Strategic Information Sharing in the Problem of the Commons

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Question

What is the scope of information exchange about the private signals that drive countries' environmental policies?

Motivation

The Kyoto Protocol envisages information exchange among countries to "the widest possible extent."

Article 9 of the Kyoto Protocol stresses the importance for a global climate policy of having the best available social, economic, technical information.

Motivation

Uncertainty about the potential impacts of climate change

- Climate change is the ultimate commons problem of the twenty-first century Stavins (2011).
- Uncertainty over the costs (Pendyck, 2007)
- No consensus as to whether the risks associated with climate change are potentially large and undesirable (Hulme, 2009; Leiserowitz, 2005).

Motivation

Uncertainty about the private information that affects decision making about environmental policies

- Full and accurate information about all players' types is a very strong assumption. Ostrom (2000).
- Political ideology is a significant factor in public perceptions of climate change. Leiserowitz et al. (2011), (Krugman, 2008).
- National interests, special interests, lobbying interests, politics, beliefs, social values influence the design of environmental policies. Hulme (2009), Holland et al. (2011); Parson and Zeckhauser (1993); Salehyan and Hendrix (2010); Buhr and Freedman (2001); Haffoudhi (2005); Shock (2004) and Gamman (1994), Adams et al. (2003)

Basic assumptions of the model

- N countries are involved in a pollution game.
- Uncertain over the costs.
- Each country takes into account a private information in making its environmental policy.

The model

For the sake of simplicity, $N = 2$, $i \in \{1, 2\}$

Country i's random net benefits from emitting is:

$$\widetilde{V}(e_i) = ce_i - \frac{\widetilde{\beta}}{2}\left[e_i + \sum_{k=1,k\neq i}^{N} e_k\right]^2, \tag{1}$$

The slope of the marginal damage $\widetilde{\beta}$ can take one of two values, β_L or β_H with $\beta_H > \beta_L$. In addition, to keep matters as simple as possible, assume that countries have common prior beliefs about $\widetilde{\beta}$ given by

$$\begin{cases} \widetilde{\beta} = \beta_L & \text{with probability } p = \frac{1}{2}, \\ \widetilde{\beta} = \beta_H & \text{with probability } 1 - p = \frac{1}{2}. \end{cases} \tag{2}$$

The conditional distribution of a country i's private signal given the actual slope of marginal damage is given by:

$$P(\widetilde{s}^i = s_L^i | \widetilde{\beta} = \beta_L) = \sigma, \tag{3}$$

and

$$P(\widetilde{s}^i = s_H^i | \widetilde{\beta} = \beta_H) = \sigma. \tag{4}$$

Assume

$$\sigma > \frac{1}{2} \tag{5}$$

The probability

$$1 - \sigma = P(\widetilde{s}^i = s_L^i | \widetilde{\beta} = \beta_H) \tag{6}$$

may be connected to the idea of "partisan reasoning" developed in political science.

A private signal in country i, is given by a team of experts according to a following function.

$$s^i = \Lambda_{expert}(\Omega^i), \tag{7}$$

where the function Λ_{expert} is not a public knowledge, and

$$\Omega^i = \left\{ \widetilde{\beta}, \widetilde{factor}^i_1, .., \widetilde{factor}^i_{Z_i} \right\},$$

is the set of environmental, political, institutional, social factors taken into account by the team of experts.

This private signal determines the degree of the stringency of the country's environmental policy. It can can take two values.

$$\widetilde{s}^i \in \mathcal{F}_i = \left\{ \{s^i_L\}, \{s^i_H\} \right\}. \tag{8}$$

1. Countries unilaterally decide wether or not to share their signals. It is assumed that countries report their signals truthfully if they decide to share information.
2. After receiving signals, the pollution game takes place.

