東京大学 海洋アライアンス
UTokyo OCEAN ALLIANCE

Cooperative Management of Trans-boundary Fish Stocks

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PICES 2015 Qingdao, China
October 24, 2015

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Science on Consensus Building Methods Related to Ocean Use

Holistic approach to manage coastal and marine resources

- Fisheries and aquaculture
- Shipping
- Energy
- Recreation
- etc.

→ Building **consensus** among resource users

Trans-boundary Fish Stocks

- 1995 UN Fish Stocks Agreement
- Consensus
  → International cooperation
- Incentives for cooperation
- What are the economic benefits from cooperatively managing the trans-boundary fish stocks?

Previous Economic Studies on Managing Trans-boundary Fish Stocks

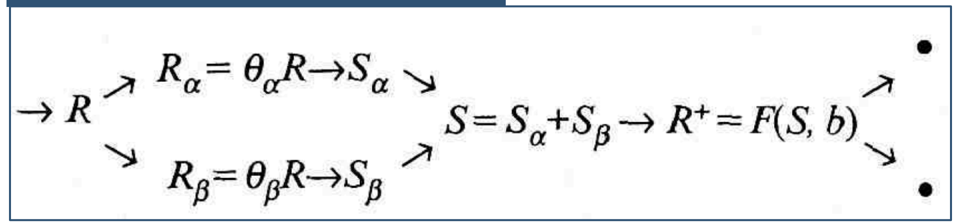
<u>Shared stocks</u>:

- Munro (1979)
- Levhari & Mirman (1980)

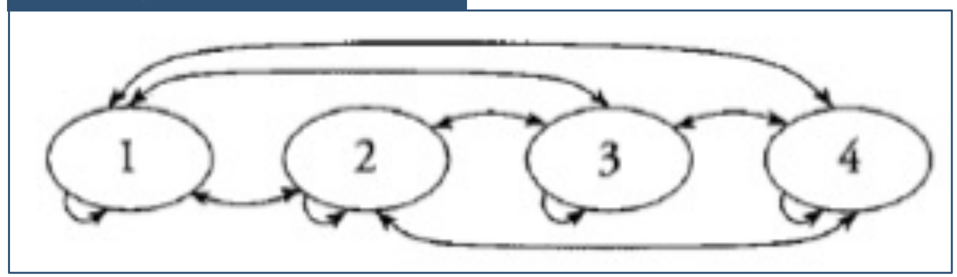
<u>Migrating stocks</u>:

- Golubtsov & McKelevy (2007)
  - Split-stream Harvesting
- Sanchirico & Wilen (1999); Costello & Polasky (2008)
  - Patchy Environment

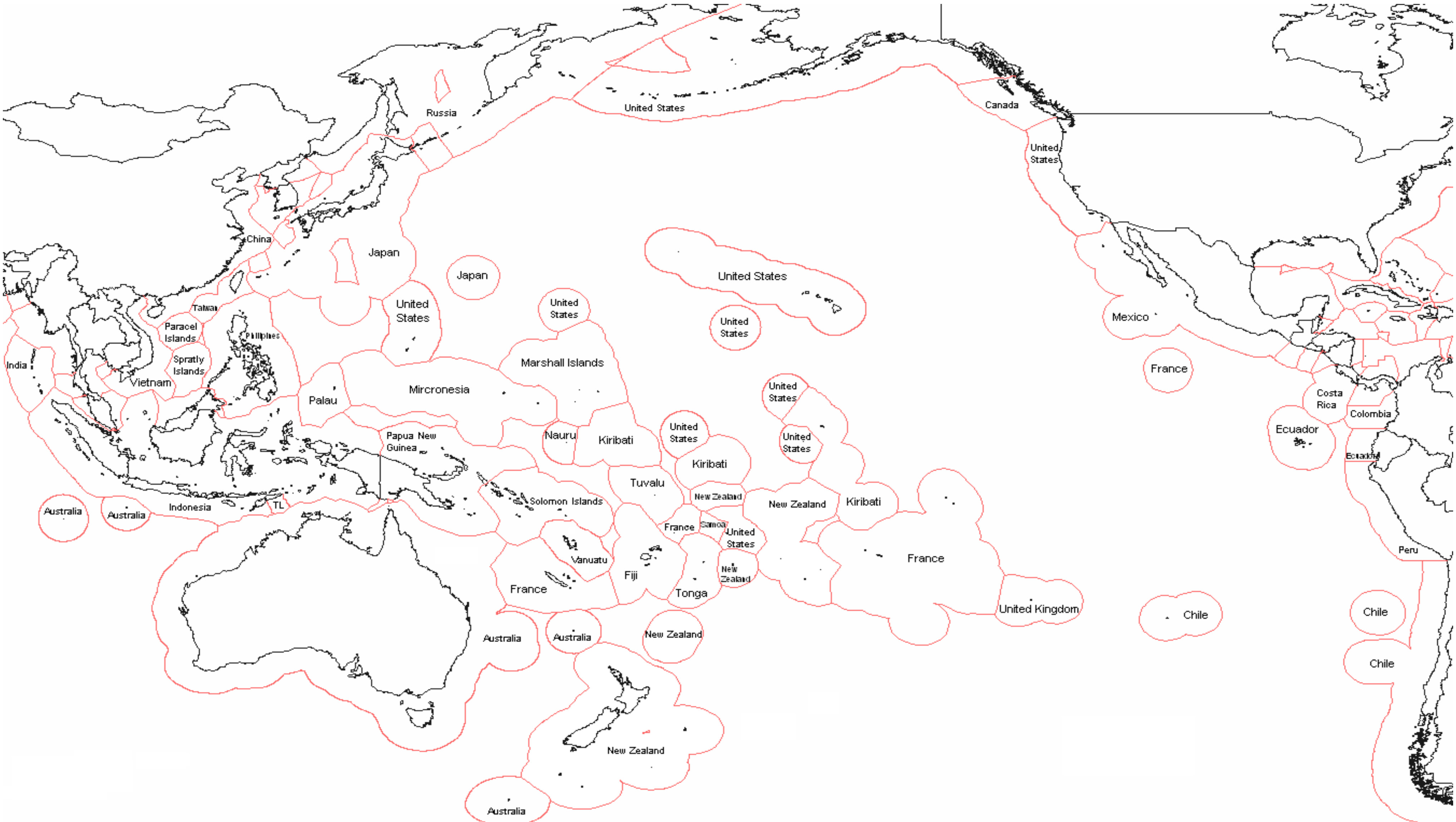
Split-stream Harvesting



Patchy Environment



International Waters



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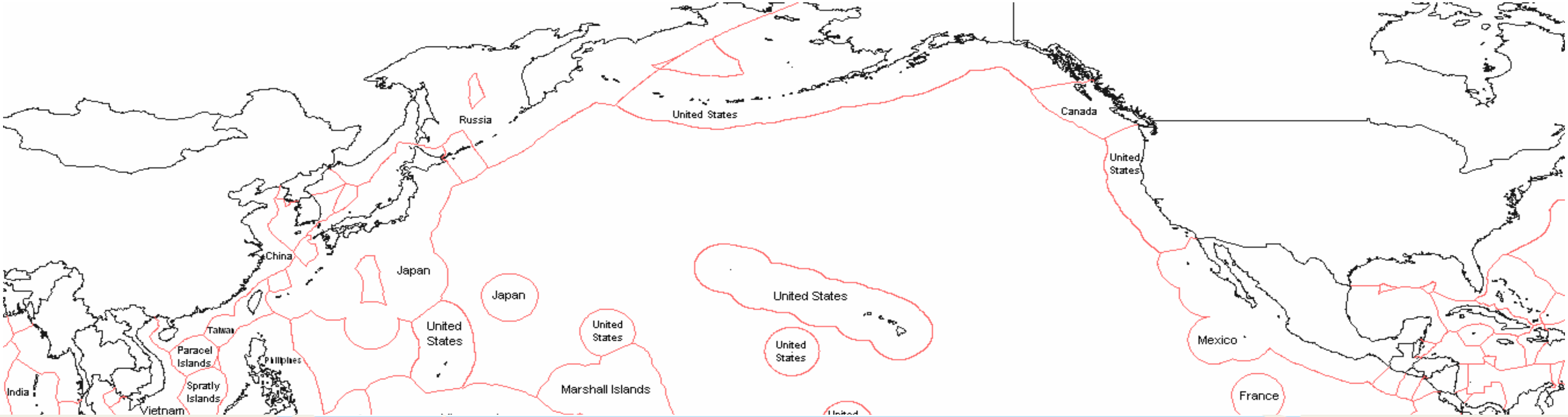
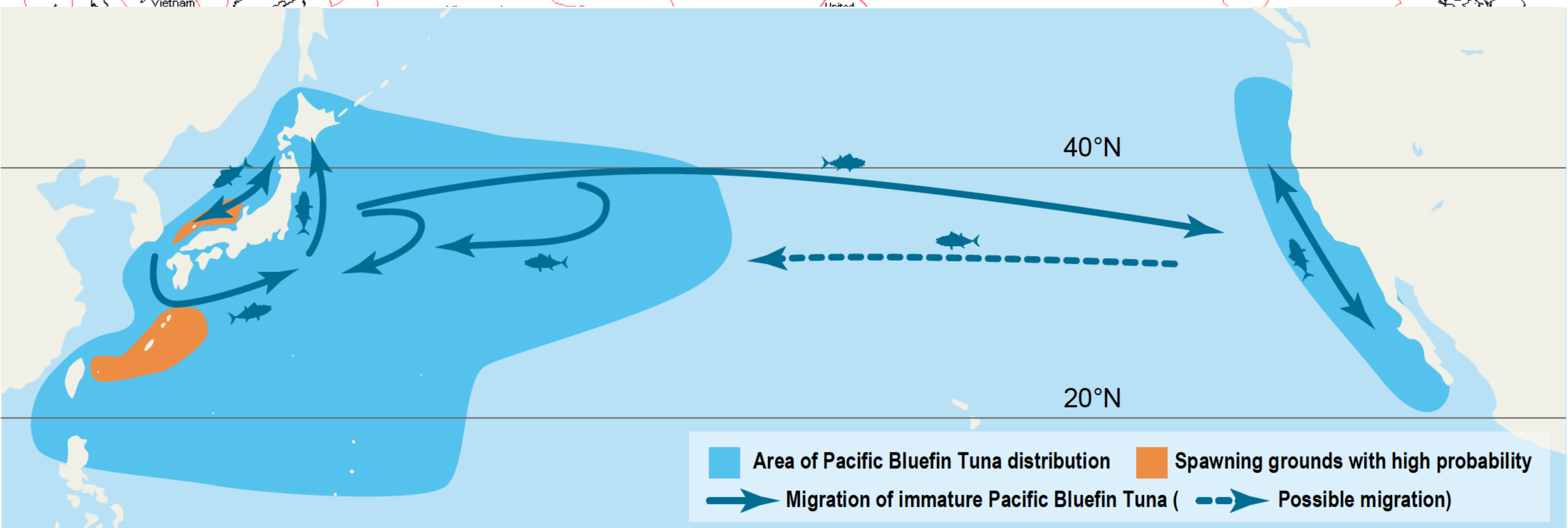
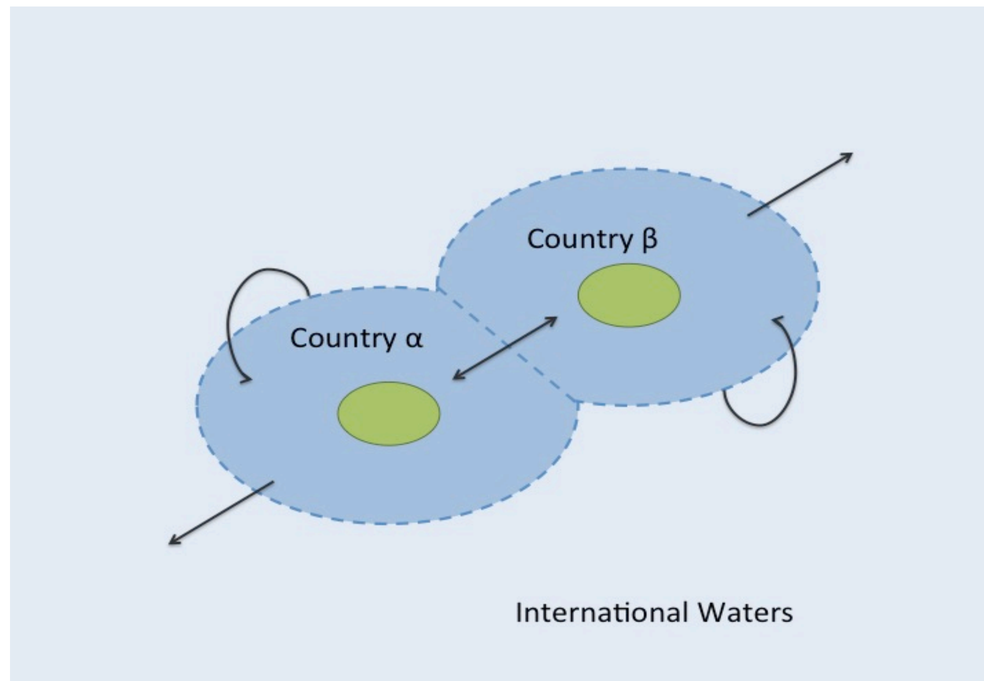




