Transportation Research Board

Applying Game Theory To Promote Strategic Decision-Making in Marine Transportation Scenarios

Presented by the
Marine Environmental Committee

Produced in June 2016

Overview of Game Theory

Game: Any activity where people interact.

Game theory: The study of rational strategic decision-making processes. The goal of game theory is to develop mathematical models of these processes.

Applications of Game Theory

- Business & Economics — Auctions, Bargaining, Pricing
- Diplomacy & Military — ”Mutually Assured Destruction” doctrine of the Cold War.
- Science – Psychology, Biology, Computer Science, Philosophy, & Mathematics
- Recreational Games – Poker, Chess, & Go,

Topics and Presenters

- Game Theory Essentials, Dr. Bryan Gorman, Johns Hopkins University
- Environmental Policy, Dr. James Corbett, University of Delaware
- Port Competition, Dr. Thomas H. Wakeman III, Stevens Institute of Technology
- Regulatory Compliance, Jose' Davalos, U.S. Coast Guard

Applying Game Theory to Promote Strategic Decision Making in Transportation

June 2016

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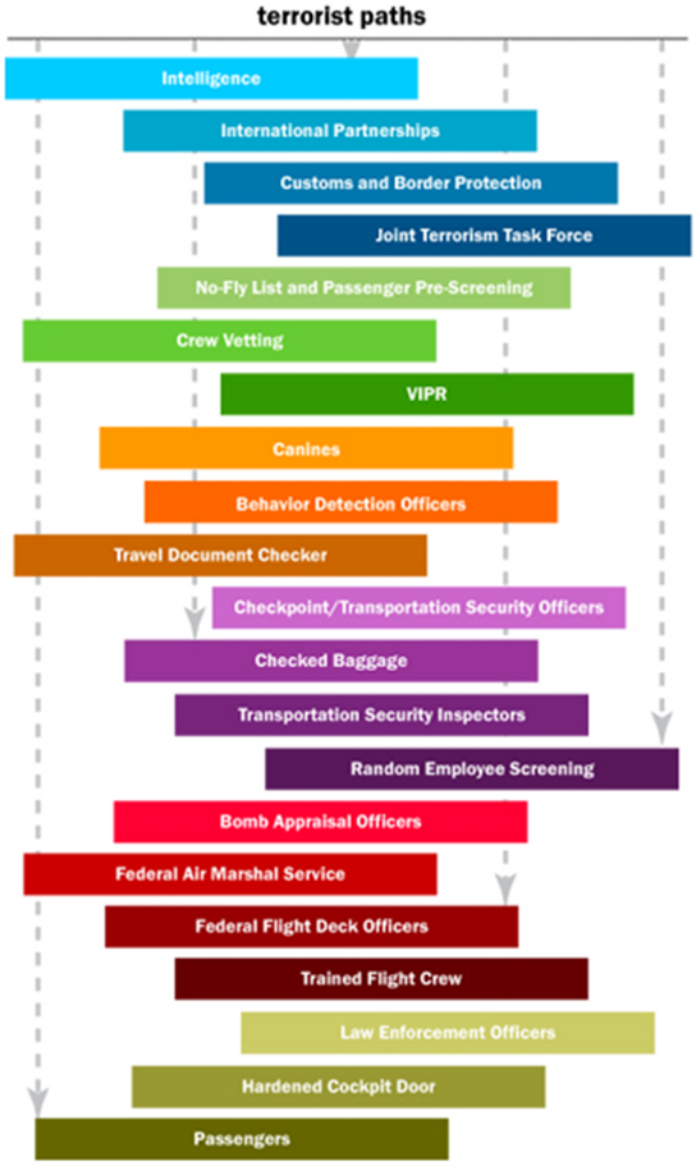
Why Game Theory? Some Questions…

- **How do we best allocate resources towards competing objectives**
  - **Security awareness**
  - **Incident responsiveness**
  - **Resilience, etc., …**
- **How do we best allocate resources to develop layered security systems…**
- **How do we set transportation policy and regulations to enhance**
  - **Safety**
  - **Security**
  - **Environmental protection…**

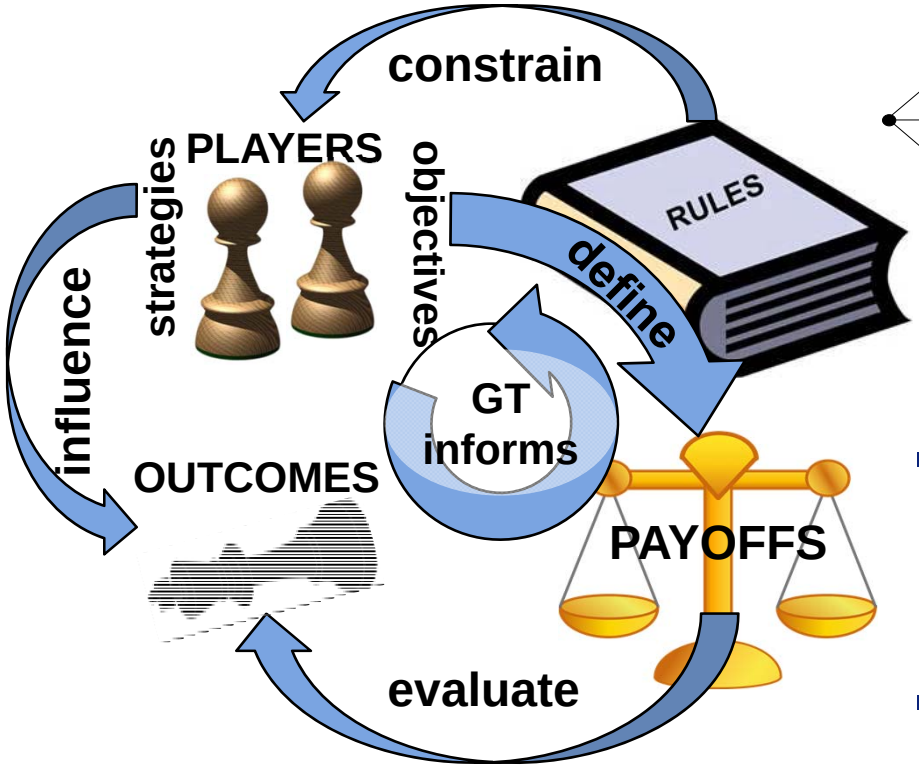
…KNOWING THAT others will exploit advantages granted by any decision we make?

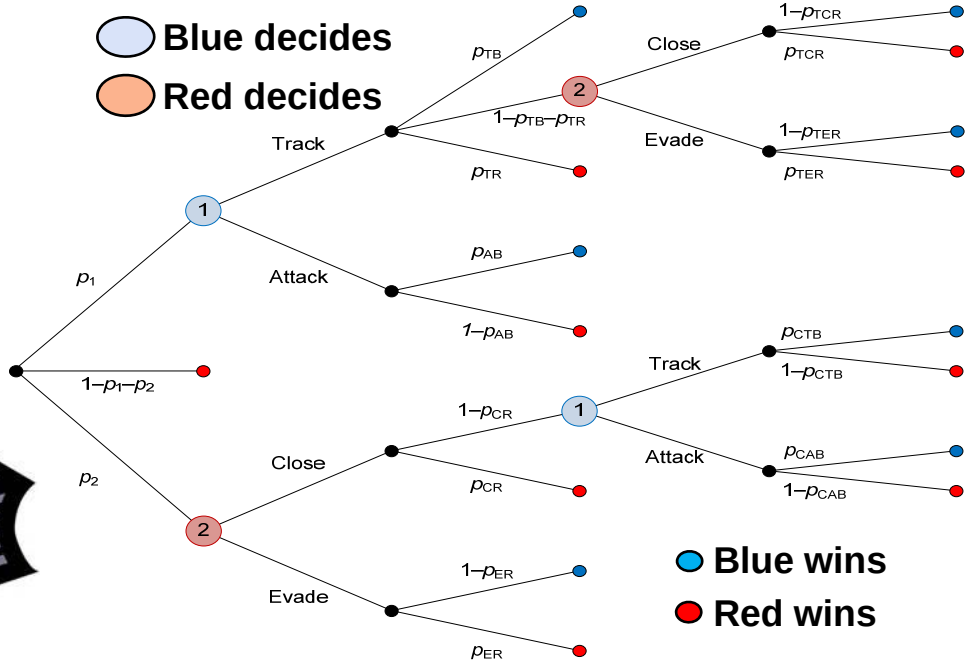


What Does Game Theory Offer?

