Learning Rates and the Green Energy Deployment Game.

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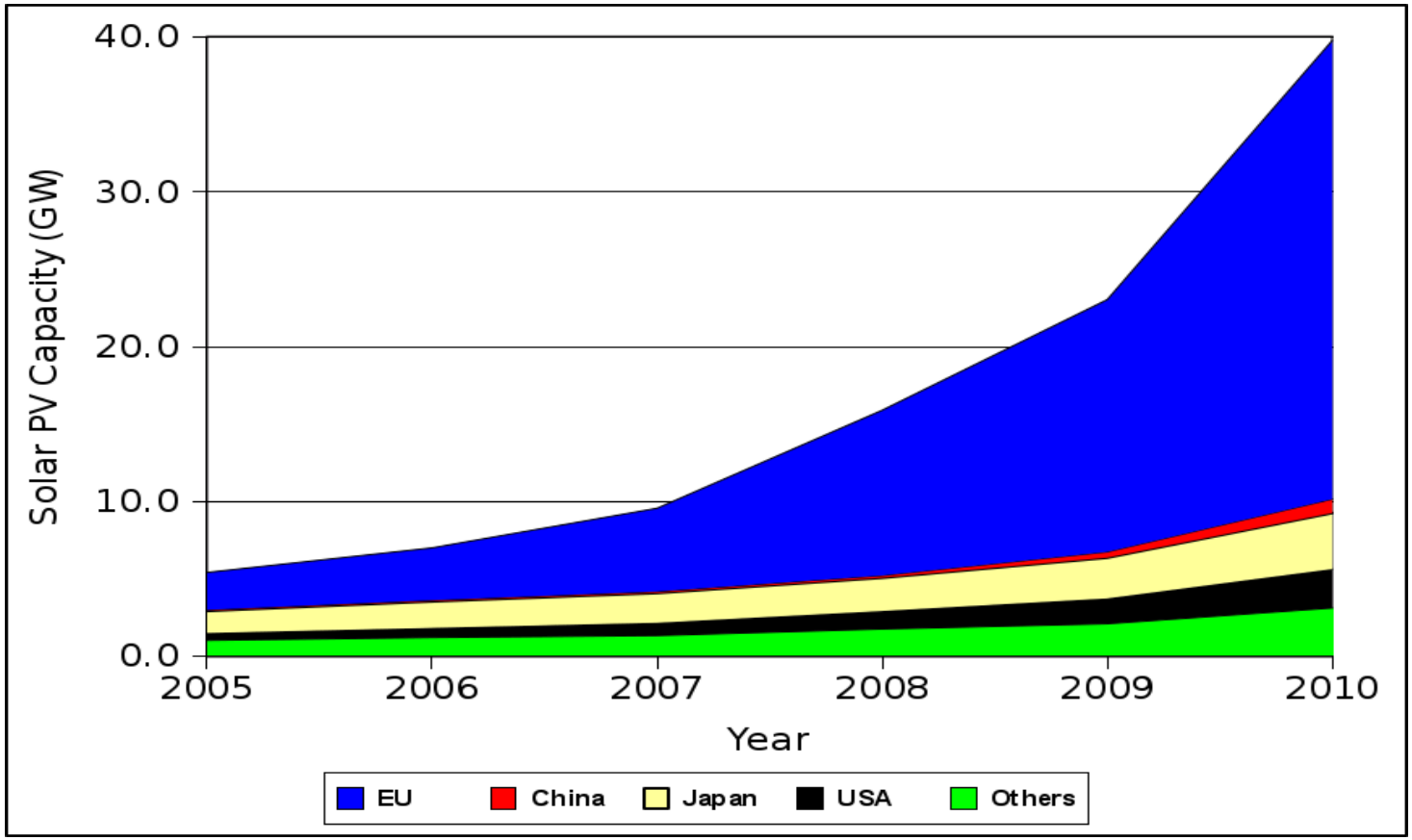
Website: http://strategicdeployment.googlecode.com/

Solar PV Deployment



Source: BP Statistical Review 2011

Same data in tabular form

Year	2005	2006	2007	2008	2009	2010	Growth
EU	2.4	3.4	5.4	10.7	16.3	29.6	>10
China	0.1	0.1	0.1	0.1	0.4	0.9	~10
USA	0.5	0.6	0.8	1.2	1.6	2.5	~5
Japan	1.4	1.7	1.9	2.1	2.6	3.6	~2.5
Others	1	1.2	1.3	1.8	2.1	3.1	~3

Cost of solar ~ 3 times average electricity cost (US).

