Political Measures for Strategic Environmental Policy with Induced Effect

A. Ohyama[#] and M. Tsujimura[*]

[#] *Graduate School of Economics, Kyoto University*
[*] *Faculty of Economics, Ryukoku University*

December 15, 2005

Supported by Daiwa Securities Group Inc and the Ministry of Education, Culture, Sports, Science and Technology

Outline

- 1. Background / Purpose
- 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- 4. Conclusion

【 Background】

Kyoto protocol on global warming came into effect on 16 February 2005.

- Japan will be obliged to reduce its greenhouse gases (GHGs) emissions by 6% at the level of 1990,
- while the European Union must reduce their emissions by 8%.

↓

To achieve the target,

- the EU has introduced the emissions trading system.
- On the other hand, Japanese government discusses introducing the environmental tax.

【 Purpose】

The purpose of this paper is to investigate environmental policies designed to reduce the emission of a pollutant like GHGs under uncertainty.

【 Formulation】

In order to investigate, we formulate the agents' problems as optimal stopping problems.

1. Single-agent case ⇐ "Optimal" case

2. Tow competing agents case

External economic effect (Induce Effect: IE)

We find that the environmental policy does not be easily enforced because of the IE.

To promote the environmental policy, we consider the following three political measures:

3.1 environmental subsidy

3.2 environmental tax

3.3 emissions trading system

The environmental subsidy and tax promote the environmental policy. However they do not create an incentive to be the leader.

On the other hand,
emissions trading system not only promotes the environmental policy but also creates an incentive to be the leader.

Outline

- □ 1. Background / Purpose
- ■ 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- □ 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- □ 4. Conclusion

【Agent】

Agents want to reduce the emission of a pollutant because they damage from it.

【Damage】

Damage function: $$B^i(X_t, Y_t^i) = X_t Y_t^i$$

Shift parameter: $$dX_t = \mu X_t dt + \sigma X_t dW_t$$

X_t converts damage into money amount and reflects demographic changes that raises the damage.

Pollutant stock:

$$dY_t^i = \begin{cases} \pi_0^i dt - \delta Y_t^i, & t < \tau^i, \\ \pi_1^i dt - \delta Y_t^i, & t \geq \tau^i. \end{cases}$$

policy enforcement time (τ^i)

natural decay ($-\delta Y_t^i$)

Pollutant flow: $\pi^{i}_{N_i, N_j}$

$$N_k = \begin{cases} 0, & \text{agent } k \text{ has not enforced the policy} \\ 1, & \text{agent } k \text{ has enforced the policy} \end{cases}$$

Enforcement Cost: K^i

【 Agent *i*'s Problem】

$$V^i(x, y) = \inf_{\tau^i} E\left[\int_0^\infty e^{-rt} B^i(X_t, Y_y^i) dt + e^{-r\tau^i} K^i \right]$$

Outline

- 1. Background / Purpose
- 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- 4. Conclusion

