Bargaining and Coalition Formation

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International Environmental Agreements

Overview

- International Environmental Agreements (IEAs) typically involve negotiations between a large number of countries so are an interesting application of coalition-formation theory.
- The global environment is a public good, and IEAs are vulnerable to two types of free-riding:
  - Choosing not to sign an agreement.
  - Signing an agreement but failing to comply with its terms.
- We will focus on the first, assuming that all signatories comply with an agreement.
- We will look at four specific issues: uniform emission reduction quotas, transfer schemes, single vs multiple agreements, and far-sighted vs myopic agents.
- The first three issues will be analyzed using the same computable general equilibrium (CGE) model: STACO.[1]

[1] See "Stability of climate coalitions in a cartel formation game", Finus, van Ierland, and Dellink (2006).

Analytical vs Numerical Analysis

- Economic models can be solved analytically (finding a "closed form" solution, possibly involving various parameters) or numerically (as in CGE models).
- Closed form solutions:
  - Allow us to find general (especially qualitative) results that are independent of specific functional forms or precise parameter values.
  - But to find closed form solutions we must often make extreme symplifying assumptions (e.g. identical agents, linear costs...), and if results depend on parameter values, what range of values is "realistic"?

Analytical vs Numerical Analysis continued

- Numerical models:
  - Allow analysis of more complex environments and can be "calibrated" to be close to the real world and give specific policy advice.
  - But require estimates of parameters which may be hard to evaluate, and different estimates may give different results (ameliorated by "sensitivity analysis": testing a range of parameter values).
- Note that both types of analysis will mostly use similar assumptions in the underlying models, such as optimizing behaviour by individuals, Nash equilibrium, etc. so both are equally sensitive to modelling errors in this regard.

STAblility of COalitions model (STACO)

- Two-stage game (baseline model):
  - Regions decide whether or not to sign agreement.
  - Coalitions (and singletons) choose abatement strategies.
- Abatement strategies are chosen based on the following payoff function:

$$\pi_i(q) = \sum_{t=1}^{T} (1 + r_i)^{-t} (B_{it}(q_t) - AC_{it}(q_{it})),$$

  - T is the time horizon,
  - r_i is the discount factor of region i,
  - $q_t = \sum_{i=1}^{N} q_{it}$, the sum of individual abatement.
  - $B_{it}(q_t)$ is a country's benifit from global abatement.
  - $AC_{it}(q_{it})$ is a region's cost from individual abatement.
- Note incentive to free-ride: private cost to abatement, but global benefit.

STACO: Solution Concepts

- In the baseline model, coalitions are assumed to choose strategies to maximise the sum of their members' payoffs (singletons maximise their own payoff), taking the strategies of others as given.
- A coalition structure is considered stable if no country has an incentive to change its membership strategy, taking the decisions of others as given. Requires:[2]
  - Internal stability: no coalition member wants to leave.
  - External stability: no non-member wants to join.
- With no agreement (Singleton coalition structure) we have the classical Nash equilibrium.
- If everyone signs an agreement (Grand Coalition) we have the social optimum.

[2] This is just a Nash equilibrium: coalitional deviations are not considered.

STACO: Callibration

- Analysis looks at the 100-year period from 2011-2110.
- World divided into 12 regions: USA, Japan, European Union (EU-15), Other OECD Countries, Central and Eastern European Countries, Former Soviet Union, Energy Exporting Countries, China, India, Dynamic Asian Economies, Brasil, and "Rest of the World."
- Abatement costs and benefits callibrated using pre-existing estimates (from mid-90's so probably now out of date).
- Discount factor assumed to be 2%.
- Clearly heroic assumptions, but:
  - Authors primarily interested in stability of coalition structures, so precision not so important.
  - Alternative specifications are tested and qualitative results are robust.
  - What is the alternative?

Preliminary notes

- In the Singleton coalition structure, individual rationality implies each country equating its marginal abatement cost (MAC) to its marginal abatement benifit (MAB).
- In a coalition, efficiency implies that the marginal cost of abatement will be equal for each coalition member: Countries with shallower marginal cost curves will take a larger share of a coalition's abatement.
- The attractiveness of a coalitions depends upon:
  - the country's MAC relative to other coalition members (the share of additional abatement it must take).
  - the country's MAB (how much it benefits from the additional abatement).