Game Theory

A mathematical means to study how decision makers interact

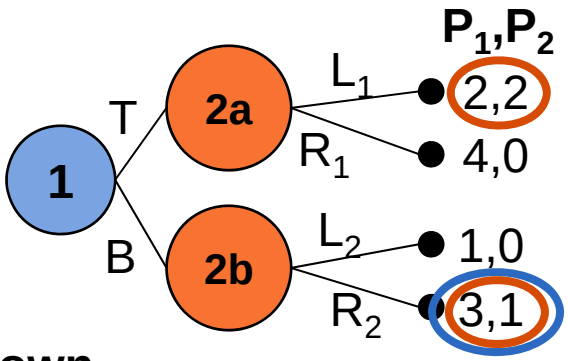




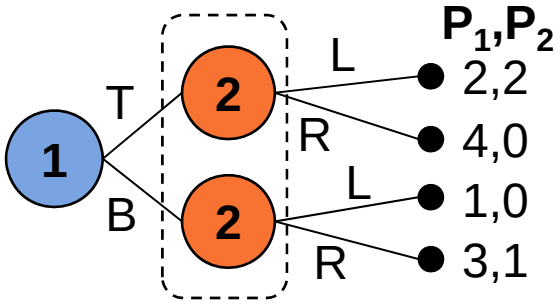
- **Provides insights to**
  - Anticipated/recommended strategies
  - Expected outcome, net benefit
  - Effects of alternative rules
- **Other benefits**
  - Factors that influence decisions
  - Value of intelligence

Illustrative Examples

- **Game tree**
  - Sequence of choices
  - Indicates what players know
  - Establishes the "pure" strategies
  - Can solve by pruning if all moves are known



- **Hidden information**
  - Cannot be solved by pruning
  - Can be solved by other means
  - Optimal strategies may be random



- **Normal (matrix) form**
  - Table of utilities to each player
  - Players assumed to know
    - All strategy options
    - All resulting utilities

P_1,P_2	L	R
T	2,2	4,0
B	1,0	3,1

Anticipating Strategy for USCG Regulations

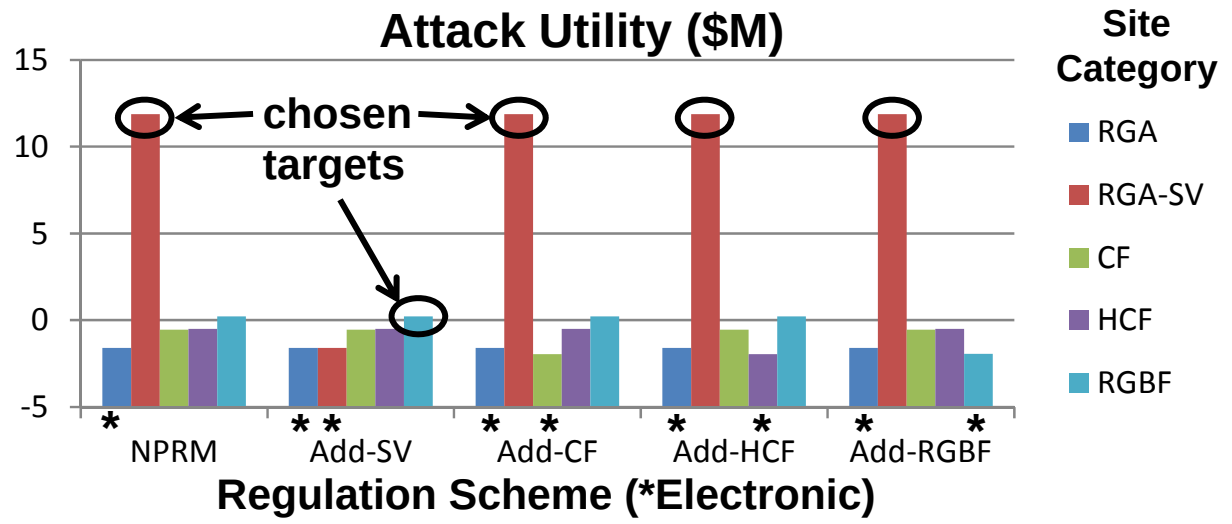
- **Need: Principled framework using game theory to understand implications of regulatory alternatives**

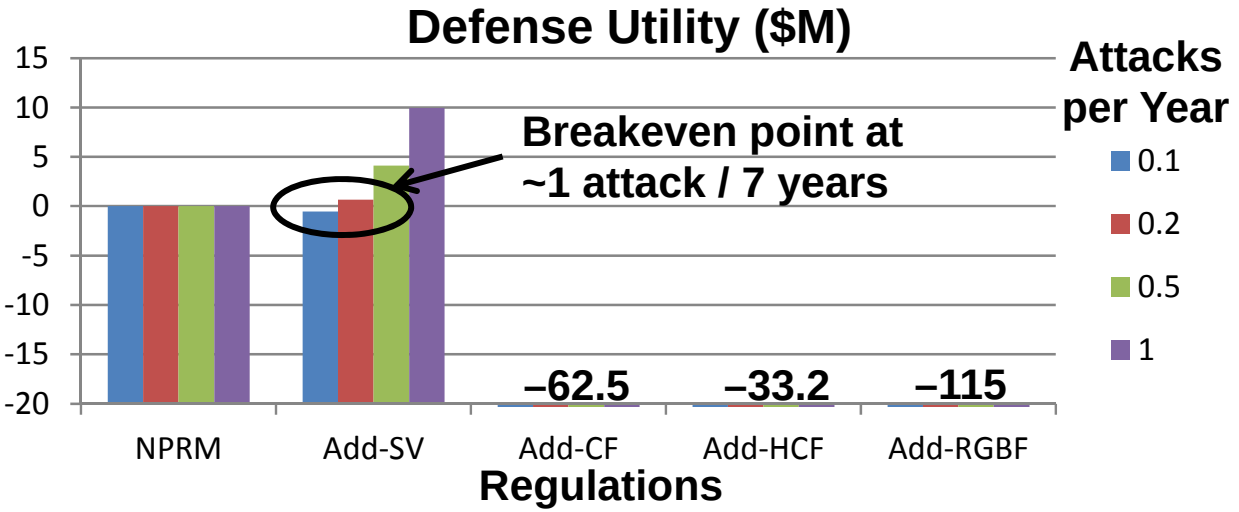
- **Efforts**
  - **Security (FY14)**
  - **Environmental (FY15)**
  - **Cumulative regulations (ongoing)**

- **Developed game theory analysis tools in Microsoft Excel®**

Example: Security Regulation Transportation Worker Identification Credential

- **Key decision: Where to require electronic validation**
  - **5 Site Categories**
  - **5 Alternative Regulations**
- **Attacker chooses site by category**
  - **Attacker chooses highest utility**
  - **Rate of attempts limited by means**
- **Defense utility based on**
  - **Attacks averted**
  - **Cost to implement**