Framework

- EEZs surrounded by international waters
- Fish stocks migrate within and across EEZs
- What's the present value of net benefits from cooperating vs. independently managing the stocks?

$$\dot{S}_{\alpha,t} = F(S_{\alpha,t}) - x_{\alpha,t} - (\phi_\alpha + \delta_\alpha)S_{\alpha,t} + \delta_\beta S_{\beta,t}$$
$$\dot{S}_{\beta,t} = F(S_{\beta,t}) - x_{\beta,t} - (\phi_\beta + \delta_\beta)S_{\beta,t} + \delta_{\alpha,t} S_{\alpha,t}$$



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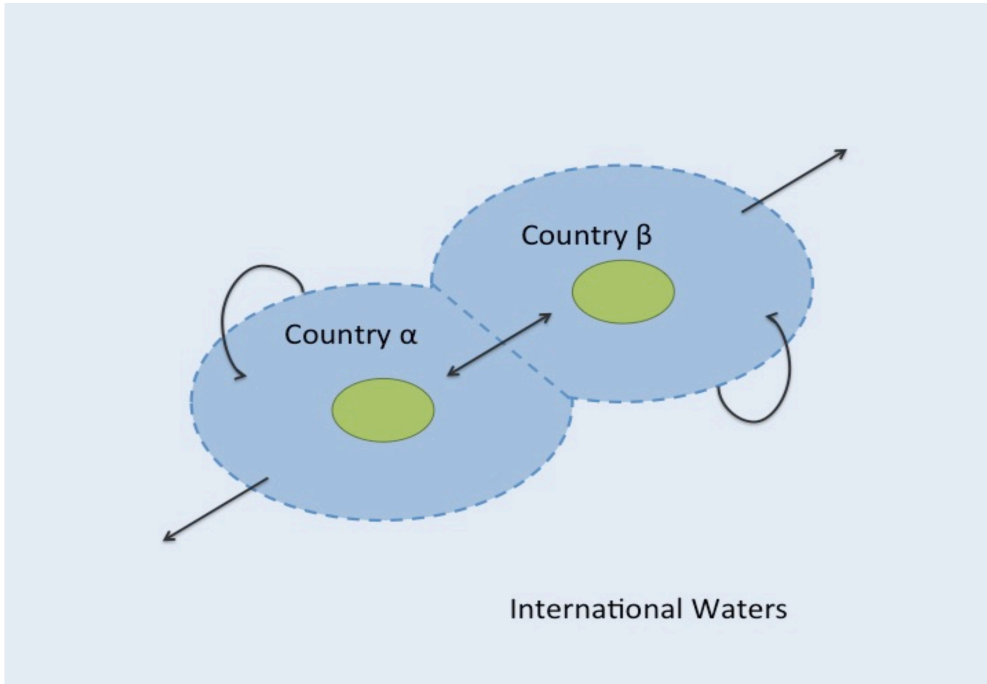
$$\dot{S}_{\beta,t} = \underbrace{F(S_{\beta,t}) - x_{\beta,t}}_{\text{Growth - Harvest}} - (\phi_\beta + \delta_\beta)S_{\beta,t} + \delta_{\alpha,t} S_{\alpha,t}$$



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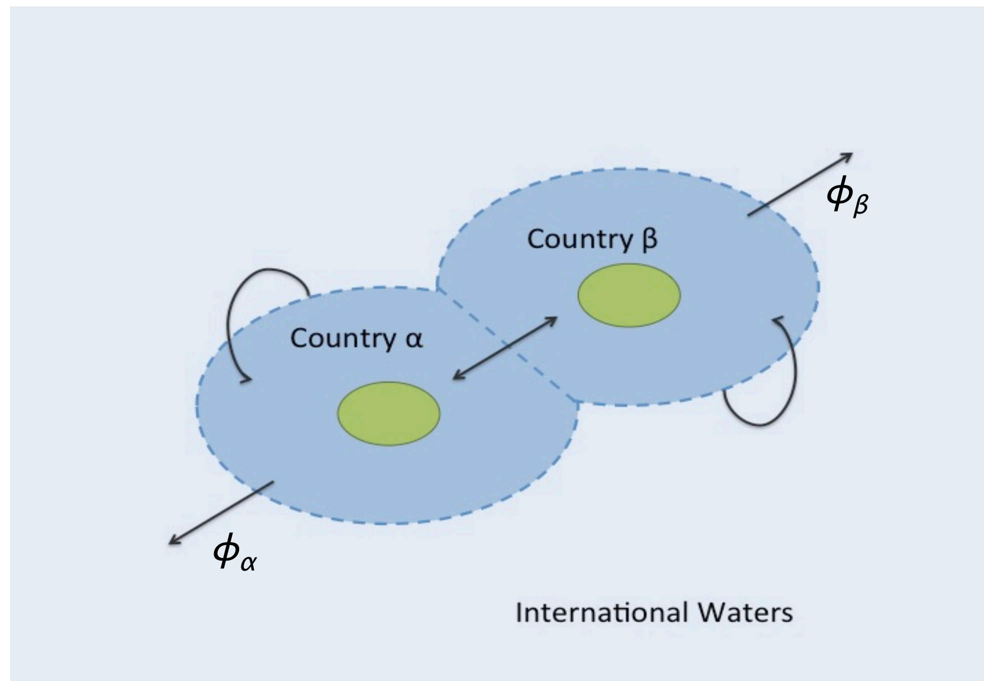
% To international waters



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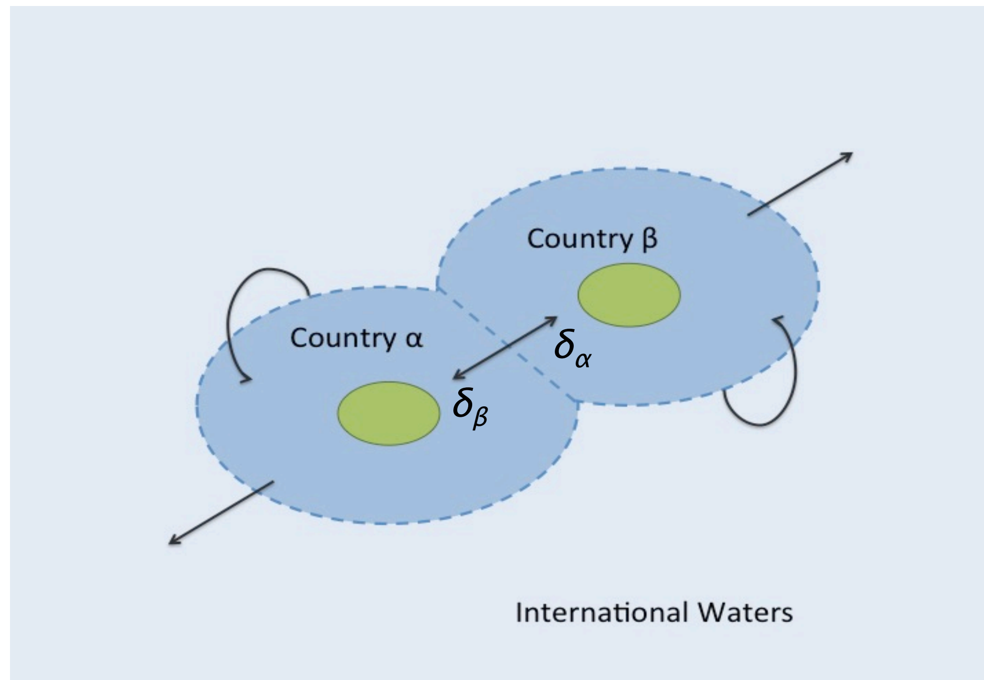
% To neighbor's waters



