

Week 4: Sustaining cooperation

■ 4.1 Group rationality and the rationality of individuals

One of the **most important** messages of Game Theory

One of the **most important** messages of Game Theory

What is good for society

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**



Keep it clean!

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**



Keep it clean!



But, .....

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**



Stop global warming!

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Cooperation

You may be tempted to **shirk**



Stop global warming!



But, .....

One of the **most important** messages of Game Theory

What is good for society  $\nRightarrow$  What is good for each individual

One of the **most important** messages of Game Theory

What is good for society  $\nRightarrow$  What is good for each individual

Group rationality

One of the **most important** messages of Game Theory

What is good for society  $\nRightarrow$  What is good for each individual

Group rationality

Rationality of individuals

Prisoner's Dilemma

<div>1 \ 2</div>	Cooperate	Defect
Cooperate		
Defect		

Prisoner's Dilemma

1 \ 2	Cooperate	Defect
Cooperate	-1, -1	
Defect		

Prisoner's Dilemma

<div>2</div> <div>1 \</div>	Cooperate	Defect
Cooperate	-1, -1	
Defect		-10, -10

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	
Defect	0, -15	-10, -10

THE UNIVERSITY OF TOKYO 19

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

THE UNIVERSITY OF TOKYO 20

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

Nash equilibrium

THE UNIVERSITY OF TOKYO 21

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

Nash equilibrium

Individual rationality

THE UNIVERSITY OF TOKYO 22

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

Nash equilibrium

Individual rationality

THE UNIVERSITY OF TOKYO 23

Prisoner's Dilemma		
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

Group rationality

Nash equilibrium

Individual rationality

THE UNIVERSITY OF TOKYO 24

Prisoner's Dilemma		
		2
1 \ 2	Cooperate	Defect
Cooperate	-1, -1	-15, 0
Defect	0, -15	-10, -10

Nash equilibrium

Group rationality  $\neq$  Individual rationality

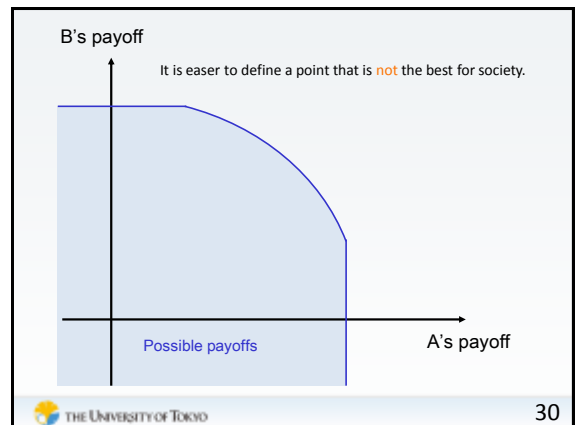
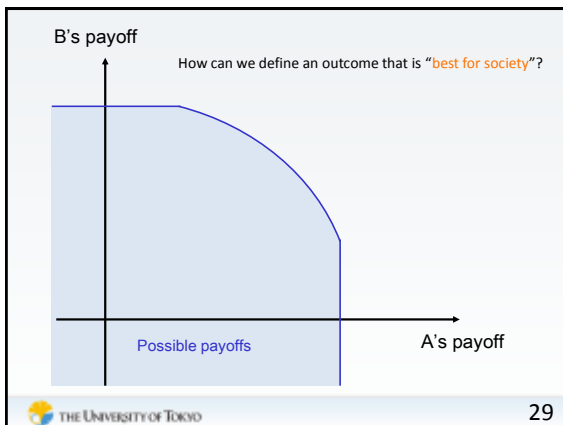
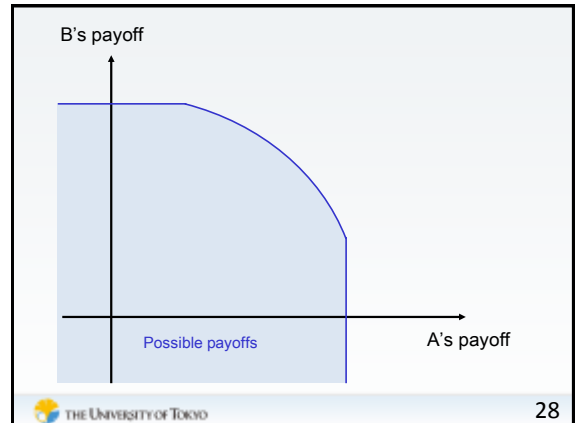
What is good for society

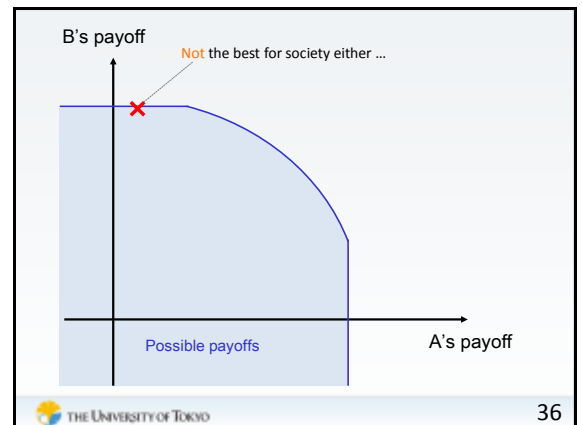
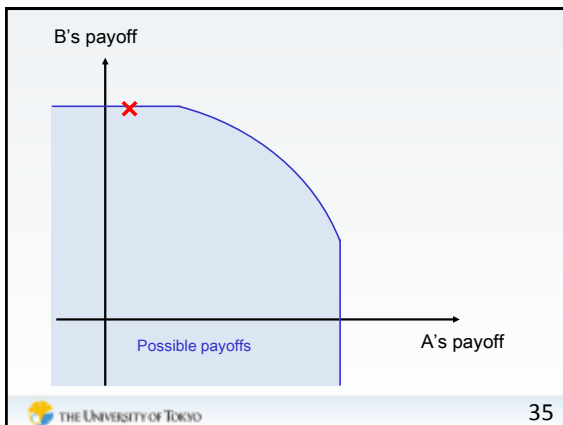
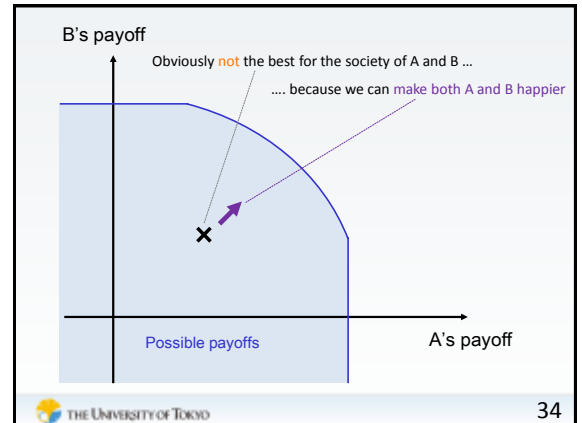
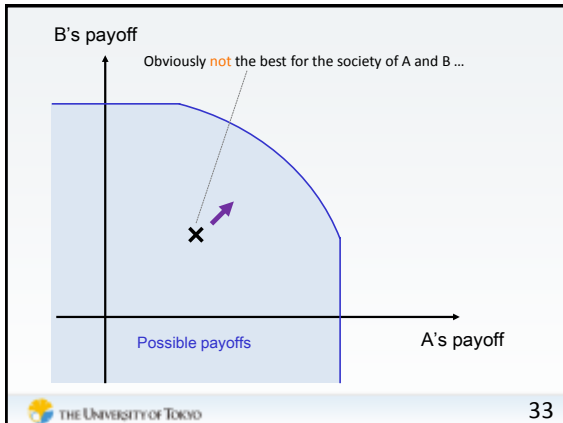
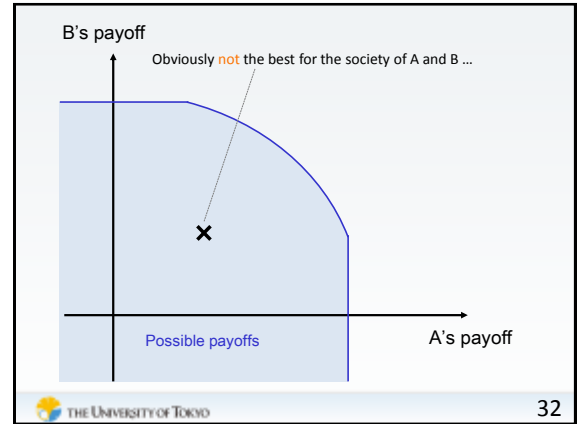
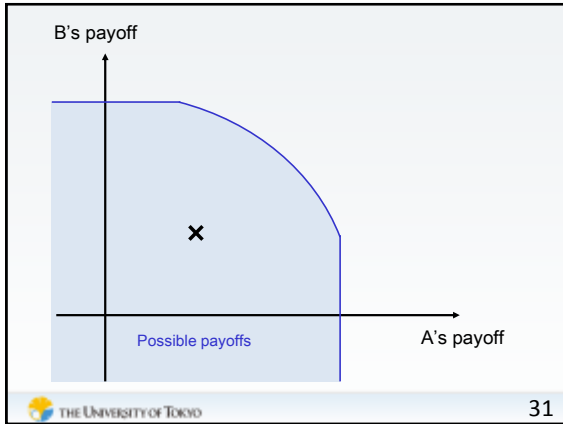
Group rationality

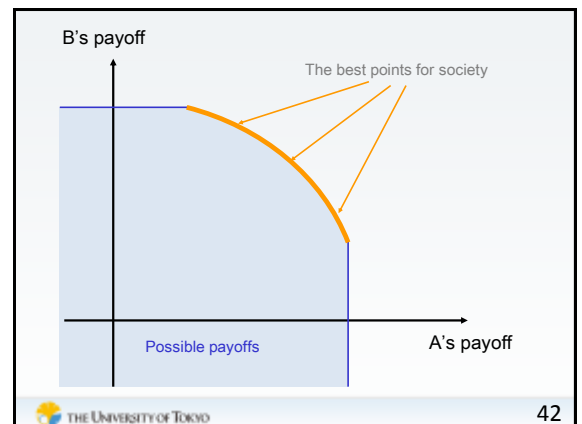
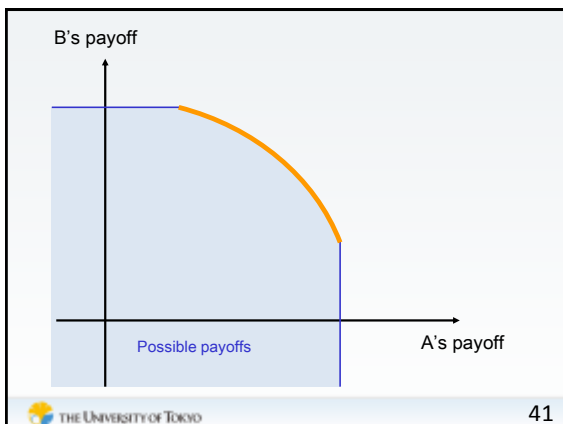
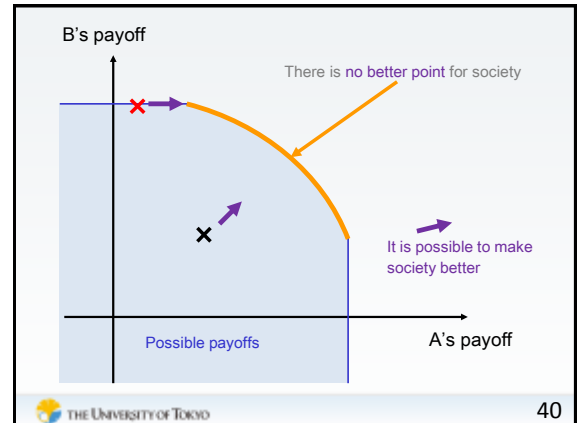
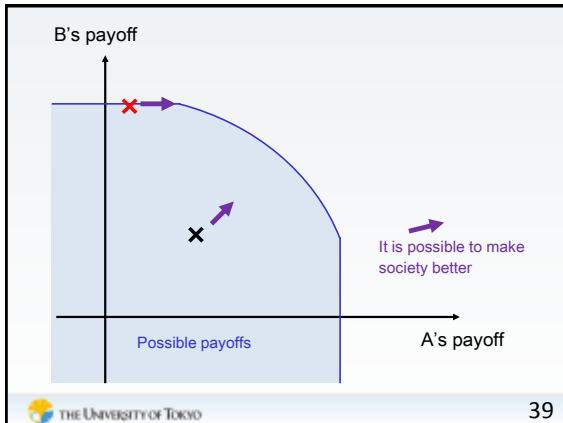
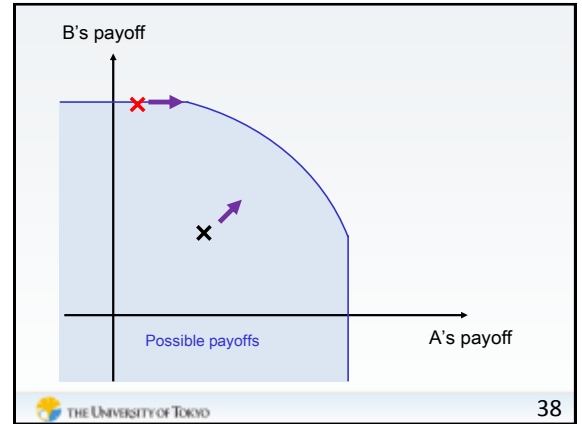
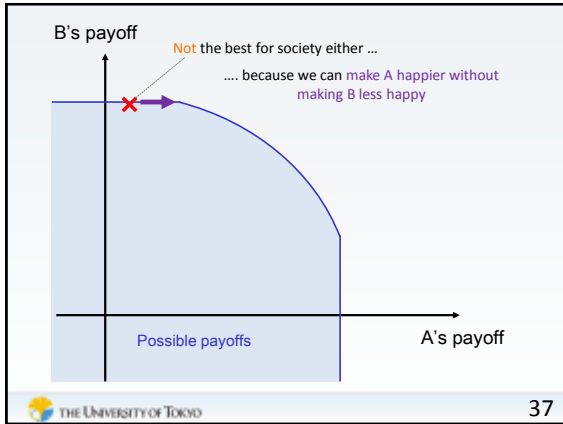
What is good for society

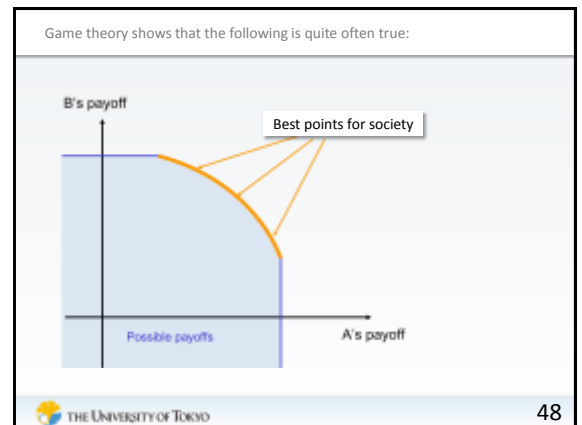
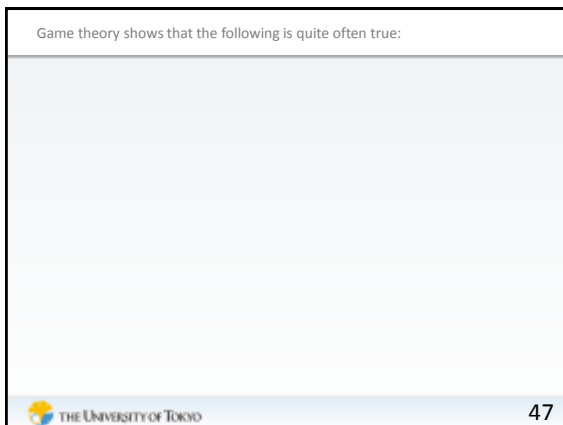
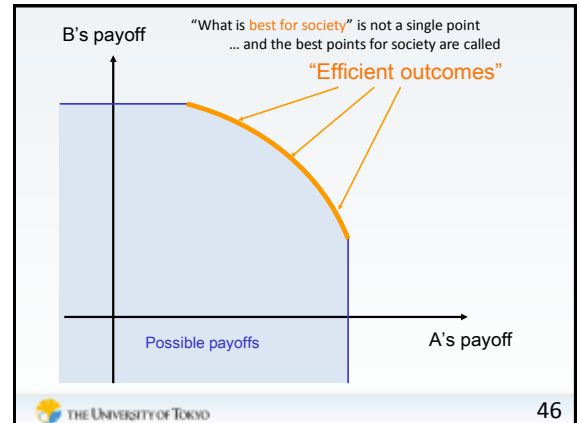
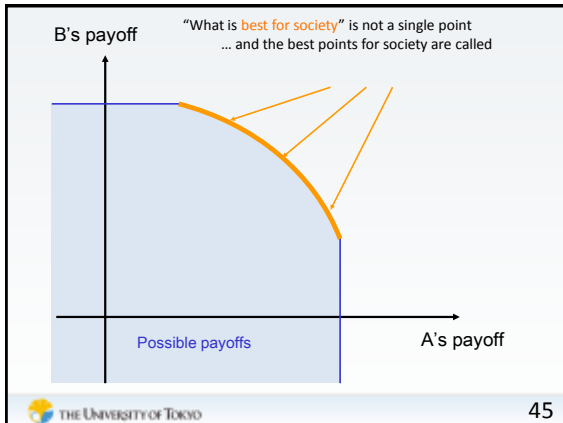
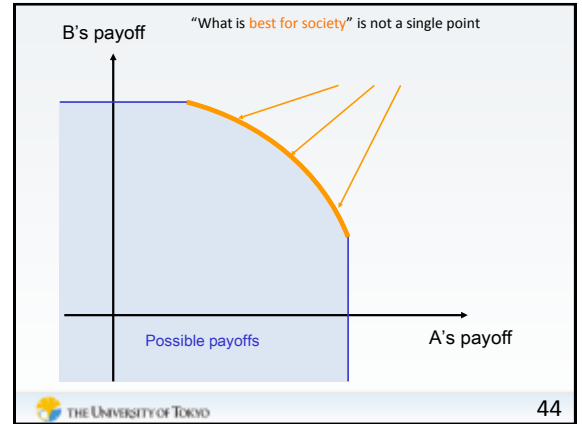
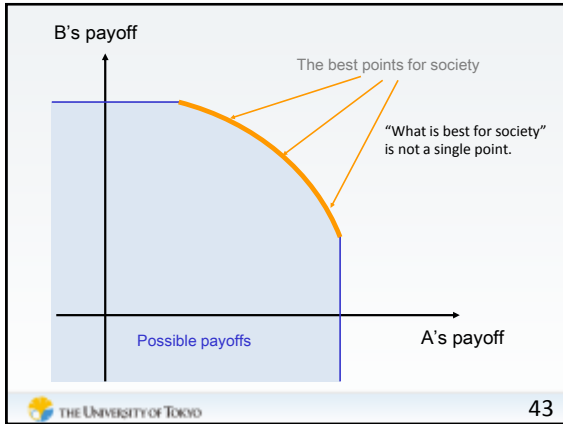
Group rationality

} Formal definition?



