International Technology Agreements

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Kyoto agreement – finally there but

- **Many participants, few with emission targets**
- **Weak emission targets (1 % of global emissions)**
- **Will targets be honored?**
- **2013- ??**

Alternatives to Kyoto

- **Agreements on policy (e.g. emission tax)**
- **Technology elements; reduce cost of abatement**
    - **Supplement an emission agreement**
    - **Separate agreement**

International technology agreement:

- **Spur climate-friendly technologies**
- **International spillovers exist**

Possible design

- **Commit governments to finance (basic) research**
- **Specify technology standards**
- **Stimulate information sharing between firms (RJV)**
- **Reduce private R&D costs (subsidy, tax breaks)**
    - **Correct for international technology spillovers**

Present paper

- **Private firms, no RJV**
- **Two types of international technology agreement**
    - **R&D expenditures determined**
    - **Technology subsidy determined**
- **Compare these agreements**
- **Compare agreements to benchmark outcomes**
    - **No international agreement**

      Countries have environmental policy
    - **First-best (ideal) outcome**

Main assumptions – international tech. agreement

- **Agreements to support the first-best outcome is possible to design, but assumed not feasible to implement**
- **Full participation**
  - **Main results probably robust under limited participation , or even strengthened**
  - **Fruitful to study incentives within an agreement (?)**
- **International technology agreements are second-best agreements; maximize global welfare given available instruments and subject to how agents will respond**
  - **Each country maximizes its welfare.**
  - **Each firm maximizes profits.**
- **Technology spillovers across firms and countries**

Technology spillovers - modeling

Y – technology level

X – R&D investment

x_i - R&D investment in other domestic firms

x_j^* - R&D investment in foreign firms

$$Y = F(X, x_1, ..., x_{m-1}, x_1^*, ..., x_N^*)$$

Features

- $F_i' > 0$
- F_1' is the largest derivative

  (diffusion coefficient less than one)
- $F_{ii}'' < 0$
- $F_{ij}'' > 0$

Technology spillovers – simplification

Linear spillovers ($F'' = 0$)

All firms are identical (*m* firms in each of *n* countries)

Technology level of representative domestic firm

$$Y = X + \gamma\left[(m-1)x + (n-1)mx^*\right], \quad \gamma < 1$$

In equilibrium ($X = x,\ X^* = x^*,\ Y = y,\ Y^* = y^*$ **)**

$$x = hy + (H-h)y^*, \quad H < h,\ H < 1$$

Technology spillovers - incentives

- **The groups of all countries take all spillovers into account when designing a second-best agreement**
- **Each country takes into account domestic spillovers, but neglects international spillovers**
- **Each firm neglects spillovers**

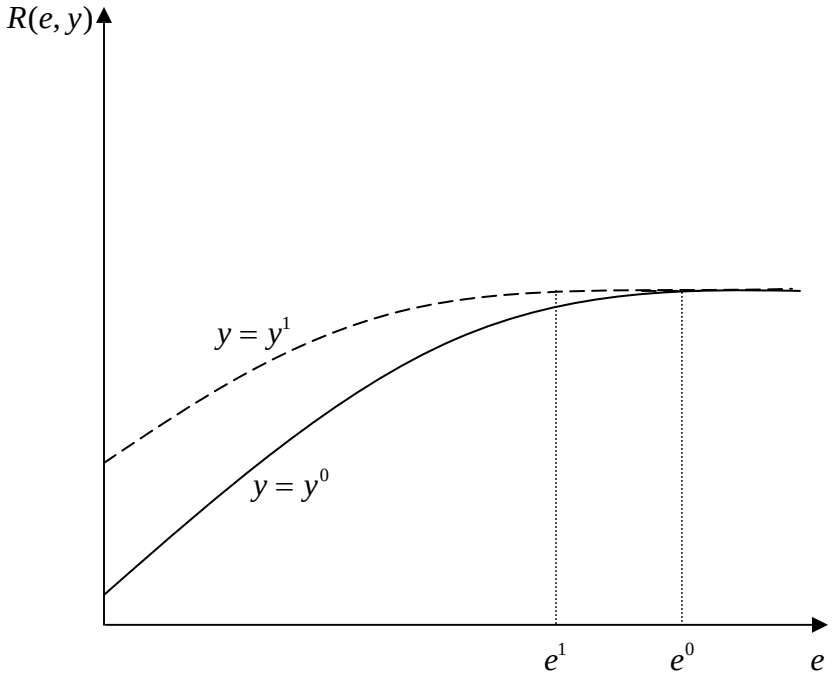
Firms – income

Income function for each firm: $R(e, y)$

$\max_e R(e, y) = \bar{R}$

$R_y > 0$ **and** $R_e > 0$ **and** $R_{ey} < 0$ **for** $R(e, y) < \bar{R}$

Improved technology reduces marginal abatement cost



Firms - R&D investment

Completely neglects spillovers

R&D is subsidized by the rate σ. Price is $1-\sigma$.

Emissions imposed on the firm by the government

(identical firms)

Each firm maximizes profits wrt. R&D investment

Derive R&D decision rule of the firm:

$R_y(e,y) = 1-\sigma$ or $y = y(e,\sigma)$; $\quad y_e < 0,\ y_\sigma > 0$

This rule is applied in all four cases.