Without information sharing, the country i's information set is $\mathcal{F}i \in \left\{ \left\{ s_L^i \right\}, \left\{ s_H^i \right\} \right\}$, and the uncertainty faced by country i is represented by $\left\{ \widetilde{s}^j(\Omega^j), \widetilde{\beta} \right\}$. The equilibrium emissions are:

$$e_L = \frac{\beta_L \left[b(\sigma) - c(\sigma) \right] + \beta_H \left[a(\sigma) - c(\sigma) \right]}{\Delta(\sigma, \beta_L, \beta_H)}, \tag{9}$$

and

$$e_H = \frac{\beta_L \left[a(\sigma) - c(\sigma) \right] + \beta_H \left[b(\sigma) - c(\sigma) \right]}{\Delta(\sigma, \beta_L, \beta_H)}. \tag{10}$$

It is worth noting that

$$e_L > e_H > 0, \tag{11}$$

which means that countries having private information that induce fewer concerns about climate change will be more polluting than countries with private information that induce them to pass stringent policy regarding climate change.

Without information sharing, the expected payoff is:

$$
\begin{aligned}
& E\left[\widetilde{V}_{no\ sharing}(e_i)\right] && (12)\\
= & \frac{1}{2}E\left[e_i\right] - \frac{1}{2}E\left[\widetilde{\beta} e_i e_j\right] - \frac{1}{2}E\left[\tilde{\beta} e_j^2\right] \\
= & 0.
\end{aligned}
$$

With information sharing, the information set consists of two elements.

$$\mathcal{F}_1 = \mathcal{F}_2 \in \left\{ \left\{ s_L^1, s_L^2 \right\}, \left\{ s_L^1, s_H^2 \right\}, \left\{ s_H^1, s_L^2 \right\}, \left\{ s_H^1, s_H^2 \right\} \right\}$$

The equilibrium emission is:

$$\begin{cases} e_{LL} = \frac{1}{2} \frac{\sigma^2 + (1-\sigma)^2}{\beta_L \sigma^2 + \beta_H (1-\sigma)^2}, \\ e_{HH} = \frac{1}{2} \frac{\sigma^2 + (1-\sigma)^2}{\beta_L (1-\sigma)^2 + \beta_H \sigma^2}, \\ e_{LH} = e_{HL} = \frac{1}{\beta_L + \beta_H}. \end{cases} \tag{13}$$

It is worth noting that:

$$e_{LL} > e_{HH} \tag{14}$$

The expected payoff is:

$$
\begin{aligned}
E\left[\widetilde{V}_{sharing}(e_{ij})\right] &= E\left[e_{ij}\right] - 2E\left[\widetilde{\beta} e_{ij}^2\right] \\
&= -\frac{1}{4}\left\{\frac{\sigma^2 + (1-\sigma)^2}{\beta_L \sigma^2 + \beta_H (1-\sigma)^2} + \frac{\sigma^2 + (1-\sigma)^2}{\beta_H \sigma^2 + \beta_L (1-\sigma)^2}\right. \\
&+ \left. 8\frac{\sigma(1-\sigma)}{\beta_L + \beta_H}\right\} < 0
\end{aligned}
\tag{15}
$$

Result 1: Private information is not shared

$$
\begin{aligned}
E\left[\widetilde{V}_{sharing}(e_i)\right] &= -\frac{1}{4}\left\{\frac{\sigma^2+(1-\sigma)^2}{\beta_L\sigma^2+\beta_H(1-\sigma)^2}+\frac{\sigma^2+(1-\sigma)^2}{\beta_H\sigma^2+\beta_L(1-\sigma)^2}\right. \\
&+ \left. 8\frac{\sigma(1-\sigma)}{\beta_L+\beta_H}\right\} \\
&< E\left[\widetilde{V}_{no\ sharing}(e_i)\right]=0
\end{aligned}
\tag{16}
$$

Do countries disclose their private information ? `The answer is NO !!!.`

Result 2: More and more incentives to share information when uncertainty increases

A good news from the model is that

$$as\ \frac{\beta_H}{\beta_L} \to \infty,\ E\left[\widetilde{V}_{sharing}(e_i)\right]\ increases\ and\ \to 0 \qquad (17)$$

As the relative magnitude of the damage parameter increases, that is, as the uncertainty about the damages increases, countries have more and more incentives to share their private information.