Motivation

- Where's my international climate treaty?
- Policies in individual countries/regions to promote renewable energy.

Deployment ⇧ Costs ⇩

- Do policymakers have foresight?
- Is there cooperation/competition between countries?

OBJECTIVE

A
simple (hopefully, realistic) model of a somewhat shortsighted policymaker dealing with
green investment/subsidy decisions.

What does the model have?

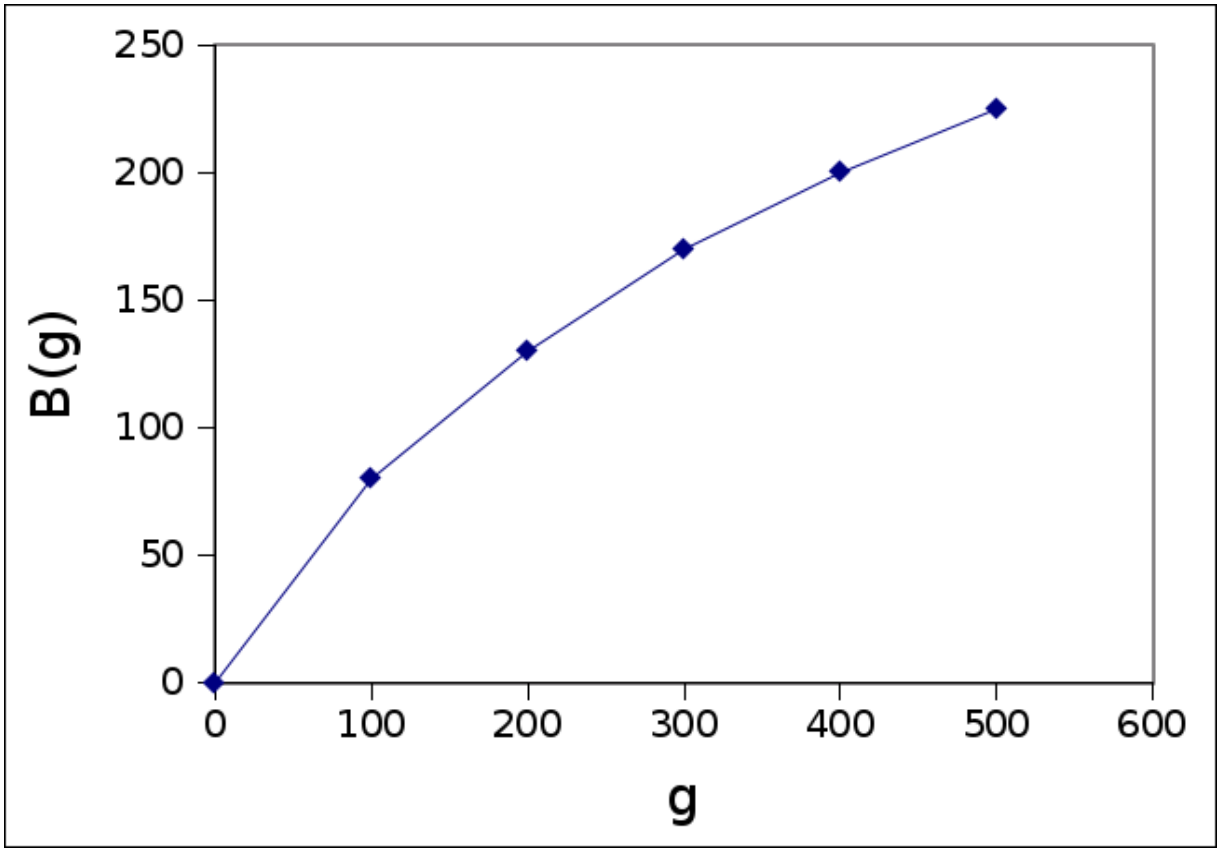
- Electricity Sector:

Solar PV (g) $300/MWh, New Fossil (f) $100/MWh and Old Fossil (o) $65/MWh

- Three or Four Region Model
  - Three: China, EU and the Rest of the World (ROW)
  - Four: China, EU, USA and the Rest of the World (ROW)
- Policymakers are
  - Myopic
  - have limited foresight, and
    - Either compete (play a Nash game) … ***or*** …cooperate
- N periods (4 years each) with multiple decision points.
- Learning by Doing: 22% for 3 doublings, 11% thereafter.

