International environmental agreements with negotiation costs:

Regional versus global cooperation

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Abstract

This study demonstrates that the regional cooperative approach is an appropriate way to address the difficulties emerging in conclusion of effective international environmental agreements (IEAs) for trans-boundary pollution by use of a repeated game model. We introduced a new concept of costs that participants in agreements owe called *negotiation costs* which increase in response to the coalition size. As a result, the negotiation costs provide three positive impacts on IEAs : (i) the regional cooperative approach yields more profits to participating countries than that of the global cooperative approach; (ii) negotiation costs tend to relax the condition under which participants cooperate in accordance with strategy as weakly renegotiation-proof (WRP) equilibrium compared with that of the case of no negotiation costs; and (iii) a cost reduction in abatement increases the effectiveness of regional IEAs in the points of increasing abating countries' payoffs, enhancing the feasibility of regional IEAs, and relaxing the condition for WRP equilibrium. Generally, a reduction in abatement cost that one would expect to enhance welfare can reduce the fraction of the welfare gains from cooperation because the cost reduction causes a smaller agreement size. However, this study shows that the conventional pessimistic view of the effect of cost reduction on IEAs can be overturned.

Keywords: International environmental agreements; Trans-boundary pollution; Regional cooperation; Negotiation cost; Repeated game

JEL Classification: F53; H41; H87; Q52; Q54

1. Introduction

The prevention of transboundary environmental problems, such as global warming and ozone layer depletion, is an important global issue. However, there is no supranational authority to resolve such problems. The abatement of the generation of such transboundary pollutants by a country can affect other countries because a reduction in such pollutions generally has the characteristics of a public good. In other words, each country receives benefits depending upon another country's abatement actions. Therefore, it is essential for countries to enter into negotiations on emissions reductions and conclude international environmental agreements (IEAs). No IEA can be fully effective without the involvement of countries that have still not adhered to such agreements.

Models of international environmental cooperation can roughly be divided into two groups−stage game models and repeated game models (see Asheim et al., 2006; Hovi et al., 2015). In a repeated game model, the number of participating countries in the agreement can be enlarged by assuming credible punishments that enforce participants to cooperate at subsequent stages through credible threats (e.g., Asheim et al., 2006; Asheim and Holtsmark, 2009; Barrett, 2003; Froyn and Hovi, 2008). The stability concept of the repeated game model is referred to as a weakly renegotiation-proof (WRP) equilibrium (in the sense of Farrell and Maskin, 1989, pp. 330–331), and the agreement is enforced using a strategy that specifies the countries' behaviors. In an infinitely repeated game model, compliance is ensured by the threat of future decreased abatement by punishing countries. Barrett (2002) has argued that there is a trade-off between "narrow, but deep" and "broad, but shallow" treaties: either only a few countries participate, each with an efficient and large abatement, or many countries participate, each with an inefficient and small abatement.

This study makes certain assumptions regarding the negotiation costs necessary to the implement the agreement. We consider that the negotiation costs should be included in IEAs to reflect the performance tendency of the agreement. This study assumes that negotiation costs can be reduced if the agreements are formed regionally because of close geographic proximity and because of the relatively smaller size of agreements compared with that of a single grand agreement that is formed globally. However, theoretical analysis of the effect of negotiation costs in the field of the international environmental cooperation is still not provided.

This study examines IEAs with negotiation costs, assuming that the negotiation cost decreases as the agreement size decreases. We compare the regional cooperative approach with the global cooperative approach in terms of global welfare and countries' payoffs from emissions abatement. To compare the efficiency between both approaches, we adopt two strategies: the *Regional Penance* for regional agreements and *Penance-m* for global agreement.

2. The model

Consider a world where $n(\geq 2)$ countries participate and abate. Each country and region is identical in all relevant characteristics. In every period of the game, each country can choose between complying at cost *c*, leading to a fixed reduction in emissions, or not complying. That is, each country must choose to *cooperate* (i.e., reduce emissions) or to *defect* (i.e., not reduce emissions). The gain of cooperation is constituted by the associated abatement costs and the benefits of avoided damages from environmental damage. Because abatement behavior is provision of public goods, benefits depends on the total number of countries that cooperate.