Interest-based trust and information sharing in a global climate policy

Assume there is a trust leading to an intrinsic valuation of information sharing . The expected intrinsic valuation of information sharing, denoted by

$$\mathcal{V}(s_1, s_2) \geq 0,$$

can be thought of as an exogenous parameter that captures the idea that information sharing is needed for the **long run success** of global climate policy.

The intrinsic valuation of information sharing may be written as

$$\mathcal{V}(s_1, s_2) = \mathcal{B}(s_1, s_2) - \mathcal{K}(s_1, s_2),$$

the difference between the intrinsic benefit and the intrinsic cost from sharing the private information.

Result 3: Trust is necessary for an effective global climate policy

$$
\begin{aligned}
E\left[\widetilde{V}_{sharing\&trust}(e_i)\right] &= E\left[\widetilde{V}_{sharing}(e_i)\right] + \mathcal{V}(s_1, s_2) \\
&- \frac{1}{4}\left\{\frac{\sigma^2 + (1-\sigma)^2}{\beta_L \sigma^2 + \beta_H (1-\sigma)^2} + \frac{\sigma^2 + (1-\sigma)^2}{\beta_H \sigma^2 + \beta_L (1-\sigma)^2}\right. \\
&+ \left. 8\frac{\sigma(1-\sigma)}{\beta_L + \beta_H}\right\} + \mathcal{V}(s_1, s_2) \qquad (18) \\
&> E\left[\widetilde{V}_{no\ sharing}(e_i)\right] = 0
\end{aligned}
$$

if the intrinsic valuation of information sharing, $\mathcal{V}(s_1, s_2)$, is high enough.

Conclusion

- This paper's results show the impossibility of information sharing among anonymous players exploiting a common pool resource.
- However, countries have more and more incentives to share their private information when the uncertainty over the costs increases.
- This paper has used the conventional game-theoretic model of individual behavior to show the mathematical necessity of reciprocity and trust for solving collective-action problems.

Thank you very much !!!

Your comments are very welcome. The full paper is now available for download at:

www.prism.gatech.edu/$\sim$jkakeu6/

$$\begin{cases} P(\beta_L|s_L^1) = \sigma, \\ P(\beta_H|s_L^1) = 1 - \sigma. \end{cases} \tag{19}$$

$$\begin{cases} P(\beta_L, s_L|s_L^1) = \sigma^2, \\ P(\beta_L, s_H^2|s_L^L) = \sigma(1-\sigma), \\ P(\beta_H, s_L^2|s_L^1) = (1-\sigma)^2, \\ P(\beta_H, s_H^2|s_L^1) = \sigma(1-\sigma), \\ P(\beta_L, s_L^2|s_H^1) = (1-\sigma)\sigma, \\ P(\beta_L, s_H^2|s_H^1) = (1-\sigma)^2, \\ P(\beta_H, s_L^2|s_H^1) = \sigma(1-\sigma), \\ P(\beta_H, s_H^2|s_H^1) = \sigma^2. \end{cases} \tag{20}$$

Note also that $P(\beta_L|s_H) = 1 - \sigma$ and $P(\beta_H|s_H) = \sigma$

$$
\begin{cases}
P(\beta_L, s_L, s_L) = \frac{1}{2}\sigma^2, \\
P(\beta_L, s_H, s_L) = \frac{1}{2}\sigma(1-\sigma), \\
P(\beta_H, s_L, s_L) = \frac{1}{2}(1-\sigma)^2, \\
P(\beta_H, s_H, s_L) = \frac{1}{2}\sigma(1-\sigma), \\
P(\beta_L, s_L, s_H) = \frac{1}{2}(1-\sigma)\sigma, \\
P(\beta_L, s_H, s_H) = \frac{1}{2}(1-\sigma)^2, \\
P(\beta_H, s_L, s_H) = \frac{1}{2}\sigma(1-\sigma), \\
P(\beta_H, s_H, s_H) = \frac{1}{2}\sigma^2,
\end{cases}
\tag{21}
$$