Single-Agent Case

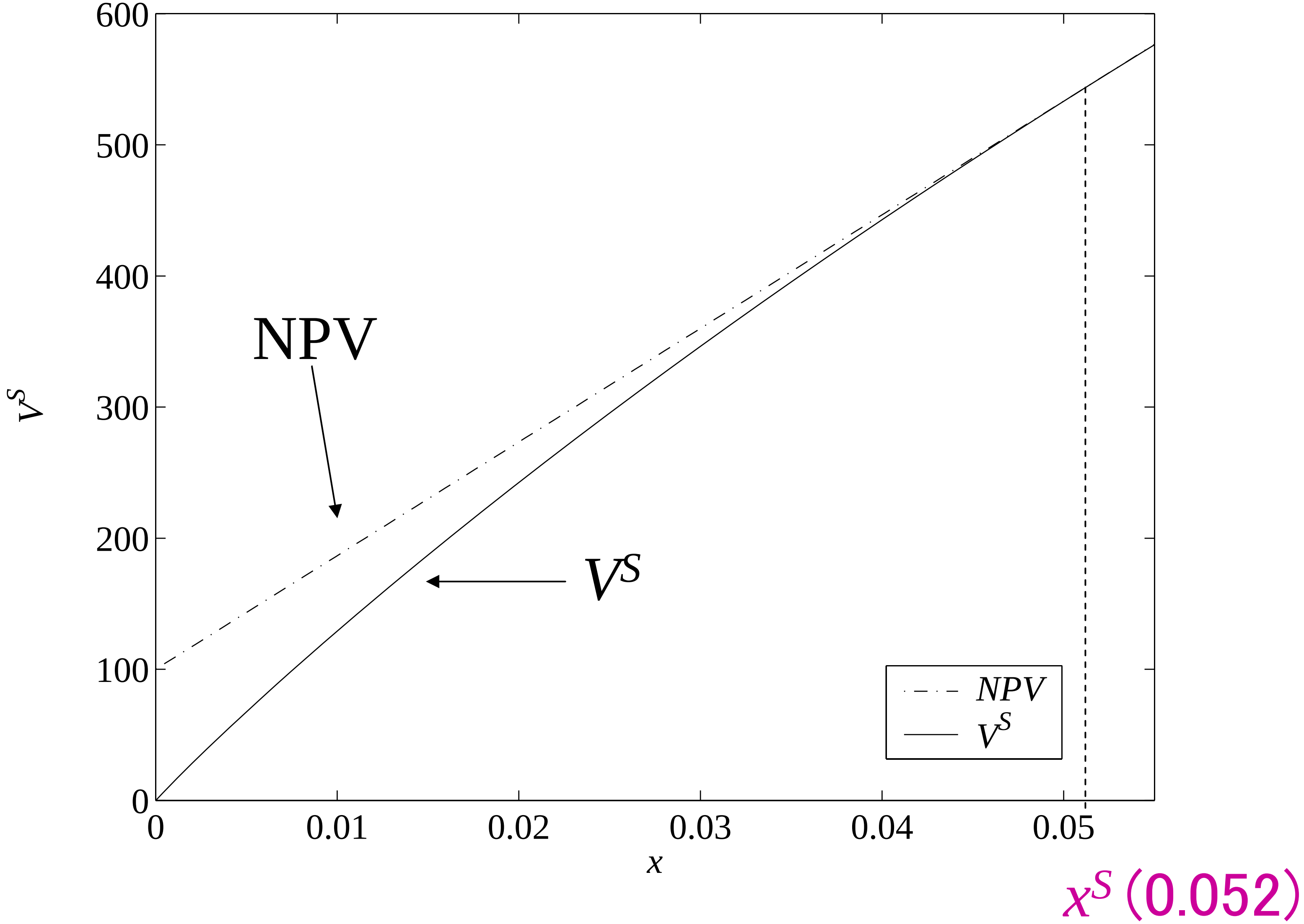
【Value function】

OV of future enforcement

PV of damage

$$V^S(x,y)=\begin{cases}A_1x^{\beta_1}+\dfrac{x\pi_0^S}{\rho_1\rho_2}+\dfrac{xy}{\rho_2}, & x<x^S,\\ \dfrac{x\pi_1^S}{\rho_1\rho_2}+\dfrac{xy}{\rho_2}+K^S, & x\geq x^S.\end{cases}$$

The value function for the single agent



Outline

- ☐ 1. Background / Purpose
- ■ 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- ☐ 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- ☐ 4. Conclusion

Assumptions

【Emission Flow】

(initial) $\pi_{00}^{L} = \pi_{00}^{F} = \pi_{0}^{S}$ (after) $\pi_{11}^{L} = \pi_{11}^{F} = \pi_{1}^{S}$

$$(\pi_0^S - \pi_1^S) = (\pi_{00}^L - \pi_{10}^L) + (\pi_{00}^F - \pi_{01}^F)$$
$$= (\pi_{10}^L - \pi_{11}^L) + (\pi_{01}^F - \pi_{11}^F) \qquad \text{(AS.2)}$$

IE

$$\pi_1^S \le \pi_{10}^L \le \frac{\pi_0^S}{2} \qquad \frac{\pi_0^S}{2} \le \pi_{01}^F \le \pi_0^S$$

【Enforcement Cost】

$$2K^S = K^L + K^F \qquad \text{(AS.3)}$$

(AS.2)

We assume that if one agent enforces the environmental policy, this affects environmental improvement for another agent.