For $i = 1, \cdots, k$, there are k coalitions and the participants in coalition i are s_i, where $n \geq s_i \geq 2$. A global agreement can be considered when s_i is equal to n. There are $\sum_{i=1} s_i$ participating countries and $n - \sum_{i=1} s_i$ non-participating countries. The periodic payoff of each of the $\sum_{i=1} s_i$ countries playing *cooperate* is

$$b\left(s_i + \sum_{j \neq i} s_j\right) - c - \alpha(s_i - 1),$$

where b is a parameter of abatement benefit and is a constant ($b > 0$), and α is a parameter of negotiation costs and a constant ($\alpha > 0$). This study assumes that each cooperating country owes the negotiation costs and the levels of negotiation costs depend on other members in its own coalition. If a participating countries playing *defect*, it receives

$$b\left(s_i - 1 + \sum_{j \neq i} s_j\right).$$

The defector does not owe abatement costs and negotiation costs and receives benefits from $\sum_{i=1} s_i - 1$ countries' abatement.

We assume that $b - c < 0$, which means that each country cannot gain its payoff by individual abatement efforts and that $bn - c - \alpha(n-1) > 0$, which means that the full participation state of a global agreement Pareto dominates the no participation state.[1]

We also assume that for all participants in $s_i \in \{1,2,\ldots,n\}$, $b(n-1) > bn - c - \alpha(s_i - 1)$, which means that *defect* is dominant in the stage game. From $c > b$, above inequality is always satisfied. In the case of one grand agreement where n countries participate, the above inequality will also be satisfied. In this study, as well as Asheim et al. (2006), and Takashima (2017a, 2017b), each country discounts its future payoffs using a common discount factor, δ ($0 < \delta < 1$), which is close to 1.

[1] If the condition that $bn - c - \alpha(n-1) > 0$ is satisfied, the condition that $bn - c - \alpha(s_i - 1) > 0$, which is the case of a full participation through regional cooperation (i.e., $s_i + \sum_{j \neq i} s_j = n$.), is also satisfied.

3. Equilibrium outcome

To be a WRP equilibrium, the strategy must satisfy two requirements for IEAs:

(1) The strategy profile must be subgame perfect. More precisely, in any repeated game with discounting, it is required that no player can gain by a one-period deviation after any history.[2] In other words, each player never changes its actions specified by the strategy if subgame perfection is satisfied. For example, the cooperating countries play *cooperate* and the punishing countries punish any deviator in accordance with the *Regional Penance* strategy.

(2) The strategy profile must be renegotiation proof. This requirement is fulfilled if not all players strictly gain by collectively restarting cooperation at once instead of carrying out the punishment when a signatory has unilaterally deviated in the previous period because all punishments last only one period in the case of *Regional Penance*. Punishment implies that all punishing countries, but not the deviator, surely choose to play *defect* in the punishment phase. This situation makes not only the deviator but also all non-punishing countries worse off with the punishment. Therefore, to be renegotiation proof requires the punishing countries' benefits from punishment to be greater than or equal to those of renegotiation.

We examine the condition of a WRP equilibrium under which the *Regional Penance* satisfies the requirements of subgame perfection and renegotiation-proofness.

We obtain the following proposition for a WRP equilibrium and the upper bound of negotiation costs.

Proposition 1

There always exists a weak renegotiation-proof equilibrium where each signatory plays cooperate in accordance with Regional Penance if

$$\frac{c-2\alpha}{b-2\alpha} < s_i \leq \frac{c+b-\alpha}{b-\alpha} \quad for \;\; i = 1, \cdots, k,$$

and

$$\alpha \leq \frac{2b-c}{2}.$$

In Proposition 1, for *Regional Penance* always to be effective, the number of s_i must at least be decided as an integer. Proposition 1 denotes that all participants cooperate in accordance with *Regional Penance* is sustained if negotiation cost is lower than or equal to

[2] From the theory of repeated games with discounting, a player cannot gain by some period deviations if he/she cannot gain by a one-period deviation (Abreu, 1988, p.390). Therefore, we need only check that no player can gain by a one-period deviation after any history.

$\frac{2b-c}{2}$. From the assumption that $c > b$ and Proposition 1, it is required that $2b > c$ $(> b)$ for α to be positive. This requirement denotes that the abatement benefits are close to abatement costs. Additionally, from the condition that $\alpha \leq \frac{2b-c}{2}$, the decrease in c and the increase in b increase the upper bound of the negotiation costs.

In the following proposition, it is revealed that the negotiation costs relax the condition that agreements are sustained as WRP equilibrium by widening the range between lower and upper bounds of s_i is maximized.