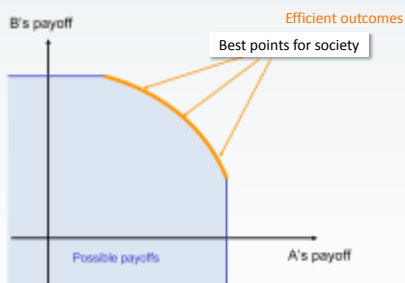




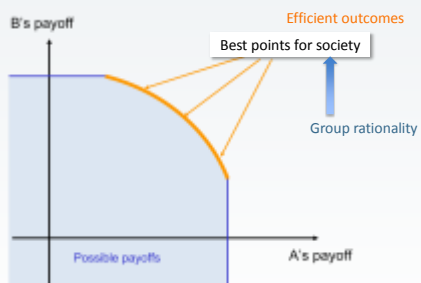




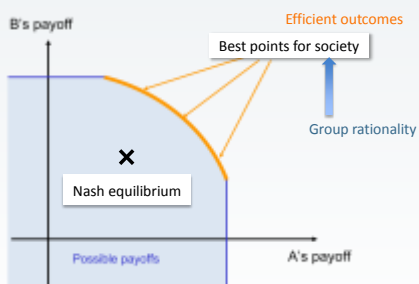
Game theory shows that the following is quite often true:



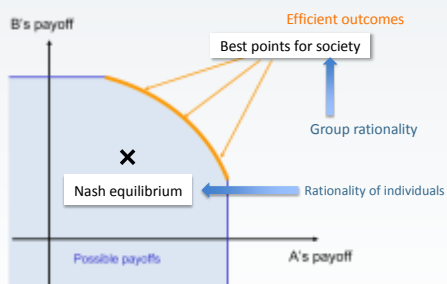
Game theory shows that the following is quite often true:



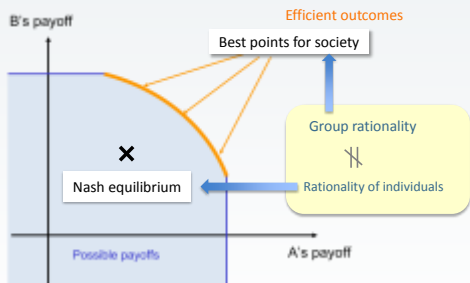
Game theory shows that the following is quite often true:



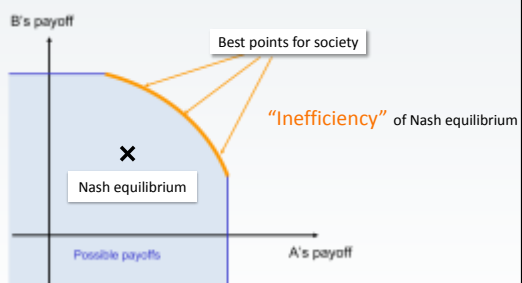
Game theory shows that the following is quite often true:



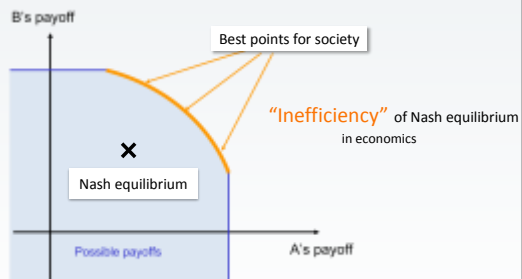
Game theory shows that the following is quite often true:



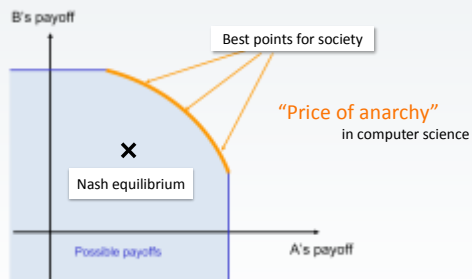
Game theory shows that the following is quite often true:



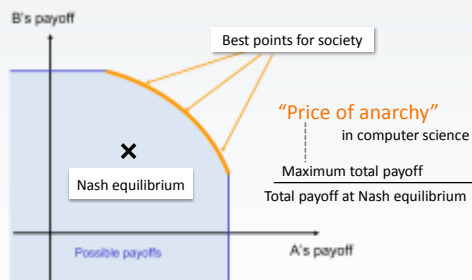
Game theory shows that the following is quite often true:



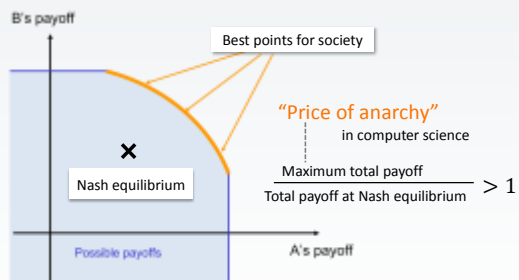
Game theory shows that the following is quite often true:



Game theory shows that the following is quite often true:



Game theory shows that the following is quite often true:



## 4.2 Why is group rationality different from rationality of individuals?

## 4.2 Why is group rationality different from rationality of individuals?

Why is Nash equilibrium often inefficient?

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

Group rationality

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

Group rationality

Rationality of individuals

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

Group rationality

Rationality of individuals

Nash equilibrium

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

Group rationality

Efficient outcome

Rationality of individuals

Nash equilibrium

A puzzle

## A puzzle

a  
A's payoff



## A puzzle

a  
A's payoff

b  
B's payoff



## A puzzle

a + b = a + b  
A's payoff B's payoff Society's payoff



## A puzzle

When individuals maximize their payoffs...

a + b = a + b  
A's payoff B's payoff Society's payoff



## A puzzle

When individuals maximize their payoffs...

a + b = a + b  
A's payoff B's payoff Society's payoff



## A puzzle

When individuals maximize their payoffs...

a + b = a + b  
A's payoff B's payoff Society's payoff



### A puzzle

When individuals maximize their payoffs... Why isn't society's payoff also maximized?

$$\begin{array}{ccccc} \boxed{a} & + & \boxed{b} & = & \boxed{a + b} \\ \text{A's payoff} & & \text{B's payoff} & & \text{Society's payoff} \end{array}$$



### A puzzle

When individuals maximize their payoffs...

$$\boxed{\text{Nash equilibrium}} \neq \boxed{\text{Best outcome for society}}$$

### A puzzle

When individuals maximize their payoffs...

$$\boxed{\text{Nash equilibrium}} \neq \boxed{\text{Best outcome for society}}$$

Two main reasons

### A puzzle

When individuals maximize their payoffs... Why isn't society's payoff also maximized?

$$\boxed{\text{Nash equilibrium}} \neq \boxed{\text{Best outcome for society}}$$

Two main reasons

### Reason #1

$$\begin{array}{ccccc} \boxed{a} & + & \boxed{b} & = & \boxed{a + b} \\ \text{A's payoff} & & \text{B's payoff} & & \text{Society's payoff} \end{array}$$



### Reason #1

$$\begin{array}{ccccc} \boxed{a} & + & \boxed{b} & = & \boxed{a + b} \\ \text{A's payoff} & & \text{B's payoff} & & \text{Society's payoff} \end{array}$$



A's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



A's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



A's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



B's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



B's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



B's effort **alone** cannot create benefit

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



They can create benefit **only if they act together**

## Reason #1

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



They can create benefit **only if they act together**

## Reason #1



Players can create benefit **only if they act together**

## Reason #1

	1	2	QWERTY	Optimal
QWERTY			1,1	0,0
Optimal			0,0	2,2

Nash equilibria



Players can create benefit **only if they act together**

## Reason #1

Society may be trapped in a **bad Nash equilibrium**

	1	2	QWERTY	Optimal
QWERTY			1,1	0,0
Optimal			0,0	2,2

Nash equilibria



Players can create benefit **only if they act together**

### Reason #1

Society may be trapped in a **bad Nash equilibrium**

1 \ 2	QWERTY	Optimal
QWERTY	1,1	0,0
Optimal	0,0	2,2

Nash equilibria



Players can create benefit **only if they act together**

### Reason #1

Society may be trapped in a **bad Nash equilibrium**

1 \ 2	QWERTY	Optimal
QWERTY	1,1	0,0
Optimal	0,0	2,2

Nash equilibria

“Coordination failure”

Players can create benefit **only if they act together**

### Reason #2

### Reason #2



Your effort **alone** cannot create benefit

### Reason #2



**can create social benefit**

Your effort **alone** cannot create benefit

### Reason #2

Benefit of good behavior may not come to you



But ....



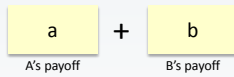
**can create social benefit**

Your effort **alone** cannot create benefit



### Reason #2

Benefit of good behavior may not come to you



### Reason #2

Benefit of good behavior may not come to you

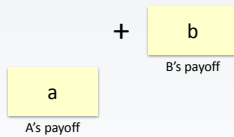


I scratch your back



### Reason #2

Benefit of good behavior may not come to you



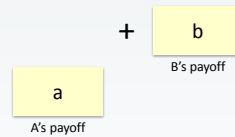
I scratch your back



### Reason #2

Benefit of good behavior may not come to you

Each individual may not have an incentive to cooperate



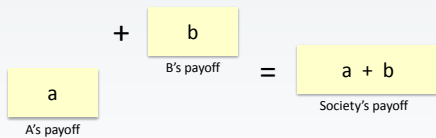
I scratch your back



### Reason #2

Benefit of good behavior may not come to you

Each individual may not have an incentive to cooperate

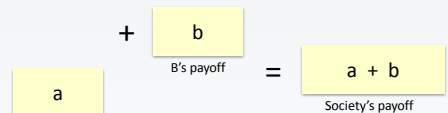


I scratch your back



### Reason #2

Benefit of good behavior may not come to you



I scratch your back



You scratch my back



### Reason #2

Benefit of good behavior may not come to you

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



I scratch your back



You scratch my back

### Reason #2

Benefit of good behavior may not come to you

But if they both cooperate, they may be better-off

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



I scratch your back



You scratch my back

### Reason #2

Benefit of good behavior may not come to you



I scratch your back



You scratch my back

### Reason #2

Benefit of good behavior may not come to you

↓  
Rational individuals may not take socially desirable behavior



I scratch your back



You scratch my back

### Reason #2

Previous slides explained why society may be trapped in a bad point

### Reason #2

Previous slides explained why society may be trapped in a bad point

Now let us examine why good point may not be not sustainable

### Reason #2

Cost of cheating may be paid by others



THE UNIVERSITY OF TOKYO

109

### Reason #2

Cost of cheating may be paid by others

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



THE UNIVERSITY OF TOKYO

110

### Reason #2

Cost of cheating may be paid by others

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



Stop global warming!



THE UNIVERSITY OF TOKYO

111

### Reason #2

Cost of cheating may be paid by others

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



..... best for society

Stop global warming!



THE UNIVERSITY OF TOKYO

112

### Reason #2

Cost of cheating may be paid by others

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



...Well, I may cheat



THE UNIVERSITY OF TOKYO

113

### Reason #2

Cost of cheating may be paid by others

$$\begin{array}{c} \boxed{a} \\ \text{A's payoff} \end{array} + \begin{array}{c} \boxed{b} \\ \text{B's payoff} \end{array} = \begin{array}{c} \boxed{a + b} \\ \text{Society's payoff} \end{array}$$



...Well, I may cheat



THE UNIVERSITY OF TOKYO

114

Reason #2

Cost of cheating may be paid by others


a

A's payoff

=

a + b

Society's payoff



+

b

B's payoff

...Well, I may cheat

THE UNIVERSITY OF TOKYO 115

Reason #2

Cost of cheating may be paid by others


a

A's payoff

=

a + b

Society's payoff



+

b

B's payoff

...Well, I may cheat

THE UNIVERSITY OF TOKYO 116

Reason #2

Cost of cheating may be paid by others

↓

Rational individuals may want to cheat at the best point for society


THE UNIVERSITY OF TOKYO 117

Reason #2

Cost of cheating may be paid by others

↓

Rational individuals may want to cheat at the best point for society



THE UNIVERSITY OF TOKYO 118

Reason #2

Rational individuals who maximize their own payoff ignore the effects to others

THE UNIVERSITY OF TOKYO 119

Reason #2

Rational individuals who maximize their own payoff ignore the effects to others

■ Rational individuals may not take good behavior that greatly benefits others, if it is costly

THE UNIVERSITY OF TOKYO 120

### Reason #2

Rational individuals who maximize their own payoff **ignore the effects to others**

- Rational individuals may not take good behavior that greatly **benefits others**, if it is costly
- Rational individuals may take bad behavior that greatly **harms others**, if it is profitable.

### Reason #2

Rational individuals who maximize their own payoff **ignore the effects to others**

### Reason #2

Rational individuals who maximize their own payoff **ignore the effects to others**

This is one of the **most important reasons** why maximization of each individual payoff does not lead to maximization of society's total payoff

### Reason #2

Rational individuals who maximize their own payoff **ignore the effects to others**

This is one of the **most important reasons** why maximization of each individual payoff does not lead to maximization of society's total payoff

Nash equilibrium  $\neq$  Best outcome for society

- 4.3 Group rationality vs. rationality of individuals in **biological evolution**

One of the **most important** messages of Game Theory

What is good for society  $\neq$  What is good for each individual

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Group rationality



THE UNIVERSITY OF TOKYO

127

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Group rationality

Rationality of individuals



THE UNIVERSITY OF TOKYO

128

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Group rationality

Rationality of individuals

**Nash equilibrium**



THE UNIVERSITY OF TOKYO

129

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Group rationality

Rationality of individuals

**Efficient outcome**

**Nash equilibrium**



THE UNIVERSITY OF TOKYO

130

One of the **most important** messages of Game Theory

What is good for society



What is good for each individual

Group rationality

Rationality of individuals

**Efficient outcome**

**Nash equilibrium**

Absent "strategic or game theoretic" reasoning,

we tend to think that this would happen



THE UNIVERSITY OF TOKYO

131

Impact to evolutionary biology



THE UNIVERSITY OF TOKYO

132

Impact to evolutionary biology

Old Idea

THE UNIVERSITY OF TOKYO

133

Impact to evolutionary biology

Old Idea

Species A

Species B

Species C

THE UNIVERSITY OF TOKYO

134

Impact to evolutionary biology

Old Idea

Species A

Species B

Species C

Maximum fitness

THE UNIVERSITY OF TOKYO

135

Impact to evolutionary biology

Old Idea

Species A

Maximum fitness

THE UNIVERSITY OF TOKYO

136

Impact to evolutionary biology

Old Idea

Evolution

Species A

Maximum fitness

THE UNIVERSITY OF TOKYO

137

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Species A

Maximum fitness

THE UNIVERSITY OF TOKYO

138

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Observed characteristics

THE UNIVERSITY OF TOKYO 139

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Observed characteristics  
body size

THE UNIVERSITY OF TOKYO 140

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Observed characteristics  
body size  
behavior

THE UNIVERSITY OF TOKYO 141

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Observed characteristics  
body size  
behavior "Wolves do not fight until they die."

THE UNIVERSITY OF TOKYO 142

Impact to evolutionary biology

Old Idea

Evolution → Maximum fitness of species

Observed characteristics  
body size  
behavior "Wolves do not fight until they die."  
⋮  
were supposed to maximize the fitness of species

THE UNIVERSITY OF TOKYO 143

Impact to evolutionary biology

New Idea

THE UNIVERSITY OF TOKYO 144



New Idea

- In each species, a variety of genes play a game



New Idea

- In each species, a variety of genes play a game
- Successful genes have more offsprings



New Idea

- In each species, a variety of genes play a game
- Successful genes have more offsprings
- Evolution leads to a Nash equilibrium



New Idea



New Idea

Evolution



New Idea

Evolution → Nash equilibrium of game played by genes



Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 151

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

Cooperation C

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 152

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

Cooperation C      Defection D

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 153

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

C

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 154

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

C

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 155

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

C

Fitness of species appears to be maximized

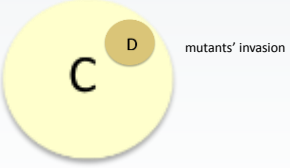
Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 156

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes



mutants' invasion

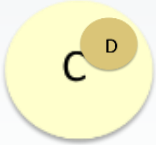
Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 157

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes



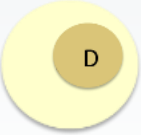
Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 158

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes




Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 159

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes




Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 160

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes




Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 161

Impact to evolutionary biology

**New Idea**

Evolution → Nash equilibrium of game played by genes



Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO 162

Impact to evolutionary biology

New Idea

Evolution → Nash equilibrium of game played by genes

D

Fitness of species may not be maximized !

Suppose genes play a game similar to Prisoner's Dilemma

THE UNIVERSITY OF TOKYO

163

New Idea

Evolution → Nash equilibrium of game played by selfish genes

D

Fitness of species may not be maximized !

THE UNIVERSITY OF TOKYO

164

Game theory has **fundamentally changed** the way we view biological evolution

New Idea

Evolution → Nash equilibrium of game played by selfish genes

D

Fitness of species may not be maximized !