Table 1 Emissions, benefit and abatement cost parameters

Regions	Emissions in 2010 (Gton)	Share of global benefits s_i		Abatement cost parameter	
		Calibration I	Calibration II	α_i	β_i
USA	2.42	0.226	0.124	0.0005	0.00398
JPN	0.56	0.173	0.114	0.0155	0.18160
EEC	1.4	0.236	0.064	0.0024	0.01503
OOE	0.62	0.035	0.017	0.0083	0
EET	0.51	0.013	0.013	0.0079	0.00486
FSU	1	0.068	0.035	0.0023	0.00042
EEX	1.22	0.030	0.030	0.0032	0.03029
CHN	2.36	0.062	0.062	0.00007	0.00239
IND	0.63	0.050	0.171	0.0015	0.00787
DAE	0.41	0.025	0.085	0.0047	0.03774
BRA	0.13	0.015	0.052	0.5612	0.84974
ROW	0.7	0.068	0.233	0.0021	0.00805
World	11.96	$\sum s_i = 1$	$\sum s_i = 1$		

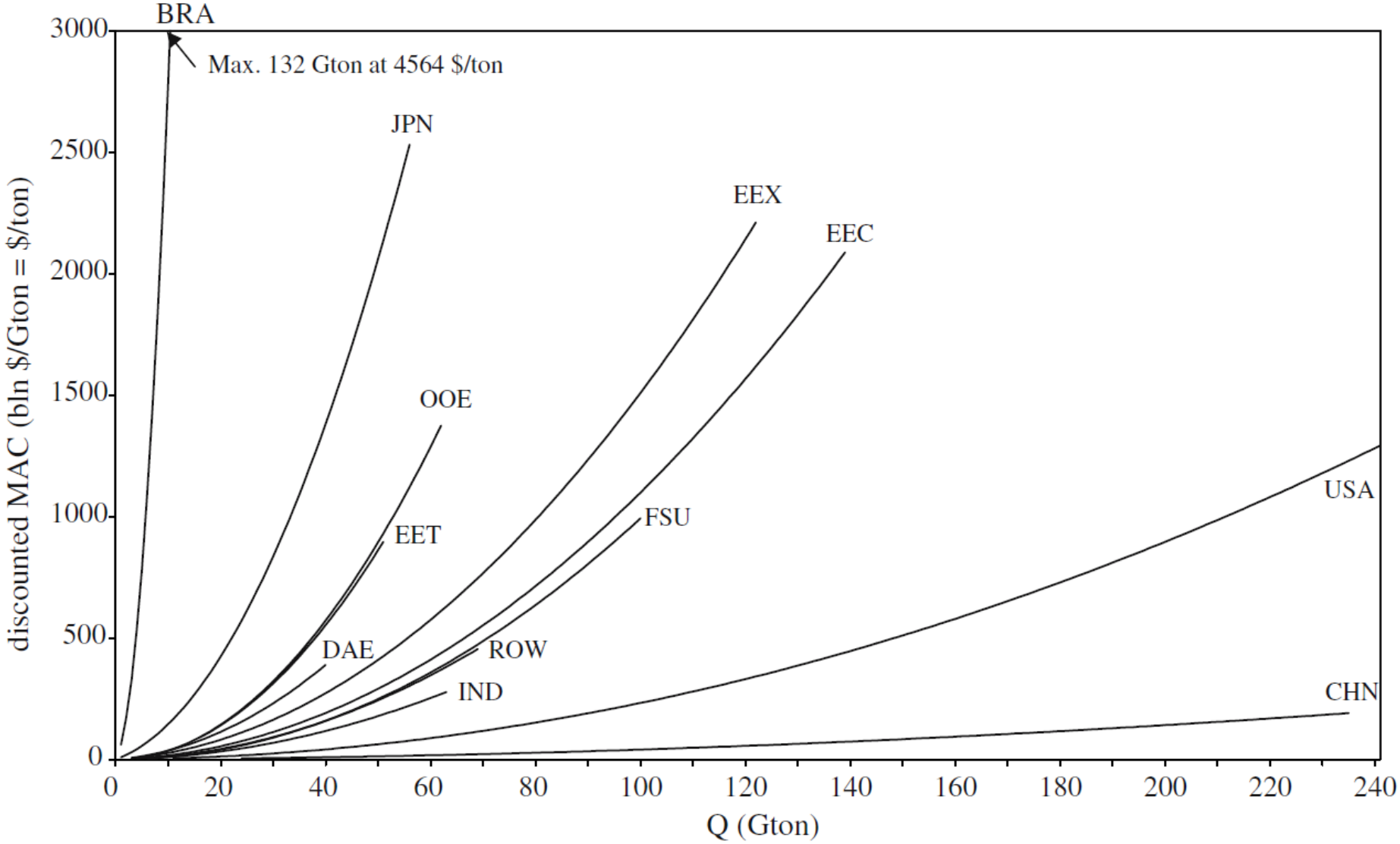

Fig. 1 Discounted marginal abatement cost functions

Table 2 All Singletons Coalition Structure

Regions	Total emission reduction Gton (over 100 years)	Annual emission reduction percentage of emissions in 2010	Total abatement costs billion US$ over 100 years	Total benefits from abatement billion US$ over 100 years	Payoff billion US$ over 100 years	Marginal abatement costs US$/ton	Marginal benefits US$/ton
USA	16	6.7	53	468	415	8.5	8.5
JPN	1	1.4	2	357	354	6.5	6.5
EEC	7	4.7	24	488	464	8.8	8.8
OOE	2	3.1	1	71	71	1.3	1.3
EET	1	1.8	0	27	27	0.5	0.5
FSU	5	4.9	4	140	135	2.5	2.5
EEX	1	0.7	0	62	62	1.1	1.1
CHN	15	6.6	16	128	112	2.3	2.3
IND	3	5.3	3	103	101	1.9	1.9
DAE	1	1.3	0	52	51	0.9	0.9
BRA	0	0.1	0	32	32	0.6	0.6
ROW	4	5.3	4	141	137	2.5	2.5
World	55	4.6	109	2,069	1,960		

Global stock of carbon dioxide in 2110 equals 1,561 Gton

Table 3 Grand Coalition Structure

Regions	Total emission reduction	Annual emission reduction	Total abatement costs	Total benefits from abatement	Payoff	Marginal abatement costs	Marginal benefits	Incentive to leave coalition