$$c_g^t = c_g^0 \left(\frac{G^{t-1}}{G^0} \right)^{\alpha} \quad \text{where} \quad 2^{\alpha} = 1 - lr$$

Shape of policymaker's benefit curve.



$$B_i^t = B_i^t \log\left(1 + g_i^t\right)$$

Policymaker's costs

$$C_i^t = \begin{cases} g_i^t(c_{gi}^t - c_{fi}^t) & \text{if} \quad c_{oi}^t < c_{fi}^t \leq c_{gi}^t \quad \text{and} \quad g_i^t \leq e_i^t \\ e_i^t(c_{gi}^t - c_{fi}^t) + (g_i^t - e_i^t)(c_{gi}^t - c_{oi}^t) & \text{if} \quad c_{oi}^t < c_{fi}^t \leq c_{gi}^t \quad \text{and} \quad g_i^t > e_i^t \\ (g_i^t - e_i^t)(c_{gi}^t - c_{oi}^t) & \text{if} \quad c_{oi}^t \leq c_{gi}^t < c_{fi}^t \quad \text{and} \quad g_i^t \geq e_i^t \\ 0 & \text{if} \quad c_{gi}^t < c_{oi}^t < c_{fi}^t \end{cases}$$

Costs = Subsidy support required

The policymaker's cost-benefit calculus

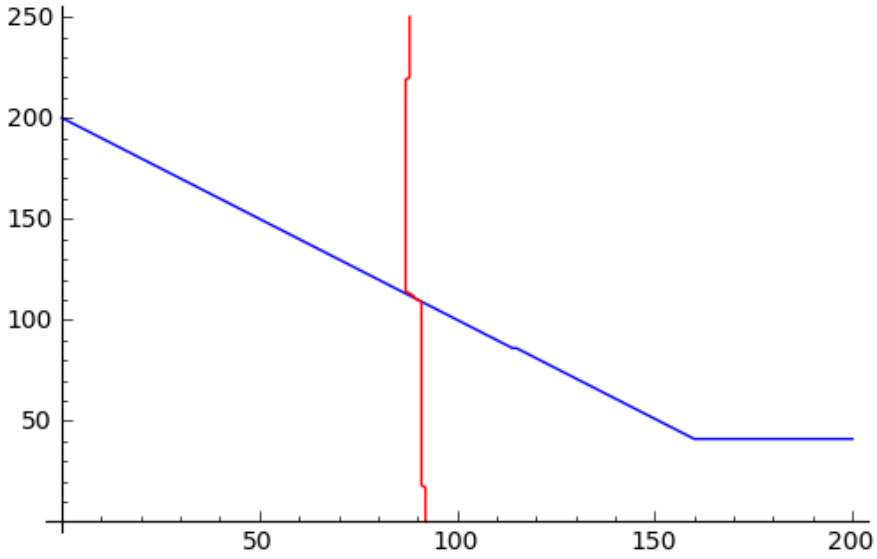
Single Period or Myopic

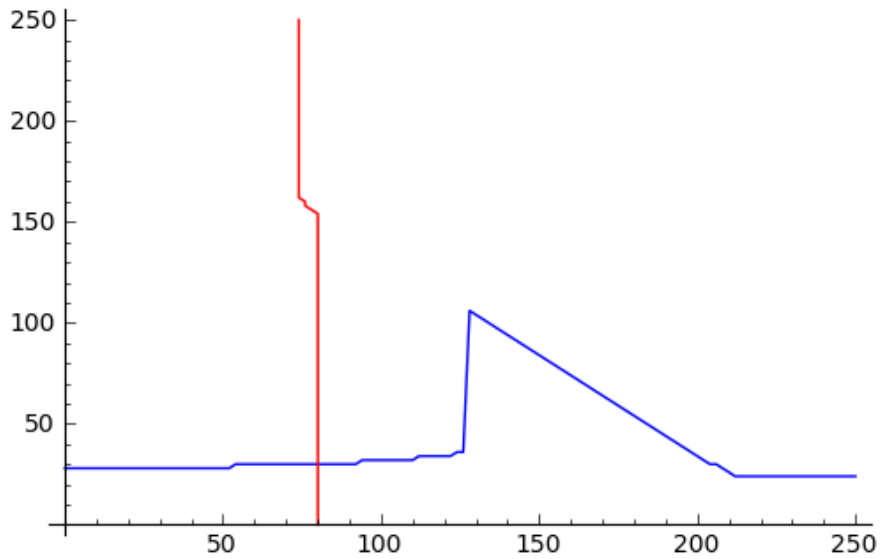
$$\mathcal{U}_i^t = \mathcal{B}_i^t - \mathcal{C}_i^t$$