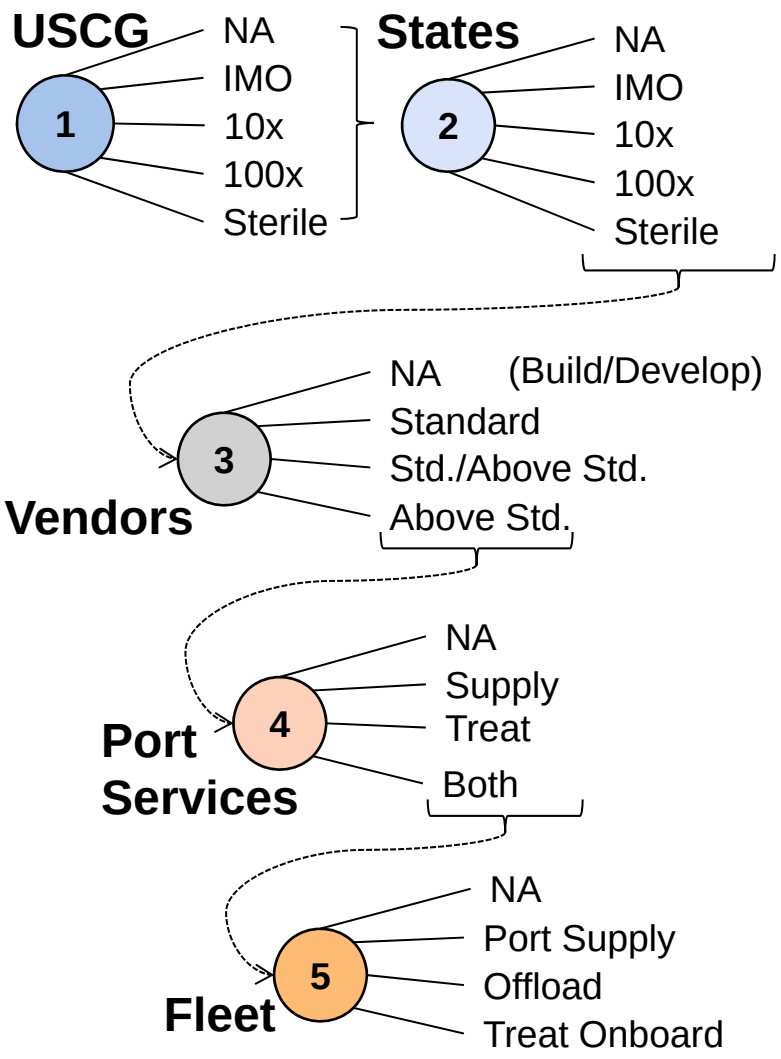




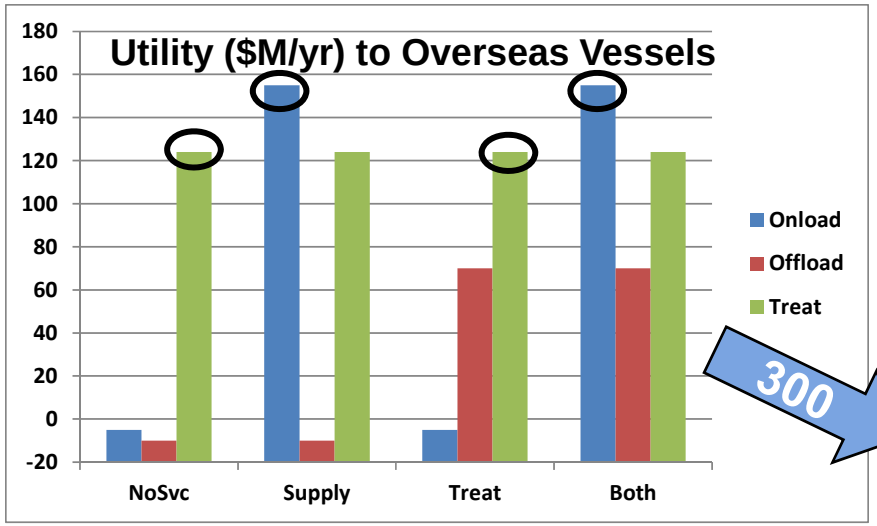
Example: Environmental Regulation Ballast Water Discharge Standards

- **Key decision: Stringency of standards limiting discharge of ballast water into US waters**
  - **USCG chooses regulation (1)**
  - **States may increase stringency (2)**
  - **Vendors develop treatment systems (3)**
  - **Port services invest in shore supply and/or treatment infrastructure (4)**
  - **Vessel owners treat onboard or use port services (5)**

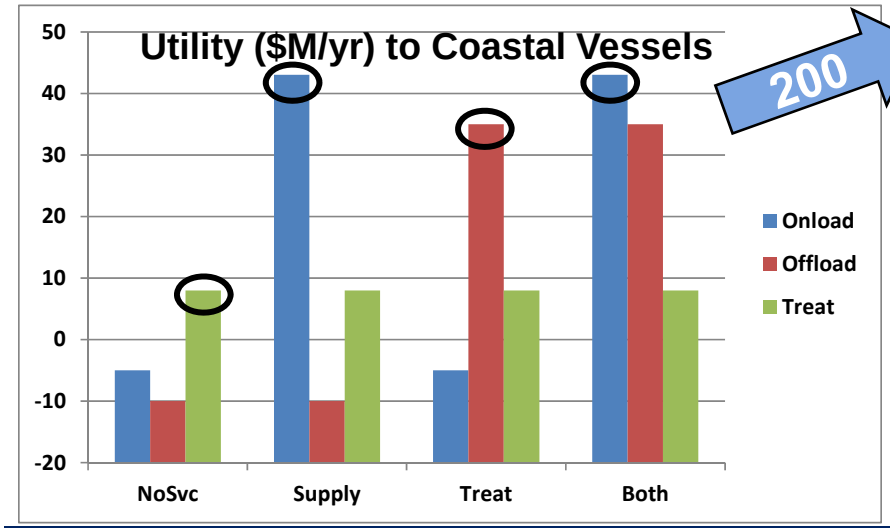
- **Alternatives selection process**
  - **Consider the effects of changing alternatives to stakeholder utilities**
  - **Choose stakeholder options in alignment with those effects**
  - **Seek to maximize exploitation or mitigation of effects**



Ballast Water Discharge Standards
Utility to Fleets and Port Services



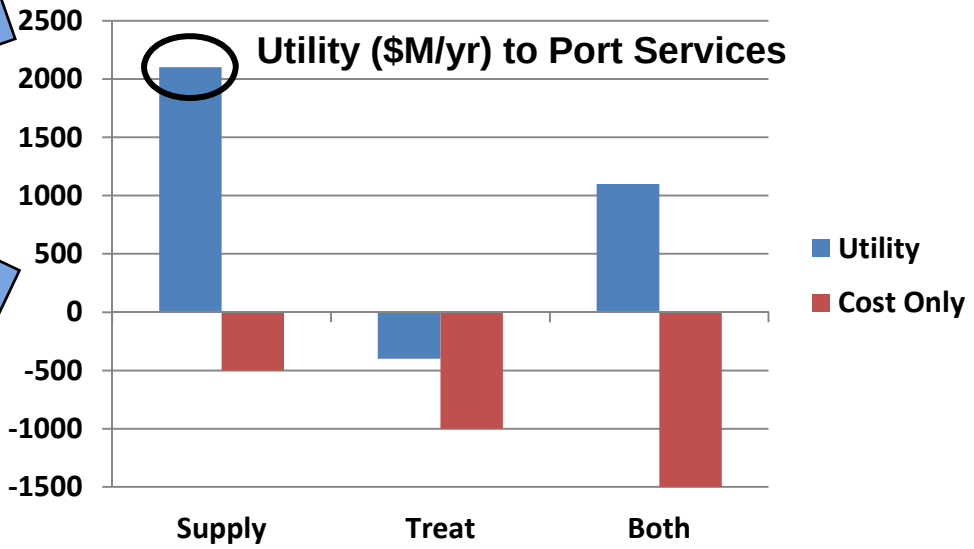
preferred action



- **Example utility to**
  - Vessel owners (overseas, coastal)
  - Port services
- **Preferred options indicated**
  - Port services favor offering ballast water supply

300

200



Example: Container Inspection

- **Motivation (HSPD-11)**

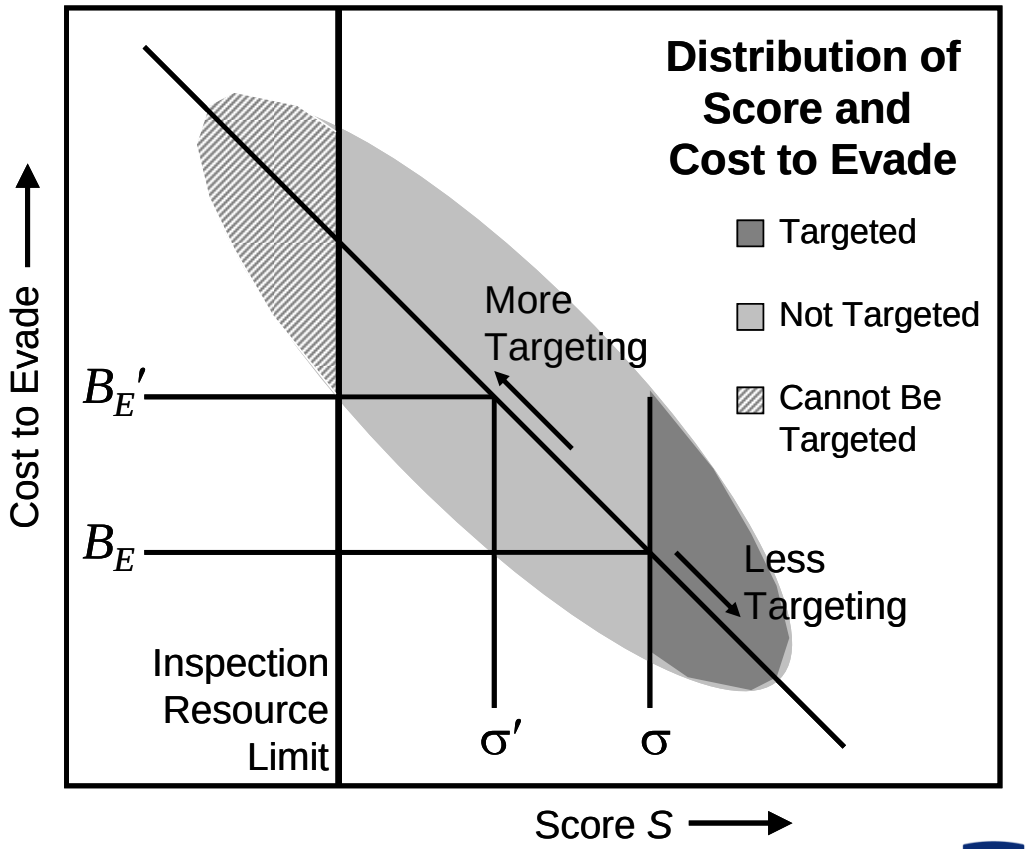
  Maintain security levels
  Resist circumvention

