Strategies of Coalition Formation under Kyoto Protocol

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Ga-hyeong Hur, Gyeong-Lyeob Cho
Korea Energy and Economics Institute

Game theory and IEA

- IEA (international environmental agreement) deals with typical public good problem
- Cooperative game theory provides a good framework

- Which country or How many countries join IEAs?
- What is global or individual countries' payoff according to the strategies of coalitions formation?
- What are stable coalitions?

A Game

- We adapt “greenhousegas abatement cost game” under Kyoto Protocol
- In IEA negotiation, the decisive factor of coalition formation is not environmental benefit but **economic cost**

  (while in domestic environmental problem, both environmental benefit and economic cost are equally important)
- The consideration of environmental benefit is highly dependant on the assumption, so that it impairs the objectivity of the gain of coalition

Objective

- **Our model aims to find**

- Which coalition is optimal in global perspective?
- Which coalition is optimal in individual country's perspective?
- Which coalition is stable?
- Which coalition is environmentally optimal?

Theoretical Model

- Assumption

- Open membership Model
- Backward induction
- Simultaneous cooperative game
- Heterogeneous countries (players)
- Transfer scheme : emission trading (among members of coalition)

- Coalition payoffs are determined by total emission abatement cost
- Annex-B countries commit Kyoto target in and outside of the coalition

※ kyoto target : USA 7%, EUO 8%, JPN 6%

- Non-cooperative strategy (Nash solution):

  Countries choose a best strategy given the other countries' strategies

$$P(\phi) = \sum_{i \in N} P_i^0$$

- Full-cooperative strategy (grand coalition):

  Countries choose a strategy to maximize the payoff of grand coalition

$$P(N) = \sum_{i \in N} P_i(N)$$

- Partial-cooperative strategy (sub-coalition):

  Coalition member countries choose a strategy to maximize the payoff of the coalition, while non-member countries choose Nash strategy

$$P(S) = \sum_{i \in S} P_i(S) + \sum_{j \notin S} Q_j(S)$$

Condition

- Condition1 : Profitability

  Coalition S is economically profitable if

  $$P(S) \leq \sum_{i \in S} Q_i^0 \quad \text{or} \quad P_i(S) \leq P_i(\phi)$$

  $P(S)$: payoff of a coalition S

  Q_j^0 : payoff of non-member country j

- Condition2 : Superadditivity

  The greenhouse abatement cost game is supposed to satisfy superadditivity condition

  $$V(S \cup T) \geq V(S) + V(T)$$

  $V(S)$: gain from the coalition S

Definitions

- Definition1 : Pareto-efficient coalition

  If at least one country become better off in the coalition, while the other member countries is not worse off, the coalition S is called Pareto-efficient coalition, i.e.

  $$\mathrm{P_i(S) \geq Q_i}(S \setminus i)$$

- Condition3 : Stability

  A coalition is stable only if there is no incentive for member countries to deviate the coalition (Internal Stability) and for non-member countries to join the coalition (External Stability), i.e.

  $$Q_i(S \setminus i) - P_i(S) < 0 \quad \text{and} \quad P_i(S \cup i) - Q_i(S) < 0$$

  $$\mathrm{Q_i}(S \setminus i) : \text{payoff when i deviates coalition S}$$

Literatures

- The bigger coalition, the less stable (Carraro/Siniscalco1993, Hoel1991)
- The abatement level of big coalitions have little difference with Nash solution (Barrett1992,1994)
- Sub-coalition (USA-EUR-CHN) is the most successful coalition (Jared/Rutherford2003)
- Transfer scheme is helpful to stabilize coalitions among heterogeneous countries (Botteon/Carraro1997,Barrett1997)
- Grand coalition provides the maximum global welfare (Eyckman/Finus2003)

Empirical Model

- KEEI CGE (based on GREEN model)
  : multi-sectoral, recursive (sequential) dynamic

- Country Group:

  LDC(leading developing countries), USA, EUO, JPN, FSU, CHI(China+India),ROW

- Data : GTAP4
- Time : 1990-2030 (5 year period)