One period foresight

$$\mathcal{V}_i^t = \mathcal{U}_i^t + \delta \mathcal{U}_i^{t+1},$$

Nash vs Cooperative solutions





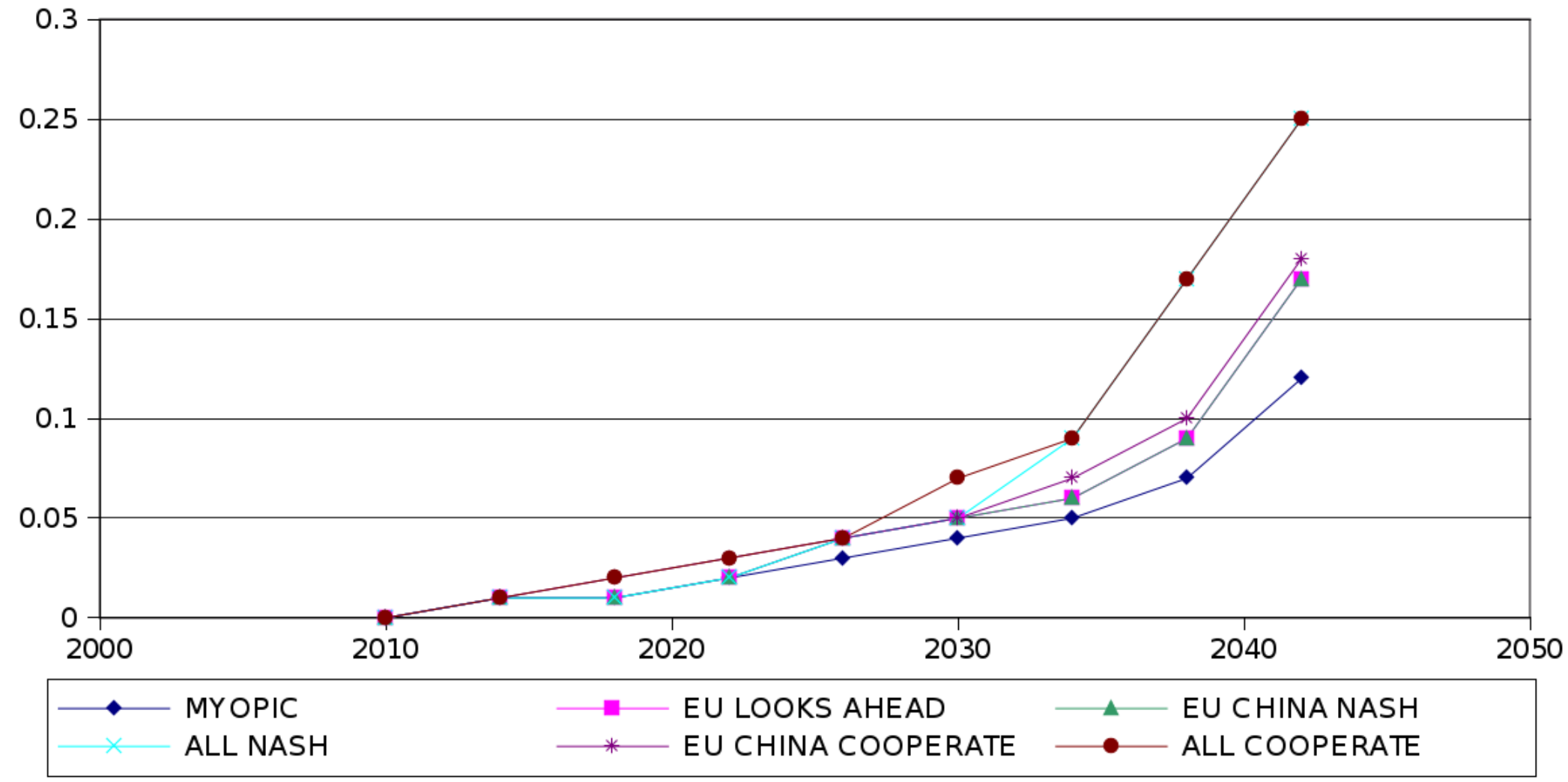
Nash solution: Find the intersection of the two “best response curves” where each region maximizes its own utility.
Cooperative solution: Find the **point** on the plane that maximizes the sum of the two regions' utilities.