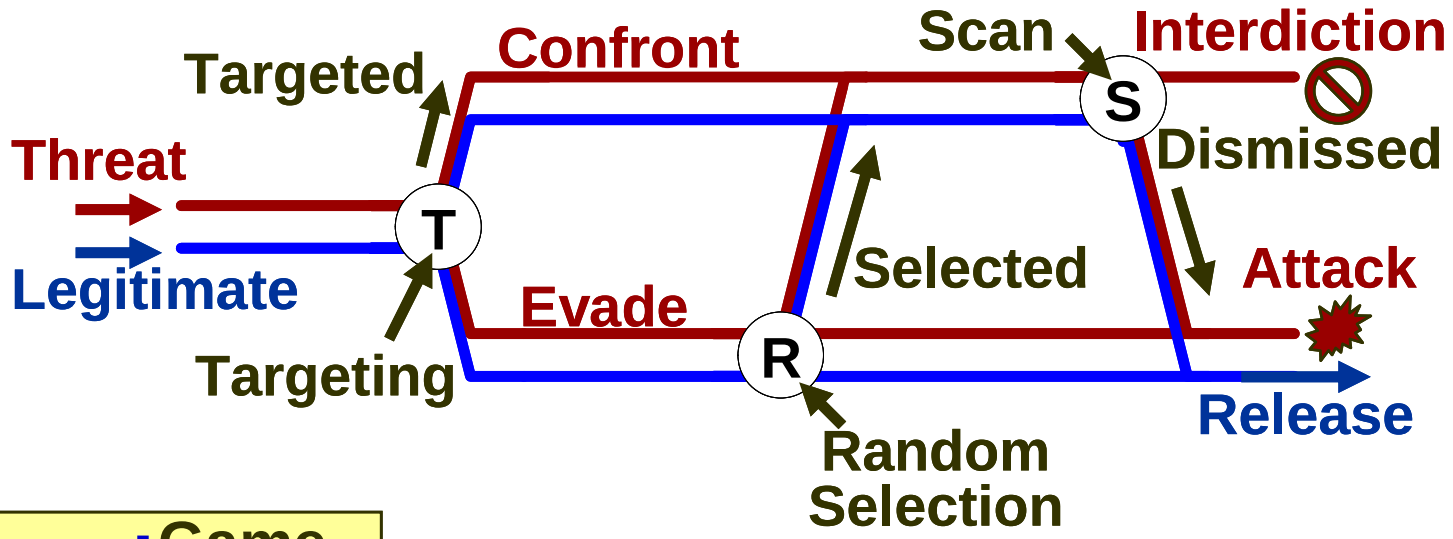
  Facilitate legitimate trade
  Limit delays

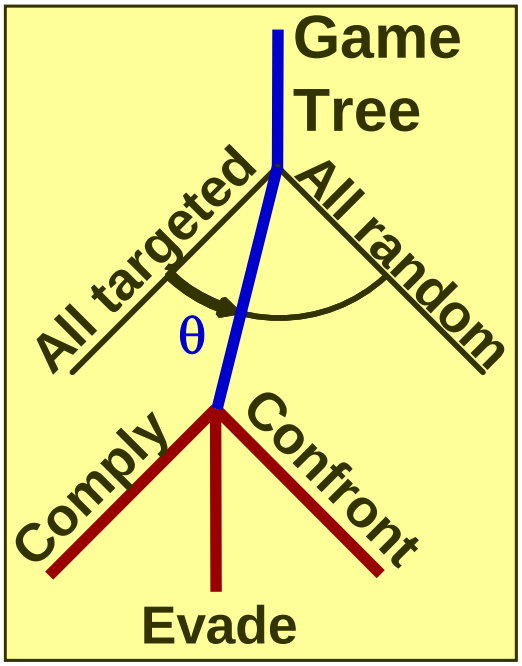
- **Container security measures**
  - **24-Hour Advance Manifest Rule**
  - **Container Security Initiative**
  - **Customs-Trade Partnership Against Terrorism**

- **Targeting and its problems**
  - **Subjectivity of risk score**
  - **Predictability**
  - **Mitigated by random inspection?**



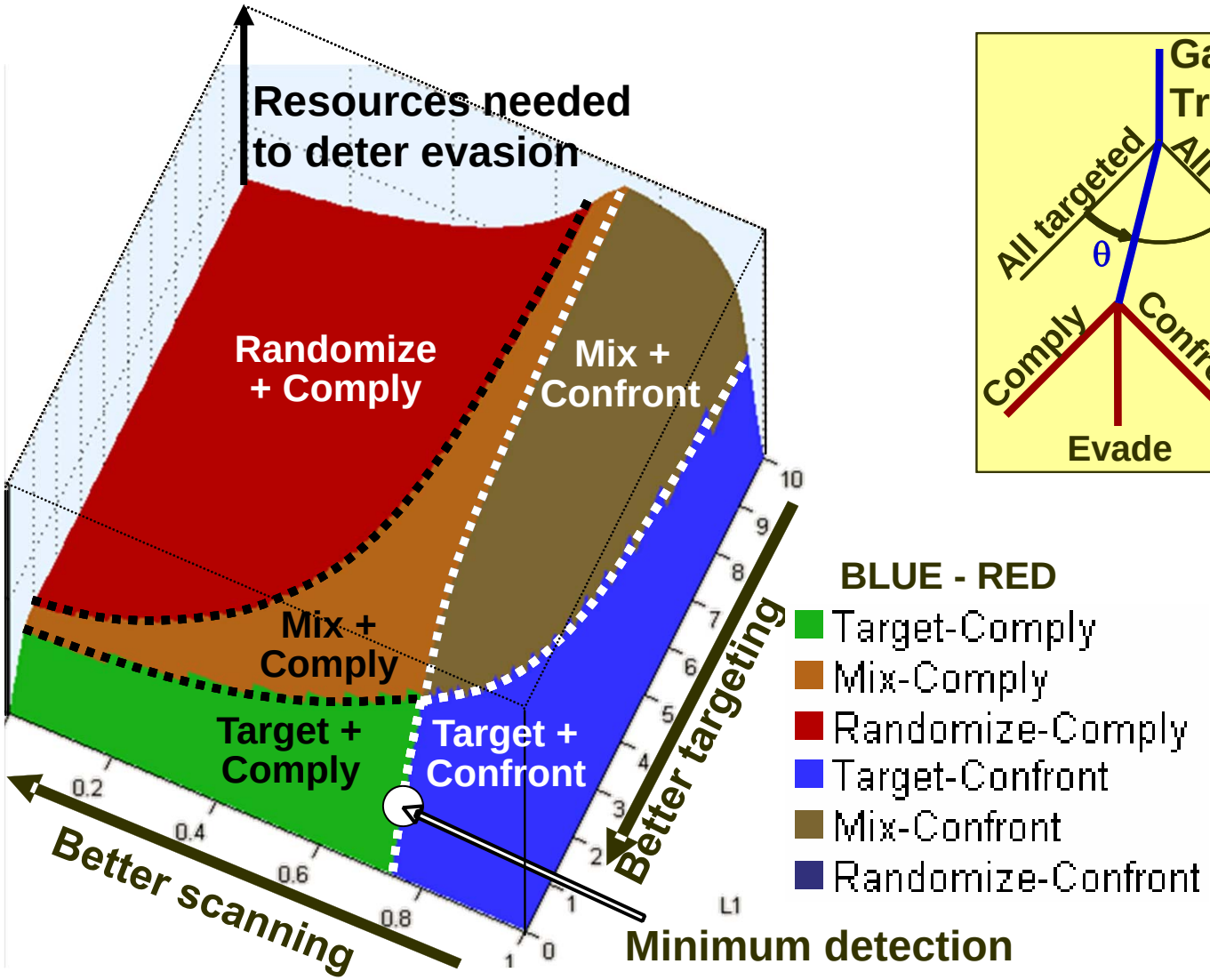
Container Inspection Model





- **Inspector Strategies**
  - Select all, some, or no containers by targeting
  - Continuous choice of mixing parameter (θ)
- **Adversary Strategies**
  - Comply: No attempt to attack
  - Confront: Attempt to attack / no evasion
  - Evade: Take measures to evade targeting
    (worst case from a defense standpoint)

Container Inspection Recommended Strategies



Summary

- **Cost-benefit and risk analysis may depend significantly on behavior of multiple actors.**
  - **Primary source of externalities or "unintended consequences"**
  - **Accounting for all actors may be necessary to ensure quality in alternatives analysis.**
- **Perspective and techniques of game theory provide means to assess alternatives, accounting for all influencing behavior**
  - **Analysis is driven by objectives vice assumed actions.**
- **Study findings:**
  - **Analysis of alternatives with competing stakeholders can be cast as a mathematical game.**
  - **Aligning stakeholder actions with competing objectives allows efficient alternatives comparison.**
  - **Game theory reduces uncertainty regarding actions by seeking alternatives to maximize net benefit with set resources.**

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Applying Game Theory to Promote Strategic Decision Making

James J. Corbett, Ph.D., P.E. Professor, University of Delaware

LCDR Adam Disque, USCG

10 June 2016

NOTE: This presentation reflects research conducted by Mr. Adam Disque during his matriculation as a student in the School of Marine Science and Policy at the University of Delaware. The data and results presented were part of his Analytical Paper, under the supervision of Dr. Corbett.

The work is currently in preparation for manuscript submittal and publication.