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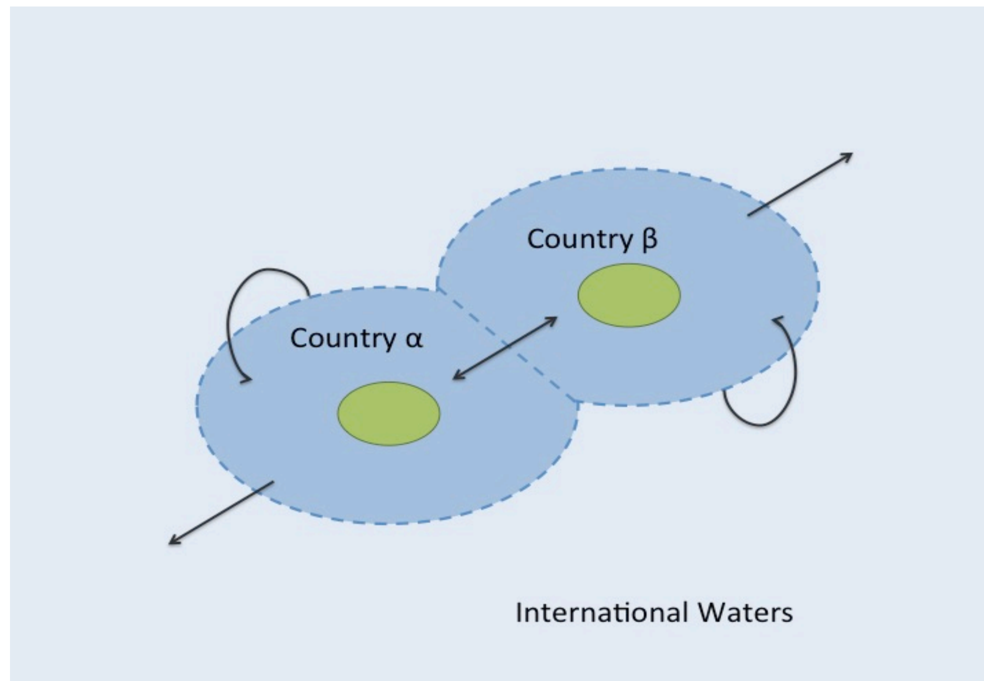
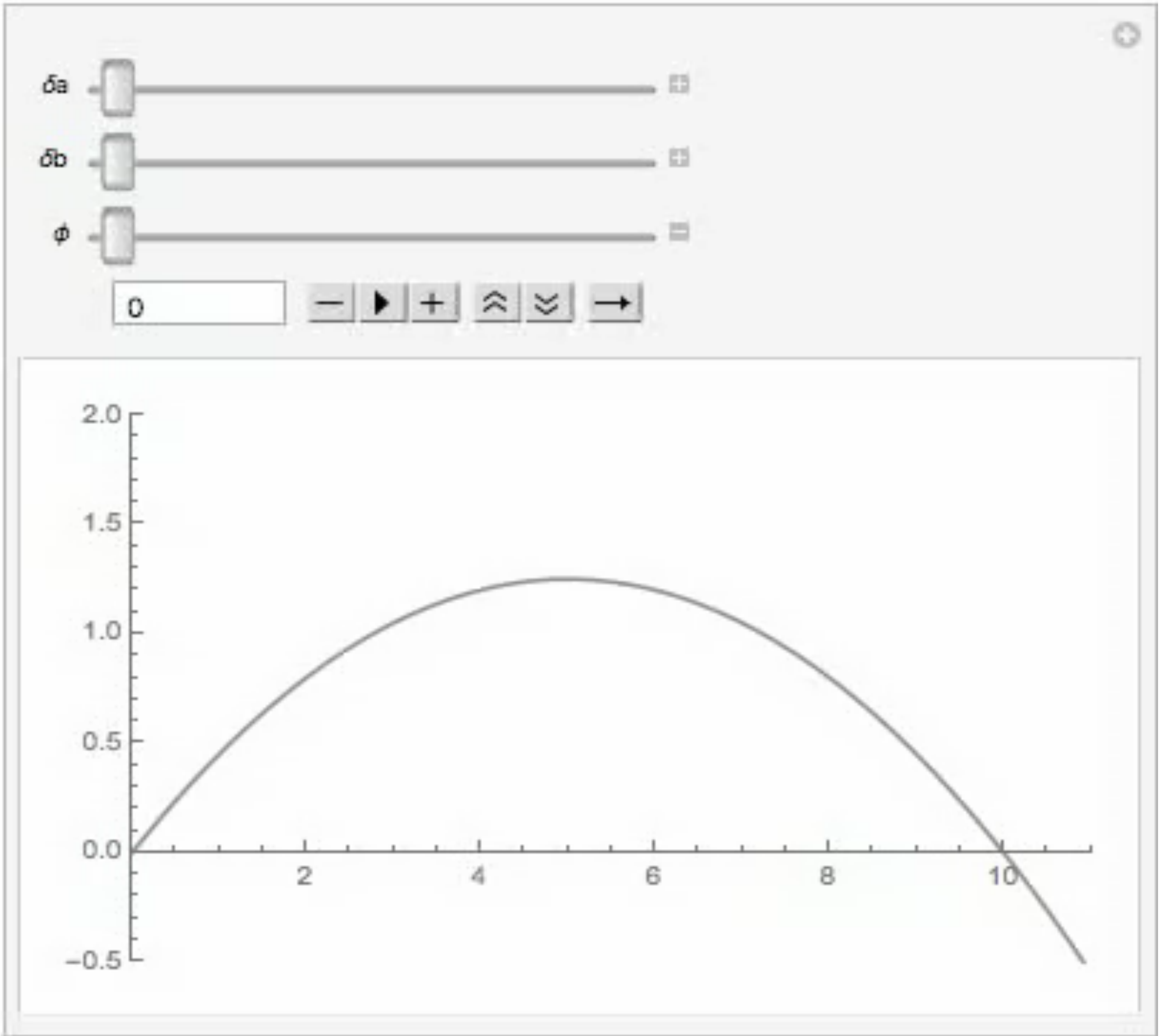
% from neighbor's waters



Fish Growth Function

$$x_{\beta,t} = F(S_{\beta,t}) - (\phi_\beta + \delta_\beta)S_{\beta,t} + \delta_\alpha \bar{S}_{\alpha,t}$$



δ_α : % from neighbor (in)
δ_β : % to neighbor (out)
ϕ_β : % to int'l waters

Cooperative Management

Maximize joint net benefit (= revenue – cost) given resource constraints

Joint Maximization Problem

$$\max_{x_{\alpha,t},x_{\beta,t}} \quad \int_0^\infty e^{-\rho t}[px_{\alpha,t} + px_{\beta,t} - c(S_{\alpha,t})x_{\alpha,t} - c(S_{\beta,t})x_{\beta,t}]dt$$

$$\text{subject to} \quad \dot{S}_{\alpha,t} = F(S_{\alpha,t}) - x_{\alpha,t} - (\phi_\alpha + \delta_\alpha)S_{\alpha,t} + \delta_\beta S_{\beta,t}$$

$$\dot{S}_{\beta,t} = F(S_{\beta,t}) - x_{\beta,t} - (\phi_\beta + \delta_\beta)S_{\beta,t} + \delta_\alpha S_{\alpha,t}$$

$$S_0 \text{ given}$$

$$x_{i,t} \in [0, x^{\max}]$$

Independent Management

α's Maximization Problem

$$\max_{x_{\alpha,t}} \quad \int_0^{\infty} e^{-\rho t}[p x_{\alpha,t} - c(S_{\alpha,t}) x_{\alpha,t}] dt$$

$$\text{subject to} \quad \dot{S}_{\alpha,t} = F(S_{\alpha,t}) - x_{\alpha,t} - (\phi_\alpha + \delta_\alpha) S_{\alpha,t} + \delta_\beta \bar{S}_{\beta,t}.$$

$$S_0 \text{ given}$$

$$x_{i,t} \in [0, x^{\max}]$$

β's Maximization Problem

$$\max_{x_{\beta,t}} \quad \int_0^{\infty} e^{-\rho t}[p x_{\beta,t} - c(S_{\beta,t}) x_{\beta,t}] dt$$

$$\text{subject to} \quad \dot{S}_{\beta,t} = F(S_{\beta,t}) - x_{\beta,t} - (\phi_\beta + \delta_\beta) S_{\beta,t} + \delta_\alpha \bar{S}_{\alpha,t}.$$

$$S_0 \text{ given}$$

$$x_{i,t} \in [0, x^{\max}]$$

Steady State Conditions

Cooperative Management

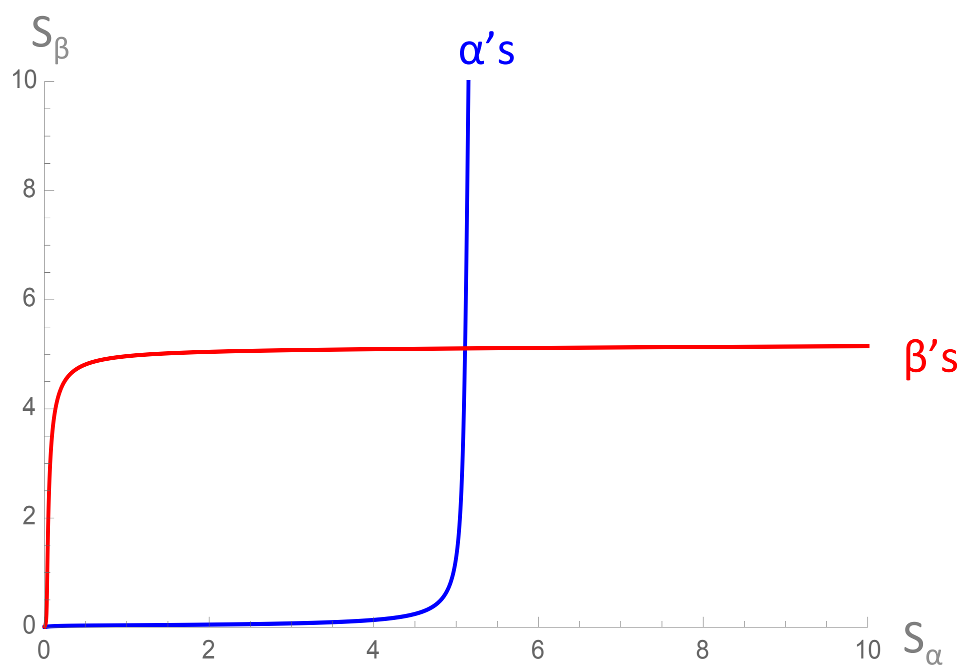
$$[\rho - F'(S_\alpha^C) + (\phi_\alpha + \delta_\alpha)][p - c(S_\alpha^C)] - \delta_\alpha[p - c(S_\beta^C)] + c'(S_\alpha^C)[F(S_\alpha^C) - (\phi_\alpha + \delta_\alpha)S_\alpha^C + \delta_\beta S_\beta^C] = 0$$