[2 regions: – intersection of lines. 3 regions: – intersection of surfaces]

Reference Case Costs (3 regions)

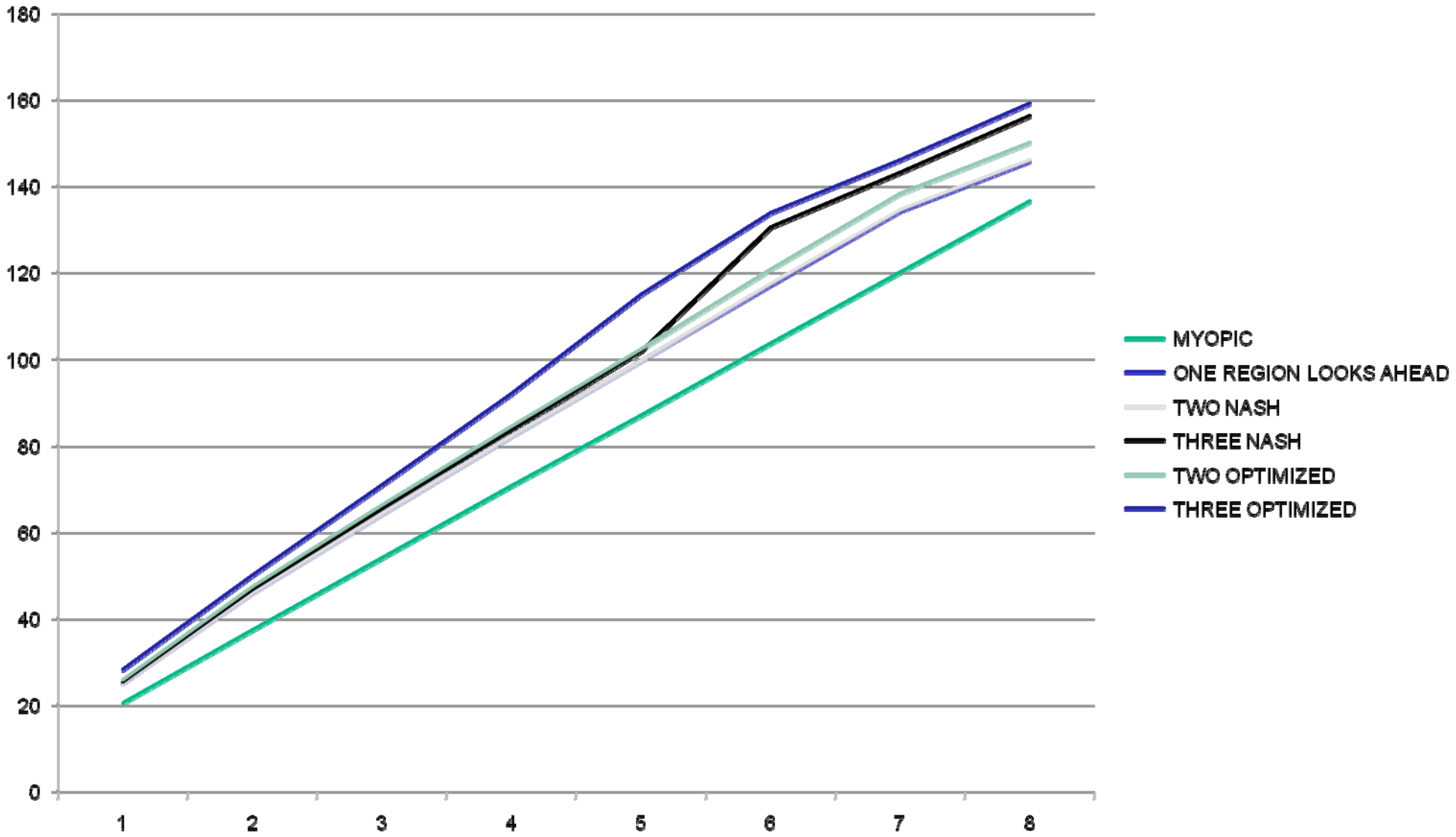
Period	MYOPIC	EU LOOKS AHEAD	EU - CHINA NASH	ALL NASH	EU -CHINA COOPERATE	ALL COOPERATE
0	300	300	300	300	300	300
1	203.23	193.13	193.06	192.6	191.88	187.3
2	157.29	146.59	146.54	145.62	144.84	142.37
3	134.95	130.39	130.36	129.8	129.52	127.35
4	124.17	120.45	120.41	119.73	119.62	116.78
5	115.97	112.7	112.65	111.68	111.83	107.16
6	109.1	105.99	105.89	**100**	104.83	**99.52**
7	102.6	**98.96**	**98.83**	88.75	**97.06**	88.52
8	**93.09**	87.72	87.66	82.19	86.81	82.05