Introduction

- Purpose : provide an introduction to game theory, an example of its application in USCG maritime context, and some initial discussion of how these ideas can inform strategic decision making.

- Background: US missions, enforcement theory and game theory
  - Enforcement involves other motivators than reward-punishment
  - Game theory concepts can be useful for collaborative decision making

- Application: Enforcement goals benefit from strategic design making
  - Sustainable fishing involves a mix of cooperative and competitive decisions
  - US Coast Guard and NOAA are primary agencies for fisheries enforcement

US Coast Guard enforcement missions at sea

Mission Name	Stated Mission Intent (USCG, 2014)
Drug interdiction/ Counter Narcotic	Reduce the supply of drugs from the source by denying smugglers the use of air and maritime routes in the Transit Zone, including the Caribbean, Gulf of Mexico and Eastern Pacific.
Migrant Interdiction	Interdict undocumented migrants at sea, denying them entry via maritime routes to the United States, its territories and possessions.
Living Marine Resource (LMR)	Protecting the U.S. Exclusive Economic Zone from foreign encroachment. Enforce domestic fisheries law. Develop and enforce international fisheries agreements.
Recreational Boater Safety	Minimize loss of life, personal injury, property damage, and environmental harm associated recreational boating.
Coastal Security	Protect the U.S. maritime domain and those who live, work or recreate near them. Prevent and disrupt terrorist attacks, sabotage, espionage, or subversive acts; and respond to and recovery from those that do occur.

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Enforcement Information

USCG: 85 Enforcement Cutters
40 Aircraft
$807,000 Budget
(fisheries net discretionary)

NOAA Enforcement
$108 Million Budget
253 agents

State Agencies also enforce
fishing regulations

Commercial Fishing Information

80,000 Commercial Fishing Vessels

$33,430 Median annual wage

$31.8 billion dollar U.S. industry

137 Commercial fisheries

3.36 million sq miles of area

Two enforcement models used by USCG

Regular Enforcement Officers

- Fisheries law enforcement is collateral to USCG “rate” or specialty duty
- Five-week law enforcement academy
- Regional fisheries training centers, with fishery regulations curriculum

Specialize Shiprider Enforcement Officers

- North Pacific Regional Fisheries Training Center, Kodiak, Alaska
- This Center sends its own personnel with the cutter to assist enforcement
- “Shiprider” separate from crew (SR) as a fisheries expert to the mission

Enforcement and compliance are related

- In its simplest form: use reward and punishment to motivate behavior
  - Punishment can serve as a deterrent, if detection/enforcement is expected
  - Rewards for compliance transfers some enforcer burden to regulated groups
  - Conditions enable economic theory to predict self-interested motivations

- Example: Fisher's proposition
  - Fishers compete for limited and regulated resources to maximize profit
    - OPTION A: follow regulations for "standard payoff"
    - OPTION B: violate regulations for higher immediate gains
  - Cooperative compliance enhances "standard payoff" with sustainable fishery
    - Opportunity: mutual cooperation provided long term benefits to all Fishers
    - Challenge: cooperation is uncertain, given asymmetric near-term benefits of violation

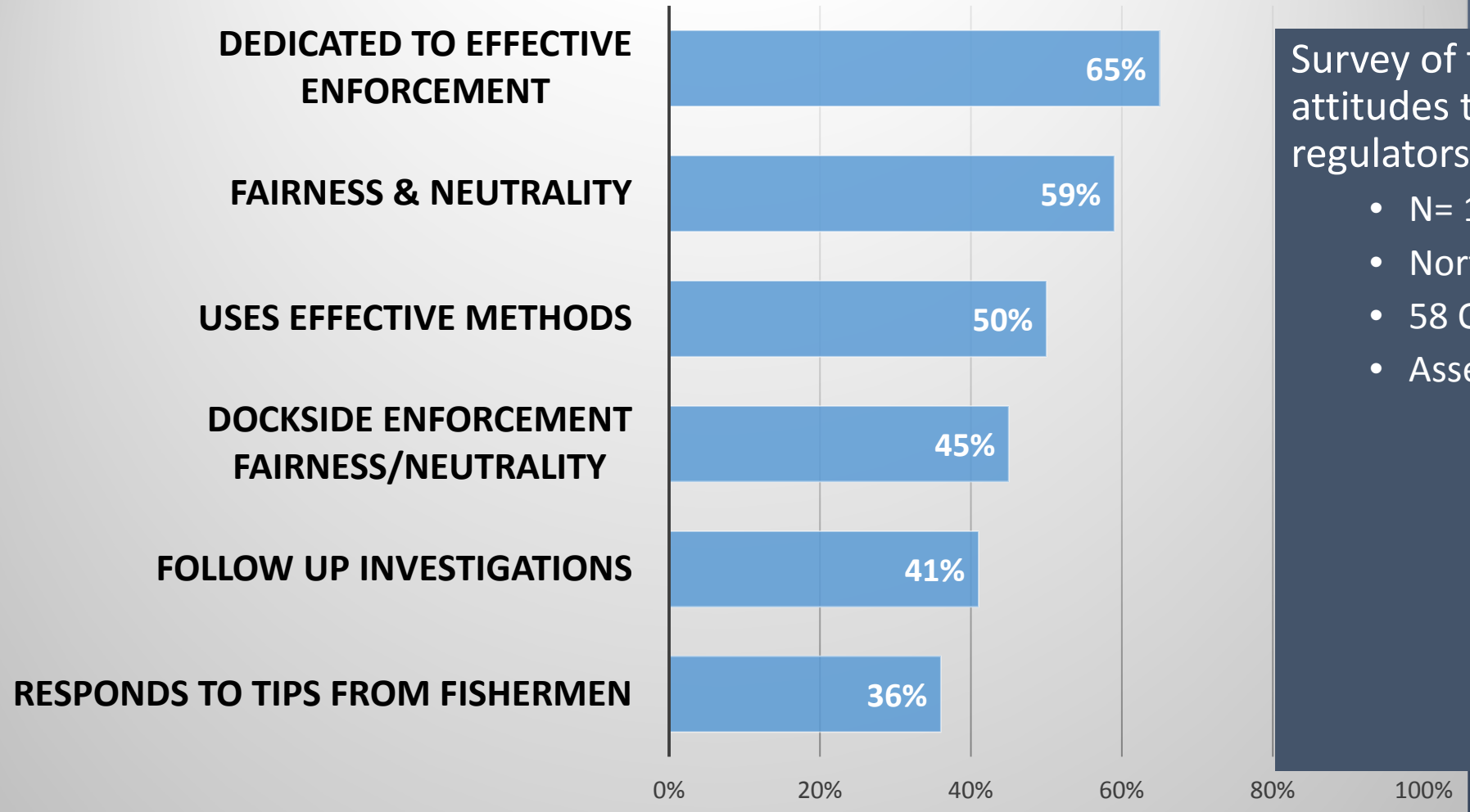
Principles of Compliance Theory

- A primary normative factor: collective and personal moral conscience
  - Enforcement policy has little effect on this condition, directly

- Influences on compliance behavior that relate to enforcement
  - Procedural justice: measure of fairness and transparency in legal process
    - Representative, consistent, non-biased, correctable, ethical
    - Regular interaction with legal authorities enables these perceptions to be confirmed
      - Examples: Fishery management council membership, satisfactory encounters with officers

  - Legitimate enforcement: derived from citizen consent, increases compliance
    - Participation during enforcement actions, neutrality, respect, trusted motives

Perceptions of USCG by Commercial Fisheries? Shaw (2005)



Survey of fishermen to assess their attitudes toward regulations, regulators, and the legal system.

- N= 1101 Response: 274
- Northeast Groundfish
- 58 Questions (Likert Scale)
- Assessed - Procedural Fairness
  Procedural Efficiency
  Outcome Fairness
  Outcome Effectiveness

Game Theory

Strategic Independent Behavior

- Prisoner's Dilemma (classic example)

Prisoner's Dilemma

Suspect 1 \ Suspect 2	Keep Quiet	Confess
Keep Quiet	-1 , -1	-12 , 0
Confess	0 , -12	-8 , -8