Proposition 2

The gap between the lower and upper bounds of the number of participants is maximized if

$$\alpha = \frac{2b^2 - \sqrt{2}\sqrt{-b^3c + b^2c^2}}{2b + 2c}.$$

Under the condition $\alpha \leq \frac{2b-c}{2}$ in Proposition 1, the range of the number of participants can be larger compared with that for the case of no negotiation costs. One might expect additional costs such as negotiation costs to strengthen the condition that IEAs are sustained as WRP equilibrium, but Proposition 2 delivers the opposite result: the range of the number of participants can be widen compared with the case of no negotiation costs. The negotiation costs relax the condition that IEAs are sustained as WRP equilibrium if the range of the number of participants is larger than one integer.

4 Regional versus global cooperation

4.1 Global cooperative approach: equilibrium outcome

We examine the condition of a WRP equilibrium under which the *Penance-m* satisfies the requirements of subgame perfection and renegotiation-proofness.

Proposition 3

There exists a weak renegotiation-proof equilibrium where each signatory plays cooperate in accordance with Penance-m if

$$\frac{c - b + \alpha n - \alpha}{b - \alpha} < m \leq \frac{c + \alpha n - \alpha}{b}.$$

Proposition 3 denotes that the number of punishing countries is not always decided as an integer because the gap between the lower and upper bounds of *m* is less than 1.

4.2 Contribution of regional cooperative approach with negotiation costs

4.2.1 WRP equilibrium

As discussed in Propositions 1 and 2, the gap of lower and upper bounds of the number of participants (or punishing countries) in regional agreements can be expanded although the gap in global agreements is unchanged by introducing the negotiation costs. Intuition behind this difference in the effects is as follows. On the punishment phase in both cases, the countries except punishing countries play *cooperate*. However, the negotiation cost in regional agreements is α irrespective of other abating countries, while this cost in global agreements is $(n-m)\alpha$ which depends on the other abating countries and the punishers. For renegotiation-proofness, the negotiation cost in regional agreements and that in global agreement if punishers renegotiate is αs_i and αn, respectively. Hence, both negotiation costs depend on the other abating countries. Therefore, in the case of regional agreements, difference between the effect of the negotiation cost on subgame perfection and that on renegotiation-proofness is increased with the increasing number of punishers.

4.2.2 Payoff

We examine the lower bound of participants in regional agreement under which each country's payoff through regional cooperative approach is equal to the payoff through global cooperative approach. We assume the total number of cooperating countries through the regional cooperative approach $\sum_{i=1} s_i$ is less than the total participants through the global cooperative approach n by n'. A cooperating country's payoff through the former approach is $b(n-n')-c-\alpha(s_i-1)$. A cooperating country's payoff through the latter approach is $bn-c-\alpha n$. If $b(n-n')-c-\alpha(s_i-1) \geq bn-c-\alpha(n-1)$, and each participant's payoff through the regional cooperative approach is higher than or equal to their respective payoffs through global cooperation.[3] Rearranging this inequality, we obtain the following condition:

$$n' \leq \frac{\alpha(n-s_i)}{b}. \tag{1}$$

4.2.3 Reduction in abatement costs

From Propositions 1, 2, and condition (1), we obtain the following proposition.

Proposition 4

If the negotiation costs and regional cooperative approach are considered, the reduction in abatement costs enhances the feasibility of IEAs in terms of: (i) increasing the upper bound of negotiation costs for stable agreements; (ii) increasing the lower bound of participants in

[3] When $\sum_{i=1} s_i = n$, each country receives higher payoffs from the regional cooperative approach than those from the global cooperative approach because $s_i \leq n$.

regional agreement under which each country's payoff through regional cooperative approach is equal to the payoff through global cooperative approach; and (iii) relaxing the condition for IEAs to be sustained as WRP equilibrium.

5. Results

Our model obtains the following results: (1) The negotiation cost can relax the condition under which participants cooperate in accordance with strategy as WRP equilibrium; (2) If the abatement cost is close to the abatement benefit (i.e., each coalition's size is small) and the negotiation cost is low, the countries' payoffs through regional cooperative approach can be higher than or equal to the payoff through global cooperative approach even if the number of participants in regional cooperation is less than that in global cooperation; and (3) A cost reduction increases the effectiveness of regional agreements in terms of increasing cooperating countries' payoffs, enhancing the feasibility of agreement, and relaxed condition for WRP equilibrium .

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