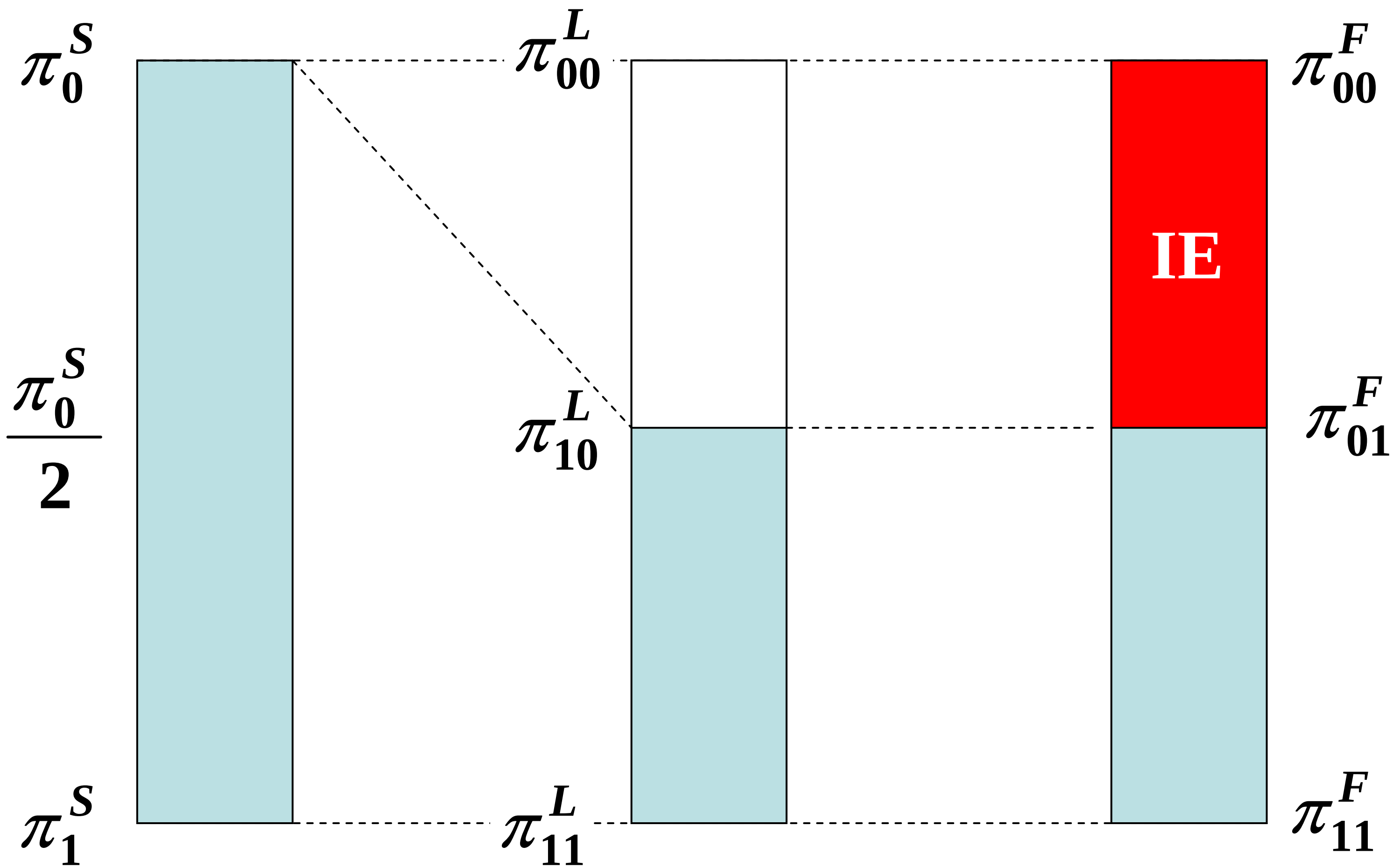
= the other agent's environment improves because of the policy enforcement.