Share of green energy

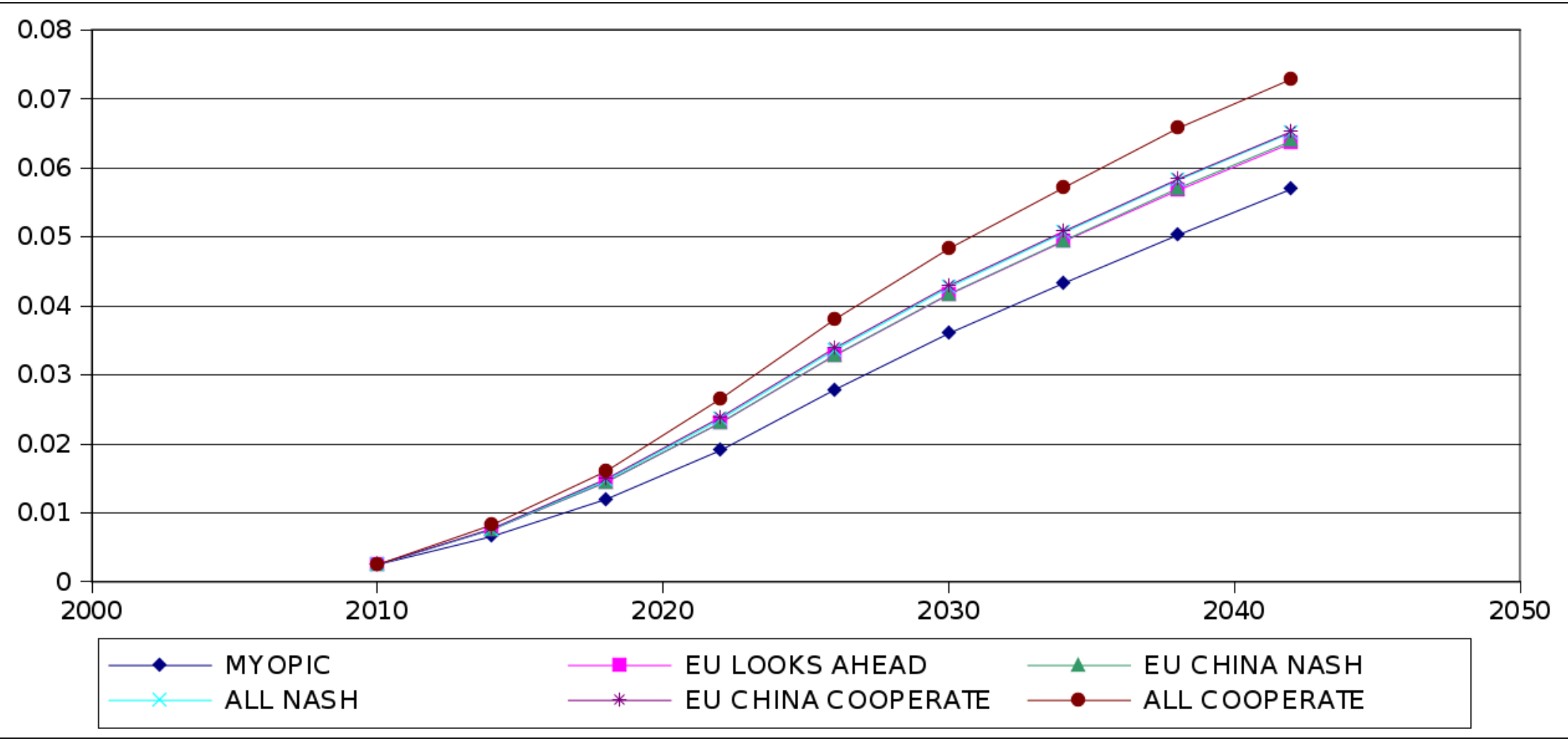


Reference Case

Global Subsidy bill in $ billion/4 yrs

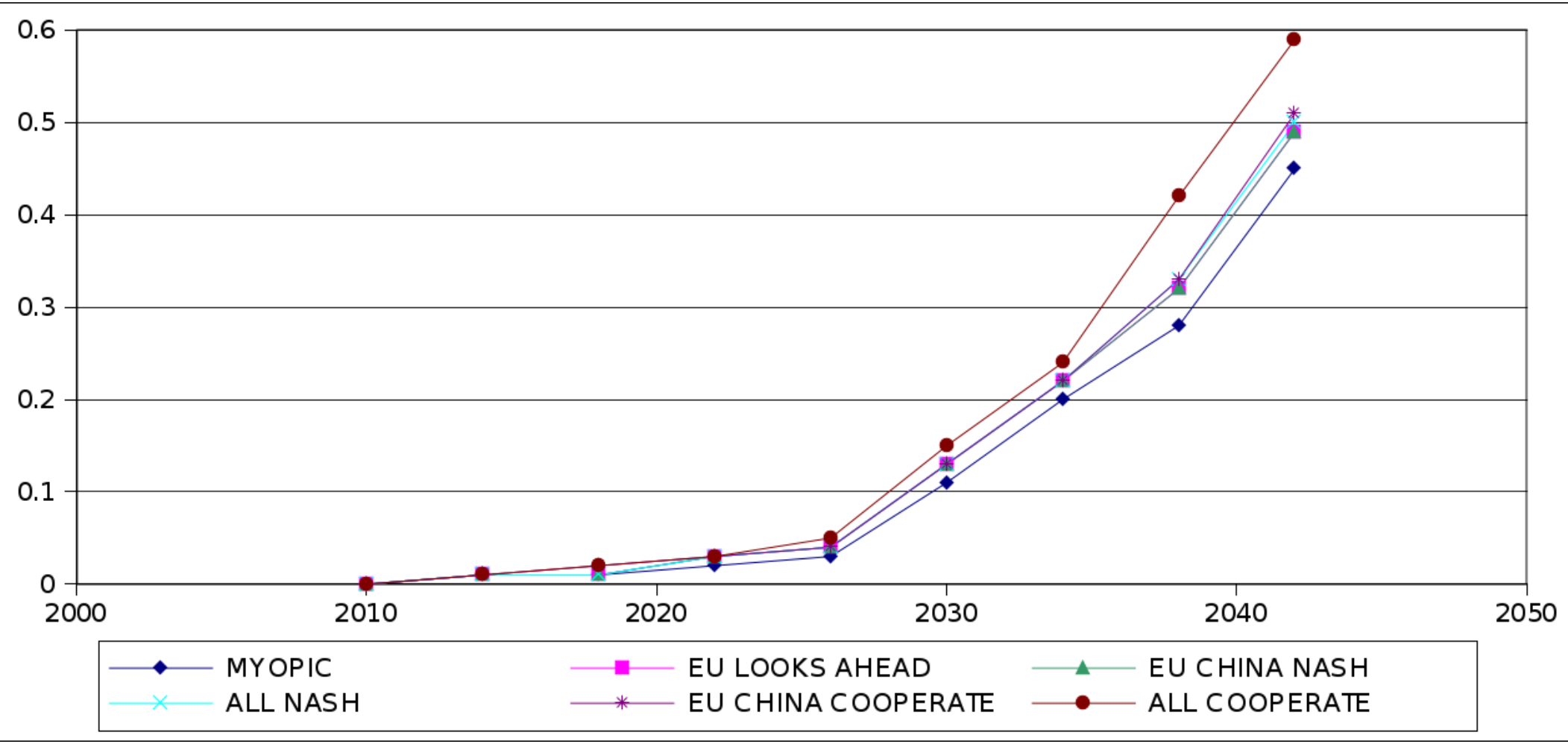


Sensitivity Analysis



Falling Fossil Costs

Sensitivity Analysis



Rising Fossil Costs

Reference Case Costs (4 regions)

Period	MYOPIC	EU LOOKS AHEAD	EU CHINA NASH	EU, CHINA, US NASH	EU CHINA COOPERAATE	EU, CHINA, US COOPERATE
0	300	**300**	300	300	300	300
1	202.63	**191.07**	*192.65*	*192.58*	191.46	189.2
2	156.31	**144.38**	*145.76*	*145.64*	144.11	142.37
3	134.33	**129.17**	*129.81*	*129.73*	128.97	127.87
4	123.45	**119.33**	*119.75*	*119.65*	118.97	117.75
5	115.15	111.61	111.87	111.73	111.05	109.54
6	108.12	104.77	104.89	104.75	103.82	**100.14**
7	101.56	**97.69**	**97.84**	**97.66**	**95.83**	88.77
8	**90.77**	87.03	87.1	87.01	86.11	82.14

What's new here?