THE UNIVERSITY OF TOKYO

165

4.4 Group rationality vs. rationality of individuals in **social thought**

THE UNIVERSITY OF TOKYO

166

One of the **most important** messages of Game Theory

What is good for society  $\nRightarrow$  What is good for each individual

THE UNIVERSITY OF TOKYO

167

One of the **most important** messages of Game Theory

What is good for society  $\nRightarrow$  What is good for each individual

Group rationality

THE UNIVERSITY OF TOKYO

168

One of the **most important** messages of Game Theory

What is good for society

Group rationality



What is good for each individual

Rationality of individuals



THE UNIVERSITY OF TOKYO

169

One of the **most important** messages of Game Theory

What is good for society

Group rationality



What is good for each individual

Rationality of individuals

**Nash equilibrium**



THE UNIVERSITY OF TOKYO

170

One of the **most important** messages of Game Theory

What is good for society

Group rationality

**Efficient outcome**



What is good for each individual

Rationality of individuals

**Nash equilibrium**



THE UNIVERSITY OF TOKYO

171

One of the **most important** messages of Game Theory

What is good for society

Group rationality

**Efficient outcome**



What is good for each individual

Rationality of individuals

**Nash equilibrium**

Absent "strategic or game theoretic" reasoning,

we tend to think that this would happen



THE UNIVERSITY OF TOKYO

172

Impact to social thought



Adam smith



THE UNIVERSITY OF TOKYO

173

Impact to social thought



Adam smith

Rational pursuit of individual happiness leads to a socially optimal outcome



THE UNIVERSITY OF TOKYO

174

Impact to social thought



Adam smith

Rational pursuit of individual happiness leads to a socially optimal outcome in competitive markets

Impact to social thought



Adam smith

Rational pursuit of individual happiness leads to a socially optimal outcome in competitive markets

"Invisible hand"

Impact to social thought

Market for used textbooks

Impact to social thought

Market for used textbooks



Willing to pay up tp \$80

Impact to social thought

Market for used textbooks



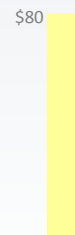
\$80



Willing to pay up tp \$80

Impact to social thought

Market for used textbooks



\$80



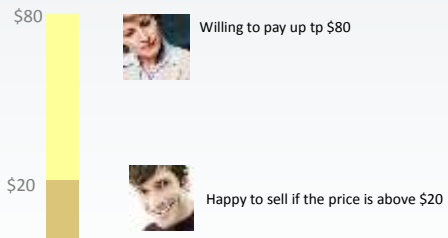
Willing to pay up tp \$80



Happy to sell if the price is above \$20

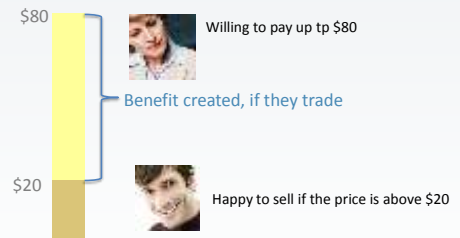
# Impact to social thought

## Market for used textbooks



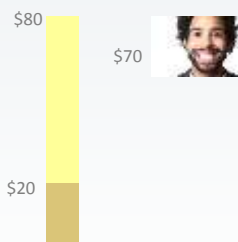
# Impact to social thought

## Market for used textbooks



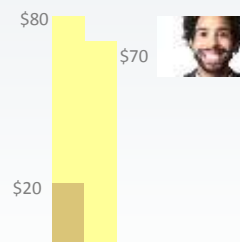
# Impact to social thought

## Market for used textbooks



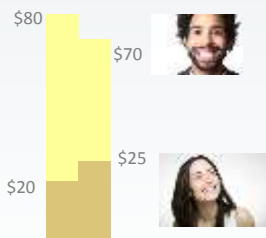
# Impact to social thought

## Market for used textbooks



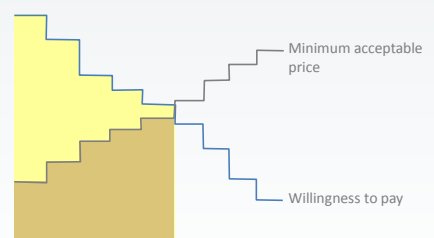
# Impact to social thought

## Market for used textbooks



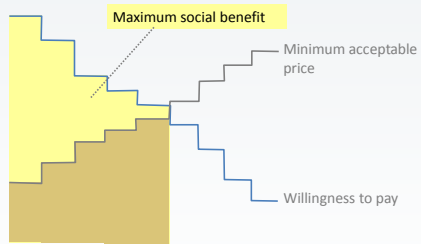
# Impact to social thought

## Market for used textbooks



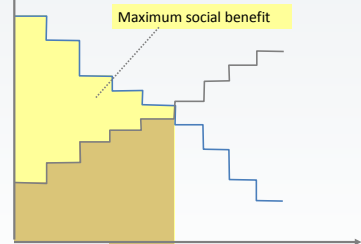
# Impact to social thought

Market for used textbooks



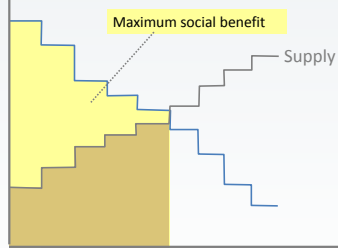
# Impact to social thought

Market Price



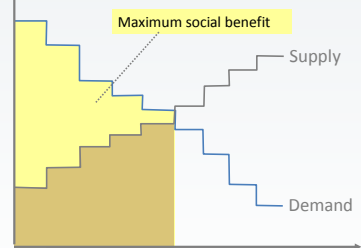
# Impact to social thought

Market Price



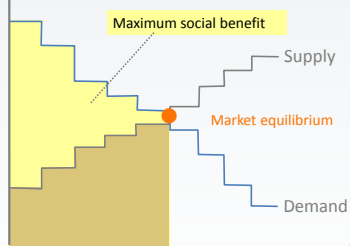
# Impact to social thought

Market Price



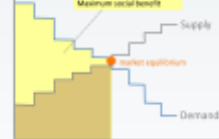
# Impact to social thought

Market Price



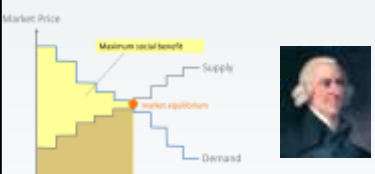
# Impact to social thought

Market Price





Impact to social thought




Adam smith

THE UNIVERSITY OF TOKYO

193

Impact to social thought



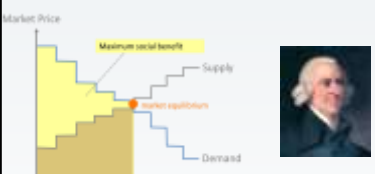
Adam smith

What is good for each individual → What is good for society

THE UNIVERSITY OF TOKYO

194

Impact to social thought



Adam smith

What is good for each individual → What is good for society

"Invisible hand"

THE UNIVERSITY OF TOKYO

195

Impact to social thought

What is good for each individual → What is good for society

"Invisible hand"

THE UNIVERSITY OF TOKYO

196

Impact to social thought

in competitive markets

What is good for each individual → What is good for society

"Invisible hand"

THE UNIVERSITY OF TOKYO

197

Impact to social thought

This idea was once **overgeneralized**

in competitive markets

What is good for each individual → What is good for society

"Invisible hand"

THE UNIVERSITY OF TOKYO

198

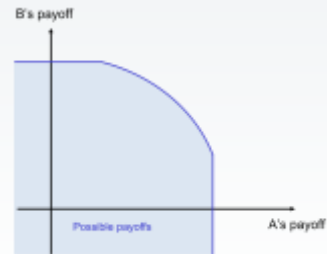
Impact to social thought

The idea of invisible hand was once **overgeneralized**



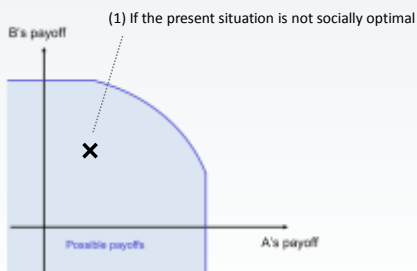
Impact to social thought

The idea of invisible hand was once **overgeneralized**



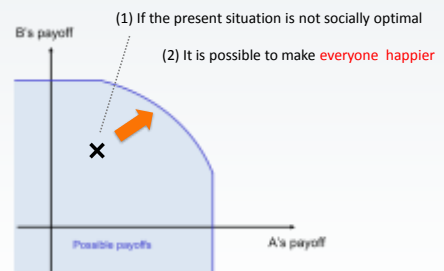
Impact to social thought

The idea of invisible hand was once **overgeneralized**



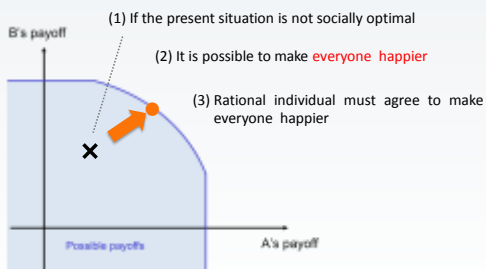
Impact to social thought

The idea of invisible hand was once **overgeneralized**



Impact to social thought

The idea of invisible hand was once **overgeneralized**



Impact to social thought



### Impact to social thought

- (1) If the present situation is not socially optimal



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals  
freedom to choose



Best outcome in society



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals  
freedom to choose



Best outcome in society

Naïve social thought for †Laissez-faire

†Laissez-faire: The policy of leaving things to take their own course, without interfering:  
From: Oxford Dictionaries



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals  
freedom to choose



Best outcome in society



Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals freedom to choose → Best outcome in society

Around 1980, a number of conservative economists forcefully advocated this idea

THE UNIVERSITY OF TOKYO 211

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals freedom to choose → Best outcome in society

THE UNIVERSITY OF TOKYO 212

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals freedom to choose → Best outcome in society

Liberal economists tried to refute this idea

THE UNIVERSITY OF TOKYO 213

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals freedom to choose → Best outcome in society

Liberal economists tried to refute this idea  
Often times their argument was that people are **not so rational**

THE UNIVERSITY OF TOKYO 214

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

Give rational individuals freedom to choose → Best outcome in society

Liberal economists tried to refute this idea  
Often times their argument was that people are **not so rational**  
Conservative economists were **not** convinced.

THE UNIVERSITY OF TOKYO 215

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone** happier
- (3) Rational individual must agree to make everyone happier

THE UNIVERSITY OF TOKYO 216

### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

Throughout the 1980's, game theory became a dominant mode of research in economics



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

### Game theory's conviction



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

There is **nothing wrong** in (1) – (3).

### Game theory's conviction



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

### Game theory's conviction



### Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

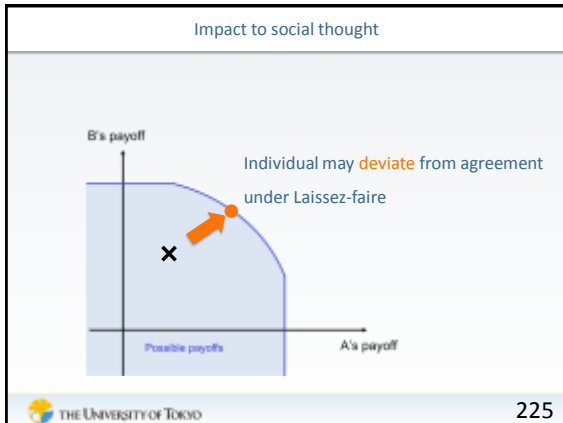
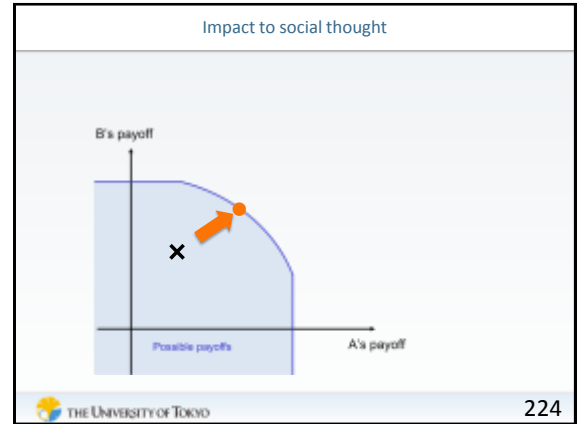
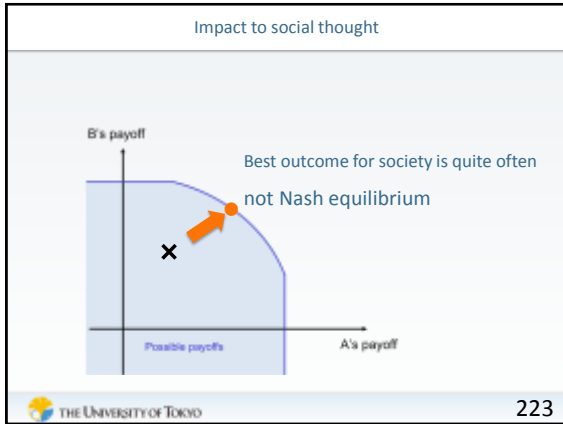
But the agreement (3) may **not be sustainable**.

### Game theory's conviction



### Impact to social thought





Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

This argument is wrong, because agreement (3) may **not be sustainable**.

Game theory's conviction

THE UNIVERSITY OF TOKYO

226

Impact to social thought

- (1) If the present situation is not socially optimal
- (2) It is possible to make **everyone happier**
- (3) Rational individual must agree to make everyone happier

This argument is wrong, because agreement (3) may **not be sustainable**.

Game theory's conviction

Economists are now fully convinced that this naïve idea is false

THE UNIVERSITY OF TOKYO

227

Impact to social thought

Give rational individuals freedom to choose

→



Best outcome in society

THE UNIVERSITY OF TOKYO

228

Impact to social thought

Give rational individuals freedom to choose → Best outcome in society

Stop global warming!      But, .....

Reality

THE UNIVERSITY OF TOKYO 229

Impact to social thought

Give rational individuals freedom to choose → Best outcome in society

THE UNIVERSITY OF TOKYO 230

Impact to social thought

Give rational individuals freedom to choose → Best outcome in society

Game theory **put an end** to this naïve social thought.

THE UNIVERSITY OF TOKYO 231

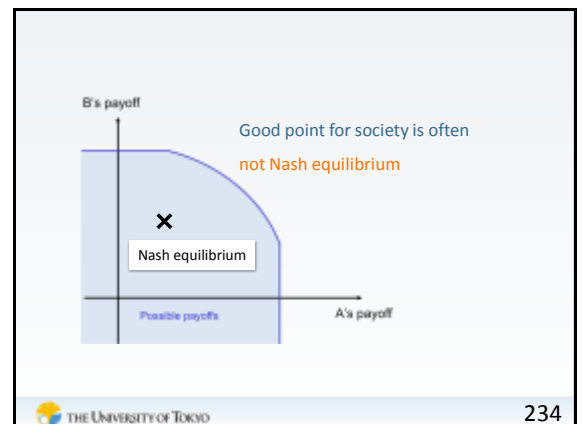
4.5 How to enforce socially desirable outcomes

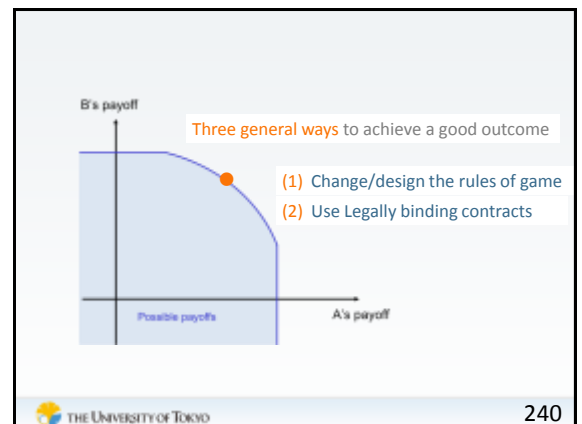
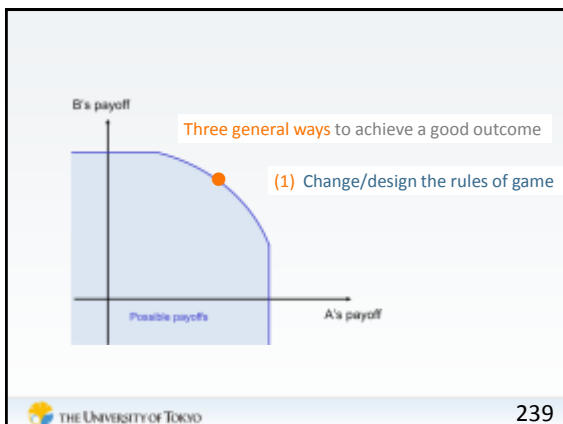
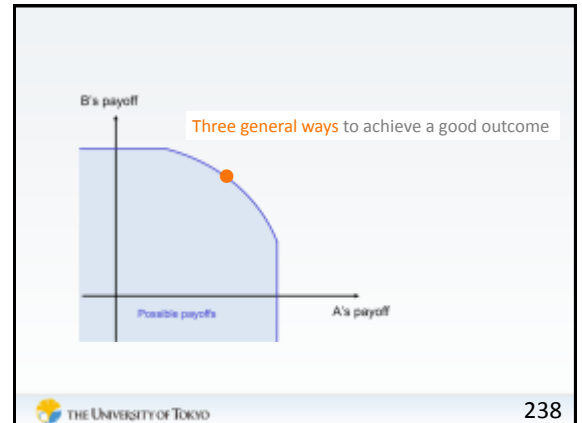
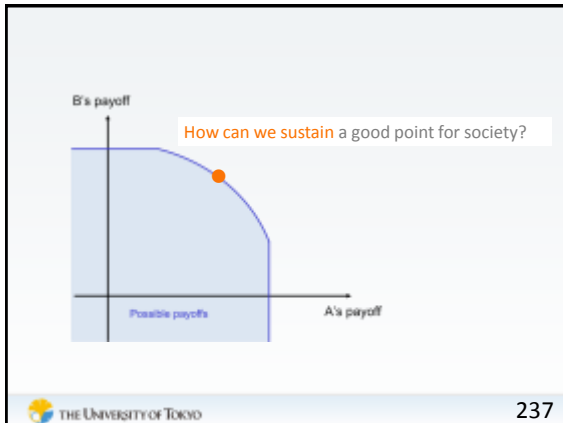
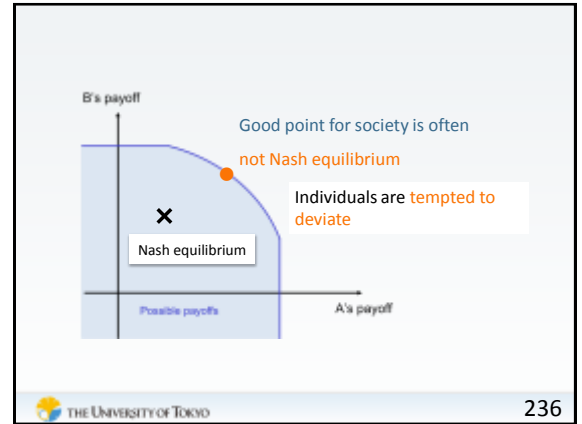
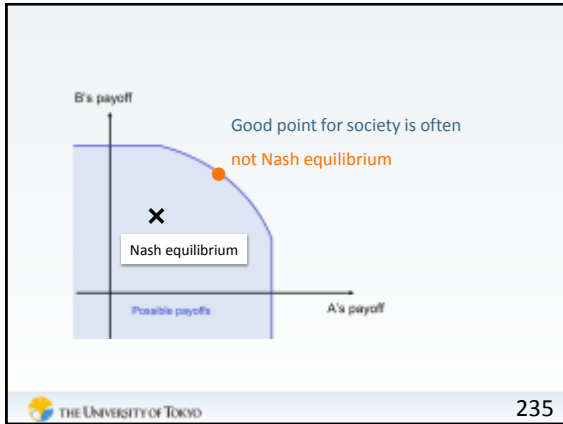
THE UNIVERSITY OF TOKYO 232