We call this effect as the induced effect (**IE**) as in Barrieu and Chesney(2001).

We consider three cases:

Induced effect is complete, partial, and nothing.

Complete Induced Effect



The complete induced effect is applied to analyze global warming problems.

Follower's Problem

As in the standard strategic real-options framework, we assume that the leader has already implemented the policy.

【Value function for the follower】

OV of future implementation

$$V^F(x,y) = \begin{cases} \dfrac{x\pi_{01}^F}{\rho_1\rho_2} + \dfrac{xy}{\rho_2} + \left(\dfrac{x}{x^F}\right)^{\beta_1}\left[K^F - \dfrac{x^F(\pi_{01}^F - \pi_{11}^F)}{\rho_1\rho_2}\right], & x < x^F \\ \dfrac{x\pi_{11}^F}{\rho_1\rho_2} + \dfrac{xy}{\rho_2} + K^F, & x \geq x^F \end{cases}$$

Leader's Problem

We assume that the leader makes a policy decision under the assumption that the follower will act optimally in the future.

【Assumptions】

1) Once the leader enforces the environmental policy, the leader has no decisions to make.

2) The leader benefits from the future policy enforcement by the follower due to the induce effect.

#【Value function】

OV of the future enforcement

$$V^L(x,y)=\begin{cases} \dfrac{x\pi_{00}^L}{\rho_1\rho_2}+\dfrac{xy}{\rho_2}+\left(\dfrac{x}{x^L}\right)^{\beta_1}\left[K^L-\dfrac{x^L(\pi_{00}^L-\pi_{10}^L)}{\rho_1\rho_2}\right] \\ \qquad -\left(\dfrac{x}{x^F}\right)^{\beta_1}\left[\dfrac{x^F(\pi_{10}^L-\pi_{11}^L)}{\rho_1\rho_2}\right], & x<x^L \\ \dfrac{x\pi_{10}^L}{\rho_1\rho_2}+\dfrac{xy}{\rho_2}+K^L-\left(\dfrac{x}{x^F}\right)^{\beta_1}\left[\dfrac{x^F(\pi_{10}^L-\pi_{11}^L)}{\rho_1\rho_2}\right], & x\in[x^L,x^F] \\ \dfrac{x\pi_{11}^L}{\rho_1\rho_2}+\dfrac{xy}{\rho_2}+K^L, & x\geq x^F \end{cases}$$

