STRATEGIC INTERACTION AND THE ENVIRONMENT

Applying game theory to make sense of the ‘games’ that governments, individuals, and firms ‘play’ that affect the environment.

Strategic Interaction and the Environment

- Introduction
- Game Theory
  - Basic concepts
  - The Prisoner’s dilemma
  - Repeated prisoner’s dilemma
  - Co-operative games
  - Transboundary pollution control
- Summary

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Introduction

- Environmental problems often arise from interactions between economic agents.
  - Externalities (green house gas emission), common pool resources (fisheries)
- Game theory (science behind strategic interaction) can be used to help examine and solve environmental problems.

Game Theory Basics

- **Game theory** is a field that is focused on understanding strategic interaction
- The study of strategic interactions among two or more actors
- Examine behavior when "players" are making **strategic decisions** – actions made based on the anticipation of others' actions
- Concepts can be applied to market situations, as well as any number of human (and nonhuman) interactions
- Applications
  - 'fish war'
  - Acid rain
  - Biodiversity
  - Land grazing

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Game Theory Basics

- **Simultaneous games**
- Games in which the participants choose their actions simultaneously without knowing their opponents' strategies
- **Repeated games**
- A series of simultaneous games among the same set of economic actors
- Successful cooperation is made possible by the repeated nature of output decisions
- **Sequential games**
- Games in which players take turns making decisions

Game Theory Basics

- Game theory is all about seeing the world through the eyes of your “opponent”
- As with consumer theory, we assume players are rationally self-interested
- Finally, rules often determine the outcome of a game; therefore, it is very important to understand the timing of moves, allowable actions, etc.

Game Theory Basics

- Every game shares three elements

1. **Players**

- A player is a participant in an economic game, who must decide his or her actions based on the actions of others

2. **Strategy**

- The action taken by a player
- Strategies may be simple or complex and depend on the actions (anticipated or actual) of other players

3. **Payoff**

- The outcome a player receives from playing the game
- The payoff to one player is dependent on the actions of other players, otherwise the former would have no incentive to act strategically

Game Theory Basics

- **Dominant and Dominated Strategies**
- Predicting behavior in games relies on finding the **optimal strategy** for the different players
  - The action that results in the highest expected payoff
- **Dominant strategy**
  - A winning strategy for a player, regardless of his or her opponents' strategies
  - If a player has a dominant strategy, that strategy is always chosen
- **Dominated strategy**
  - A losing strategy for a player, regardless of his or her opponents' strategies
  - Dominated strategies are never chosen, and once identified, can be ignored
  - If there exists a dominant strategy, all other strategies are dominated

Game Theory Basics

- A **payoff matrix** is a table that lists the players, strategies, and payoffs of an economic game
- For example, consider the decisions facing fishermongers regarding their advertising choices post fish-catch.
- It is reasonable to assume that the fishermongers are competing with one another for customers.

Game Theory Basics

	Fishmonger 2		
Fishmonger 1		Advertise	Don't Advertise
	Advertise	(150,150)	(450,-75)
	Don't Advertise	(-75, 450)	(225, 225)

- In this game, Fishermonger 2 (payoffs in blue) has a dominant strategy of advertise, regardless of what Fishermonger 1 does.

Game Theory Basics

- When individuals or firms engaged in strategic competition have dominant strategies, determining equilibrium is easy
- However, in most games, the optimal strategy for a player depends on the actions of the other player(s)
  - In these cases, we rely on the stronger concept of **Nash equilibrium**
  - The Nash equilibrium requires that an action is the best thing a player can do *given the action the opponent is taking*
- The first step to finding a Nash equilibrium is to understand the three elements of the game: players, strategies, and payoffs
  - A common way to do this is to use the **normal form:** the organization of an economic game into its players, strategies, and payoffs in a payoff matrix

Game Theory Basics

- **Tips for Finding a Nash Equilibrium: The Check Method**
- Always analyze players' strategy/payoff combinations one at a time
- Call our players "Row" and "Column," and assume each has two "actions" available. What should Row do?
- First, ask: "If Column chooses action A, what is the best action for Row to take?" Then place a check mark next to the payoff for that action for Row
- Next, ask, "If Column chooses action B, what is the best action for Row to take?" Then place a check mark next to that option
- Repeat these steps for Column
- If one of the boxes has two check marks, that represents the Nash equilibrium. If there is more than one box with two check marks, there is no "pure strategy" Nash equilibrium
- **Pure strategy:** A strategy that results in an equilibrium after a single action

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Prisoners Dilemma

- Prisoners dilemma occurs when incentives lead people to the worst outcome.
- Now consider the decisions facing fishermen regarding their harvesting choices.
- It is reasonable to assume that the fishermen are competing with one another for fish.

Fishery Prisoners Dilemma

	Fisherman 2		
Fisherman 1		High Harvest (Don't Cooperate)	Low Harvest (Cooperate)
	High Harvest (Don't Cooperate)	(1.07,1.07)	(1.35,0.9)
	Low Harvest (Cooperate)	(0.9, 1.35)	(1.2, 1.2)

- In this game, Fisherman 2 (payoffs in blue) has a dominant strategy of high harvest, regardless of what Fisherman 1 does.