4.5 How to enforce socially desirable outcomes

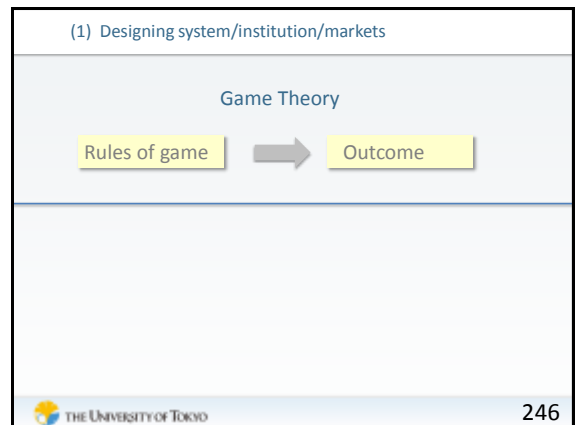
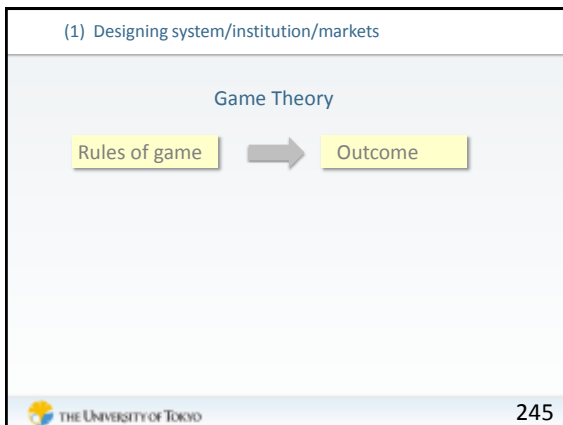
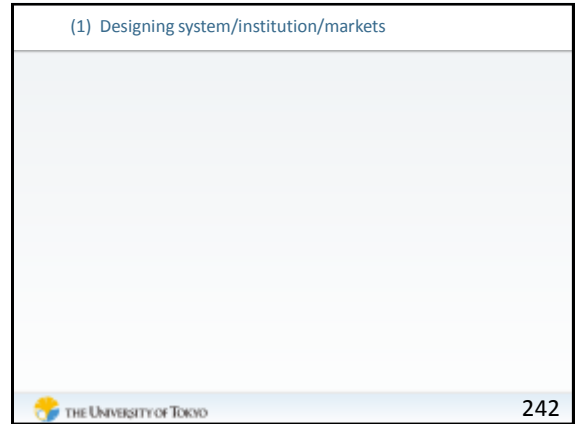
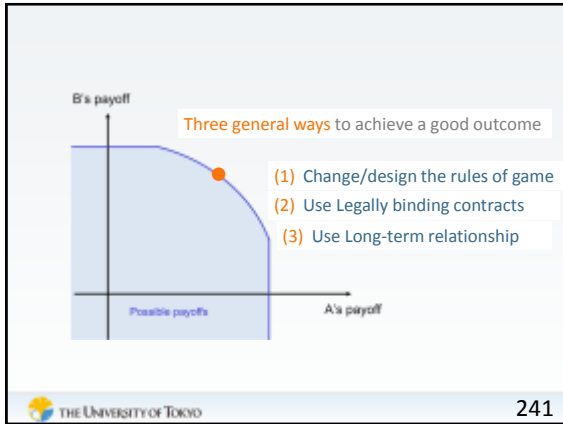
There are **three** general ways.

THE UNIVERSITY OF TOKYO 233









Game Theory

Rules of game



Outcome

Good outcome

Game Theory

Rules of game



Outcome

Rules of game?



Good outcome

Game Theory

Rules of game



Outcome

Rules of game?



Good outcome

Design system/institution/trading rules carefully,

Game Theory

Rules of game



Outcome

Rules of game?



Good outcome

Design system/institution/trading rules carefully, in such a way that individuals have an incentive to achieve a good outcome

Game Theory

Rules of game



Outcome

Mechanism Design / Market Design

Rules of game?



Good outcome

Design system/institution/trading rules carefully, in such a way that individuals have an incentive to achieve a good outcome

Mechanism Design / Market Design

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

- Matching young doctors to hospitals for on the job training

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

- Matching young doctors to hospitals for on the job training



Nobel Prize in Economics 2012



Alvin E. Roth  
Credit: Bengt Nyman, CC BY 2.0



Lloyd S. Shapley  
Credit: Bengt Nyman, CC BY 2.0

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

- Matching young doctors to hospitals for on the job training

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

- Matching young doctors to hospitals for on the job training
- Matching students to public schools

(1) Designing system/institution/markets

Mechanism Design / Market Design

Game theory has been applied to design real-life institutions

- Matching young doctors to hospitals for on the job training
- Matching students to public schools
- Auction rules to sell spectrum bands to mobile phone companies

(2) Sign a legally binding contract



(2) Sign a legally binding contract

to enforce a desirable outcome,



(2) Sign a legally binding contract

to enforce a desirable outcome, where individuals have an incentive to deviate



(2) Sign a legally binding contract

to enforce a desirable outcome, where individuals have an incentive to deviate

■ Employment contract



(2) Sign a legally binding contract

to enforce a desirable outcome, where individuals have an incentive to deviate

■ Employment contract

■ Construction contract

⋮



(2) Sign a legally binding contract

to enforce a desirable outcome, where individuals have an incentive to deviate

■ Employment contract

■ Construction contract

⋮

"Legally binding" contract is enforced by the court



(2) Sign a legally binding contract

to enforce a desirable outcome, where individuals have an incentive to deviate

- Employment contract
- Construction contract

⋮

"Legally binding" contract is enforced by the court

If contract is breached, penalty is imposed by the court



(2) Sign a legally binding contract

Individuals have an incentive to cheat



(2) Sign a legally binding contract

Individuals have an incentive to cheat



Gain from cheating



(2) Sign a legally binding contract

Individuals have an incentive to cheat



Gain from cheating

If contract is breached, penalty is imposed by the court



(2) Sign a legally binding contract

Individuals have an incentive to cheat



Gain from cheating

Penalty



If contract is breached, penalty is imposed by the court



(2) Sign a legally binding contract

Individuals have an incentive to cheat



Gain from cheating

$\leq$

Penalty



If contract is breached, penalty is imposed by the court



(2) Sign a legally binding contract

$$\text{Gain from cheating} \leq \text{Penalty}$$

(2) Sign a legally binding contract

$$\text{Gain from cheating} \leq \text{Penalty}$$

Condition to **sustain desirable outcome**

(2) Sign a legally binding contract

$$\text{Gain from cheating} \leq \text{Penalty}$$

Condition to **sustain desirable outcome**

“Incentive compatibility condition”

(2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

(2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

■ Legal contract is **costly**

(2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

■ Legal contract is **costly**

Writing a detailed contract

## (2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

- Legal contract is **costly**

**Writing** a detailed contract

**Litigation** when it is breached



## (2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

- Legal contract is **costly**

**Writing** a detailed contract

**Litigation** when it is breached

- The court may be unable to **observe** if the right actions were taken.



## (2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

- Legal contract is **costly**

**Writing** a detailed contract

**Litigation** when it is breached

- The court may be unable to **observe** if the right actions were taken.

- There may be **no legal system** to enforce a contract



## (2) Sign a legally binding contract

However, we do **not** sign a legal contract **so often**.

- Legal contract is **costly**

**Writing** a detailed contract

**Litigation** when it is breached

- The court may be unable to **observe** if the right actions were taken.

- There may be **no legal system** to enforce a contract



Stop global warming!



But, .....



## (3) Use long-term relationship



## (3) Use long-term relationship

A less costly and more flexible alternative to legal contract



### (3) Use long term relationship

Recall how a legal contract works

### (3) Use long term relationship

Recall how a legal contract works

Individuals have an incentive to cheat



Gain from cheating

### (3) Use long term relationship

Recall how a legal contract works

Individuals have an incentive to cheat



Gain from cheating

Penalty



If contact is breached, penalty is imposed by the court

### (3) Use long term relationship

Recall how a legal contract works

Individuals have an incentive to cheat



Gain from cheating  $\leq$  Penalty



If contact is breached, penalty is imposed by the court

### (3) Use long-term relationship

How long-term relationship works

Gain from cheating  $\leq$  Penalty

### (3) Use long-term relationship

How long-term relationship works

If you cheat, you can gain today....

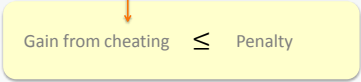
Gain from cheating  $\leq$  Penalty



### (3) Use long-term relationship

How long-term relationship works

If you cheat, you can gain today....



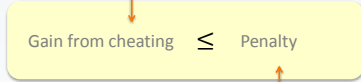
Gain from cheating  $\leq$  Penalty

The diagram consists of a yellow rounded rectangle containing the text 'Gain from cheating ≤ Penalty'. An orange arrow points from the text 'If you cheat, you can gain today....' down to the 'Gain from cheating' part of the equation.

### (3) Use long-term relationship

How long-term relationship works

If you cheat, you can gain today....



Gain from cheating  $\leq$  Penalty

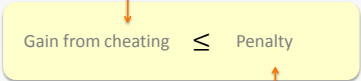
The diagram consists of a yellow rounded rectangle containing the text 'Gain from cheating ≤ Penalty'. An orange arrow points from the text 'If you cheat, you can gain today....' down to the 'Gain from cheating' part of the equation. Another orange arrow points from the text '... but your partner will penalize you in the future' up to the 'Penalty' part of the equation.

... but your partner will penalize you in the future

### (3) Use long-term relationship

We will see how it works in the next lecture

If you cheat, you can gain today....



Gain from cheating  $\leq$  Penalty

The diagram consists of a yellow rounded rectangle containing the text 'Gain from cheating ≤ Penalty'. An orange arrow points from the text 'If you cheat, you can gain today....' down to the 'Gain from cheating' part of the equation. Another orange arrow points from the text '... but your partner will penalize you in the future' up to the 'Penalty' part of the equation.

... but your partner will penalize you in the future

## 4.6 Cooperation of gas stations in long-term relationship

## 4.6 Cooperation of gas stations in long-term relationship

Part I: Need for cooperation

Gas stations at near-by locations

### Gas stations at near-by locations



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

Different prices



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

Different prices → All customers go to cheaper station



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

Different prices → All customers go to cheaper station

Same prices



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

Different prices → All customers go to cheaper station  
 Same prices → Customers are split equally



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

Different prices → All customers go to cheaper station  
 Same prices → Customers are split equally



Credit: Kikuya-Nakamura

- Same unit cost

### Gas stations at near-by locations

- Prices posted every morning
- Selling identical product (gasoline)

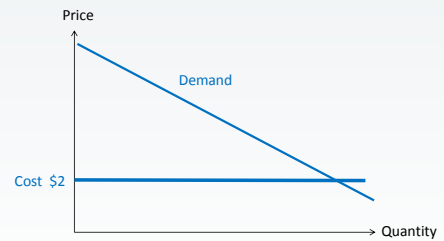
Different prices → All customers go to cheaper station  
 Same prices → Customers are split equally



Credit: Kikuya-Nakamura

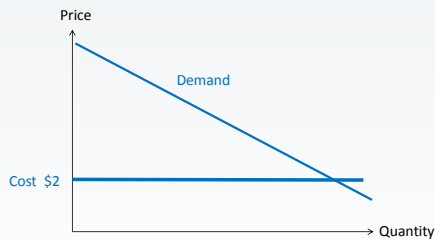
- Same unit cost (wholesale price of gas + labor ...)

### Gas stations at near-by locations



### Gas stations at near-by locations

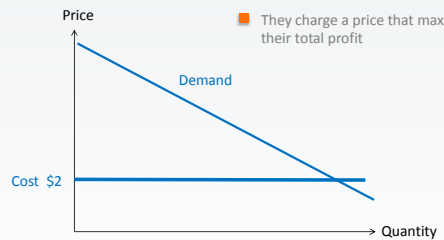
Best outcome for gas stations



### Gas stations at near-by locations

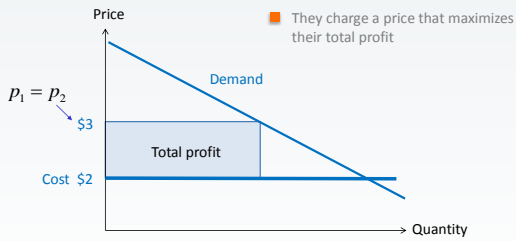
Best outcome for gas stations

- They charge a price that maximizes their total profit



Gas stations at near-by locations

Best outcome for gas stations

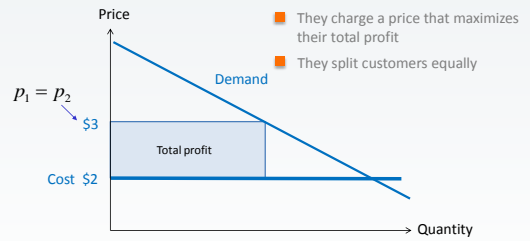


THE UNIVERSITY OF TOKYO

307

Gas stations at near-by locations

Best outcome for gas stations

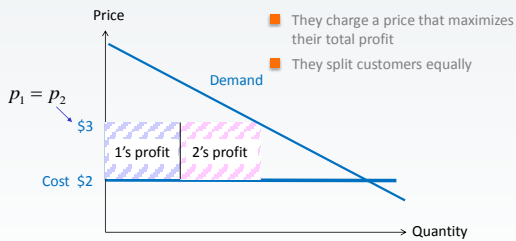


THE UNIVERSITY OF TOKYO

308

Gas stations at near-by locations

Best outcome for gas stations

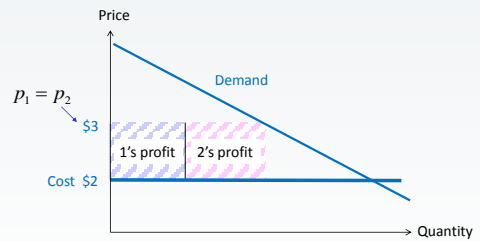


THE UNIVERSITY OF TOKYO

309

Gas stations at near-by locations

Best outcome for gas stations



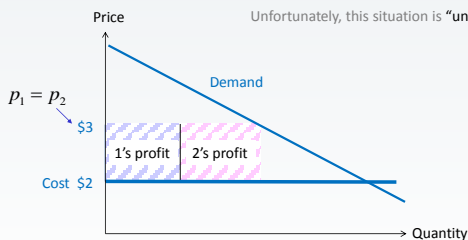
THE UNIVERSITY OF TOKYO

310

Gas stations at near-by locations

Best outcome for gas stations

Unfortunately, this situation is "unstable"



THE UNIVERSITY OF TOKYO

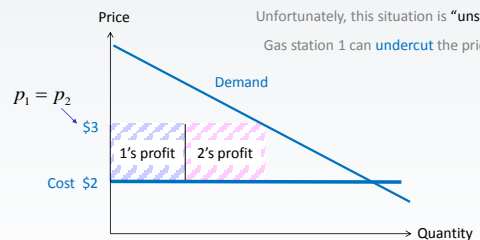
311

Gas stations at near-by locations

Best outcome for gas stations

Unfortunately, this situation is "unstable"