the option-like term

Proposition 3.1, 3.2

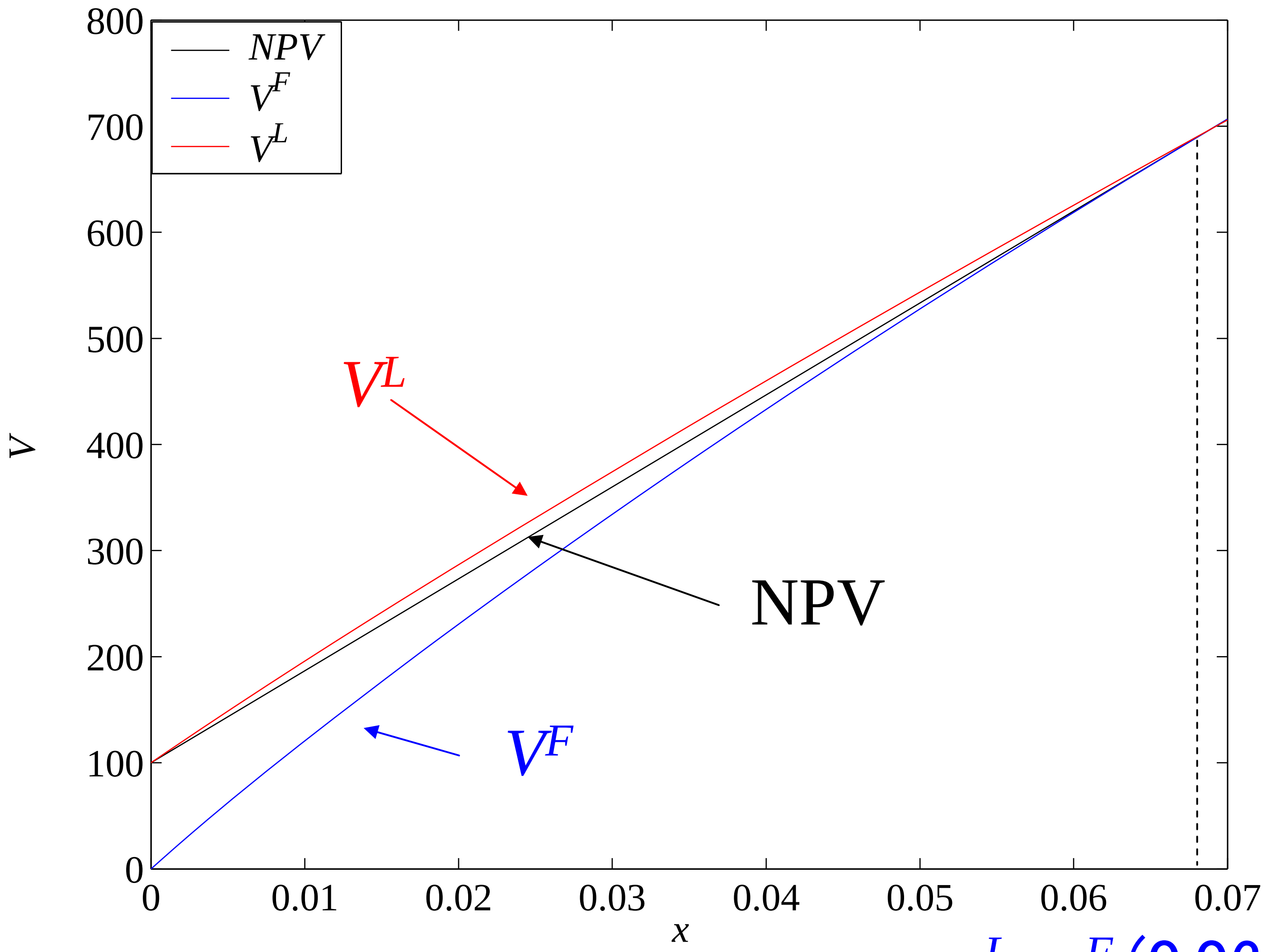
- $x^L = x^F$

The leader and follower simultaneously enforce the environmental policy.

- $x^S < x^L = x^F$ Degree of inequality depends on the IE

This implies that the environmental policy does not be easily enforced because of the IE.

The value for the leader and follower



$x^L = x^F$ (0.069) > x^S

Outline

- 1. Background / Purpose
- 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- 4. Conclusion

Standard threshold

In part 2, we show that if there exists the IE, the thresholds of the leader and follower are larger than the threshold of the single-agent case.

↓

We assume that x^S is a standard threshold.

In this part, we investigate political measures:
(1) environmental subsidy,
(2) environmental tax and
(3) emissions trading system
in order to resolve the induced effect.

↓

Standard threshold

We show that the magnitude of political measures:

- the amount of the environmental subsidy
- the amount of environmental tax
- the price of emission permits

so that the thresholds in these political measures coincide with x^S.

In this context, we use “optimal” magnitude of political measures.

We assume that $K := K^S = K^L = K^F$

Outline

- 1. Background / Purpose
- 2. Optimal timing for environmental policy
  - 2.1 Single-agent case
  - 2.2 Strategic competing agents case
- 3. Political measures
  - 3.1 Environmental subsidy
  - 3.2 Environmental tax
  - 3.3 Emissions trading system
- 4. Conclusion

Tradable emission permits (TEP)

We assume that each agent is regulated by a constant allocation of allowances for each pollutant emission flow.

Suppose that the leader enforces the environmental policy earlier than the follower.

- Then, the leader can sell excess allowances to the follower in the market.
- On the other hand, the follower must purchase emissions allowances in order to offset the excess amount of the emission standard.