Game Theory

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Best cooperative outcome

Game Theory

Strategic Independent Behavior

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Prisoner's Dilemma

Suspect 1 \ Suspect 2	Keep Quiet	Confess
Keep Quiet	-1 , -1	-12 , 0
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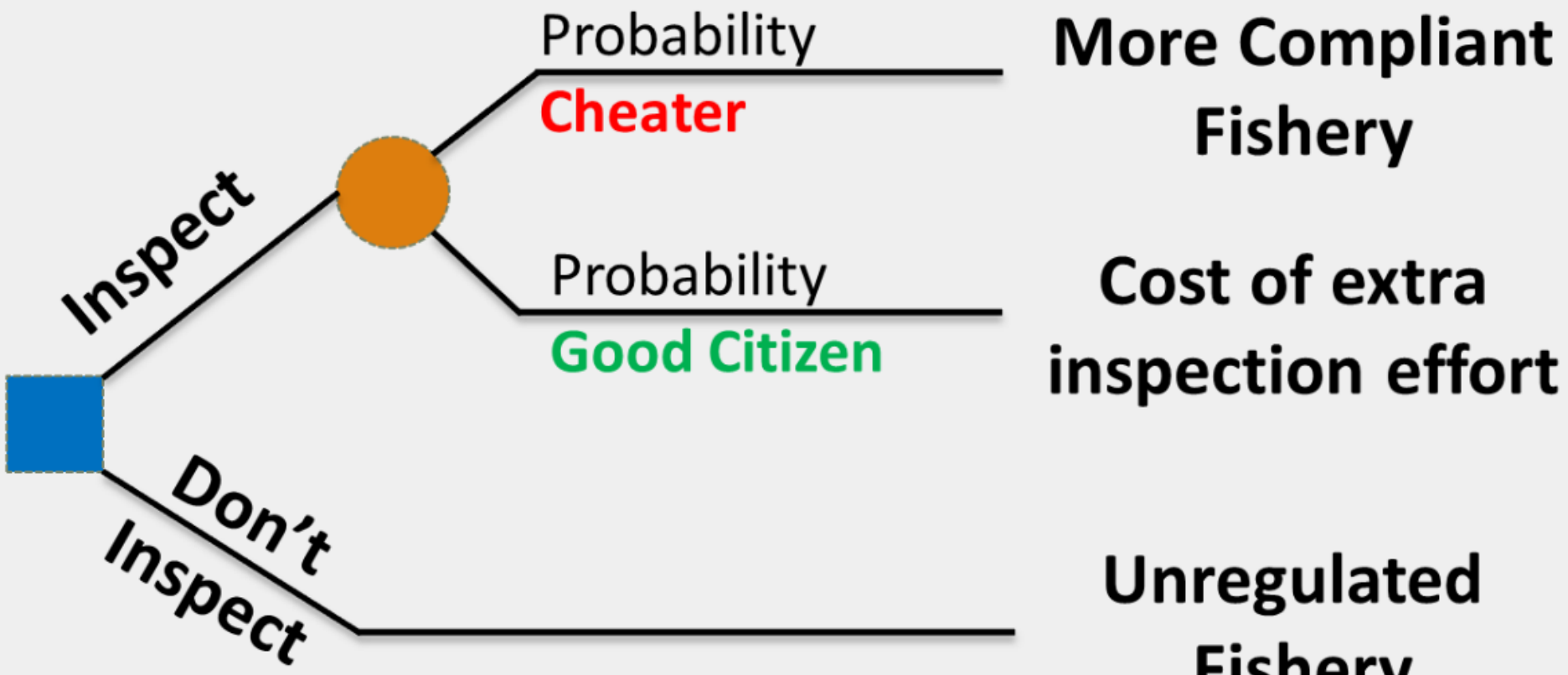
Best competitive outcome

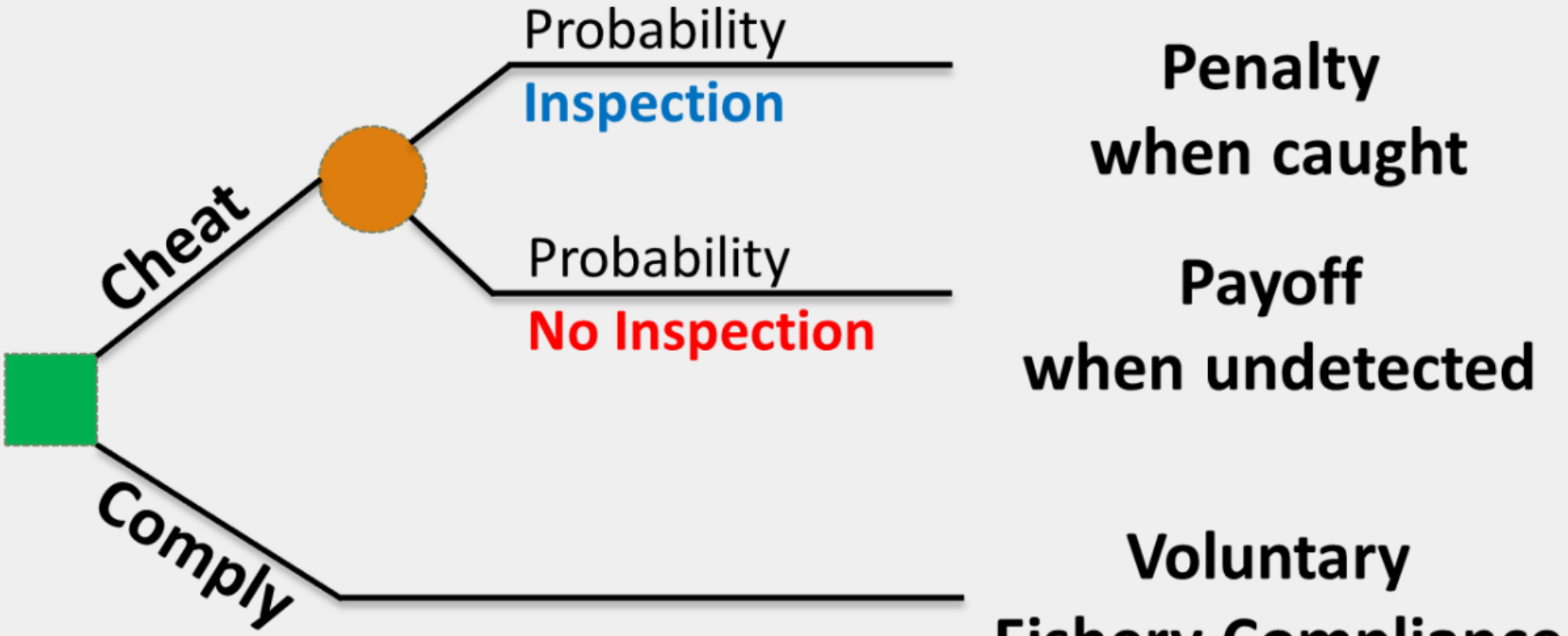
What deters criminal behavior?

Enforcement Perspective



What motivates criminal behavior?

Fisherman's Perspective



Fisherman's Dilemma:
Compliance and Enforcement in U.S. Fisheries

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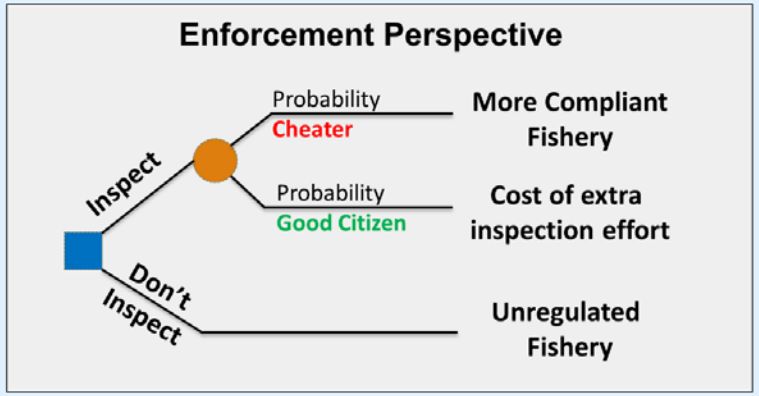

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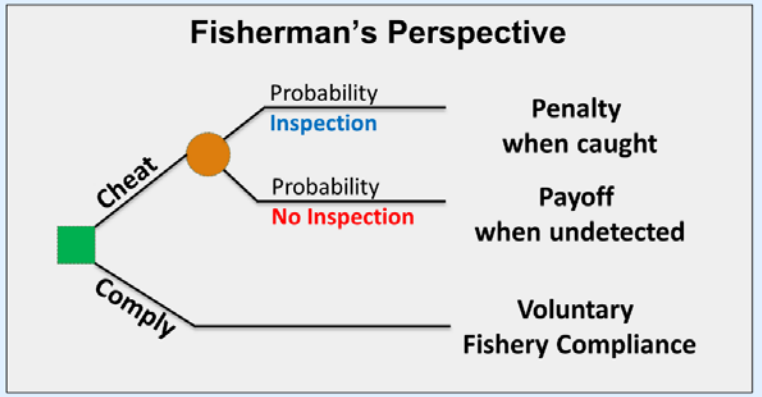

Inspection Game

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Enforcer

Citizen (Fisherman)

Let's Play!	Do Crime	Comply
Inspect	,	,
Don't Inspect	,	,

Commercial Fishing Information

80,000 Commercial Fishing Vessels

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Adam Disque, © 2014

Inspection Game

Tough Guy Fisherman

Nice Guy Fisherman

Citizen (Fisherman)

Let's Play!

Tough Guy Enforcer

Enforcer

Nice Guy Enforcer

	Do Crime	Comply
Inspect	,	,
Don't Inspect	,	,

Inspection Game

Equal payoffs for behavior
Equal chance of enforcement

Tough Guy Fisherman

Nice Guy Fisherman

Tough Guy Enforcer

Nice Guy Enforcer

Enforcer

Citizen (Fisherman)

Let's Play!