Prisoners Dilemma Examples and Considerations

- Pollution (pollute vs. don't pollute)

	Country 2	
Country 1	**Don't Pollute (Cooperate)**	**Pollute (Don't Cooperate)**
Don't Pollute (Cooperate)	(-1,-1)	(-5,0)
Pollute (Don't Cooperate)	(0,-5)	(-3, -3)

- Climate change discussions

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Repeated Games

Finitely Repeated Games

- When a simultaneous game is played repeatedly, strategies are now temporal in nature, consisting of a strategy for each period
- To analyze finitely repeated games, we use a technique called **backward induction**
  - The process of solving a multistep game by first solving the last step and then working backward
- Again, consider the prisoner's dilemma situation that arises in the acid rain example
  - Total payoffs are maximized when both firms decide not to advertise
  - ✓ **Can the prisoner's dilemma be avoided in two periods?**

Repeated Games

Infinitely Repeated Games

- Infinitely repeated games can, in some circumstances, sustain cooperation; however, they are more difficult to analyze
- Rather than attempting to determine the optimal strategy for each firm, instead consider a specific strategy and decide whether it represents a Nash equilibrium
- Assume the two fishermen plan to continue to fish indefinitely
- Possible strategy: Fisherman 1 will harvest low in the first period and will continue to advertise low as long as Fisherman 2 does not harvest high; if Fisherman 2 harvest high, then Fisherman 1 will start harvesting high and continue to do so forever
- Fisherman 2 does the same
- To determine whether this set of strategies is a Nash equilibrium, we must evaluate whether either fisherman can do better by defecting

Repeated Games

- A strategy to encourage cooperating in repeated games is known as **tit-for-tat**
- A strategy in which the player mimics her opponent's prior-period action in each round
- For example, the player cheats when her opponent cheated in the preceding round, and cooperates when her opponent cooperated in the previous round

- An alternative strategy should either firm "defects" is for firms to defect from that point forward. This strategy is often referred to as a **grim trigger strategy**
- A strategy in which cooperative play ends when one player cheats

Tit-for-Tat

	Fisherman 2		
Fisherman 1		Advertise	Don't Advertise
	Advertise	(D,D)	(H,L)
	Don't Advertise	(L, H)	(C,C)

- Defect once if

$$(H - C) > \frac{(C - L)}{(1 + r)}$$

Tit-for-Tat Application

- **Tit-for-tat, Reciprocity, and Vampire Bats**

✓ **Do animals follow consistent strategies in the wild?**

- Wilkinson (1984) studied vampire bats in Costa Rica to examine how bats help each other prevent starvation
- Vampire bats feed on the blood of birds and mammals
- If foraging efforts are unsuccessful, starvation can occur rapidly
- To prevent starvation, bats will sometimes consume regurgitated blood, donated from other bats

✓ **Is this a sign of altruism, or an evolutionary strategy?**

- Wilkinson found that bats that had donated blood for other starving bats in the past were more likely to receive donations from the same bats after unsuccessful foraging efforts
- When a given bat did not help in the past, it was not helped when it was starving. This reciprocity is similar to a tit-for-tat strategy

Images: FreeDigitalPhotos.net

citation: Wilkinson, G.S. 1984. Reciprocal food sharing in the vampire bat. *Nature 308*: 181-184.

Grim Strategy

	Fisherman 2		
Fisherman 1		Advertise	Don't Advertise
	Advertise	(D,D)	(H,L)
	Don't Advertise	(L, H)	(C,C)

- Defect forever if

$$(H - C) > \sum_{t=1}^{\infty} \frac{(C - D)}{(1 + r)^t}$$

or

$$(H - C) > \frac{(C - D)}{r}$$

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Co-operative Game Theory Examples

- Co-operative games occur when players decide to form coalitions instead of competing against each other.
  - Fisherman or ranchers come together to determine how to share a resource (fish or grazing land)
  - EU negotiations over fishing quotas
- Forming an alliance or coalition is a strategy
  - Current Colorado River water usage
- Not always stable or can break down over time

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Acid Rain Game

- Transboundary pollution problems exhibit both non-cooperative and cooperative behavior

	Sweden		
UK		Don’t Cooperate	Cooperate
	Don’t Cooperate	(27.0,6.5)	(27.3,6.3)
	Cooperate	(22.3, 15.9)	(23.4,15.4)

- From a social planner perspective

	Sweden		
UK		Don’t Cooperate	Cooperate
	Don’t Cooperate	(33.5)	(33.6)
	Cooperate	(38.2)	(38.8)

- A side payment from Sweden could help coordination
  - $3.6\ (27 - 23.4) < payment < 8.9\ (15.4 - 6.5)$

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Summary

- Strategic interaction is likely to occur in scenarios where property rights are poorly defined (or shared ownership) and people compete over a fixed resource.
  - Game theory lets us examine possible outcomes here
- Prisoners dilemma occurs when all parties involved are worse off than if they had co-operated.
- Co-operative game theory is concerned with forming coalitions to manage the use of a resource.
- Game theory also shows us why environmental problems exist in the first place and how environmental conflicts may be resolved (e.g. transboundary pollution).