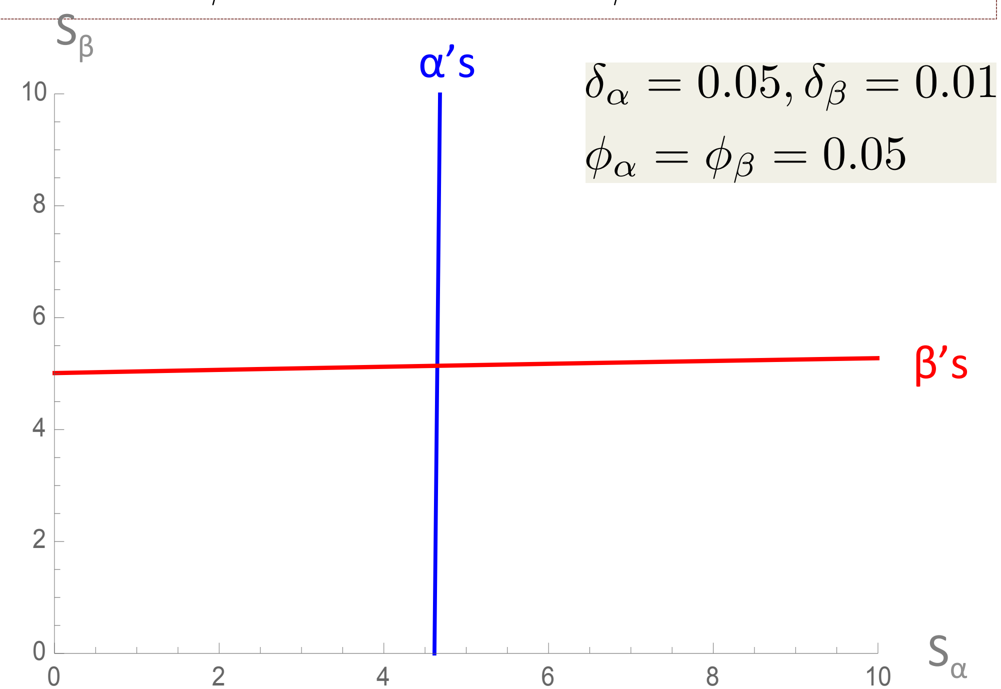
$$[\rho - F'(S_\beta^C) + (\phi_\beta + \delta_\beta)][p - c(S_\beta^C)] - \delta_\beta[p - c(S_\alpha^C)] + c'(S_\beta^C)[F(S_\beta^C) - (\phi_\beta + \delta_\beta)S_\beta^C + \delta_\alpha S_\alpha^C] = 0$$

Independent Management

$$[\rho - F'(S_\alpha^I) + (\phi_\alpha + \delta_\alpha)][p - c(S_\alpha^I)] + c'(S_\alpha^I)[F(S_\alpha^I) - (\phi_\alpha + \delta_\alpha)S_\alpha^I + \delta_\beta \bar{S}_\beta] = 0$$

$$[\rho - F'(S_\beta^I) + (\phi_\beta + \delta_\beta)][p - c(S_\beta^I)] + c'(S_\beta)[F(S_\beta^I) - (\phi_\beta + \delta_\beta)S_\beta^I + \delta_\alpha \bar{S}_\alpha] = 0$$

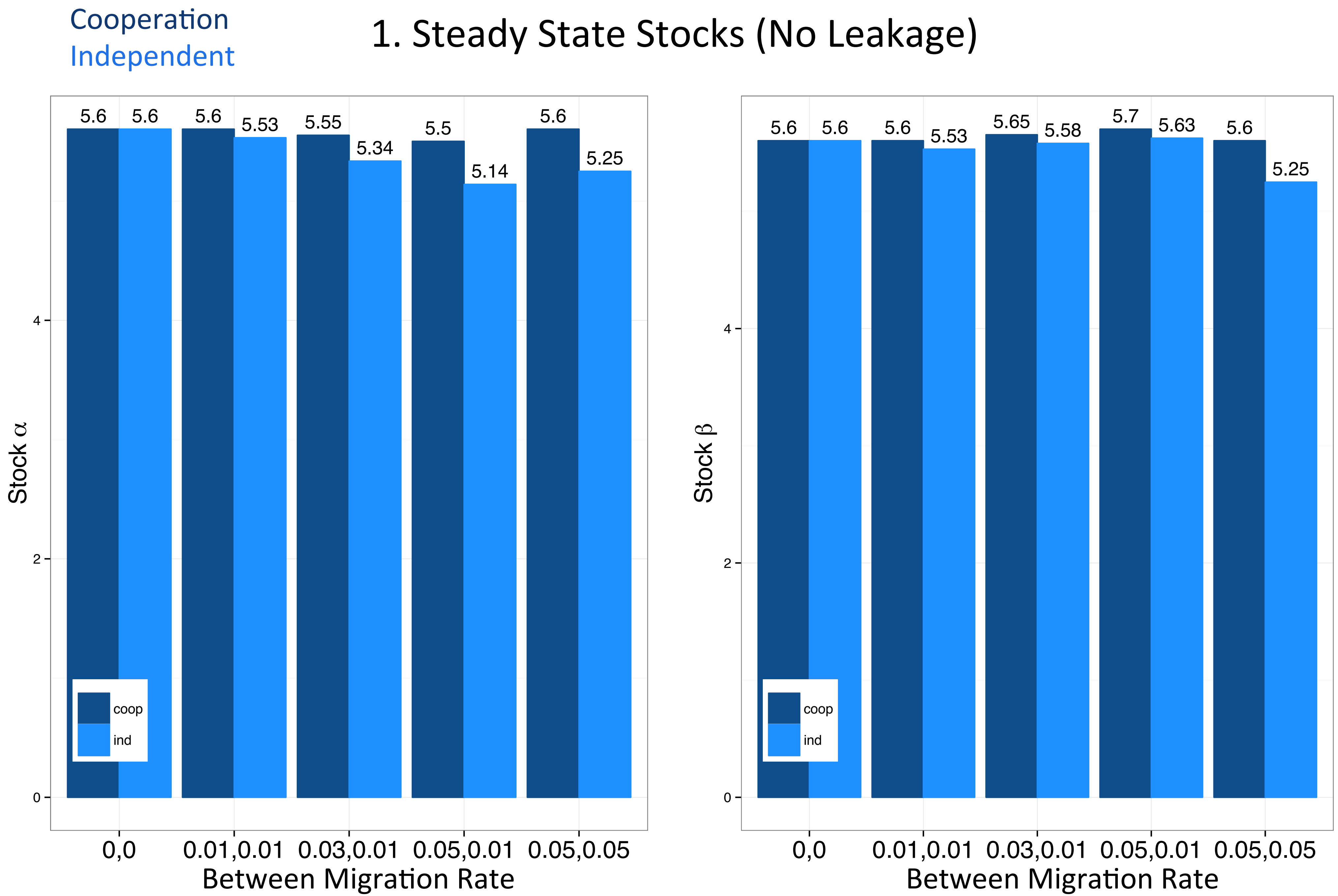




Numerical Illustration Outline

δ_i : % to/from neighbor (Between Migration)
ϕ_i : % to int'l waters (Leakage)

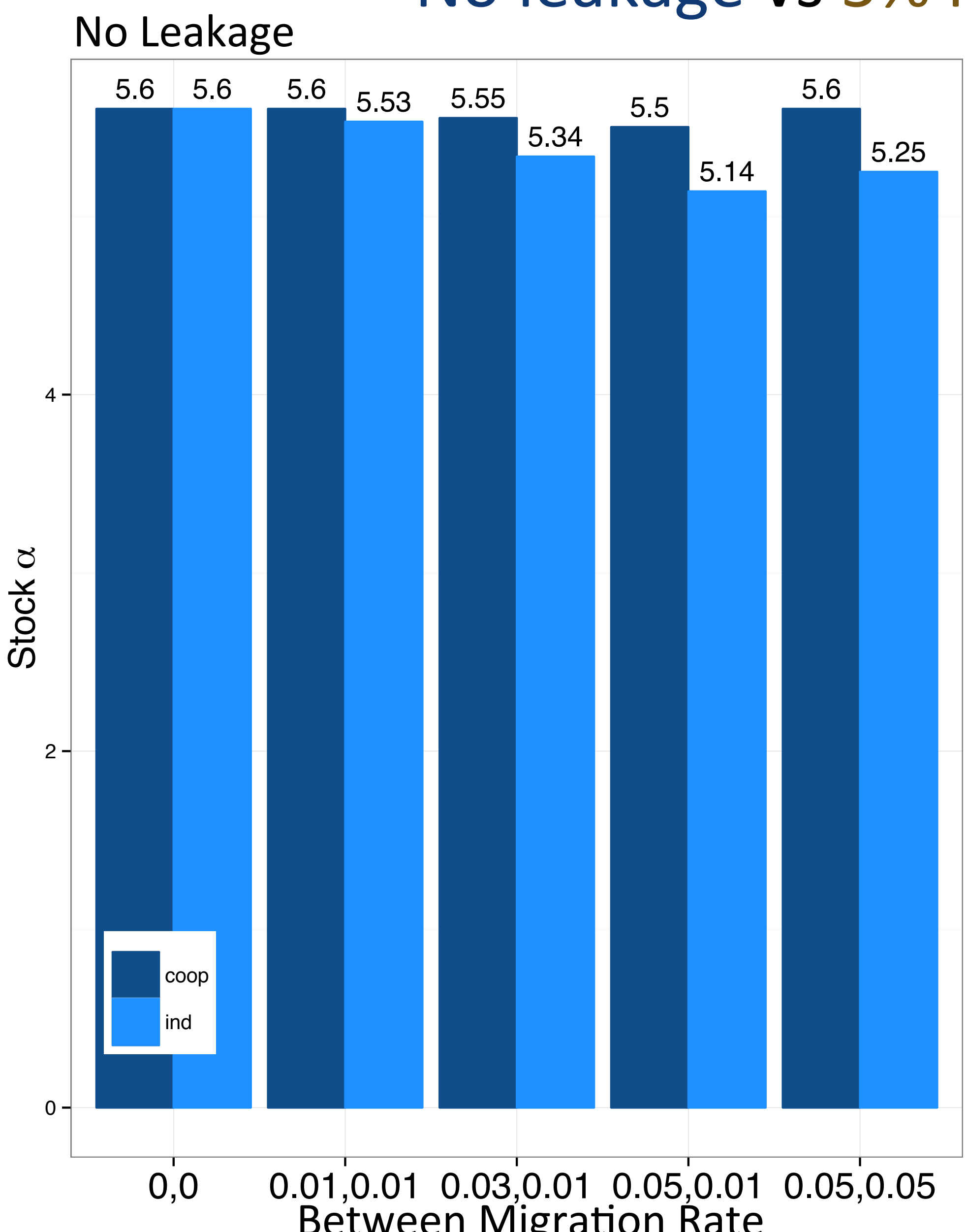
1. Steady states stocks (No leakage)
2. Steady state stocks (No leakage vs. 5% leakage)
3. Steady state stocks (No migration)
4. Cooperative management dynamics
5. Independent management dynamics
6. Cooperation surplus (No leakage)
7. Cooperation surplus (No leakage vs. 5% leakage)