TEP

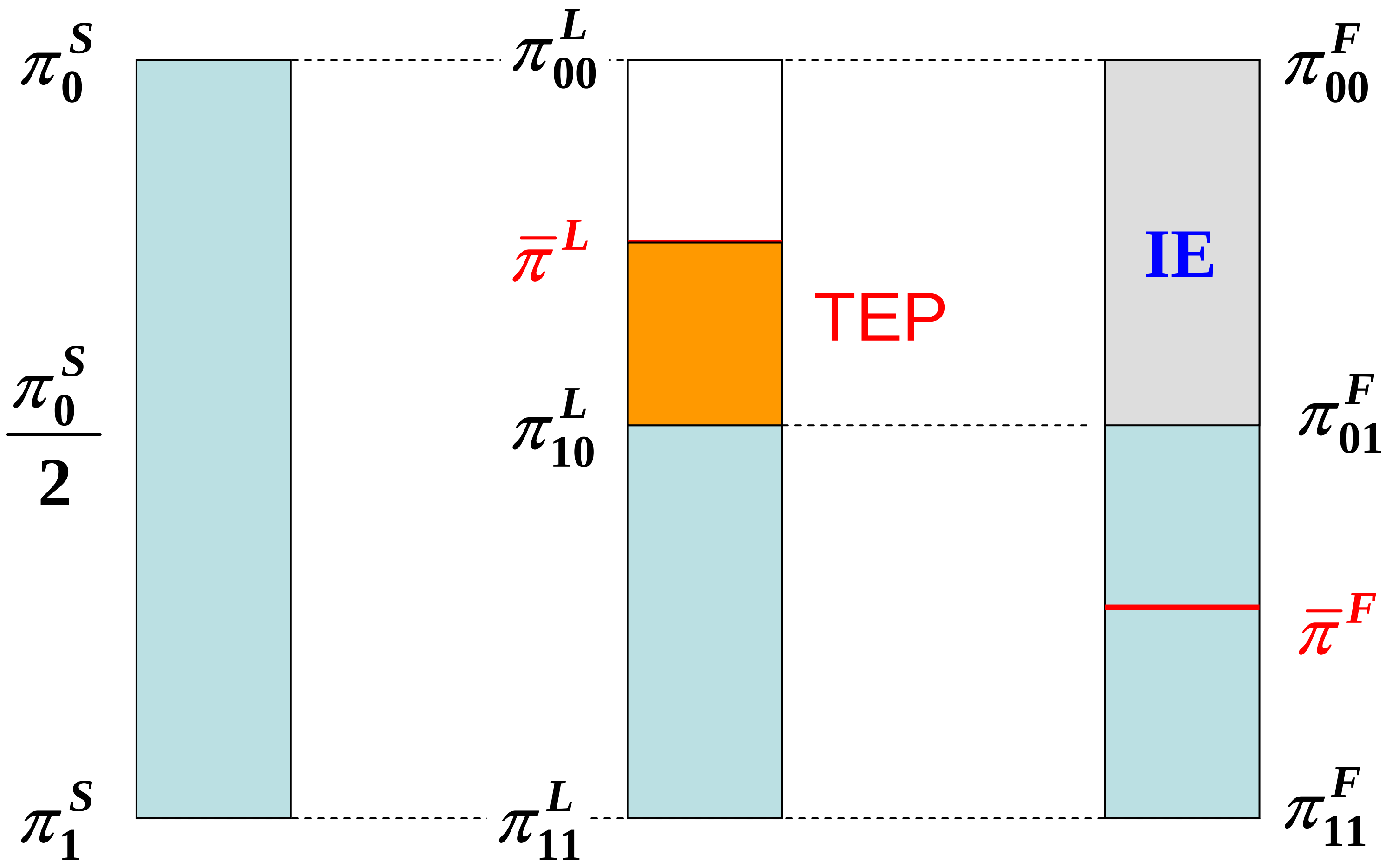
【emission standard】

$$\overline{\pi}^{L} = \pi_{10}^{L} + \frac{\pi_{00}^{L} - \pi_{10}^{L}}{2}, \quad \overline{\pi}^{F} = \pi_{11}^{F} + \frac{\pi_{01}^{F} - \pi_{11}^{F}}{2}.$$

We assume that the trading terminates after both agents enforce the environmental policy.