Gas station 1 can undercut the price slightly

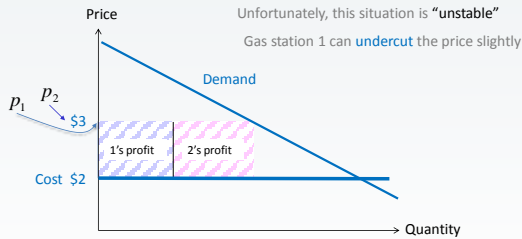


THE UNIVERSITY OF TOKYO

312

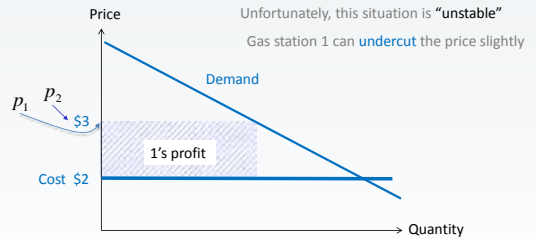
Gas stations at near-by locations

Best outcome for gas stations



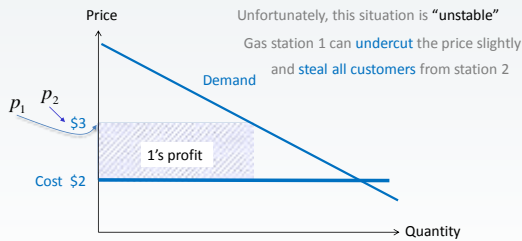
Gas stations at near-by locations

Best outcome for gas stations



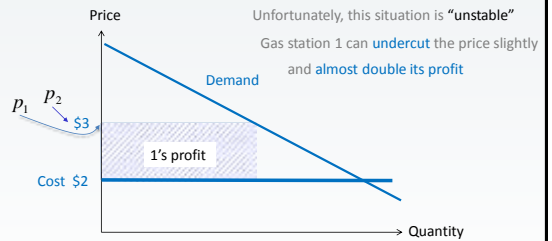
Gas stations at near-by locations

Best outcome for gas stations



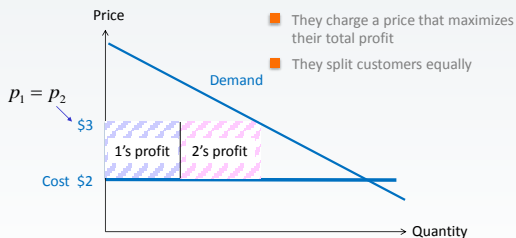
Gas stations at near-by locations

Best outcome for gas stations



Gas stations at near-by locations

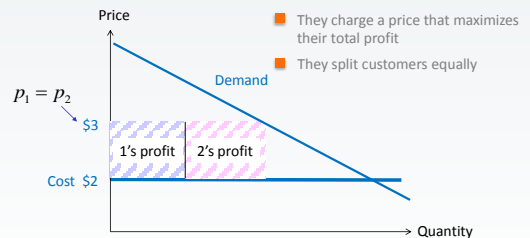
Best outcome for gas stations



Gas stations at near-by locations

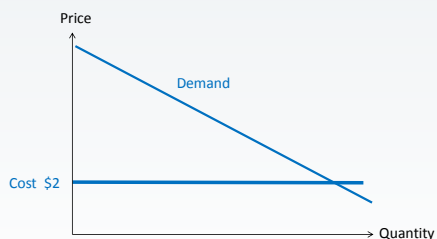
Not Nash equilibrium

Best outcome for gas stations



Gas stations at near-by locations

Nash equilibrium of price competition

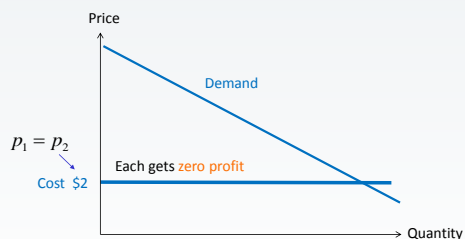


THE UNIVERSITY OF TOKYO

319

Gas stations at near-by locations

Nash equilibrium of price competition



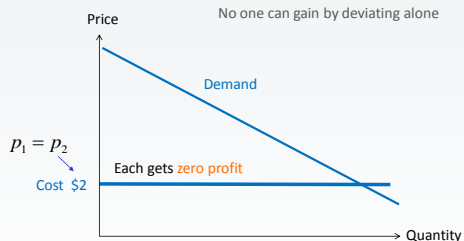
THE UNIVERSITY OF TOKYO

320

Gas stations at near-by locations

Nash equilibrium of price competition

No one can gain by deviating alone



THE UNIVERSITY OF TOKYO

321

Gas stations at near-by locations

Total profit maximization



What is good for each gas station



THE UNIVERSITY OF TOKYO

322

Gas stations at near-by locations

Total profit maximization



What is good for each gas station

Group rationality



THE UNIVERSITY OF TOKYO

323

Gas stations at near-by locations

Total profit maximization



What is good for each gas station

Group rationality

Rationality of individuals



THE UNIVERSITY OF TOKYO

324

Gas stations at near-by locations



Credit: Kikuya-Nakamura

Gas stations at near-by locations



Credit: Kikuya-Nakamura

Nash equilibrium of price competition predicts **zero profit**

Gas stations at near-by locations

They enjoy **positive profits** in reality



Credit: Kikuya-Nakamura

Nash equilibrium of price competition predicts **zero profit**

Gas stations at near-by locations

They enjoy **positive profits** in reality



Credit: Kikuya-Nakamura

Why ?

Nash equilibrium of price competition predicts **zero profit**

Gas stations at near-by locations

This is true when they play the price competition game **only once**



Credit: Kikuya-Nakamura

Nash equilibrium of price competition predicts **zero profit**

Gas stations at near-by locations

But in reality they play the price competition game **every day**



Credit: Kikuya-Nakamura

Nash equilibrium of price competition predicts **zero profit**

### Gas stations at near-by locations

In their **long-term relationship**, positive profits may be achieved



Credit: Kikuya-Nakamura

Nash equilibrium of price competition predicts **zero profit**

### Gas stations at near-by locations



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- The same players



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- The same players
- Gas stations 1 and 2



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- The same players
- Gas stations 1 and 2
- play the same game



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- The same players
- Gas stations 1 and 2
- play the same game
- Price competition



Credit: Kikuya-Nakamura



## Gas stations at near-by locations

- The same players  
Gas stations 1 and 2
- play the same game  
Price competition
- repeatedly



Credit: Kikuya-Nakamura

## Gas stations at near-by locations

- The same players  
Gas stations 1 and 2
- play the same game  
Price competition
- repeatedly  
Today, tomorrow, .....



Credit: Kikuya-Nakamura

## Gas stations at near-by locations

- The same players  
Gas stations 1 and 2
- play the same game  
Price competition
- repeatedly  
Today, tomorrow, .....



Credit: Kikuya-Nakamura

“Repeated Game”

## Gas stations at near-by locations

- The same players  
Gas stations 1 and 2
- play the same game  
Price competition
- repeatedly  
Today, tomorrow, .....



Credit: Kikuya-Nakamura

“Repeated Game”

A model of long-term relationship

## Gas stations at near-by locations

- The same players  
Gas stations 1 and 2
- play the same game  
Price competition
- repeatedly  
Today, tomorrow, .....



Credit: Kikuya-Nakamura

“Repeated Game”

A model of long-term relationship

## Gas stations at near-by locations

How do they sustain a high price  
in long-term relationship?



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

How do they sustain a high price in long-term relationship?

#### Plausible considerations



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

How do they sustain a high price in long-term relationship?

#### Plausible considerations

- I can undercut the price and increase my profit today



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

How do they sustain a high price in long-term relationship?

#### Plausible considerations

- I can undercut the price and increase my profit today
- But it may trigger **cut-throat price competition** in the future



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

How do they sustain a high price in long-term relationship?

#### Plausible considerations

- I can undercut the price and increase my profit today
- But it may trigger **cut-throat price competition** in the future
- That's not good for me after all, so let me stick to the high price



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

How do they sustain a high price in long-term relationship?

#### Plausible considerations

- I can undercut the price and increase my profit today
- But it may trigger **cut-throat price competition** in the future
- That's not good for me after all, so let me stick to the high price



Credit: Kikuya-Nakamura

## 4.7 Cooperation of gas stations in long-term relationship

## 4.7 Cooperation of gas stations in long-term relationship

### Part II: Mechanism of cooperation

### Gas stations at near-by locations

A high price may be sustained  
in long-term relationship



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A high price may be sustained  
in long-term relationship

#### Plausible considerations



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A high price may be sustained  
in long-term relationship

#### Plausible considerations

- I can undercut the price and increase my profit today



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A high price may be sustained  
in long-term relationship

#### Plausible considerations

- I can undercut the price and increase my profit today
- But it may trigger cut-throat price competition in the future



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A high price may be sustained  
in long-term relationship

#### Plausible considerations

- I can undercut the price and increase my profit today
- But it may trigger cut-throat price competition in the future
- That's not good for me after all, so let me stick to the high price



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration

- Start with high price



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration

- Start with high price
- Keep on charging high price,



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration

- Start with high price
- Keep on charging high price, if no one has deviated



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated from high price,



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

A strategy in long-term relationship that formalizes the plausible consideration

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated from high price, set price equal to cost forever



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated from high price, set price equal to cost forever



Credit: Kikuya-Nakamura

### Gas stations at near-by locations

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated from high price, set price equal to cost forever



Credit: Kikuya-Nakamura

In equilibrium, high price is maintained everyday

### Gas stations at near-by locations

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated from high price, set price equal to cost forever



Credit: Kikuya-Nakamura

Deviation triggers cut-throat price competition

### Gas stations at near-by locations

- Start with high price
- Keep on charging high price, if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

### Gas stations at near-by locations

- Start with cooperation
- Keep on charging high price, if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

### Gas stations at near-by locations

- Start with cooperation
- Keep on cooperating if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

# Gas stations at near-by locations

- Start with cooperation
- Keep on cooperating if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

# Gas stations at near-by locations

- Start with cooperation
- Keep on cooperating if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

Nash equilibrium of price competition game in one day

# Gas stations at near-by locations

- Start with cooperation
- Keep on cooperating if no one has deviated
- If anyone has deviated, set price equal to cost forever



Credit: Kikuya-Nakamura

"Trigger strategy"

Nash equilibrium of the "stage game"

# Gas stations at near-by locations

- Start with cooperation
- Keep on cooperating if no one has deviated
- If anyone has deviated, play Nash equilibrium of stage game forever

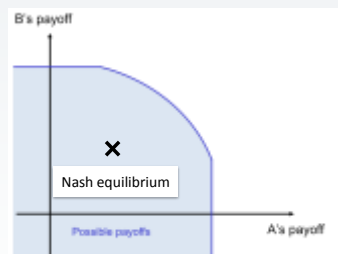


Credit: Kikuya-Nakamura

"Trigger strategy"

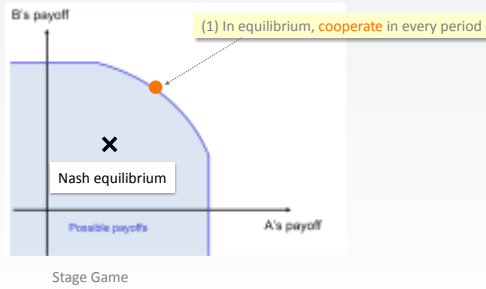
In general, trigger strategy works as follows:

In general, trigger strategy works as follows:

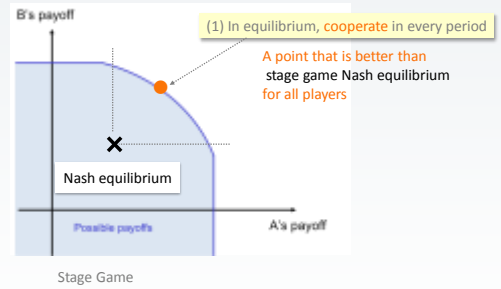


Stage Game

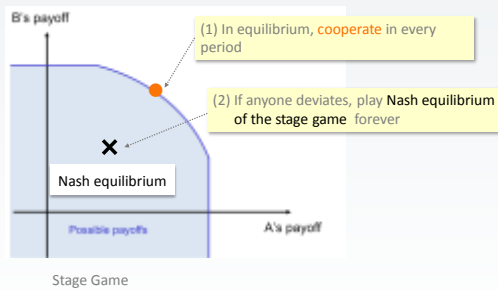
In general, **trigger strategy** works as follows:



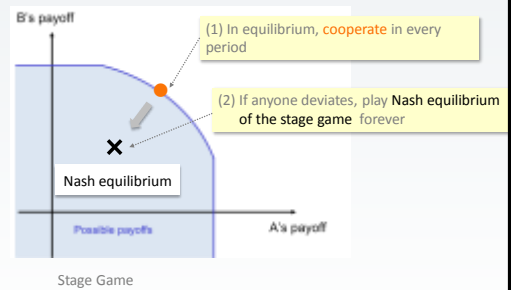
In general, **trigger strategy** works as follows:



In general, **trigger strategy** works as follows:



In general, **trigger strategy** works as follows:



## Gas stations at near-by locations

Let us examine the **condition** for the trigger strategy to support cooperation

## Gas stations at near-by locations

Let us examine the **condition** for the trigger strategy to support cooperation

Cooperation



### Gas stations at near-by locations

Let us examine the **condition** for the trigger strategy to support cooperation

**Cooperation** (charging a high price)



### Gas stations at near-by locations

Let us examine the **condition** for the trigger strategy to support cooperation

**Cooperation** (charging a high price)

Each gas station gets **\$100** every day



### Gas stations at near-by locations

A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....



### Gas stations at near-by locations

A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection					



### Gas stations at near-by locations

A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection					

By slightly undercutting the price,



### Gas stations at near-by locations

A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection					

By slightly undercutting the price,  
one can **steal all customers** from the other station





# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200				

By slightly undercutting the price,  
one can steal all customers from the other station



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200				

Gain from defection



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200				

Gain from defection



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200				

Gain from defection  
\$100 today



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200				



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Defection triggers cut-throat price competition



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday

How do we evaluate this?



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday

\$1 on Dec 31 is not as good as \$1 today



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday

We discount future payoff



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday

Let  $d$  = the value of \$1 tomorrow



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
\$100 everyday

Let  $d$  = the value of \$1 tomorrow

$d < 1$  (we discount future payoff)



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss

Let  $d$  = the value of \$1 tomorrow

$d < 1$  (we discount future payoff)



# Gas stations at near-by locations

## A gas station's payoff under trigger strategy

	March 1	March 2	March 3	March 4	.....
Cooperation	\$100	\$100	\$100	\$100	.....
Defection	almost \$200	\$0	\$0	\$0	.....

Future loss  
 $100d + 100d^2 + 100d^3 + \dots$

Let  $d$  = the value of \$1 tomorrow

$d < 1$  (we discount future payoff)



# Gas stations at near-by locations

Future loss

$$100d + 100d^2 + 100d^3 + \dots$$

$d$  = the value of \$1 tomorrow



# Gas stations at near-by locations

Today's gain from defection

100

Future loss

$$100d + 100d^2 + 100d^3 + \dots$$

$d$  = the value of \$1 tomorrow



Gas stations at near-by locations

$$\begin{array}{|c|c|} \hline \text{Today's gain from defection} & \text{Future loss} \\ \hline 100 & 100d + 100d^2 + 100d^3 + \dots \\ \hline \end{array} <$$

$d$  = the value of \$1 tomorrow



Gas stations at near-by locations

$$\begin{array}{|c|c|} \hline \text{Today's gain from defection} & \text{Future loss} \\ \hline 100 & 100d + 100d^2 + 100d^3 + \dots \\ \hline \end{array} <$$

$d$  = the value of \$1 tomorrow

Defection is not profitable under trigger strategy



Gas stations at near-by locations

In reality,  $d$  is almost equal to 1, and this condition is satisfied

$$\begin{array}{|c|c|} \hline \text{Today's gain from defection} & \text{Future loss} \\ \hline 100 & 100d + 100d^2 + 100d^3 + \dots \\ \hline \end{array} <$$

$d$  = the value of \$1 tomorrow



Gas stations at near-by locations

In reality,  $d$  is almost equal to 1, and this condition is satisfied

$$\begin{array}{|c|c|} \hline \text{Today's gain from defection} & \text{Future loss} \\ \hline 100 & 100d + 100d^2 + 100d^3 + \dots \\ \hline \end{array} <$$

$d$  = the value of \$1 tomorrow

Trigger strategy **sustains cooperation**



Gas stations at near-by locations

Gas stations can **cooperate** and maintain a high price



Credit: Kikuya-Nakamura



Gas stations at near-by locations

Gas stations can **cooperate** and maintain a high price by their **long-term relationship**



Credit: Kikuya-Nakamura



4.8 Reputation and brand name

Restaurant in touristic place



Restaurant in touristic place



Dinner  
\$50

Restaurant in touristic place



Dinner  
\$50



Restaurant in touristic place



Dinner  
\$50



High quality ?

Restaurant in touristic place



Dinner  
\$50



High quality ?

Low quality ?

Restaurant in touristic place



High quality ?

Low quality ?

You know the quality **only after eating**



Restaurant in touristic place



High quality ?

Low quality ?

Hence, you may be **cheated**



Restaurant in touristic place



High quality ?

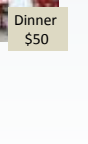
Low quality ?

How can the restaurant **assure high quality**?



Restaurant in touristic place

If you come to this place **every day**



Restaurant in touristic place

If you come to this place **every day**  
your **trigger strategy** may support high quality



Restaurant in touristic place

If you come to this place **every day**  
your **trigger strategy** may support high quality



Low quality



### Restaurant in touristic place

If you come to this place **every day**  
your **trigger strategy** may support high quality



Dinner  
\$50



### Restaurant in touristic place

If you come to this place **every day**  
your **trigger strategy** may support high quality



Dinner  
\$50



### Restaurant in touristic place

If you come to this place **every day**  
your **trigger strategy** may support high quality



Dinner  
\$50



This is a quite common situation



- You can observe **quality** of product/service **only after buying**

This is a quite common situation



- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**

This is a quite common situation



- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant

- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant

Expensive clothes

- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant

Expensive clothes

Car

- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant

Expensive clothes

Car

House



- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery



- You can observe **quality** of product/service **only after buying**
- Hence, you may be **cheated**
- You do **not** buy the same product/service **so often**

This is a quite common situation

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery  
Lawyer for legal consulting



How do they assure high quality?

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery  
Lawyer for legal consulting



**"Reputation"** or **"Brand name"** can assure high quality  
and prevent cheating

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery  
Lawyer for legal consulting



How reputation works



How reputation works

When restaurant has **good reputation** ...



### How reputation works

When restaurant has **good reputation** ...



customers **believe high quality**

### How reputation works

When restaurant has **good reputation** ...



customers **believe high quality**

Dinner  
\$50

restaurant can charge **high price**

### How reputation works

When restaurant has **good reputation** ...



customers **believe high quality**

Dinner  
\$50

restaurant can charge **high price**  
and earn **high profit**

### How reputation works

When restaurant has **good reputation** ...



customers **believe high quality**

Dinner  
\$50

restaurant can charge **high price**  
and earn **high profit**

Quality is actually high

### How reputation works

When restaurant has **good reputation** ...



customers **believe high quality**

Dinner  
\$50

restaurant can charge **high price**  
and earn **high profit**

Quality is actually high

Why ?

### How reputation works

If the restaurant **cheats**



Dinner  
\$50

### How reputation works

If the restaurant **cheats**



THE UNIVERSITY OF TOKYO

445

### How reputation works

If the restaurant **cheats**



★☆☆☆☆  
What a disappointment ....



THE UNIVERSITY OF TOKYO

446

### How reputation works

If the restaurant **cheats**



★☆☆☆☆  
What a disappointment ....

... restaurant **loses good reputation**



THE UNIVERSITY OF TOKYO

447

### How reputation works

Restaurant **loses good reputation**



customers **believe low quality**



THE UNIVERSITY OF TOKYO

448

### How reputation works

Restaurant **loses good reputation**



customers **believe low quality**

restaurant can only charge **low price**



THE UNIVERSITY OF TOKYO

449

### How reputation works

Restaurant **loses good reputation**



customers **believe low quality**

restaurant can only charge **low price**



THE UNIVERSITY OF TOKYO

450

### How reputation works



Dinner  
\$20

Restaurant **loses good reputation**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

### How reputation works



Dinner  
\$20

Restaurant **loses good reputation**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

Quality is **actually low**

### How reputation works



Dinner  
\$20

Restaurant **loses good reputation**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

Quality is **actually low**

because restaurant has no reputation  
to lose by providing low quality

### How reputation works

This is a dangerous **self-sustaining**  
situation that restaurant wants to  
avoid

**Good reputation is lost**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

Quality is **actually low**

because restaurant has no reputation  
to lose by providing low quality

### How reputation works

**Reputation or brand name** is a  
valuable asset

**Good reputation is lost**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

Quality is **actually low**

because restaurant has no reputation  
to lose by providing low quality

### How reputation works

**Reputation or brand name** is a  
valuable asset that assures high  
quality and high profit

**Good reputation is lost**



customers **believe low quality**

restaurant can only charge **low price**  
and earn **low profit**

Quality is **actually low**

because restaurant has no reputation  
to lose by providing low quality

The basic mechanism of reputation is similar to trigger strategy

Suppose ....