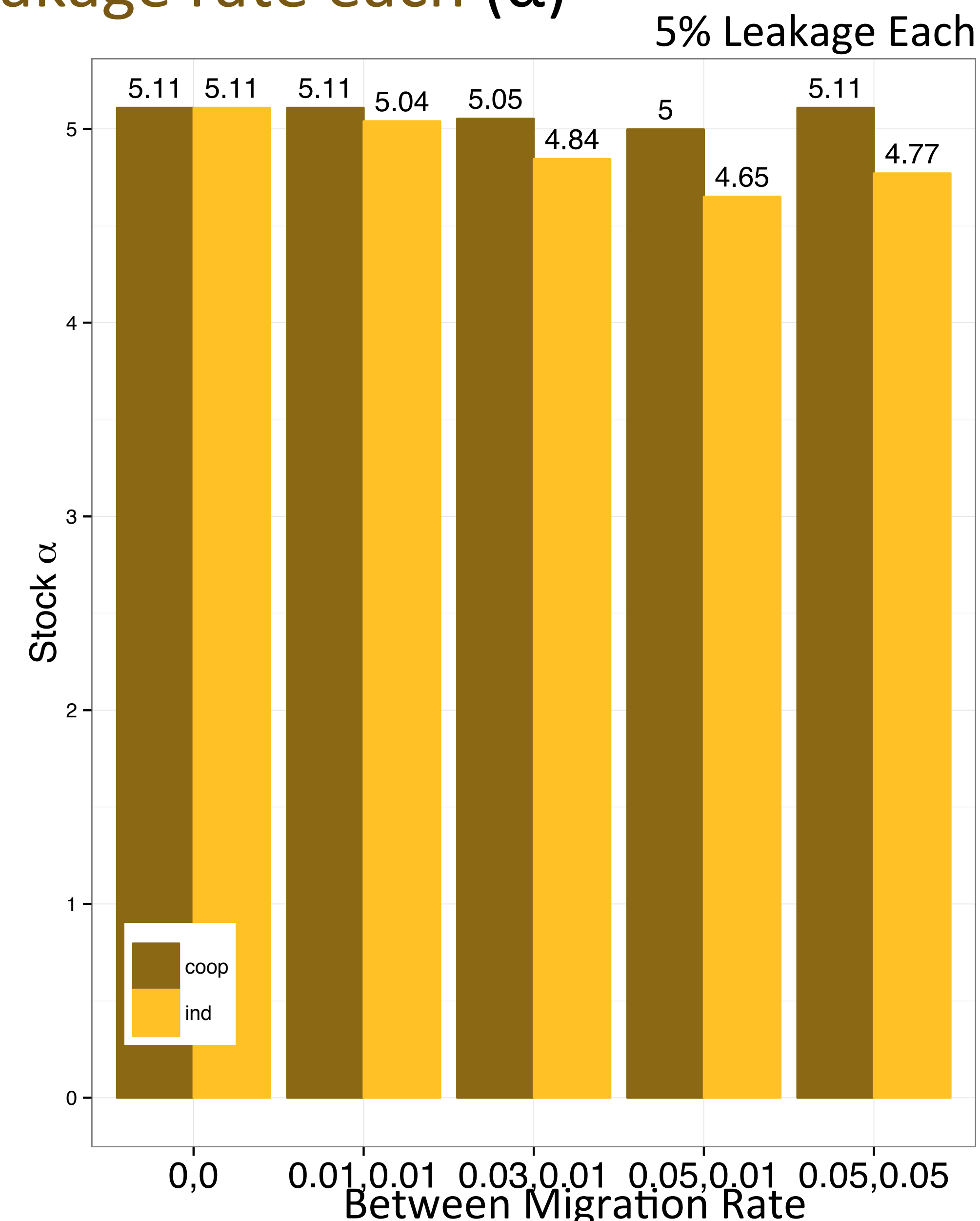

Cooperation
Independent
1. Steady State Stocks (No Leakage)
Stock α
Stock β
5.6
5.6
5.6
5.53
5.55
5.34
5.5
5.14
5.6
5.25
5.6
5.6
5.6
5.53
5.65
5.58
5.7
5.63
5.6
5.25
0
2
4
coop
ind
0,0
0.01,0.01
0.03,0.01
0.05,0.01
0.05,0.05
Between Migration Rate
Between Migration Rate