	Gton (over 100 years)	percentage of emissions in 2010	billion US$ over 100 years	billion US$ over 100 years	billion US$ over 100 years	US$/ton	US$/ton	billion US$ over 100 years
USA [a]	38	15.7	513	2,169	1,656	37.4	8.5	23.6
JPN [a]	4	6.5	63	1,653	1,590	37.4	6.5	−123.8
EEC [a]	16	11.5	229	2,262	2,033	37.4	8.8	−180.1
OOE [a]	10	16.5	127	331	203	37.4	1.3	109.6
EET [a]	10	19.6	130	125	**−6**	37.4	0.5	124.9
FSU [a]	19	19.3	242	647	405	37.4	2.5	178.1
EEX [a]	12	10.2	188	288	99	37.4	1.1	169.9
CHN [a]	96	40.6	1,348	594	**−754**	37.4	2.3	1133.2
IND [a]	22	33.8	295	479	184	37.4	1.9	245.8
DAE [a]	10	25.1	155	239	84	37.4	0.9	142.1
BRA [a]	1	5.5	12	147	135	37.4	0.6	10.0
ROW [a]	19	26.5	250	652	401	37.4	2.5	185.1
World	256	21.4	3,553	9,584	6,031			

Global stock of carbon dioxide in 2110 equals 1,475 Gton

[a] indicates that the region is a coalition member

Summary of Basic Results

- Even without cooperation (i.e. in the Singleton coalition structure) it is in every country's interest to unilaterally reduce emmisions (a total of 4.6% of global emmisions).
- With global cooperation, abatement is significantly higher (21.4%).
- The total net benefit of abatement for the Grand coaltion is $6,031 billion compared with $1,960 in the Singleton coalition structure: large potential gains from cooperation.
- All regions except Japan and the EU have an incentive to leave the Grand Coalition (high MAC so small share of abatement costs, and high MAB so remaining coalition members would reduce abatement a lot): it is not stable.
- EET and China are worse off under the Grand Coaltion than the Singleton coalition structure (because of low MAB for EET; and low MAC for China implying they bear much of the abatement costs).