Gain from cheating  
\$250 today

The basic mechanism of reputation is similar to trigger strategy

Suppose ....

Gain from cheating  
\$250 today

Future profit is reduced by  
\$100 everyday

The basic mechanism of reputation is similar to trigger strategy

Today's gain from cheating  
250

The basic mechanism of reputation is similar to trigger strategy

Today's gain from cheating  
250

Future loss  
 $100d + 100d^2 + 100d^3 + \dots$

$d$  = the value of \$1 tomorrow

The basic mechanism of reputation is similar to trigger strategy

Today's gain from cheating  
250

<

Future loss  
 $100d + 100d^2 + 100d^3 + \dots$

$d$  = the value of \$1 tomorrow

The basic mechanism of reputation is similar to trigger strategy

Today's gain from cheating  
250

<

Future loss  
 $100d + 100d^2 + 100d^3 + \dots$

$d$  = the value of \$1 tomorrow

If this condition holds, reputation mechanism assures high quality/high profit

The basic mechanism of reputation is similar to trigger strategy



The basic mechanism of reputation is similar to trigger strategy



In long-term relationship, punishment is given by the **person who was cheated**

The basic mechanism of reputation is similar to trigger strategy



In reputation mechanism, punishment is given by **future customers**

The basic mechanism of reputation is similar to trigger strategy



In reputation mechanism, punishment is given by **future customers**

Information transmission (about reputation) is a substitute for long-term relationship

## Summary

### ■ Quality matters a lot

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery  
Lawyer for legal consulting

## Summary

### ■ You cannot verify quality before buying

Restaurant  
Expensive clothes  
Car  
House  
Doctor for surgery  
Lawyer for legal consulting

Summary

- You may be cheated ...
  - Restaurant
  - Expensive clothes
  - Car
  - House
  - Doctor for surgery
  - Lawyer for legal consulting

THE UNIVERSITY OF TOKYO 469

Summary

- Sellers with good reputation or brand name earn extra profit
  - Restaurant
  - Expensive clothes
  - Car
  - House
  - Doctor for surgery
  - Lawyer for legal consulting

THE UNIVERSITY OF TOKYO 470

Summary

- Sellers with good reputation or brand name earn extra profit
  - Their incentive to maintain this valuable asset assures high quality
    - Restaurant
    - Expensive clothes
    - Car
    - House
    - Doctor for surgery
    - Lawyer for legal consulting

THE UNIVERSITY OF TOKYO 471

4.9 Cooperation in loosely knit organization

THE UNIVERSITY OF TOKYO 472

Cooperation has been associated with closely knit group/organization

THE UNIVERSITY OF TOKYO 473

Cooperation has been associated with closely knit group/organization

- Individuals know each other well

THE UNIVERSITY OF TOKYO 474

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time



Credit: Ministry of Land, Infrastructure, Transport and Tourism  
1993 ANNUAL REPORT ON THE TRANSPORT ECONOMY

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time



Villagers help each other to maintain the roofs of their houses

Credit: Ministry of Land, Infrastructure, Transport and Tourism  
1993 ANNUAL REPORT ON THE TRANSPORT ECONOMY

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time



Villagers help each other to maintain the roofs of their houses  
Shirakawa-go village in Japan

Credit: Ministry of Land, Infrastructure, Transport and Tourism  
1993 ANNUAL REPORT ON THE TRANSPORT ECONOMY

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time



Villagers help each other to maintain the roofs of their houses  
Shirakawa-go village in Japan  
We saw that the theory of repeated games explains cooperation in a closely knit group

Credit: Ministry of Land, Infrastructure, Transport and Tourism  
1993 ANNUAL REPORT ON THE TRANSPORT ECONOMY



Credit: Kikuya-Nakamura

Cooperation has been associated with closely knit group/organization

- Individuals know each other well
- They stay in the group for a long time



Credit: Ministry of Land, Infrastructure, Transport and Tourism  
1993 ANNUAL REPORT ON THE TRANSPORT ECONOMY



Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

THE UNIVERSITY OF TOKYO 481

Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

THE UNIVERSITY OF TOKYO 482

Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently

THE UNIVERSITY OF TOKYO 483

Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently
- They do not know each other well

THE UNIVERSITY OF TOKYO 484

Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently
- They do not know each other well
- They stay for a short time

THE UNIVERSITY OF TOKYO 485

Cooperation has been associated with **closely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently
- They do not know each other well
- They stay for a short time

is not only theoretically possible,

THE UNIVERSITY OF TOKYO 486

Cooperation has been associated with **loosely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently
- They do not know each other well
- They stay for a short time

is not only theoretically possible, but also there is a **remarkable real-life example**

THE UNIVERSITY OF TOKYO 487

Cooperation has been associated with **loosely knit group/organization**

Received idea in Sociology

A sociologist and I collaborated to show:

Cooperation in a **loosely-knit organization**

- Individuals enter and exit frequently
- They do not know each other well
- They stay for a short time

is not only theoretically possible, but also there is a **remarkable real-life example**

M. Kandori and S. Obayashi (2014) "Labor union members play an OLG repeated game", *Proceedings of the National Academy of Science*

THE UNIVERSITY OF TOKYO 488

Theory of cooperation in loosely-knit organization

THE UNIVERSITY OF TOKYO 489

Theory of cooperation in loosely-knit organization

OLG repeated game

THE UNIVERSITY OF TOKYO 490

Theory of cooperation in loosely-knit organization

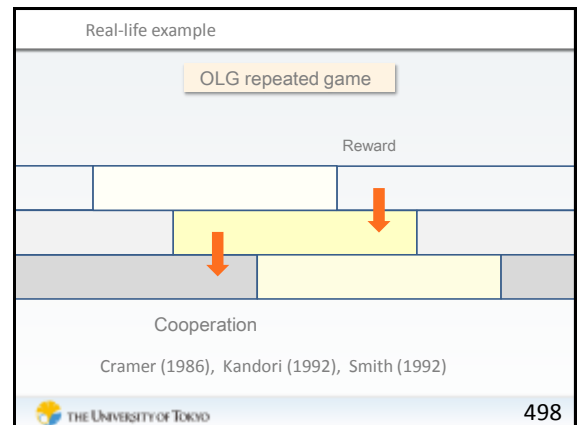
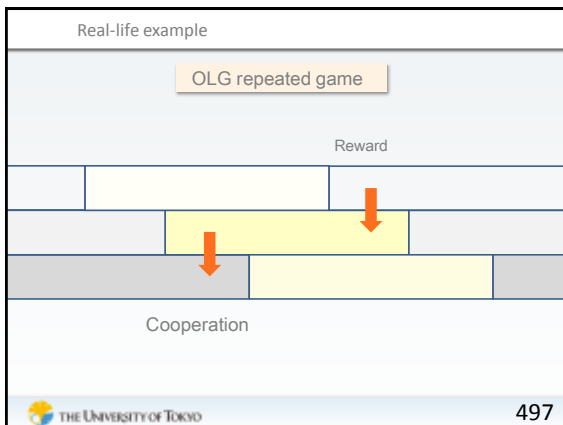
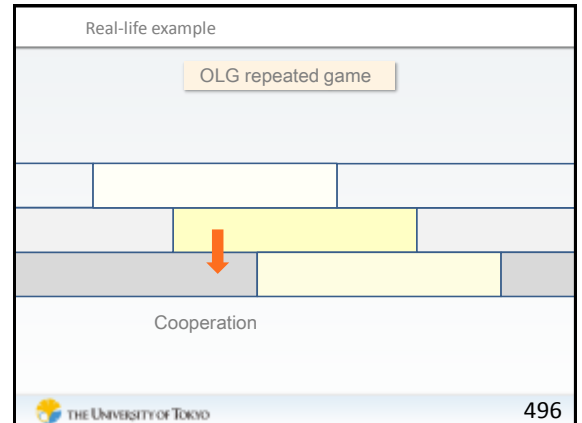
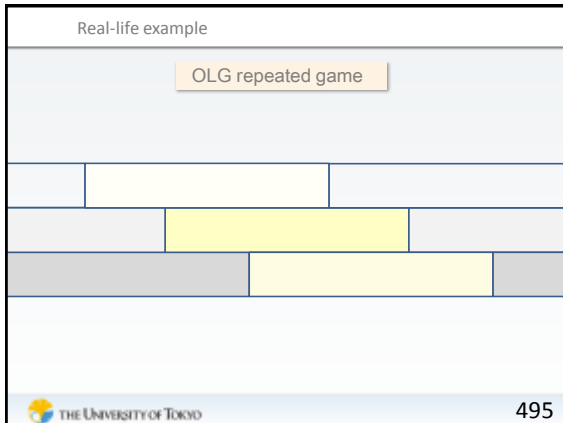
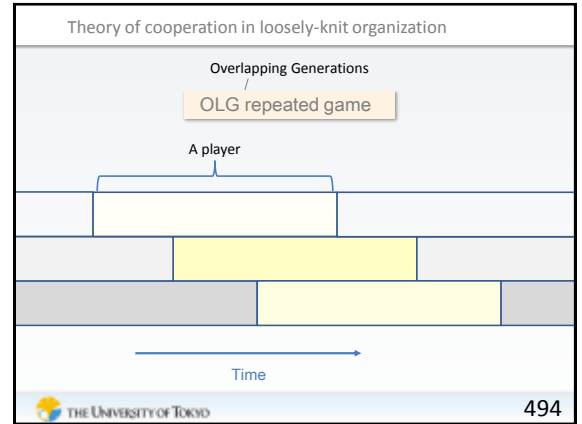
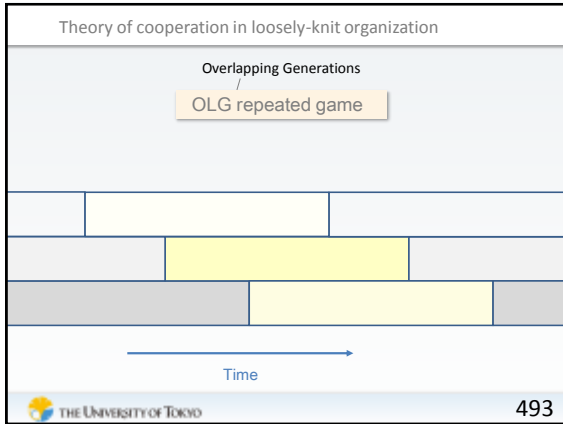
Overlapping Generations  
OLG repeated game

THE UNIVERSITY OF TOKYO 491

Theory of cooperation in loosely-knit organization

Overlapping Generations  
OLG repeated game

THE UNIVERSITY OF TOKYO 492





“Community Unions”



Labor unions with quite unusual form

“Community Unions”



Community Union



Individual-affiliate labor union

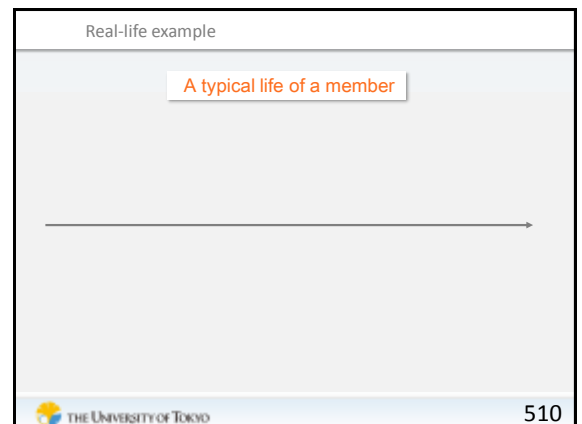
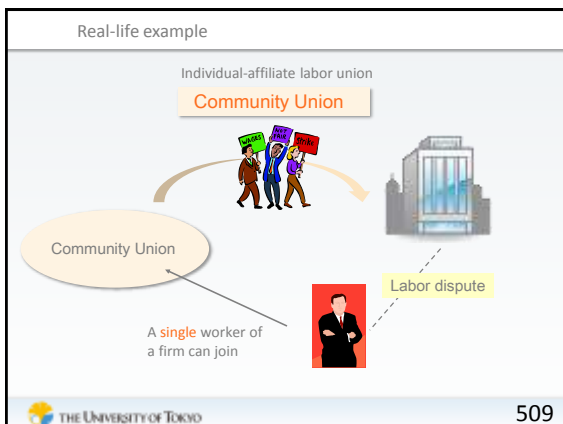
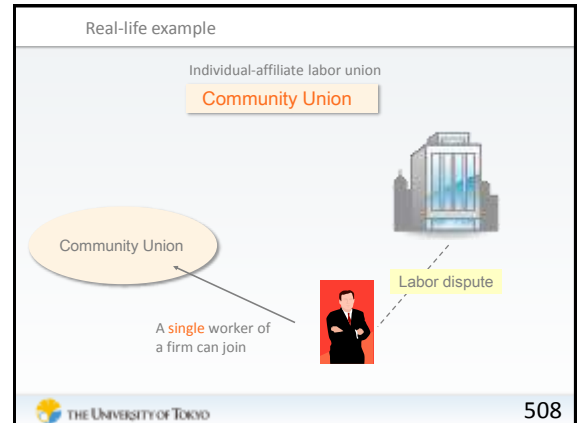
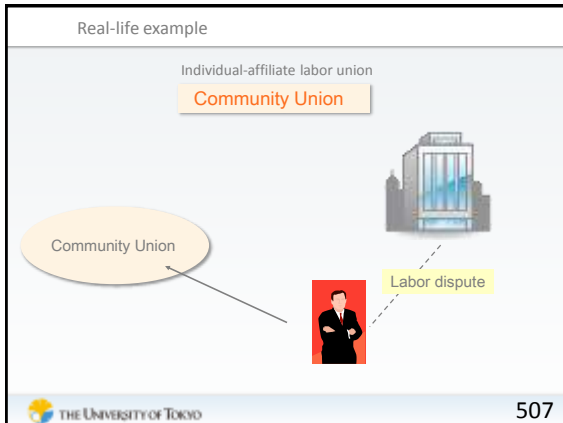
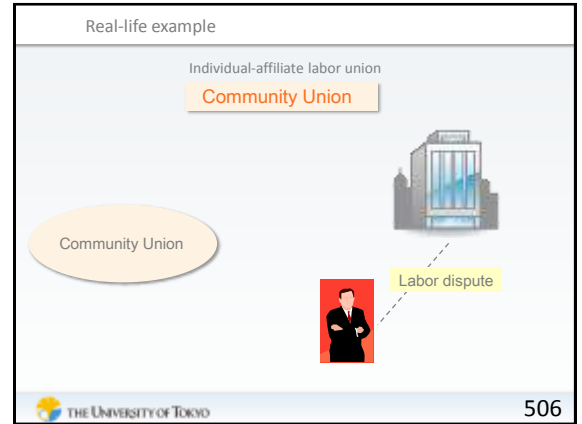
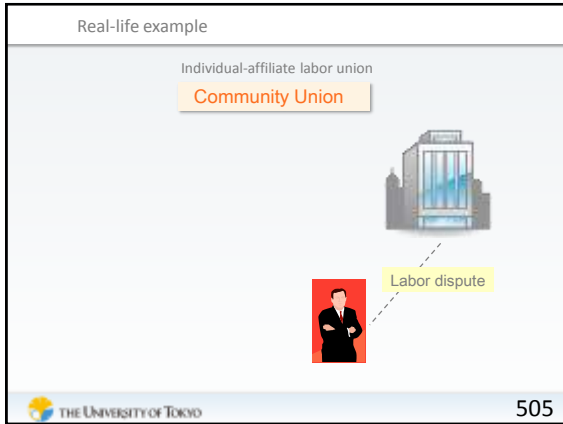
Community Union

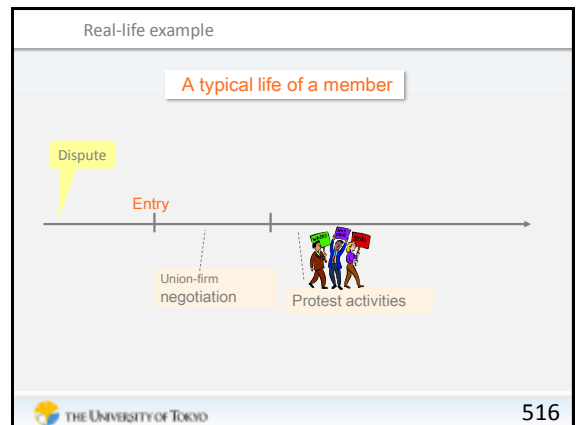
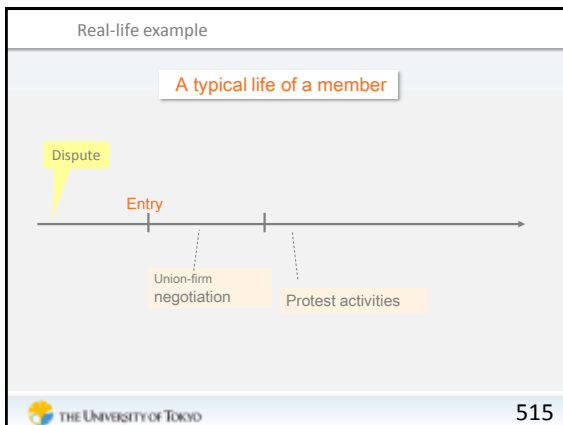
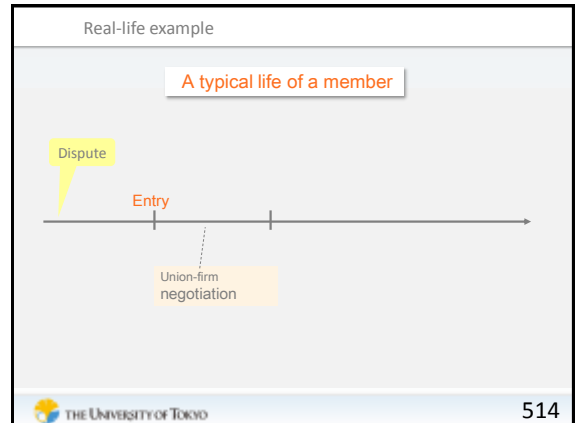
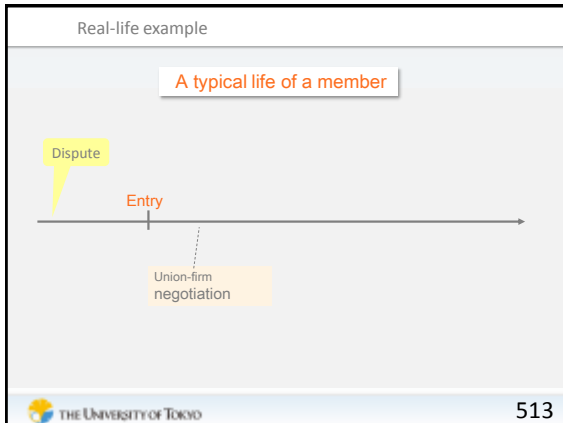
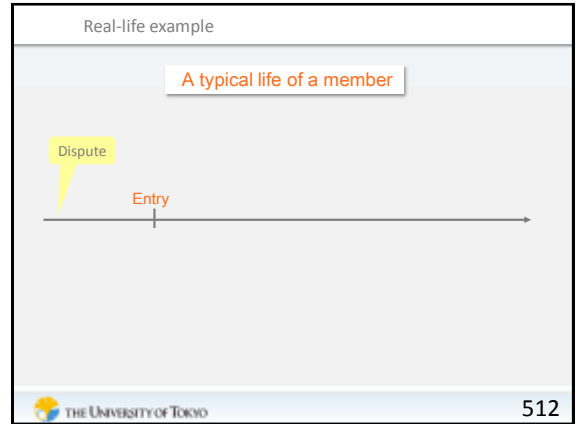
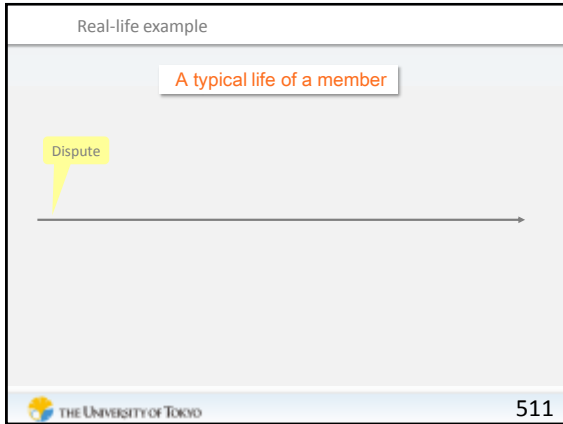