$$
\begin{cases}
P(\beta_L | s_L, s_L) = \frac{\sigma^2}{\sigma^2+(1-\sigma)^2}, \\
P(\beta_L | s_L, s_H) = \frac{1}{2}, \\
P(\beta_L | s_H, s_L) = \frac{1}{2}, \\
P(\beta_L | s_H, s_H) = \frac{(1-\sigma)^2}{\sigma^2+(1-\sigma)^2}, \\
P(\beta_H | s_L, s_H) = \frac{1}{2}, \\
P(\beta_H | s_L, s_L) = \frac{(1-\sigma)^2}{\sigma^2+(1-\sigma)^2}, \\
P(\beta_H | s_H, s_L) = \frac{1}{2}, \\
P(\beta_H | s_H, s_H) = \frac{\sigma^2}{\sigma^2+(1-\sigma)^2}.
\end{cases}
\tag{22}
$$

Without information sharing, there are two best response emission strategies to be determined for each country.

$$\begin{cases} e_L^i\left(s_L^i, \widetilde{s}^j(\Omega^j), \widetilde{\beta}\right), e_H^i\left(s_H^i, \widetilde{s}^j(\Omega^j), \widetilde{\beta}\right) & \text{for player } i, \\ e_L^j\left(s_L^j, \widetilde{s}^i(\Omega^i), \widetilde{\beta}\right), e_H^j\left(s_H^j, \widetilde{s}^i(\Omega^i), \widetilde{\beta}\right) & \text{for player } j. \end{cases} \tag{23}$$

Hence $\left\{\widetilde{s}^j(\Omega^j), \widetilde{\beta}\right\}$ represents the uncertainty which country i faces when making a decision

Without information sharing,

$$
\begin{aligned}
& E\left[\widetilde{V}_{no\ sharing}(e_i)\right] \\
= \quad & \frac{1}{2}E\left[e_i\right] - \frac{1}{2}E\left[\widetilde{\beta} e_i e_j\right] - \frac{1}{2}E\left[\tilde{\beta} e_j^2\right] \\
= \quad & \frac{1}{2}(\beta_L e_L + \beta_H e_H) \\
- \quad & \frac{1}{2}\{\beta_L e_L e_L P(\beta_L, s_L, s_L) + \beta_L e_L e_H P(\beta_L, s_L, s_H) + \beta_L e_H e_L P(\beta_L, s_H, s_L \\
+ \quad & \beta_L e_H e_H P(\beta_L, s_H, s_H) + \beta_H e_L e_L P(\beta_H, s_L, s_L) + \beta_H e_L e_H P(\beta_H, s_L, s_H \\
+ \quad & \beta_H e_H e_L P(\beta_H, s_H, s_L) + \beta_H e_H e_H P(\beta_H, s_H, s_H) \\
- \quad & \frac{1}{2}\beta_L e_L^2 P(\beta_L, s_L) - \beta_L e_H^2 P(\beta_L, s_H) - \beta_H e_L^2 P(\beta_H, s_L) \\
- \quad & \beta_H e_H^2 P(\beta_H, s_H))\} \\
= \quad & 0.
\end{aligned}
$$

$$
\begin{aligned}
& E\left[\widetilde{V}_{sharing}(e_i)\right] && (24) \\
= \;& E\left[e_{ij}\right] - 2E\left[\widetilde{\beta} e_{ij}^2\right] \\
= \;& e_{LL}P(s_L, s_L) + 2e_{LH}P(s_L, s_H) + e_{HH}P(s_H, s_H) \\
- \;& 2\left[e_{LL}^2 P(\beta_L, s_L, s_L) + 2e_{LH}^2 P(\beta_L, s_L, s_H) + e_{LL}^2 P(\beta_L, s_H, s_H)\right]\beta_L \\
- \;& 2\left[e_{LL}^2 P(\beta_H, s_L, s_L) + 2e_{LH}^2 P(\beta_H, s_L, s_H) + e_{LL}^2 P(\beta_H, s_H, s_H)\right]\beta_H.
\end{aligned}
$$

Given that all other countries report their private information, country i obtains full benefits from increased precision in estimating the aggregate damage, and withholding its private information reduces the correlation among equilibrium emissions. This unambiguously raises the expected net welfare for country i, compared to the case where it reports its private information.