Furthermore, we assume that the IE is complete. That is, we can think a pollutant as a GHG like CO2.

TEP: Complete Induced Effect



TEP

【price of the TEP】

$$C = cX_t, \qquad c > 0.$$

【damage functions】

$$B^F(X_t, Y_t^F) = \begin{cases} X_t Y_t^F + cX_t(\pi_{01}^F - \bar{\pi}^F), & t < \tau^{F\text{tep}}, \\ X_t Y_t^F, & t \geq \tau^{F\text{tep}}. \end{cases}$$

$$B^L(X_t, Y_t^L) = \begin{cases} X_t Y_t^L, & t < \tau^{\text{Ltep}}, \\ X_t Y_t^L - cX_t(\bar{\pi}^L - \pi_{10}^L), & \tau^{\text{Ltep}} \leq t < \tau^{F\text{tep}}, \\ X_t Y_t^L, & t \geq \tau^{F\text{tep}}. \end{cases}$$

TEP : Follower

【Value function for the follower】

$$V^{Ftep}(x,y) = \begin{cases} V^{F}(x,y)\Big|_{x^{F}=x^{F\mathrm{tep}}} + \dfrac{cx(\pi_{01}^{F}-\overline{\pi}^{F})}{r-\mu}, & x < x^{F\mathrm{tep}}, \\ V^{F}(x,y), & x \geq x^{F\mathrm{tep}}. \end{cases}$$

TEP : Leader

【Value function for the leader】

$$V^{Ltep}(x,y)=\begin{cases} V^{L}(x,y)\Big|_{x^{L}=x^{Ltep},\,x^{F}=x^{Ftep}}-\left(\dfrac{x}{x^{Ltep}}\right)^{\beta_1}\dfrac{cx(\overline{\pi}^{L}-\pi_{10}^{L})}{r-\mu} \\ \quad +\left(\dfrac{x}{x^{Ftep}}\right)^{\beta_1}\dfrac{cx^{Ftep}(\overline{\pi}^{L}-\pi_{10}^{L})}{\rho_1}, & x<x^{Ltep}, \\ V^{L}(x,y)\Big|_{x^{F}=x^{Ftep}}-\dfrac{cx(\overline{\pi}^{L}-\pi_{10}^{L})}{r-\mu} \\ \quad +\left(\dfrac{x}{x^{Ftep}}\right)^{\beta_1}\dfrac{cx^{Ftep}(\overline{\pi}^{L}-\pi_{10}^{L})}{\rho_1}, & x\in[x^{Ltep},x^{Ftep}] \\ V^{L}(x,y), & x\geq x^{Ftep}. \end{cases}$$

Proposition 4.1

If

$$c > \frac{\pi_{10}^L - \pi_{11}^L}{\rho_2(\pi_{00}^L - \pi_{10}^L)} = \frac{2IE}{\rho_2(\pi_{00}^L - \pi_{10}^L)} \quad \Rightarrow \quad V_{xx}^{Ltep} > 0$$