2. Steady state stock comparison: No leakage vs 5% leakage rate each (α)

Cooperation
Independent

Cooperation
Independent

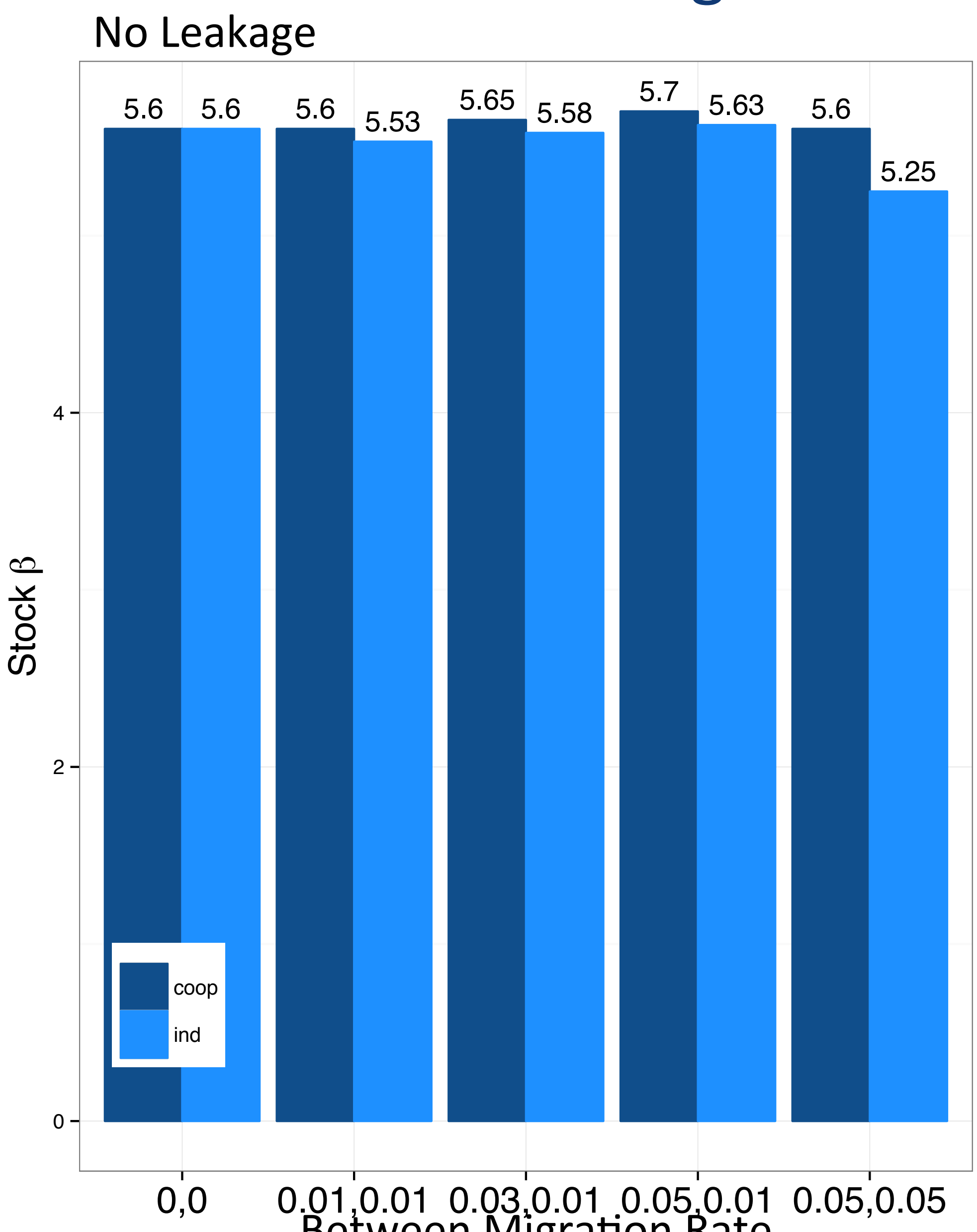


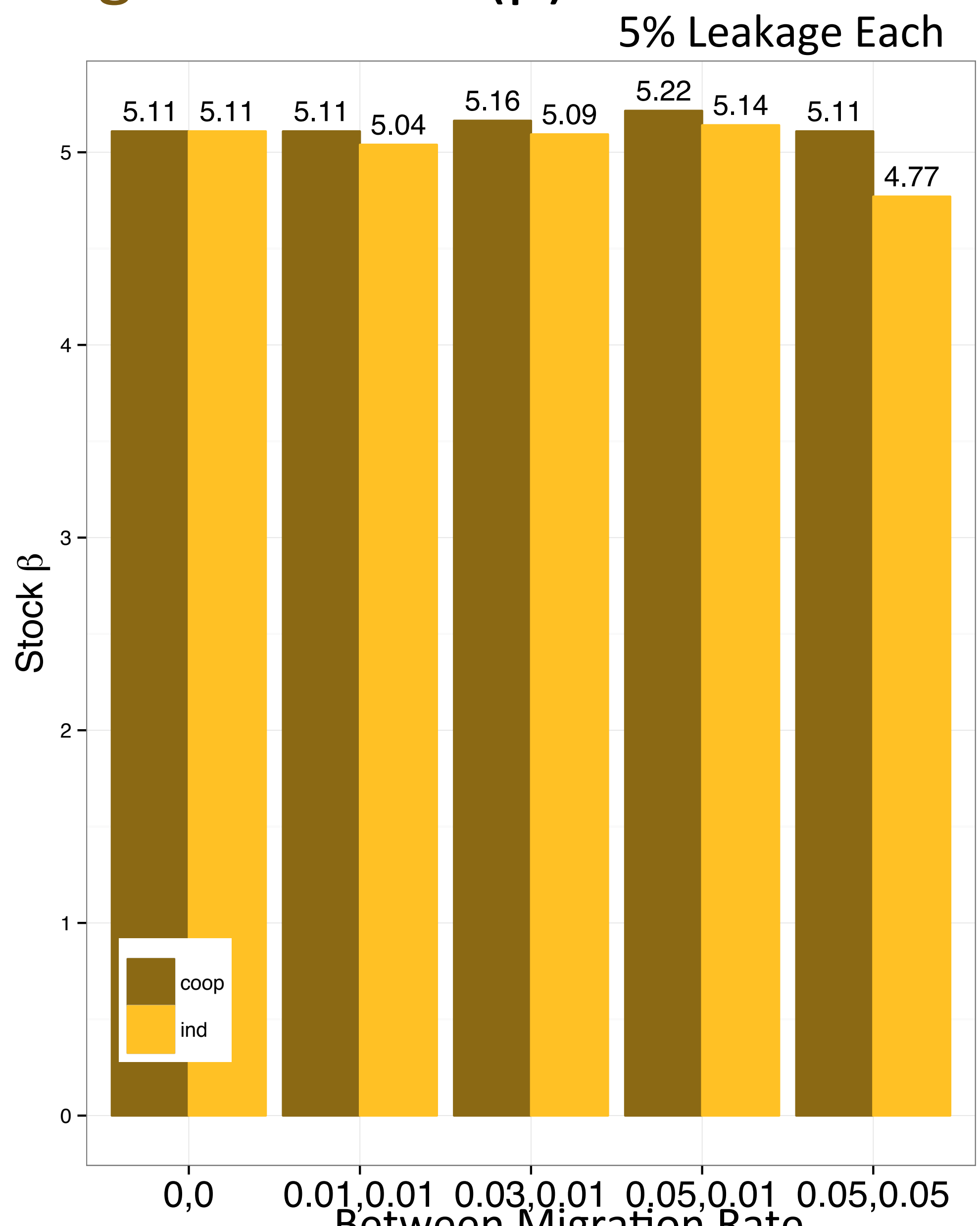


2. Steady state stock comparison: No leakage vs 5% leakage rate each (β)

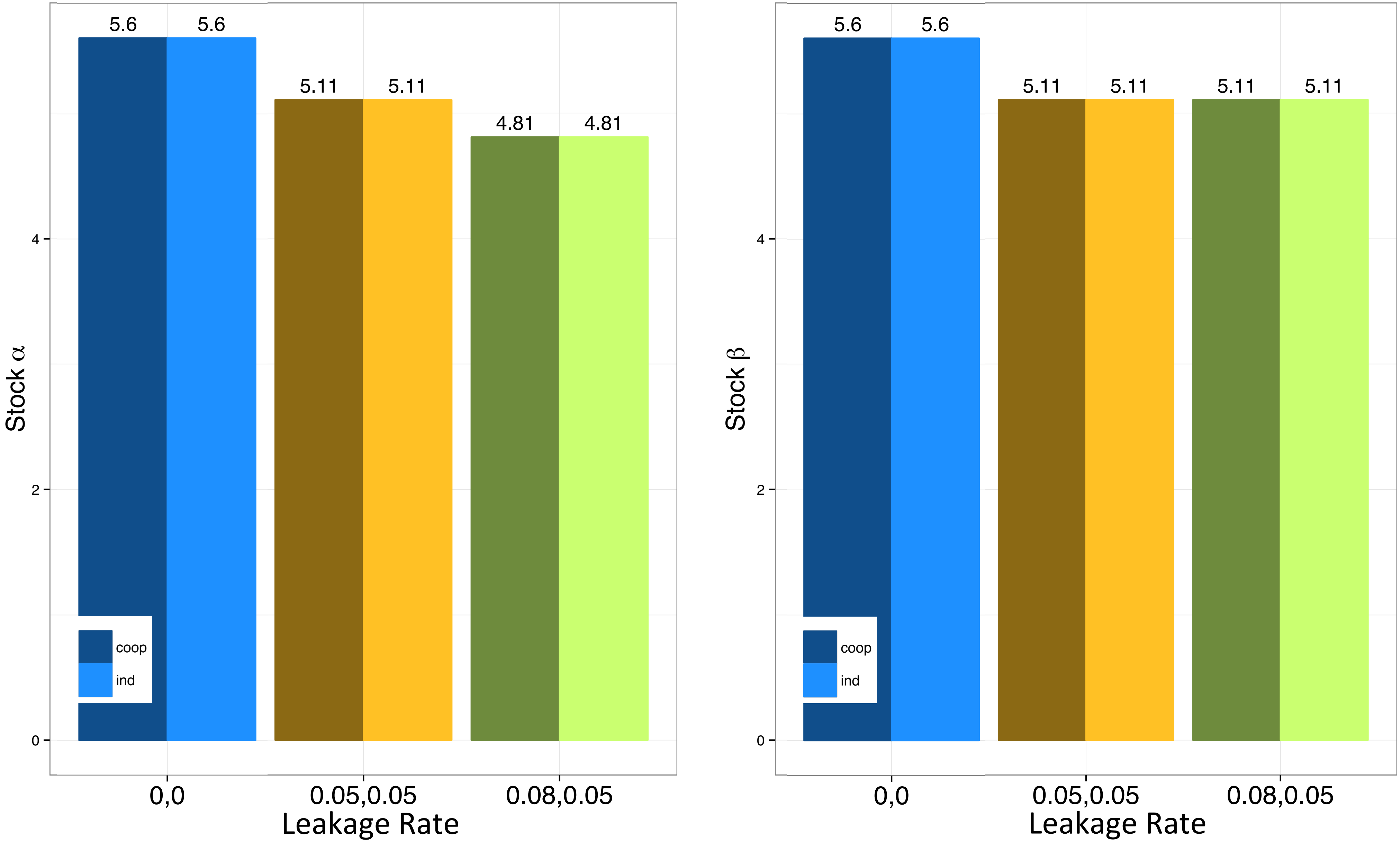
Cooperation
Independent

Cooperation
Independent





3. Steady state stock comparison: No Migrations between the Two Countries

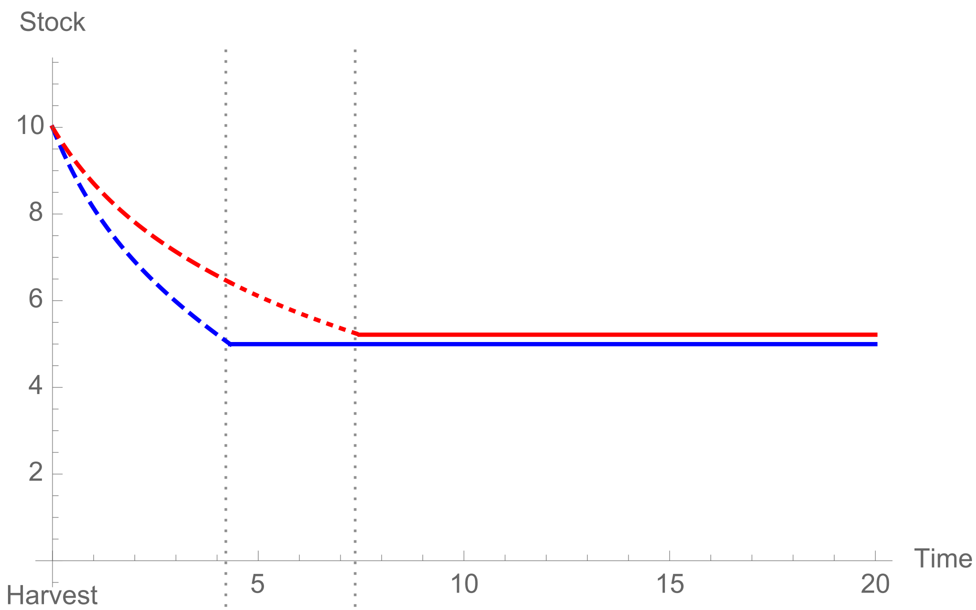