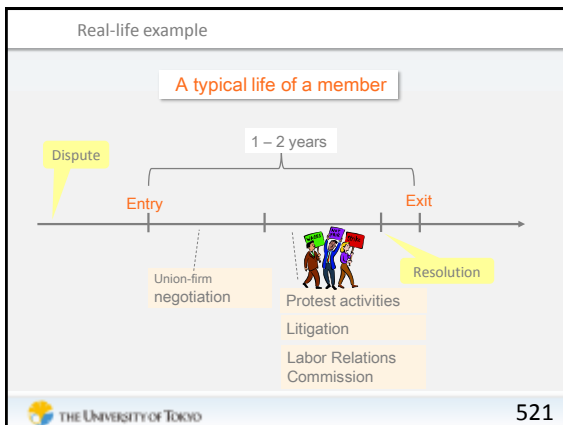
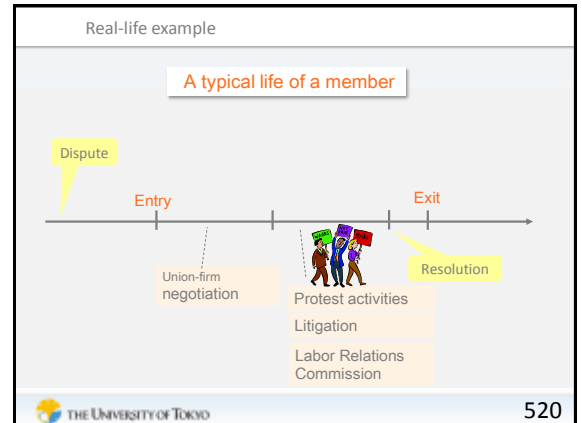
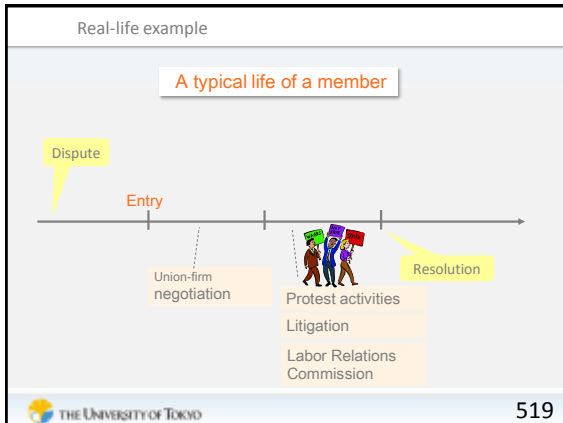
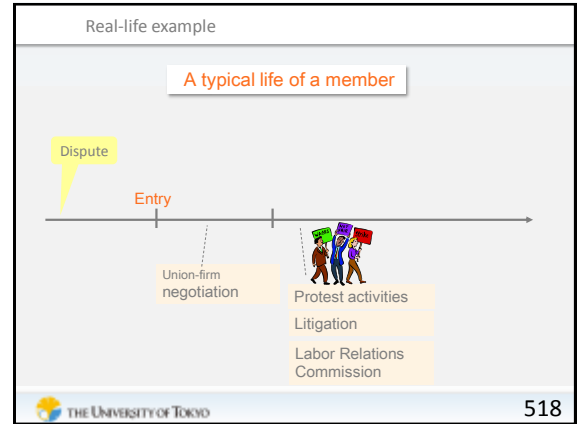
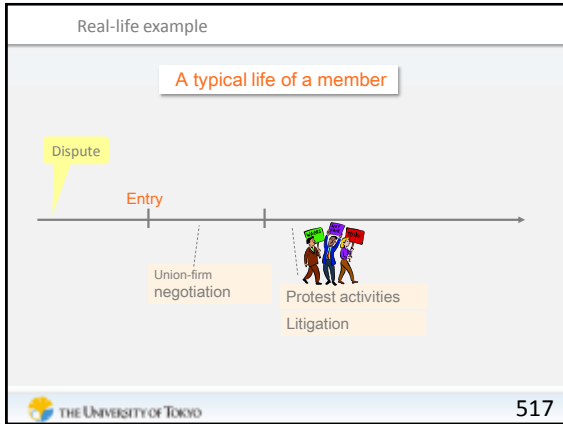
Individual-affiliate labor union

Community Union









Real-life example

A case study: Tokyo Managers' Union



THE UNIVERSITY OF TOKYO

523

Real-life example

A case study: Tokyo Managers' Union

231 members (2012)



THE UNIVERSITY OF TOKYO

524

Real-life example

A case study: Tokyo Managers' Union

231 members (2012)

Frequent entry and exit



THE UNIVERSITY OF TOKYO

525

Real-life example

A case study: Tokyo Managers' Union

231 members (2012)

Frequent entry and exit

Fiscal year 2012	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Entry	9	8	7	13	11	11	15	11	5	6	3	6	105
Exit	3	6	7	4	4	9	2	9	4	6	6	48	108



THE UNIVERSITY OF TOKYO

526

Real-life example

A case study: Tokyo Managers' Union

231 members (2012)

Frequent entry and exit

Fiscal year 2012	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Entry	9	8	7	13	11	11	15	11	5	6	3	6	105
Exit	3	6	7	4	4	9	2	9	4	6	6	48	108

Average stay: 1.92 years

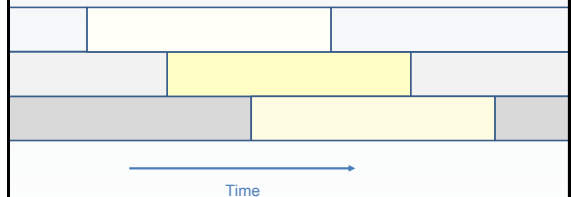


THE UNIVERSITY OF TOKYO

527

Real-life example

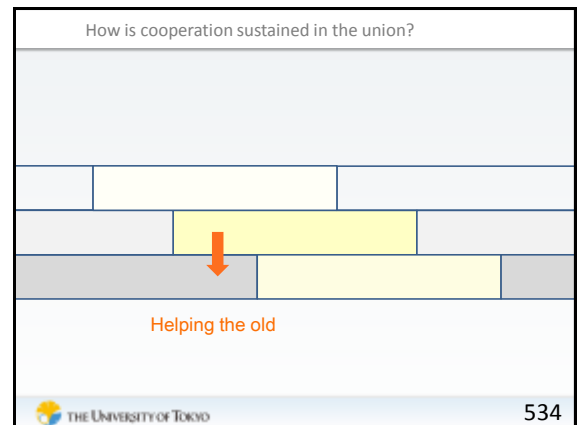
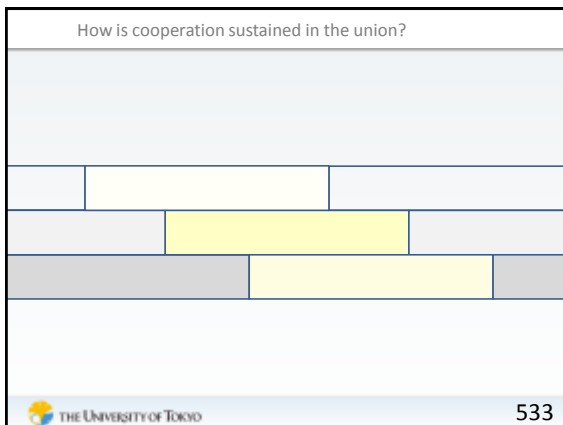
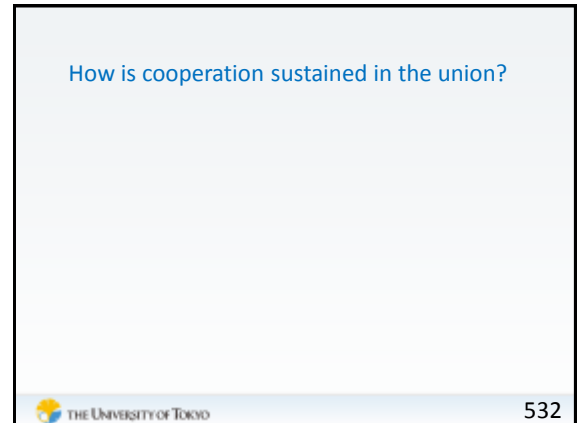
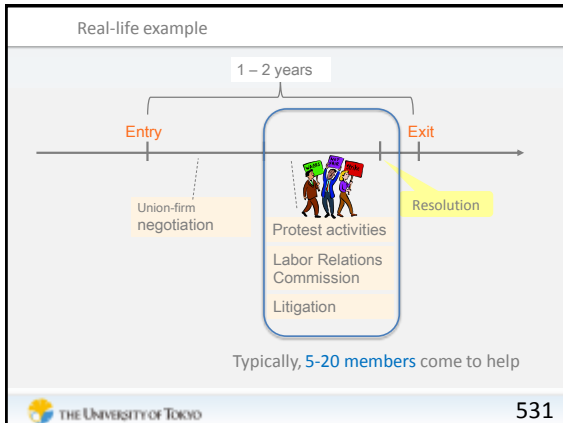
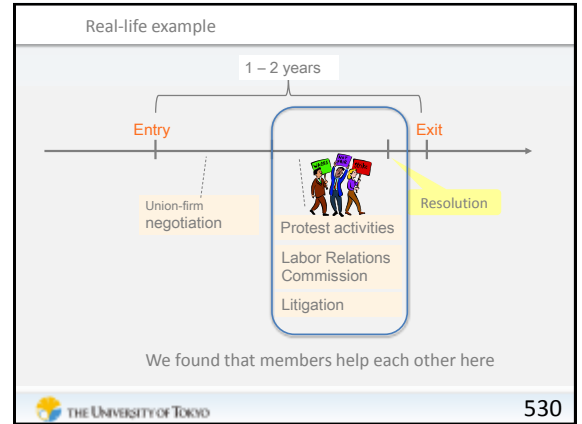
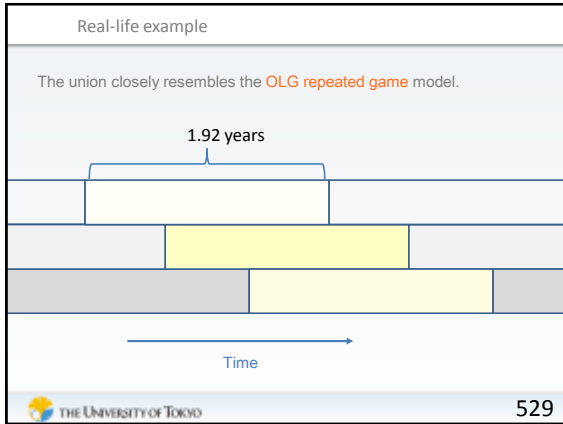
The union closely resembles the OLG repeated game model.

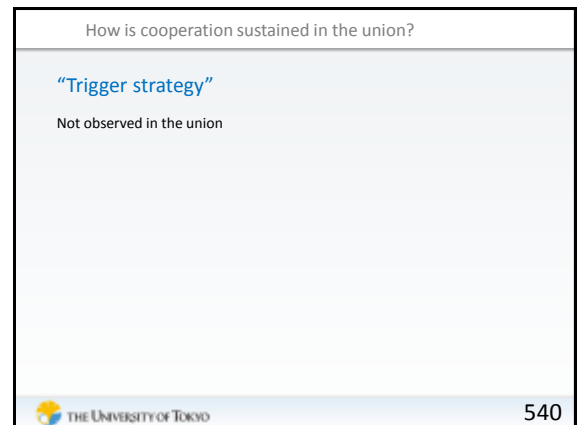
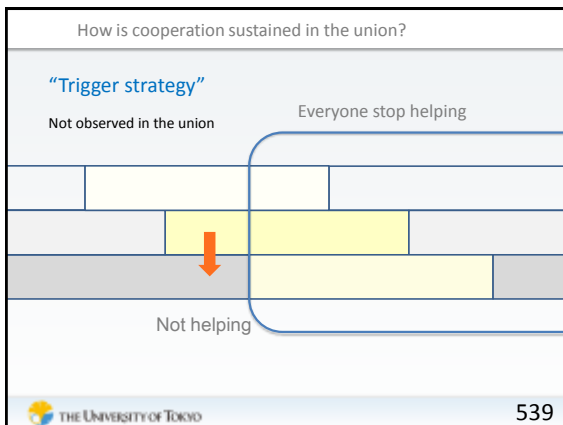
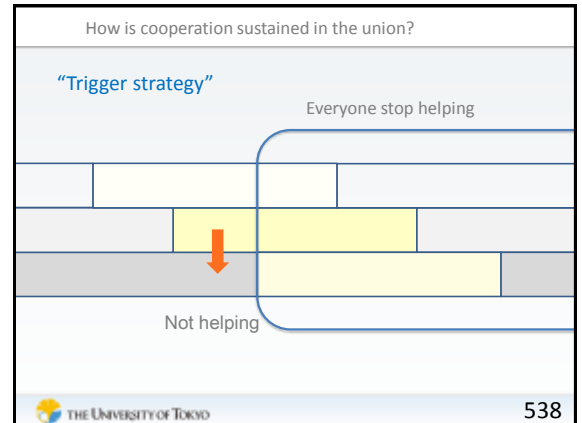
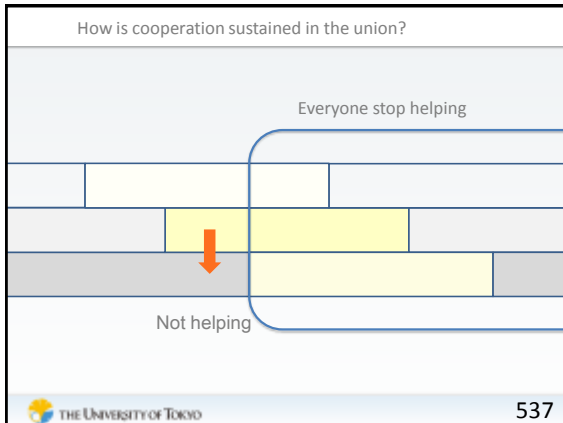
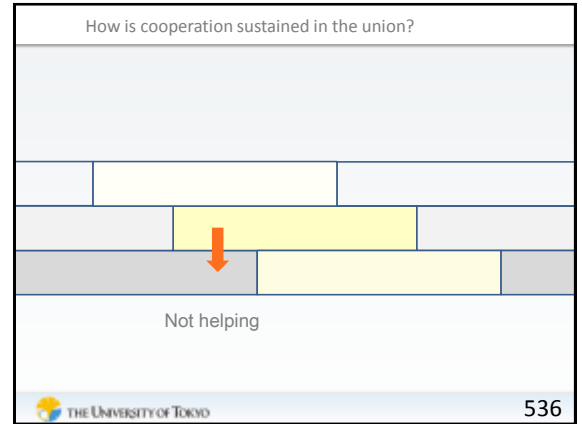
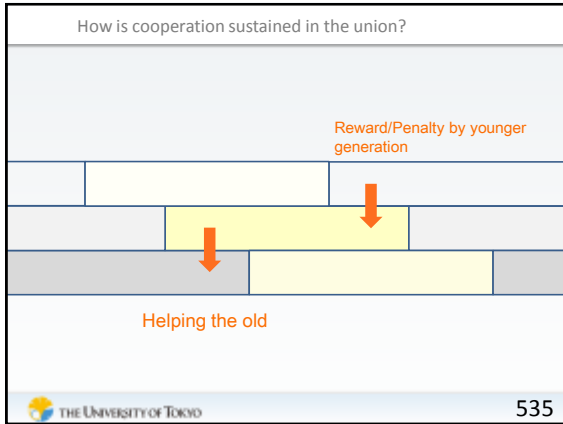


THE UNIVERSITY OF TOKYO

528







How is cooperation sustained in the union?

### "Trigger strategy"

Not observed in the union

Theory of repeated games show that there are **many other ways** to sustain cooperation

How is cooperation sustained in the union?

### "Trigger strategy"

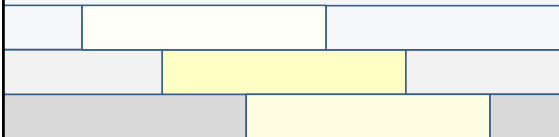
Not observed in the union

Theory of repeated games show that there are **many other ways** to sustain cooperation

The challenge is to **find out** the mechanism used in this union

How is cooperation sustained in the union?