- Net abatement

$$\sum_{i\in S, i\in AnnexB}(A_i + \mathrm{Im}_i) + \sum_{i\notin S, i\in AnnexB} A_i + \sum_{i\in S, i\notin AnnexB} A_i - \sum_{i\notin S, i\notin AnnexB} leakage_i$$

A_i Ghg abatement of i country domestically

Im_i Imported emission permit of i country

$leakage_i$ Ghg abatement of i country

- Marginal abatement cost

$$Tx_{t,n+1} = Tx_{t,n}\left[\frac{\sum_{i\in S} TCO_{2,t,S,n}}{\sum_{i\in S} x_{t,S} TCO_{2,1990,S}}\right]$$

Tx_t Permit price in coalition S

- Total abatement Cost

$$\sum_{i \in S} A_i * pcarb_i + \sum_{i \notin S} A_i * pcarb_i + \sum_{j \in S} \mathrm{Im}_j * pcarb_j$$

$pcarb_i$ Marginal abatement cost of i country or emission permit price

Global greenhouse gas emission

(Unit: billion ton of carbon)

	Coalition	Value
Min	LDC+ EUO+ JPN+ CHI+ ROW	7.75
	LDC+ USA+ EUO+ JPN+ CHI+ ROW	
Max	USA+ FSU	8.046

Net Emission Abatement

(Unit: billion ton of carbon)

	LDC	USA	EUO	JPN	FSU	CHI	ROW	Global
Nash	-0.01	0.59	0.32	0.10	-0.04	-0.02	-0.05	0.88
Grand	0.02	0.15	0.10	0.01	0.13	0.28	0.09	0.78
Old-Kyoto	-0.01	0.32	0.20	0.03	0.23	-0.02	-0.05	0.71
New-Kyoto	-0.01	0.59	0.08	0.00	0.11	-0.01	-0.04	0.72
LDC+EUO+JPN+CHI+ROW	0.01	0.59	0.09	0.01	-0.03	0.25	0.07	0.98
USA + FSU	-0.01	0.20	0.32	0.10	0.16	-0.02	-0.05	0.70

Total Abatement Cost

Unit : 10 billion

	LDC	USA	EUO	JPN	FSU	CHI	ROW	Global
Nash	0.00	16.79	10.29	5.28	0.00	0.00	0.00	32.36
Grand	0.07	2.42	1.32	0.42	0.54	1.15	0.36	6.28
Old-Kyoto	0.00	5.61	3.06	0.98	2.18	0.00	0.00	11.83
New-Kyoto	0.00	16.64	1.01	0.32	0.33	0.00	0.00	18.31
UEJ	0.00	20.18	10.41	3.32	0.00	0.00	0.00	33.91

Emission Permit Revenue
of non-Annex B countries

(Unit : 10 billion)

	LDC	CHI	ROW	Total
Nash	0	0	0	0
LDC+USA+EUO+JPN	1.34	0	0	1.34
USA+EUO+JPN+CHI	0	4.24	0	4.24
USA+EUO+JPN+ROW	0	0	4.27	4.27
Grand	0.074	1.15	0.36	1.57

Results

1)The greenhouse abatement cost game roughly satisfy superadditivity and profitability conditions

2)Grand coalition is the only coalition satisfying internal and external stability

3)Grand Coalition is the only self-enforcing coalition

4)Grand coalition has the least total abatement cost

5)USA+EUO+JPN coalition has the largest total abatement cost and very unstable. i.e. the three countries will not join a coalition without FSU

6)LDC+EUO+JPN+CHI+ROW coalition is best in the respect of environment (least emitting coalition)

7)USA prefers LDC+USA+FSU+CHI+ROW coalition

8) LDC prefers LDC+USA+EUO+JPN

(i.e. The social optimal coalition does not correspond with individual countries' optimal coalitions)

9)Hot air of FSU amounts to 0.23 billion TC and plays an important role in coalition payoff and emission.

10)In Nash solution, leakage effect offsets 12% of emission abatement

Conclusion

- Grand coalition is the only stable coalition (self-enforcing) and achieves the least global abatement cost
- The participation of FSU is crucial for the payoff of coalitions
- It is beneficial for developing countries to join coalitions in both economic and environmental perspectives
- Financial transfer including emission trading is helpful for the stability of coalitions, therefore, it should be considered in the future design of Climate Change Convention

Thank You