- Model the imperfect world: short-sighted policymakers.
- Iterative decision making [repeated game]
- Key findings?

Even Non-cooperative Policymaking with foresight is better than myopic policy-making.

Cooperation is a little better still.

Comparison with other models?

- WITCH (World Induced Technical Change Model) from FEEM

Optimal growth model with climate damages.

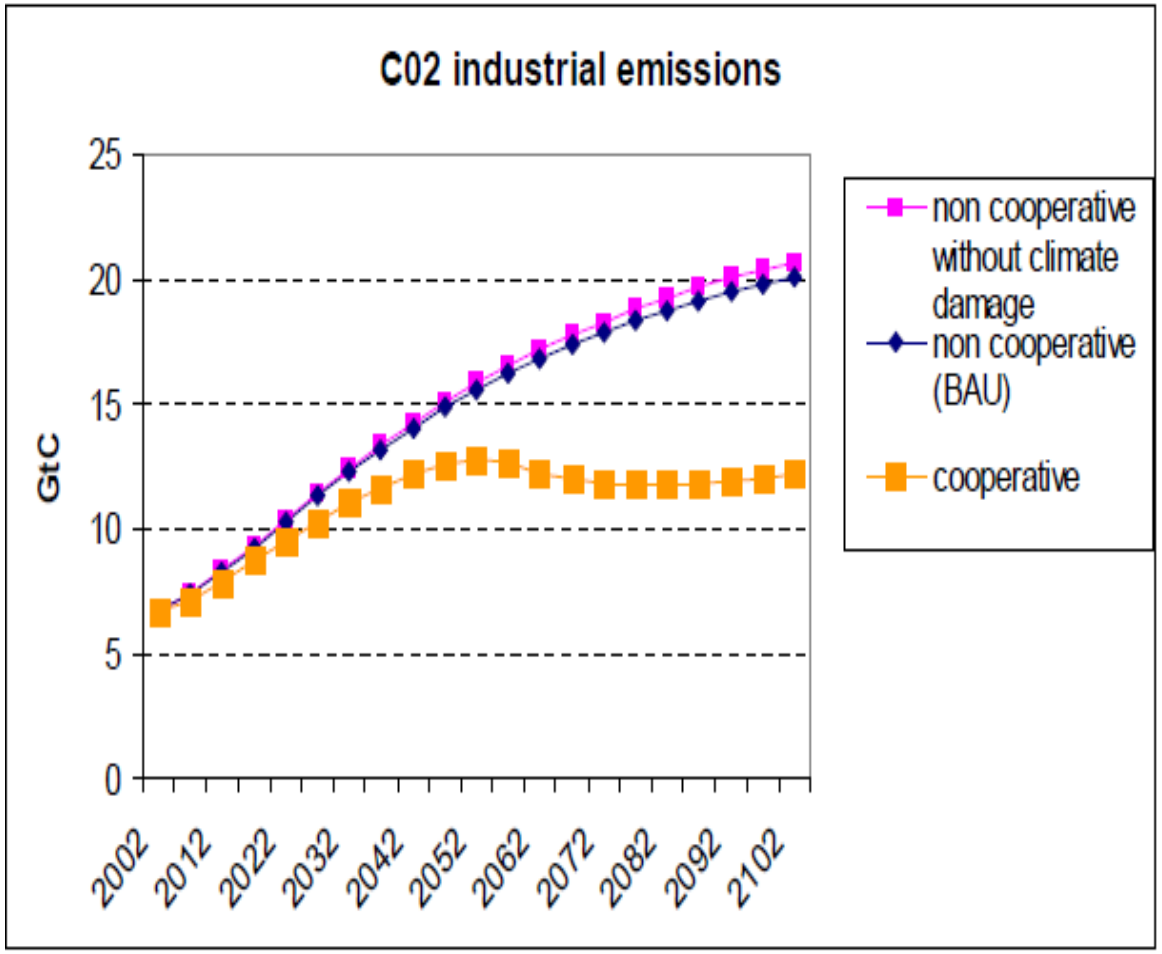
Very sophisticated representation of energy sector and technological learning.

12 regions.

Nash solution: One-off game maximizing regions' Net Present Value (NPV)

Cooperative solution: Maximize global NPV

Big Difference between Nash and Cooperative Solution?



Conclusions and Unresolved Questions

- For short-sighted policymakers, some foresight is better than none.
- A Nash regime without cooperation is good enough. Cooperation is better.
- Why the difference between the iterative decision making and a WITCH type one-off game?