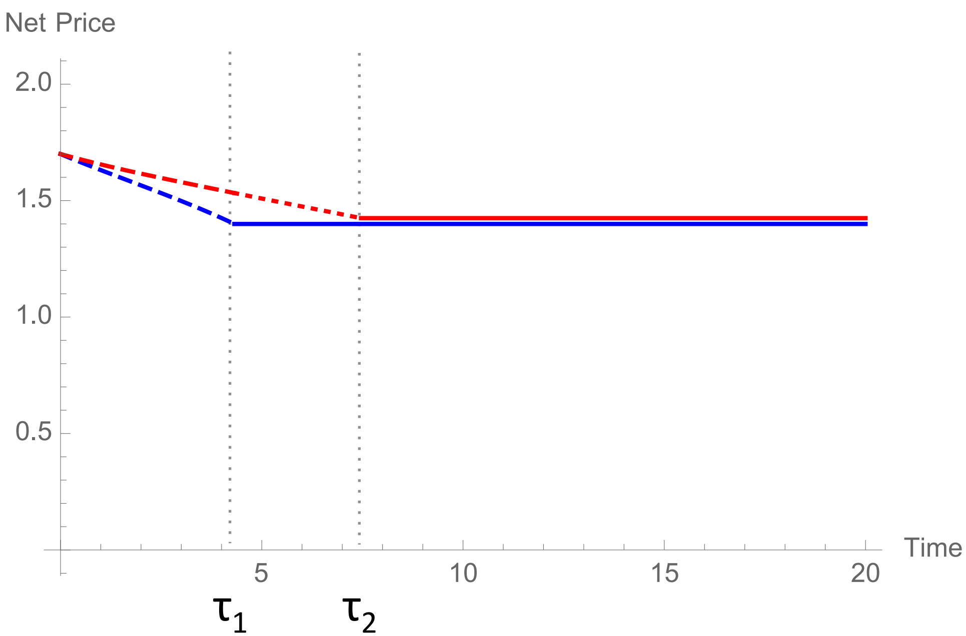
4. Cooperative Management Dynamics

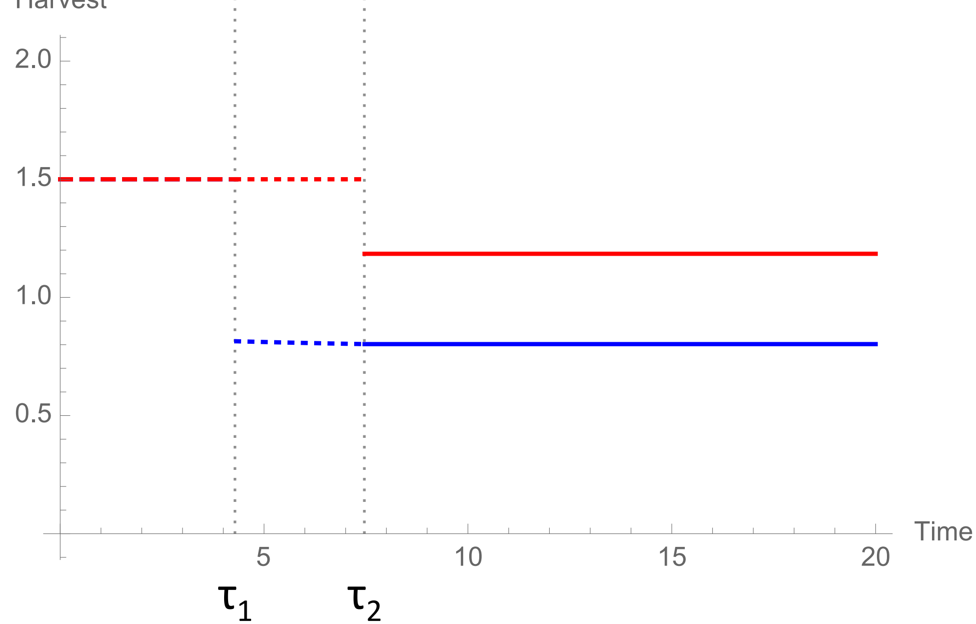
α's dynamics

β's dynamics

$$\delta_\alpha = 0.05, \delta_\beta = 0.01$$
$$\phi_\alpha = \phi_\beta = 0.05$$





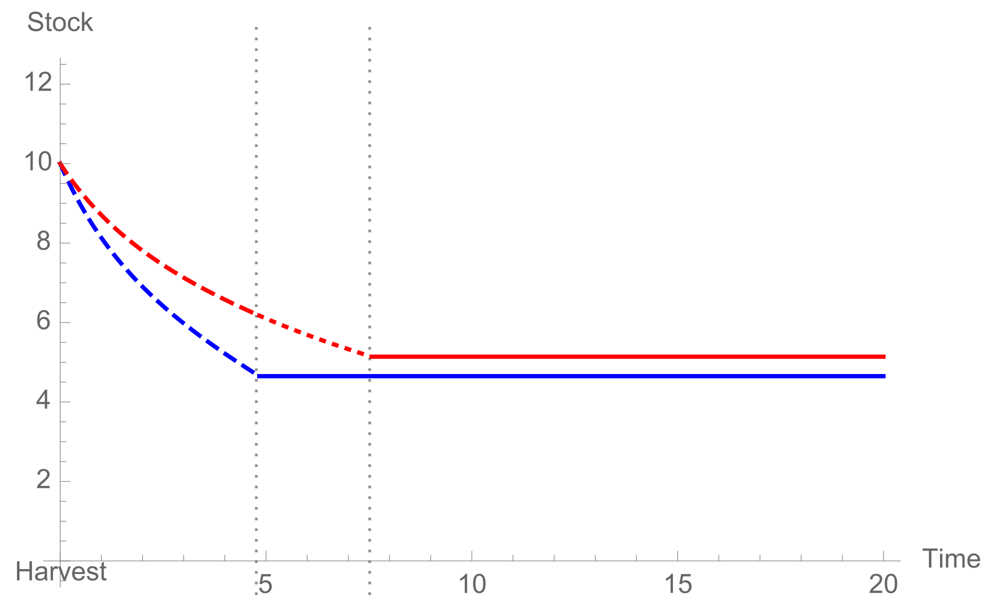


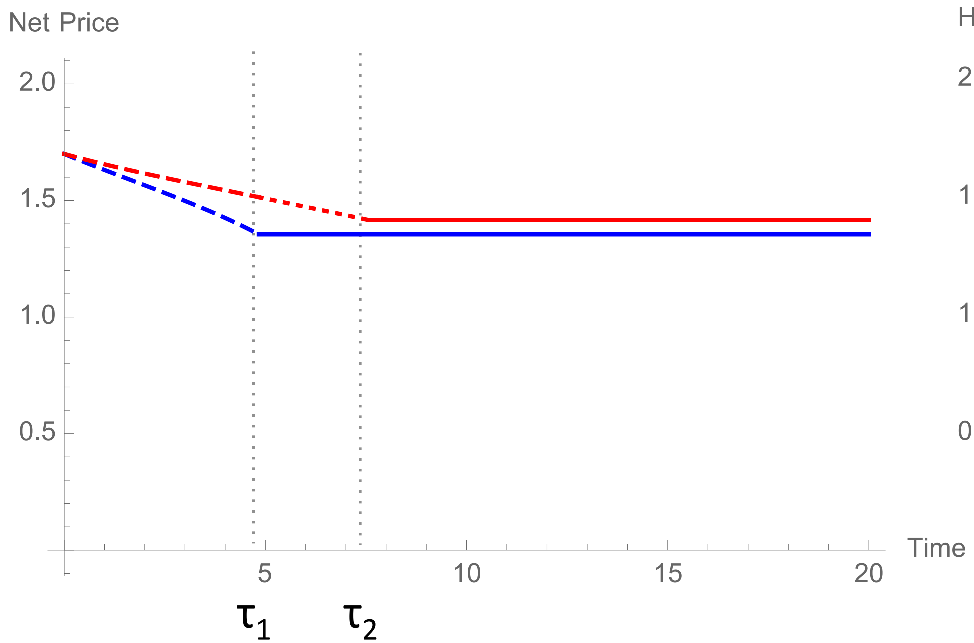
5. Independent Management Dynamics

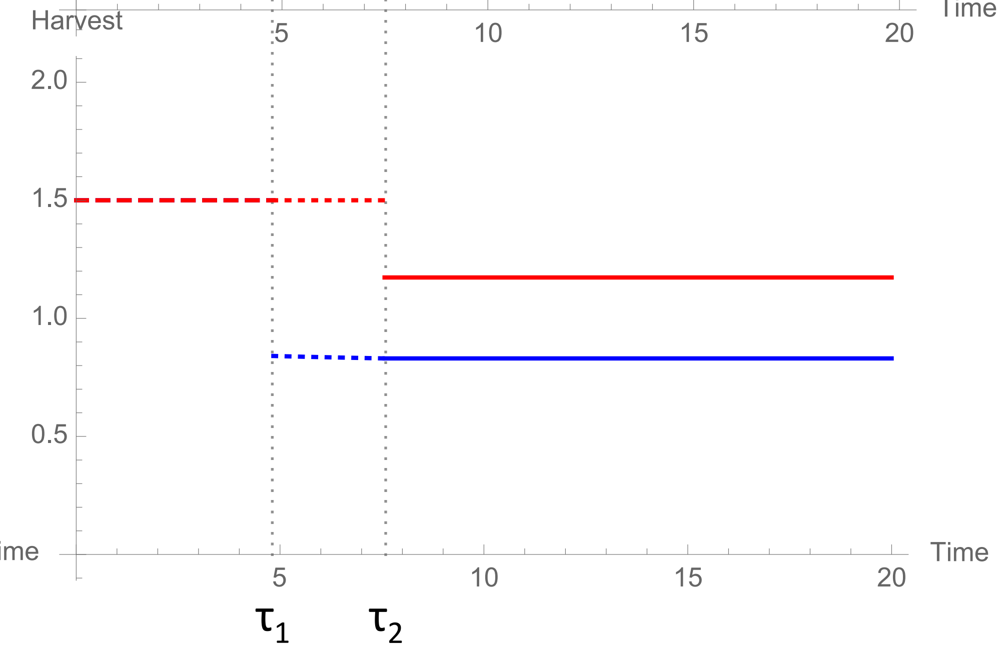
α’s dynamics

β’s dynamics

$$\delta_\alpha = 0.05, \delta_\beta = 0.01$$
$$\phi_\alpha = \phi_\beta = 0.05$$