### "Reputation mechanism"



How is cooperation sustained in the union?

### "Reputation mechanism"



How is cooperation sustained in the union?

### "Reputation mechanism"



Helping the old

How is cooperation sustained in the union?

### "Reputation mechanism"



Reward by younger generation

Helping the old

How is cooperation sustained in the union?

"Reputation mechanism"

Not observed in the union

Reward by younger generation

Good reputation

Helping the old

THE UNIVERSITY OF TOKYO

547

The main difficulty

THE UNIVERSITY OF TOKYO

548

How is cooperation sustained in the union?

The main problem

THE UNIVERSITY OF TOKYO

549

How is cooperation sustained in the union?

The main problem

Not helping

THE UNIVERSITY OF TOKYO

550

How is cooperation sustained in the union?

The main problem

This can be interpreted in two different ways

Not helping

THE UNIVERSITY OF TOKYO

551

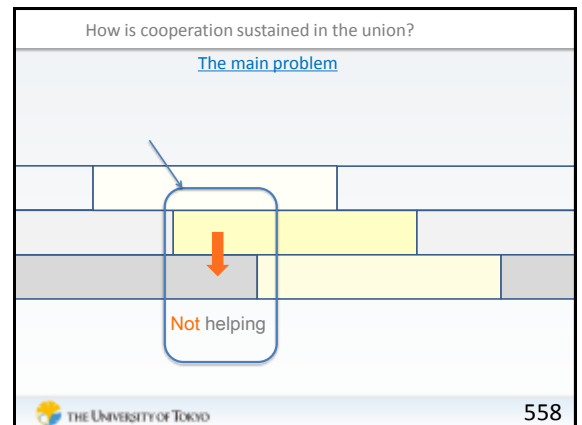
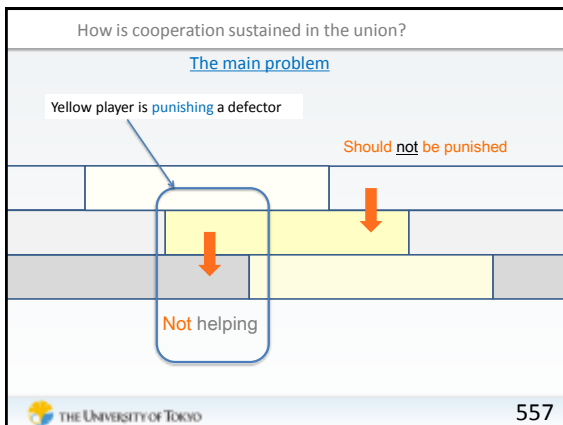
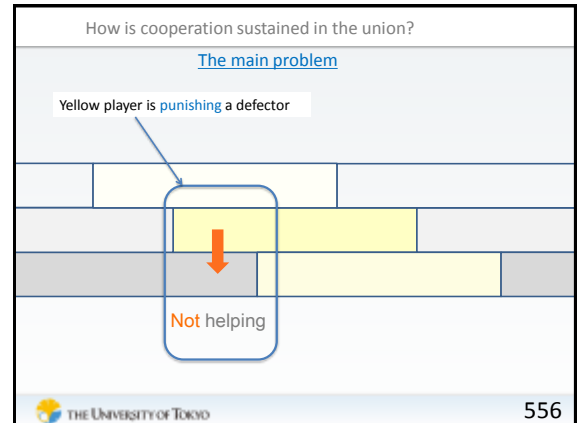
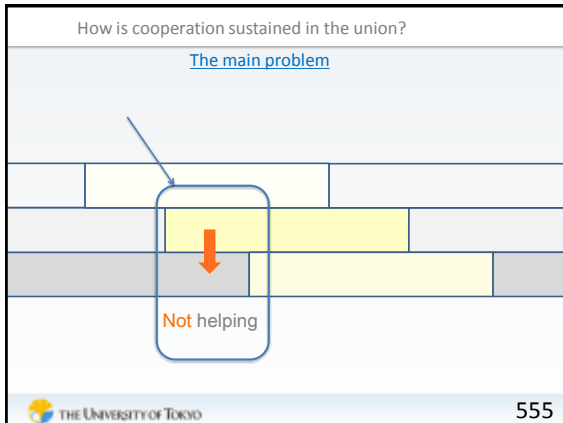
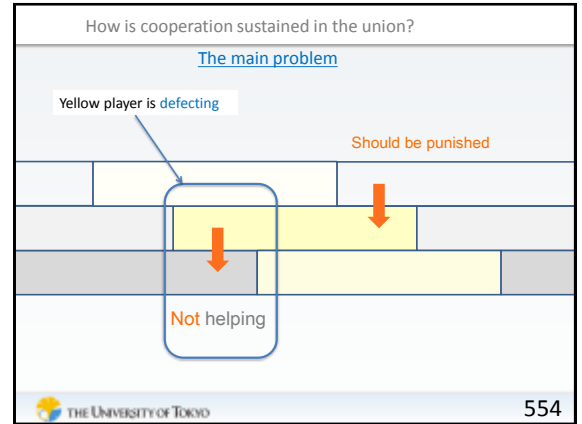
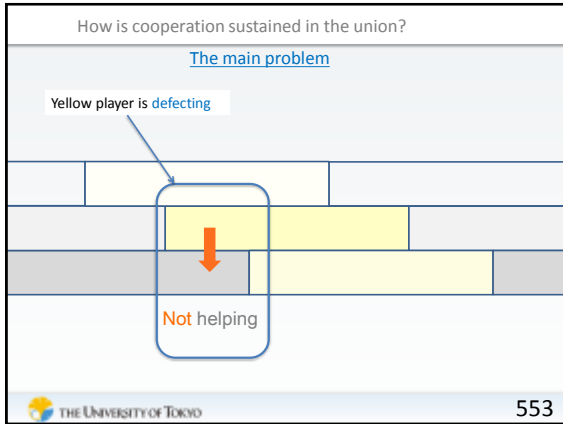
How is cooperation sustained in the union?

The main problem

Not helping

THE UNIVERSITY OF TOKYO

552



How is cooperation sustained in the union?

The main problem

Defecting ?

Not helping

THE UNIVERSITY OF TOKYO

559

How is cooperation sustained in the union?

The main problem

Defecting ?  
Punishing a defector?

Not helping

THE UNIVERSITY OF TOKYO

560

How is cooperation sustained in the union?

The main problem

Defecting ?  
Punishing a defector?

Younger players in the union typically  
do **not** know **which is true**

Not helping

THE UNIVERSITY OF TOKYO

561

How is cooperation sustained in the union?

The main problem

Defecting ?  
Punishing a defector?

Younger players in the union typically  
do **not** know **which is true**

- Finding out how to sustain cooperation in such a situation is a challenging theoretical problem

THE UNIVERSITY OF TOKYO

562

How is cooperation sustained in the union?

The main problem

Defecting ?  
Punishing a defector?

Younger players in the union typically  
do **not** know **which is true**

- Finding out how to sustain cooperation in such a situation is a challenging theoretical problem
- Based on an interview of a member, we discovered a **clever equilibrium strategy** that can function well in such a situation

THE UNIVERSITY OF TOKYO

563

How is cooperation sustained in the union?

The main problem

Defecting ?  
Punishing a defector?

Younger players in the union typically  
do **not** know **which is true**

- Finding out how to sustain cooperation in such a situation is a challenging theoretical problem
- Based on an interview of a member, we discovered a **clever equilibrium strategy** that can function well in such a situation

➡ See the paper (publicly available at PNAS web site)

THE UNIVERSITY OF TOKYO

564

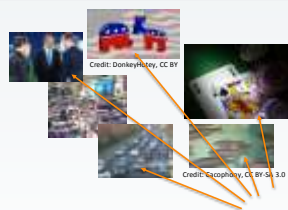
## 4.10 Summary of the course

1. Game theory provides a **governing principle** that can be applied to  
all social problems

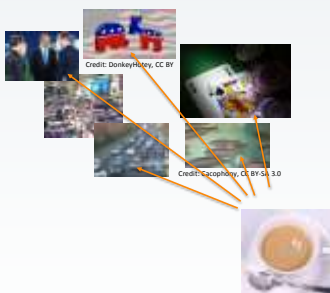
1. Game theory provides a **governing principle** that can be applied to  
all social problems



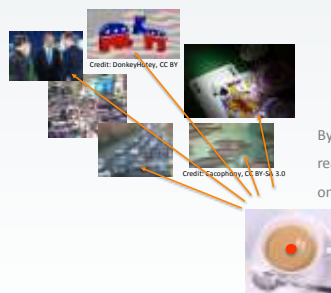
1. Game theory provides a **governing principle** that can be applied to  
all social problems



1. Game theory provides a **governing principle** that can be applied to  
all social problems

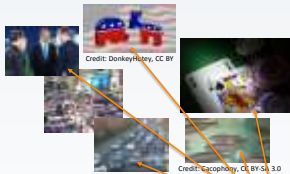


1. Game theory provides a **governing principle** that can be applied to  
all social problems



By the same mathematical  
reason that a vortex point exists  
on coffee surface....

1. Game theory provides a **governing principle** that can be applied to  
all social problems



... game theory shows that  
any social problem has a  
point where **players are doing  
their best against others**

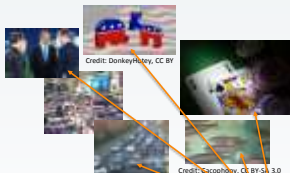


1. Game theory provides a **governing principle** that can be applied to  
all social problems



**Nash equilibrium**

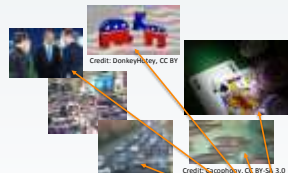
1. Game theory provides a **governing principle** that can be applied to  
all social problems



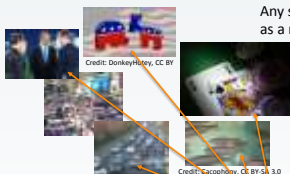
**Players are doing their best  
against others**

**Nash equilibrium**

1. Game theory provides a **governing principle** that can be applied to  
all social problems



1. Game theory provides a **governing principle** that can be applied to  
all social problems



**Any social problem can be formulated  
as a mathematical model of**

1. Game theory provides a **governing principle** that can be applied to  
all social problems

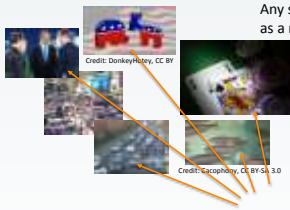


**Any social problem can be formulated  
as a mathematical model of**

**Game**  
(1) Players  
(2) Strategies  
(3) Payoffs



1. Game theory provides a **governing principle** that can be applied to **all social problems**



Any social problem can be formulated as a mathematical model of

**Game**

- (1) Players
- (2) Strategies
- (3) Payoffs

Using the power of math, game theory finds out

1. Game theory provides a **governing principle** that can be applied to **all social problems**



Any social problem can be formulated as a mathematical model of

**Game**

- (1) Players
- (2) Strategies
- (3) Payoffs

Using the power of math, game theory finds out

**Nash equilibrium**

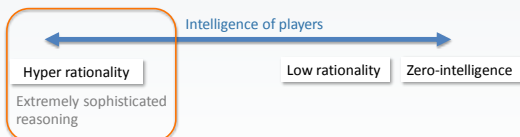
This is a "stable situation" where each player can no longer improve his/her payoff

2. **Nash equilibrium** may emerge by a variety of reasons

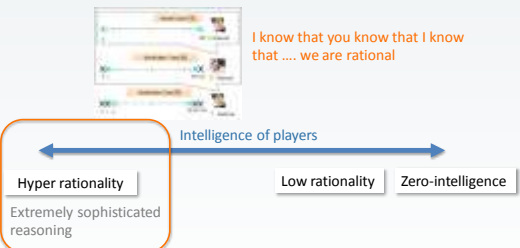
2. **Nash equilibrium** may emerge by a variety of reasons



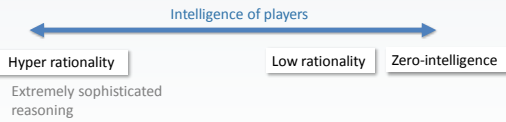
2. **Nash equilibrium** may emerge by a variety of reasons



2. **Nash equilibrium** may emerge by a variety of reasons

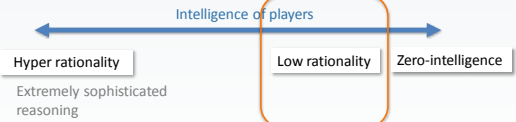


2. Nash equilibrium may emerge by a variety of reasons



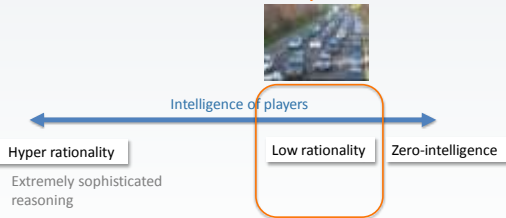
2. Nash equilibrium may emerge by a variety of reasons

Trial and error adjustment

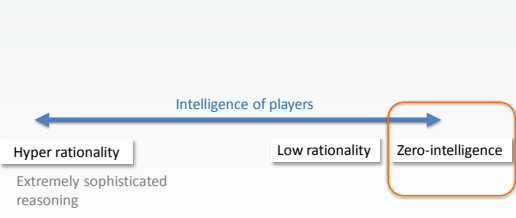


2. Nash equilibrium may emerge by a variety of reasons

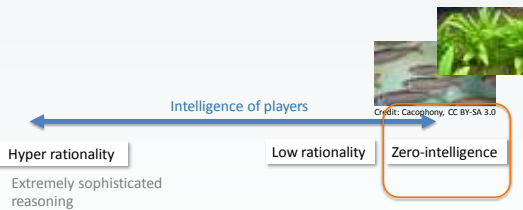
Trial and error adjustment



2. Nash equilibrium may emerge by a variety of reasons

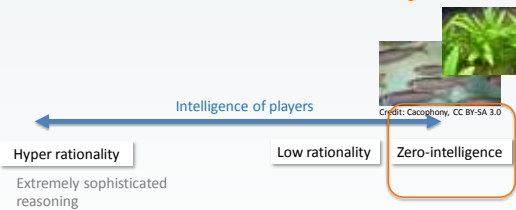


2. Nash equilibrium may emerge by a variety of reasons



2. Nash equilibrium may emerge by a variety of reasons

Biological evolution



3. Prediction power of game theory varies across applications



THE UNIVERSITY OF TOKYO

589

3. Prediction power of game theory varies across applications



Card game



THE UNIVERSITY OF TOKYO

590

3. Prediction power of game theory varies across applications



Card game



Penalty kick



THE UNIVERSITY OF TOKYO

591

3. Prediction power of game theory varies across applications



Card game



Penalty kick

Good fit



THE UNIVERSITY OF TOKYO

592

3. Prediction power of game theory varies across applications



Card game



Penalty kick



Traffic allocation

Good fit



THE UNIVERSITY OF TOKYO

593

3. Prediction power of game theory varies across applications



Card game



Penalty kick

Good fit



Traffic allocation

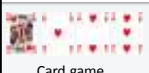
Reasonable fit



THE UNIVERSITY OF TOKYO

594

3. Prediction power of game theory varies across applications



Card game



Penalty kick

Good fit



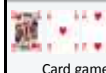
Traffic allocation

Reasonable fit



Policy choice

3. Prediction power of game theory varies across applications



Card game



Penalty kick

Good fit



Traffic allocation

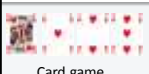
Reasonable fit



Policy choice

"Exactly the same policy"

3. Prediction power of game theory varies across applications



Card game



Penalty kick

Good fit



Traffic allocation

Reasonable fit



Policy choice

"Exactly the same policy"

Not exactly.....

4. Prediction power of game theory is not perfect, but it is useful

4. Prediction power of game theory is not perfect, but it is useful



Policy choice

"Exactly the same policy"

Not exactly.....

4. Prediction power of game theory is not perfect, but it is useful



Policy choice

"Exactly the same policy"

Not exactly.....

Game theory provides useful insights

4. Prediction power of game theory is **not perfect, but it is useful**



Policy choice                      Not exactly.....  
"Exactly the same policy"

- Game theory provides useful **insights**  
Parties are tempted to choose similar policies  
to steal voters from the opponent

4. Prediction power of game theory is **not perfect, but it is useful**



Policy choice                      Not exactly.....  
"Exactly the same policy"

- Game theory provides useful **insights**  
Parties are tempted to choose similar policies  
to steal voters from the opponent
- Game theory provides useful **benchmark**

4. Prediction power of game theory is **not perfect, but it is useful**



Policy choice                      Not exactly.....  
"Exactly the same policy"

- Game theory provides useful **insights**  
Parties are tempted to choose similar policies  
to steal voters from the opponent
- Game theory provides useful **benchmark**  
If parties are not choosing the same policy, why is that...?

4. Prediction power of game theory is **not perfect, but it is useful**

4. Prediction power of game theory is **not perfect, but it is useful**

There is **no reason** to believe that people always come to play Nash equilibrium

4. Prediction power of game theory is **not perfect, but it is useful**

There is **no reason** to believe that people always come to play Nash equilibrium  
But **stylized facts** are likely to be Nash equilibria

4. Prediction power of game theory is **not perfect, but it is useful**

There is **no reason** to believe that people always come to play Nash equilibrium

But **stylized facts** are likely to be Nash equilibria

Stable mode of behavior  
that is repeatedly observed

4. Prediction power of game theory is **not perfect, but it is useful**

There is **no reason** to believe that people always come to play Nash equilibrium

But **stylized facts** are likely to be Nash equilibria

Stable mode of behavior  
that is repeatedly observed



5. One of the most important messages: there is a **conflict** between  
**group rationality** and **rationality of individuals**

5. One of the most important messages: there is a **conflict** between  
**group rationality** and **rationality of individuals**

What is good for society

5. One of the most important messages: there is a **conflict** between  
**group rationality** and **rationality of individuals**

What is good for society  $\neq$  What is good for each individual

5. One of the most important messages: there is a **conflict** between  
**group rationality** and **rationality of individuals**

What is good for society  $\neq$  What is good for each individual



Stop global warming!

5. One of the most important messages: there is a **conflict** between **group rationality** and **rationality of individuals**

What is good for society



What is good for each individual



Stop global warming!



But, .....

5. One of the most important messages: there is a **conflict** between **group rationality** and **rationality of individuals**

What is good for society



What is good for each individual



Stop global warming!



But, .....

Game theory shows how we can possibly overcome this problem