	Do Crime	Comply
Inspect	5 , -5	-5 , 5
Don't Inspect	-5 , 5	5 , 5

Inspection Game

Greater payoffs for violation
Equal chance of enforcement

Tough Guy Fisherman

Nice Guy Fisherman

Fishers more likely to compete with enforcers

Enforcer	Citizen (Fisherman): Do Crime	Citizen (Fisherman): Comply
Inspect	5 , -5	-5 , 5
Don't Inspect	-5 , 15	5 , 5

Tough Guy Enforcer

Nice Guy Enforcer

Inspection Game

Greater penalties for violation
Equal chance of enforcement

Tough Guy Fisherman

Nice Guy Fisherman

Citizen (Fisherman)

Fishers more likely to consider deterrent

Tough Guy Enforcer

Enforcer

Nice Guy Enforcer

	Do Crime	Comply
Inspect	5 , -25	-5 , 5
Don't Inspect	-5 , 15	5 , 5

Inspection Game

Greater payoffs for violation
High chance of enforcement

Tough Guy Fisherman

Nice Guy Fisherman

Fishers more likely to cooperate with enforcers

Enforcer	Citizen (Fisherman): Do Crime	Citizen (Fisherman): Comply
Inspect	10, -5	10, 5
Don't Inspect	-5, 15	5, 5

Tough Guy Enforcer

Nice Guy Enforcer

Game theory insights

Competitive game conditions

1. Game 1: When the odds of enforcement are low, the fishery may be considered less regulated. Fishers behavior depends on fishing culture of compliance/competition as informed by fishery science.
2. Game 2: A less regulated fishery may be more likely to be overfished if it offers high gains for violations and lower penalties if caught.
   - Analogies exist in transportation policy: use of compliant fuels, efficiency measures, safe speed limits and throttle governor devices
3. Game 3: Changing the penalties may offer some deterrent, conditioned by the chance of detection and enforcement

Cooperative game conditions

4. Game 4: Improved enforcement may create a cooperative game

Game theory insights

Competitive game conditions

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Cooperative game conditions

4. Game 4: Improved enforcement may create a cooperative game

Application: Comparing enforcement models

- Qualitative data: what are the perceptions of specialized enforcement?
- Quantitative data: what are the outcomes of specialized enforcement?
- Analysis:
  - Co-benefits of strategic enforcement beyond the game?
  - Costs of specialized enforcement in terms of outcomes?

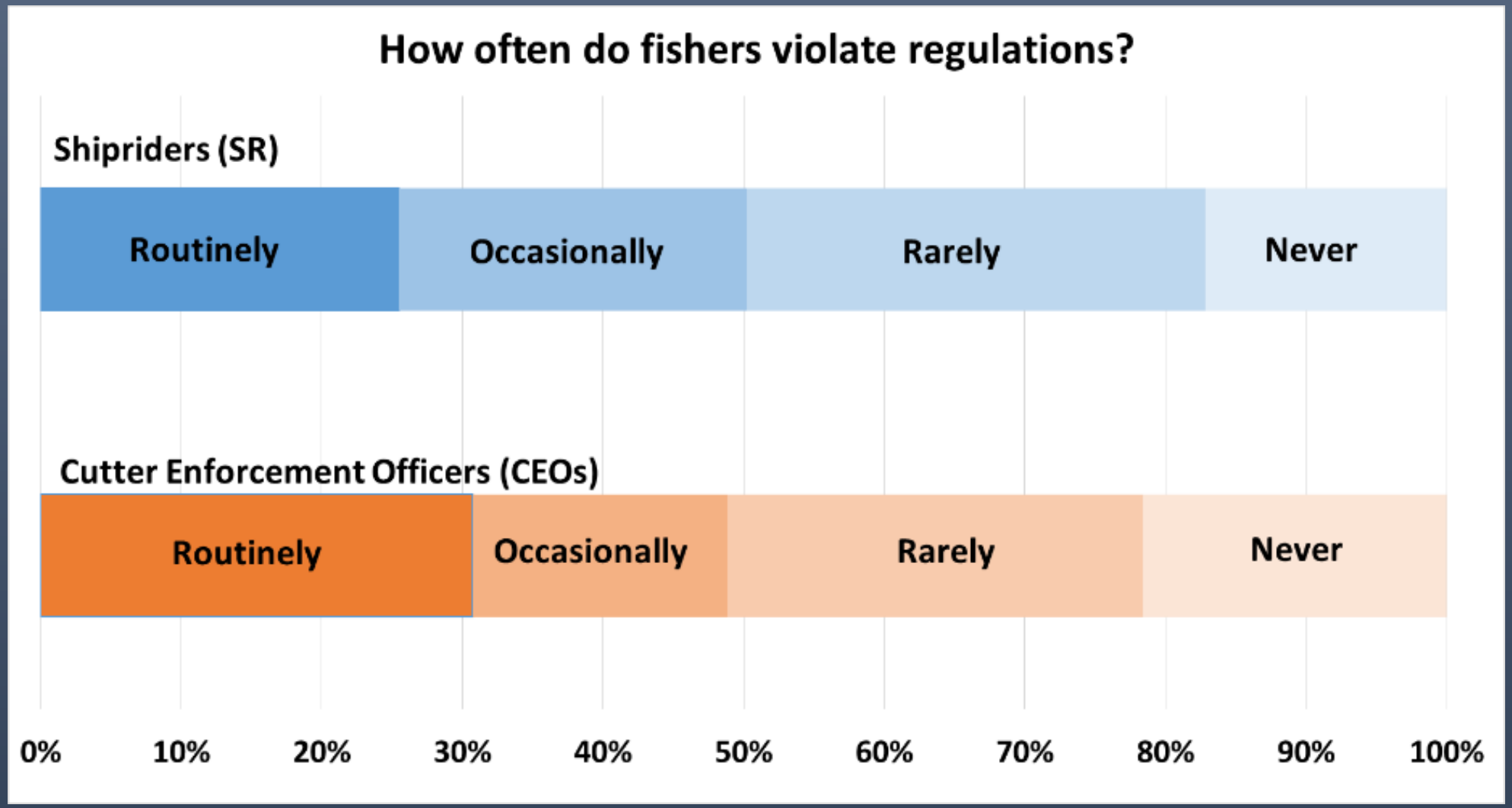
Possible outcomes

	Fishers and SRs have improved enforcement perspectives	Fishers and SRs lack improved enforcement perspectives
SRs detect more violations	Outcome One Combined improvements in detection and legitimacy. Fishery specialization is a determining factor. Suggests a wider application of SR program	Outcome Two Improvements in violation detection only. Training and enforcement experience are determining factors. Legitimacy and procedural justice benefits are lower or absent.
SRs do not detect more violations	Outcome Three Legitimacy and procedural justice improvement remain effective.	Outcome Four SR program does not increase probability of detection or legitimacy. No positive change identified.

Possible outcomes (Enforcer's views tested)

	SRs have improved enforcement perspectives	SRs lack improved enforcement perspectives
SRs detect more violations	Outcome One Combined improvements in detection and legitimacy. Fishery specialization is a determining factor. Suggests a wider application of SR program	Outcome Two Improvements in violation detection only. Training and enforcement experience are determining factors. Legitimacy and procedural justice benefits are lower or absent.
SRs do not detect more violations	Outcome Three Legitimacy and procedural justice improvement remain effective.	Outcome Four SR program does not increase probability of detection or legitimacy. No positive change identified.

Enforcement officer's compliance assessment

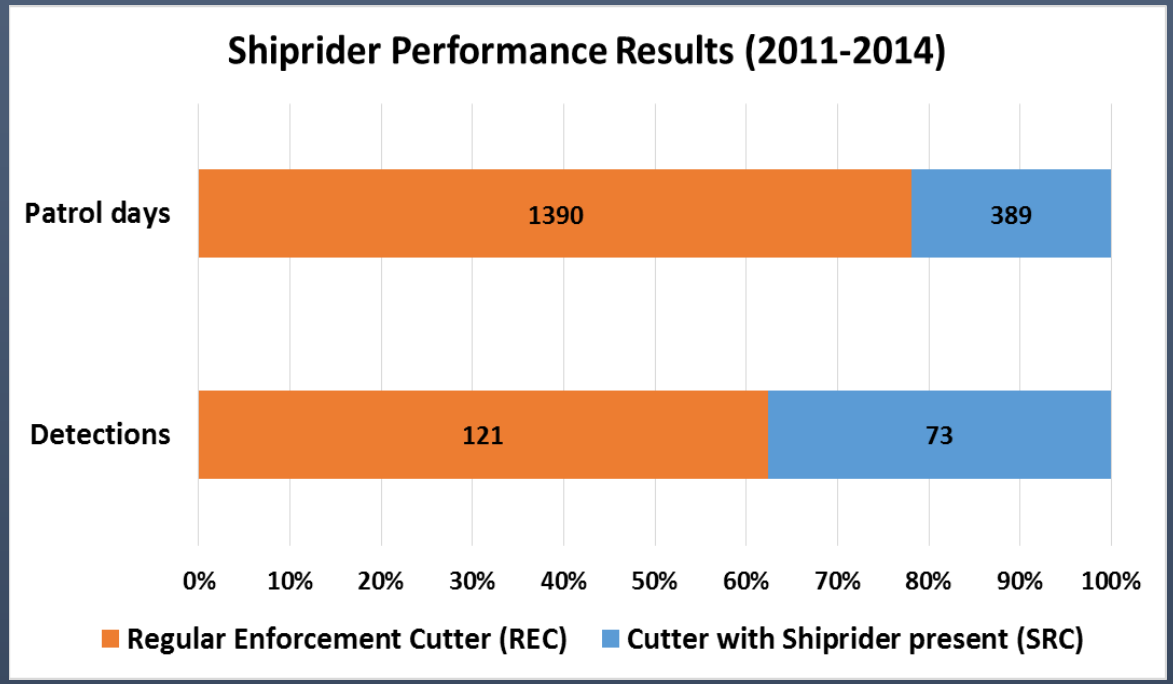


Quantitative Results

Performance characteristics

Cutter detection rates 2011-2014	SRCs	RECs
Total days deployed	389	1390
Total items detected	73	121
Violations per days deployed	19%	9%
Percent increase in detection rate	125%	