No international agreement (N)

Each country maximizes its net benefit wrt. its emissions and technology subsidy, taking foreign emissions and foreign technology subsidies as given.

Net benefit: Revenue less R&D costs and environmental costs
Linear damage function

$$R_e(e, y) = \delta$$

$$R_y(e, y) = h \text{ or } R_y h^{-1} = 1$$

<u>Implementing the solution</u>

Remember $R_y(e, y) = 1 - \sigma$ **for each firm**

$$\sigma^N = 1 - h$$

Remember $R_e(e, y) = \delta$ **under no agreement**

Carbon tax: δ

First best (F)

Benovelent planer maximizes global welfare wrt. emissons and R&D, taking into account international technology spillovers.

$R_e(e, y) = n\delta$

$R_y(e, y) = H$ **or** $R_y H^{-1} = 1$

Implement the solution

Remember $R_y(e, y) = 1 - \sigma$ **for each firm**

$\sigma^F = 1 - H > 1 - h = \sigma^N$ **because** $H < h$

Remember $R_e(e, y) = n\delta$

Carbon tax: $n\delta$

Comparing *F* and *N*

$e^N > e^F$

$y^N < y^F$

Technology agreement – R&D determined directly (RD)

Stages:

(1) The group of all countries jointly determines R&D level in each country so that global welfare is maximized, given how countries and firms will respond in the next stages.

(2) Each country determines its emissions and imposes a technology subsidy so that firms in the next stage choose R&D expenditures which are equal to the imposed R&D level from the agreement.

(3) Firms choose R&D, given imposed emission level and technology subsidy.

R&D agreement - results

Determination of emissions

$R_e(e, y) = \delta$

Similar rules as in the case of no agreement

Determination of R&D: second –best agreement

$\sigma^{RD} > \sigma^{F}$

Intuition:

Each country uses $R_e = \delta$, but ideal rule is $R_e = n\delta$.

How to reduce emissions?

Stimulate R&D through a high technology subsidy as

increased R&D makes abatement cheaper.

Technology subsidy agreement (*S*)

Stages:

(1) The group of all countries jointly determines common technology subsidy so that global welfare is maximized, given how countries and firms will respond in the next stages.

(2) Each country determines its emissions and imposes the agreed upon technology subsidy.

(3) Firms choose R&D, given imposed emission level and technology subsidy.

Subsidy agreement – results

Each country maximizes its welfare by choosing emission level, given the agreed upon technology subsidy.

Relationship between emission level and subsidy depends on third-order derivatives of the income function *R*.

For optimal subsidy; $R_e < \delta$ **(** $R_e(e, y) = \delta$ **under no agreement)**

Intuition:

$\sigma^S > \sigma^N$ **; a country is forced to a higher R&D than the R&D level following from its pure self interest.**

How can the country reduce its R&D level?

Increased emissions will make R&D investment less profitable

Comparing second-best agreements – main result

Global welfare higher under R&D agreement than under subsidy agreement.

Intuition:

Subsidy agreement; country has incentive to increase emissions in order to reduce the high R&D level that follows from the high technology subsidy imposed by the agreement.

Increased emissions lower welfare.

R&D agreement; no such incentive to increase emissions because R&D level is determined by the agreement.

How much better is R&D agreement than subsidy agreement?

What is the gain of supplementing a quota agreement with R&D elements?

Calibration

$R(e,y) = \bar{R} - (e-b)^2 y^{-\alpha}$ (meets all requirements if $0 < \alpha < 1$)

$b = e_{BAU} = 1$

$\alpha = 0.5$

$\gamma = 0.01$

$nm = 100$

$e_{BAU} = 2e_F$

Base case: $n = 10 \rightarrow h = 0.96, \quad H = 0.50$

Three second-best agreements:

Technology subsidy (S)

R&D determined directly (RD)

Tradable quota agreement (Q)

	$n=10$ $\gamma=0.01$			$n=2$ $\gamma=0.01$			$n=10$ $\gamma=0.001$		
	S	*RD*	*Q*	*S*	*RD*	*Q*	*S*	*RD*	*Q*
h	0.96	0.96	0.96	0.76	0.76	0.76	0.99	0.99	0.99
H	0.50	0.50	0.50	0.50	0.50	0.50	0.91	0.91	0.91
Welfare	1	4	88	22	56	95	1	4	99.8
Emissions	0.999	0.991	0.56	0.959	0.813	0.526	0.999	0.991	0.50
Technology	$1*_{10^{-5}}$	0.01	0.22	0.01	0.22	0.28	$2*_{10^{-5}}$	0.01	0.25

Welfare under $BAU = 0$

Welfare under $F = 100$

- $n=10$, $S/N \rightarrow RD < Q \rightarrow F$
- $n=2$, $S/N \rightarrow RD > Q \rightarrow F$ **(but:** Q **close to** F**)**
- $n=10$, $\gamma=0.001$, $S/N \rightarrow RD > Q \rightarrow F$ **(but:** $Q \approx F$**)**

Welfare always higher under Q **than under** RD**, but reverse ranking is possible under other assumptions; GH (2006)**

Main findings

- **Design of technology agreement matters**
- **Agreement on R&D outperforms subsidy agreement**
- **Maybe more important to supplement quota agreement with technology elements than to establish technology agreement**