firms
- Emissions are represented by the amount of invested tokens
- 20 available choices
- Gain of a period
  - Individual investment
  - Investment of the group
- 24 periods
- Earned points are accumulated and converted into euros at the end
  - 1h15mn
  - 23 euros
4.2. Experiment treatments

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>No cheap talk throughout the experiment.</td>
</tr>
<tr>
<td>CT</td>
<td>CT at the end of each four periods (before the 5\textsuperscript{th}, 9\textsuperscript{th}, 13\textsuperscript{th}, 17\textsuperscript{th} and 21\textsuperscript{st} periods)</td>
</tr>
<tr>
<td>LCV</td>
<td>A communication session held after a vote when the majority approves it.</td>
</tr>
<tr>
<td>HCV</td>
<td>Same as treatment LCV except that the cost of voting is high</td>
</tr>
<tr>
<td>ICC</td>
<td>Same as treatment NC except that communication is costly</td>
</tr>
</tbody>
</table>

- 4 independent groups of 8 subjects are considered under each treatment with the exception of treatment CT
4.3. Experiment parameters

Profit function: \(-2x^2 + 84x + 500\); Damage function: \(D(X) = 52X\)

Tax rate: 6.5
• Theoretical predictions

➢ Standard microeconomic theory

➢ Folk theorem

<table>
<thead>
<tr>
<th></th>
<th>Non-cooperative prediction</th>
<th>Cooperative prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ind. Invest.</td>
<td>19</td>
<td>8</td>
</tr>
<tr>
<td>Group. Invest</td>
<td>152</td>
<td>64</td>
</tr>
<tr>
<td>Ind. payoff</td>
<td>756</td>
<td>1044</td>
</tr>
</tbody>
</table>

Communication cost

200 in HCV (70% of the cooperation gain)

10 in LCV (4% of the cooperation gain)
• Hypotheses

- Hypothesis 1: Cooperation will be more more important in CT than in NC

- Hypothesis 2: More cooperation in CT treatment than in ICC.

- Hypothesis 3: Communication after a vote should result in a strong cooperation (more than in CT). Moreover, those who voted “no” will behave in the same way than those who voted “yes”.

- Hypothesis 4: The number of members who vote for the holding of a communication session could be more important with a lower cost (more cooperation in the LCV treatment than in the HCV treatment).
5. Results

5.1. Summary statistics

![Bar chart showing average emissions for different treatments: NC, CT, ICC, HCV, LCV. The chart compares 110.11 (8.17) for NC, 84.67 (7.68) for CT, 91.31 (10.35) for ICC, 108.62 (5.74) for HCV, and 89.65 (8.59) for LCV.](chart.png)
5. Results

Average emissions by period, sorted by treatment
5.2. Econometric analysis

\[ E_{it} = \alpha_0 + \alpha_1 HCV_{it} + \alpha_2 LCV_{it} + \alpha_3 CT_{ti} + \alpha_4 ICC_{it} + \alpha_5 Period + \mu_i + \varepsilon_{it} \]

\( E_{it} \) : the emissions of polluter \( i = 1, \ldots, 160 \) at period \( t = 5, \ldots, 20 \)

The explanatory variables are treatment-specific indicators equal to 0 in the baseline treatment and 1 otherwise

Estimation of the model \( \rightarrow \) Generalized Least Squares (GLS) clustered by groups

Robustness of the results \( \rightarrow \) estimations based on robust standard errors

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients (S.E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>12.37*** (1.43)</td>
</tr>
<tr>
<td>CT</td>
<td>-3.17** (1.49)</td>
</tr>
<tr>
<td>ICC</td>
<td>-2.34 (1.78)</td>
</tr>
<tr>
<td>LCV</td>
<td>-2.55 (1.73)</td>
</tr>
<tr>
<td>HCV</td>
<td>-0.18 (1.61)</td>
</tr>
<tr>
<td>Period</td>
<td>0.11** (0.05)</td>
</tr>
<tr>
<td>N obs.</td>
<td>3072</td>
</tr>
<tr>
<td>Overall R²</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Note: *** Denotes that parameter estimate is statistically significant at the 1% level, ** at the 5% level.
• Impact of holding communication

Average emissions per group by period in the HCV treatment
Average emissions per group by period in the HCV treatment
- Vote’s effect on individual behaviour

Average individual emission in the four periods that followed the communication sessions

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Communication</th>
<th></th>
<th>No communication</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>HCV</td>
<td>8.10 (0.31)</td>
<td>9.33 (1.96)</td>
<td>15.31 (5.04)</td>
<td>13.44 (6.03)</td>
</tr>
<tr>
<td>LCV</td>
<td>9.55 (3.74)</td>
<td>10.92 (4.21)</td>
<td>11.88 (5.07)</td>
<td>12.57 (5.11)</td>
</tr>
</tbody>
</table>

Average individual emission in the direct periods that followed the communication sessions

<table>
<thead>
<tr>
<th>Treatments</th>
<th>If communication</th>
<th>If no communication</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vote expressed</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>HCV</td>
<td>8 (0)</td>
<td>8.67 (1.15)</td>
<td>15.5 (5.36)</td>
</tr>
<tr>
<td>LCV</td>
<td>8.04 (0.66)</td>
<td>9.91 (3.97)</td>
<td>11.42 (4.64)</td>
</tr>
</tbody>
</table>
Conclusion

Result: When communication takes place, those who have voted for it comply with the social optimum in contrast to those who vote against it. This difference in behaviour explains the failure of the cooperation over time.

Policy implication

The cost of voting might be a means to distinguish the different types of agents.

Regulation could be based on the willingness of some polluters to undertake costly efforts. Those who credibly justify the reduction of their emissions to be exempt from taxation.

The refusal to vote for communication is motivated by the unwillingness to cooperate.