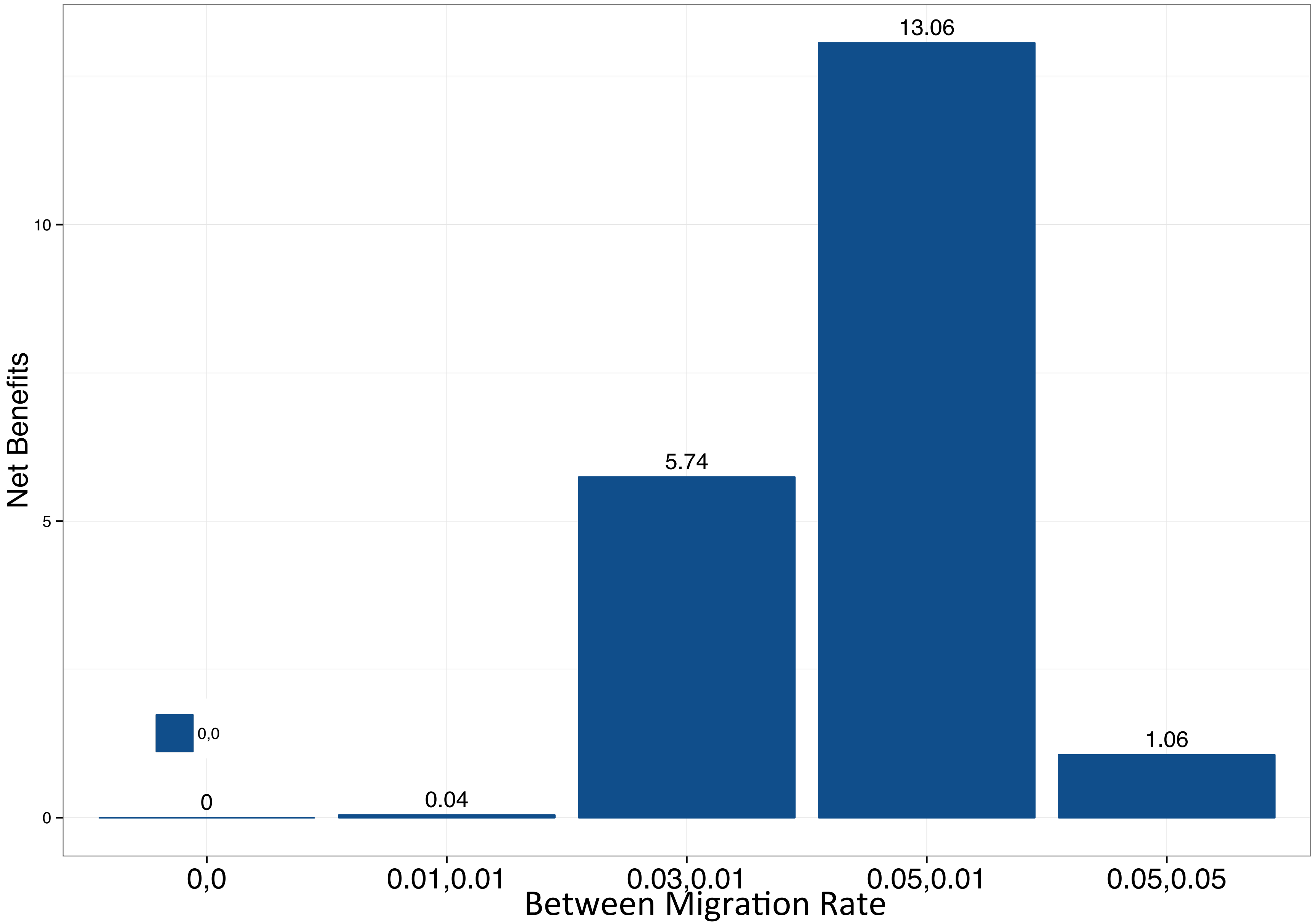






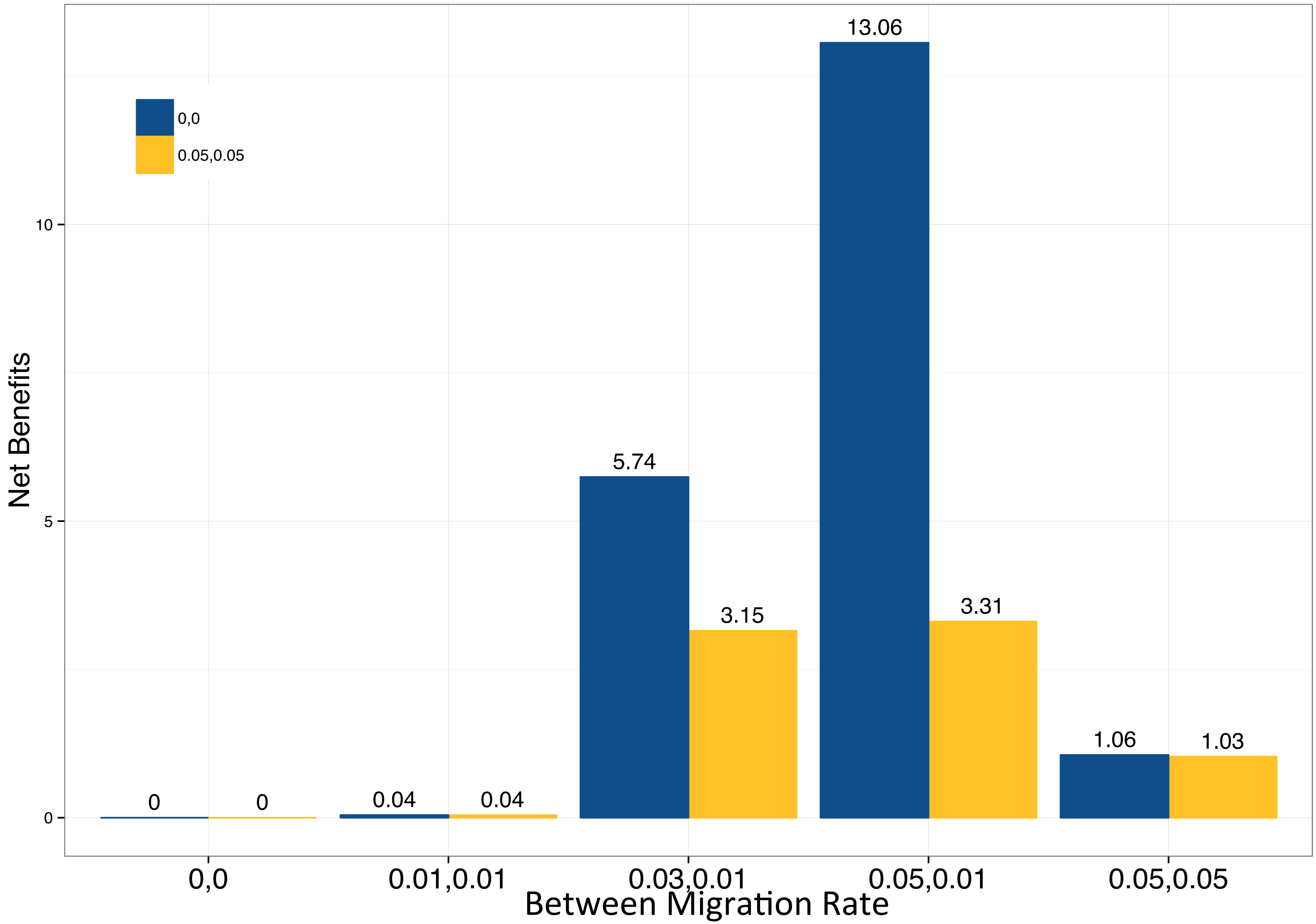
6. Cooperation Surplus

No leakage



7. Cooperation Surplus

No leakage vs. (5%, 5%) leakage rate



Allocation of the Benefits

Nash bargaining rule

$$\max_{\pi_\alpha,\pi_\beta} \quad (\pi_\alpha - \pi_\alpha^I)^\sigma (\pi_\beta - \pi_\beta^I)^{1-\sigma}$$

$$\text{subject to} \quad \pi_\alpha + \pi_\beta = \bar{\pi}$$

Benefits are shared 50:50 if the two countries have the equal negotiation power

Proportionate rule

$$(NB)_i^{Coop} - (NB)_i^{Ind}$$

If equal migration rates, benefits are shared 50:50

If no leakage, a country with the higher migration rate gains more

Long story short,

- Cooperative management yields greater net benefits when fish migrates across boarders
- Leakages reduce cooperation benefits
- Gains from cooperation can be shared by the cooperating countries (i.e. Present value of the net benefits from the joint maximization does not always equal the share!)

Long story short,

- Cooperative management yields greater net benefits when fish migrates across boarders
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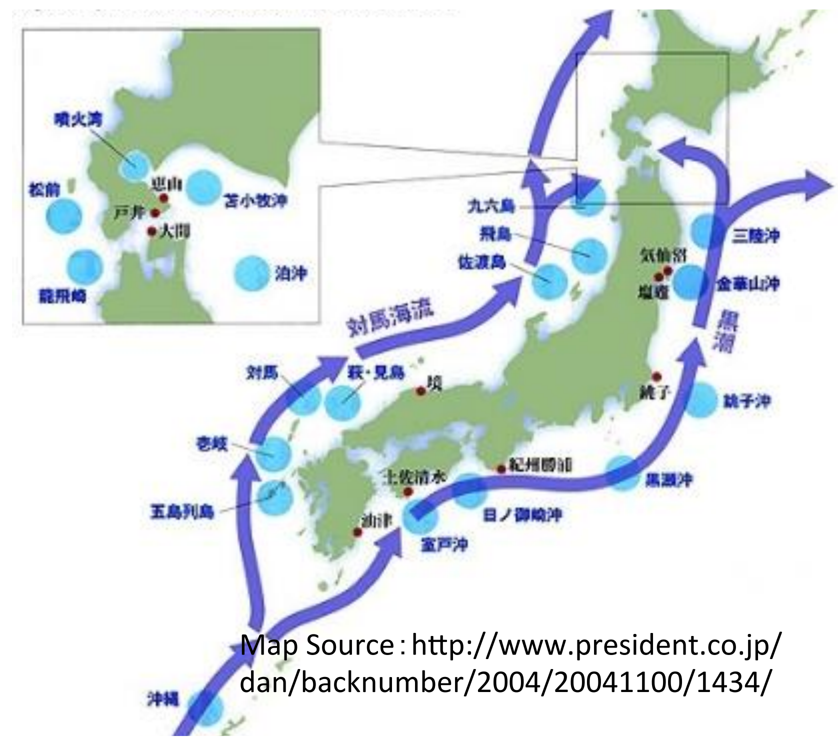
What about domestic fisheries management!?

Implication for the Domestic Management

- Chicken-and-egg problem
  - Need domestic management
  - Domestic management not in place because of escapement
- Benefits may be small due to leakages of stocks outside of the EEZ
- Possibly, international cooperation may forge better domestic stocks management

Implication for the Domestic Management
Fisheries Management in Japan

- Fisheries are managed and operated independently by regional coops for the most part
- Fishermen are concerned with their stocks escaping to neighboring countries waters
- Is cooperative management possible?



Map Source：http://www.president.co.jp/dan/backnumber/2004/20041100/1434/

Conclusion and Future Research Direction

- This study is a good representative of tropical tuna fisheries in the Western and Central Pacific
- In the Northern Pacific, the problem is multi-layered (domestic & international)
- Possibly, international cooperation could forge cooperation among domestic fisheries

Thank You

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