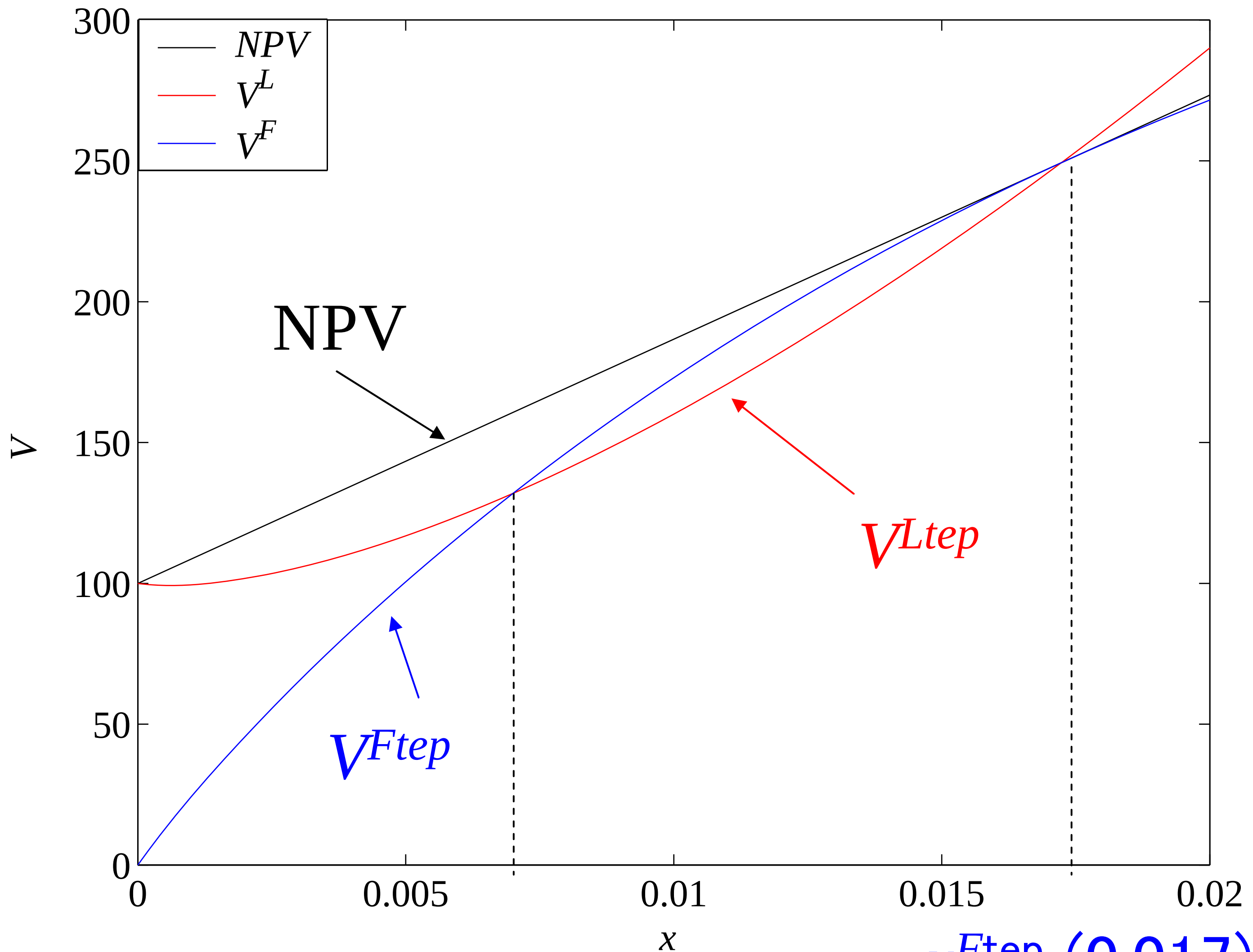
⇒ V^{Ltep} intersects with V^{Ftep} before $x = x^{F\text{tep}}$.

⇒ Agents have an incentive to be a leader.

Furthermore, if the IE is complete,

⇒ $$c > \frac{2}{\rho_2}$$

Value functions: c=200 (> 2/ ρ 2)



$x^{L\text{tep}}$ (0.007)

$x^{F\text{tep}}$ (0.017) < x^S

Outline

Conclusion

The results of our analysis are as follows:

(1) $x^L = x^F$.

(2) $x^S < x^L (= x^F)$

(3) x^L-x^S depends on the magnitude of the IE.

(4) In order to resolve the induced effect ($x^{Lsub} = x^S$, $x^{Ltax} = x^S$, $x^{Ltep} = x^S$), we find the “optimal” magnitude of 3 political measures: subsidy, tax, and emissions trading system.

Furthermore, emissions trading system creates an incentive to be a leader. ($x^{Ltep} < x^{Ftep}$)

In this context, emissions trading system is the most preferable among 3 political measures.