Shiprider performance results (2011-14)



Summary of some insights from this research

- Application of game theory advances enforcement/compliance theory
- Enforcement specialization achieve greater detection performance
- Enforcement specialization does not significantly bias enforcement views of industry or cause comparatively negative views of fishers
- Developing better cooperative strategies can improve compliance and make enforcement more efficient and effective

Maritime Sector Competition

Using Game Theory to Analyze Competitive Strategies

Presentation Agenda
Presenter: Dr. Thomas Wakeman

- Maritime Competition Background
- Ocean Shipping and Ships
- Growth of Global Ports
- Port Economics and Oligopoly
- Game Theory & Competitive Strategies
- Duopoly Competition Model
- Cooperation as Win-Win Strategies
- Summary

Context of Maritime Competition

Source: http://2.bp.blogspot.com/-srP9a40bL80/T_ymi4pAouI/AAAAAAAADZ8/j1Lm9noxaaU/s1600/Tall+Ships3.jpg

Competition in the Maritime Sector

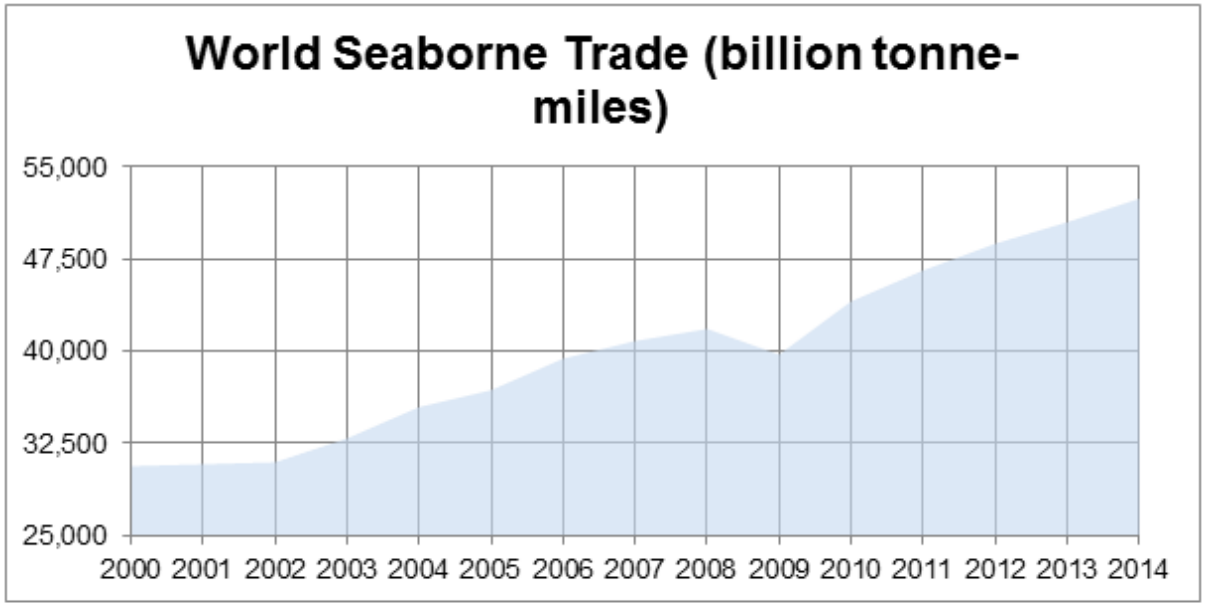
- Maritime businesses compete to gain market share and increase their profits.
- Early days competition was between ship owners as sellers of transport services.
- Thereafter, there was competition between city-ports (e.g., 1200s Venice vs Genoa) followed by competition between nations.
- Today maritime competition is focused on international ports and terminal operators.

Commercial Maritime Services

- Around 85 to 90% of international trade is annually carried by the marine shipping industry.
- Maritime transportation includes ship movement on marine waters and/or on inland waters, cargo handling at terminals (loading and unloading vessels and other modes), and terminal services (e.g., berthing, security, warehousing, etc.)
- Maritime transportation is a demand-derived service that collects payment from the user.
- The customer may be a passenger or shipper and depending on the service provided, will pay a “fare” for passage or “freight” for cargo shipment.

Growth in Maritime Trade

- Over the last four decades total seaborne trade has quadrupled, from just over 8 thousand billion ton-miles in 1968 to over 32 thousand billion ton-miles in 2008.
- In fact, the volume of waterborne trade has nearly doubled between 2000 and 2014.

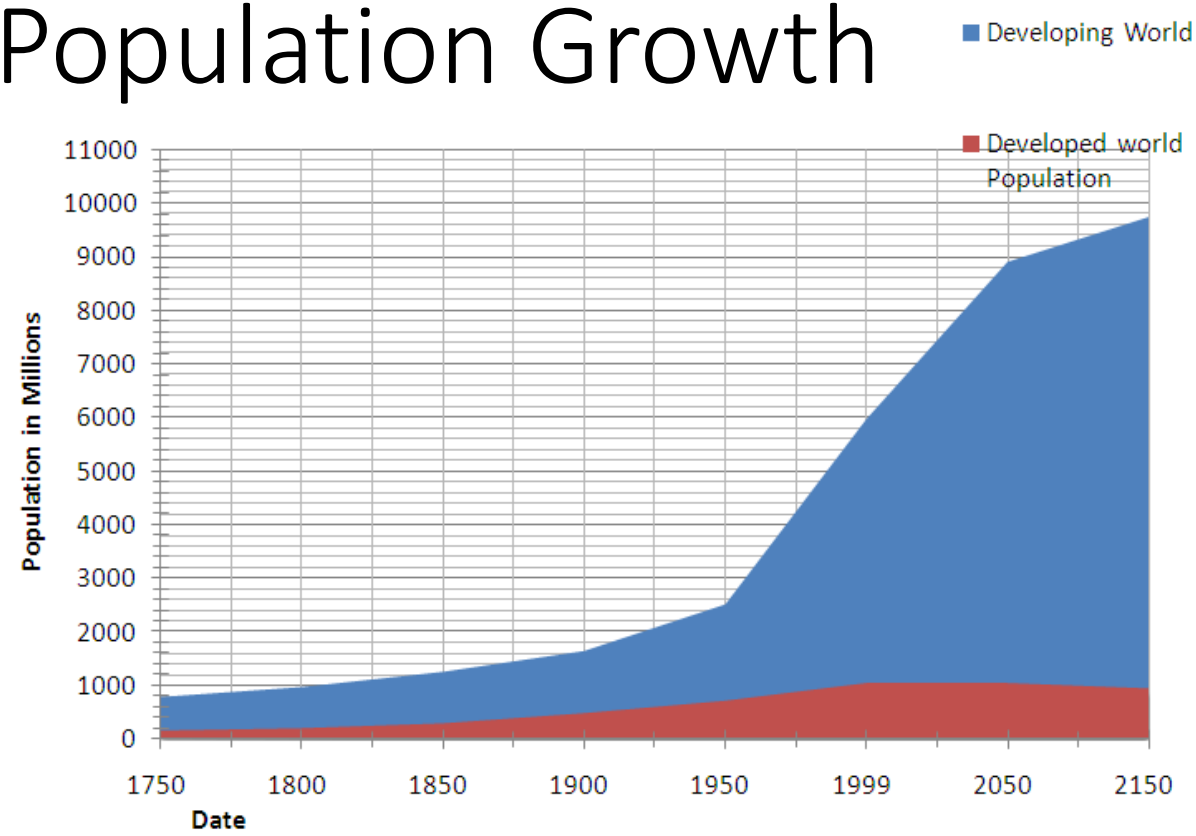


Source: UNCTAD Review of Maritime Transport, 2014

Population is driving this growth in international trade…

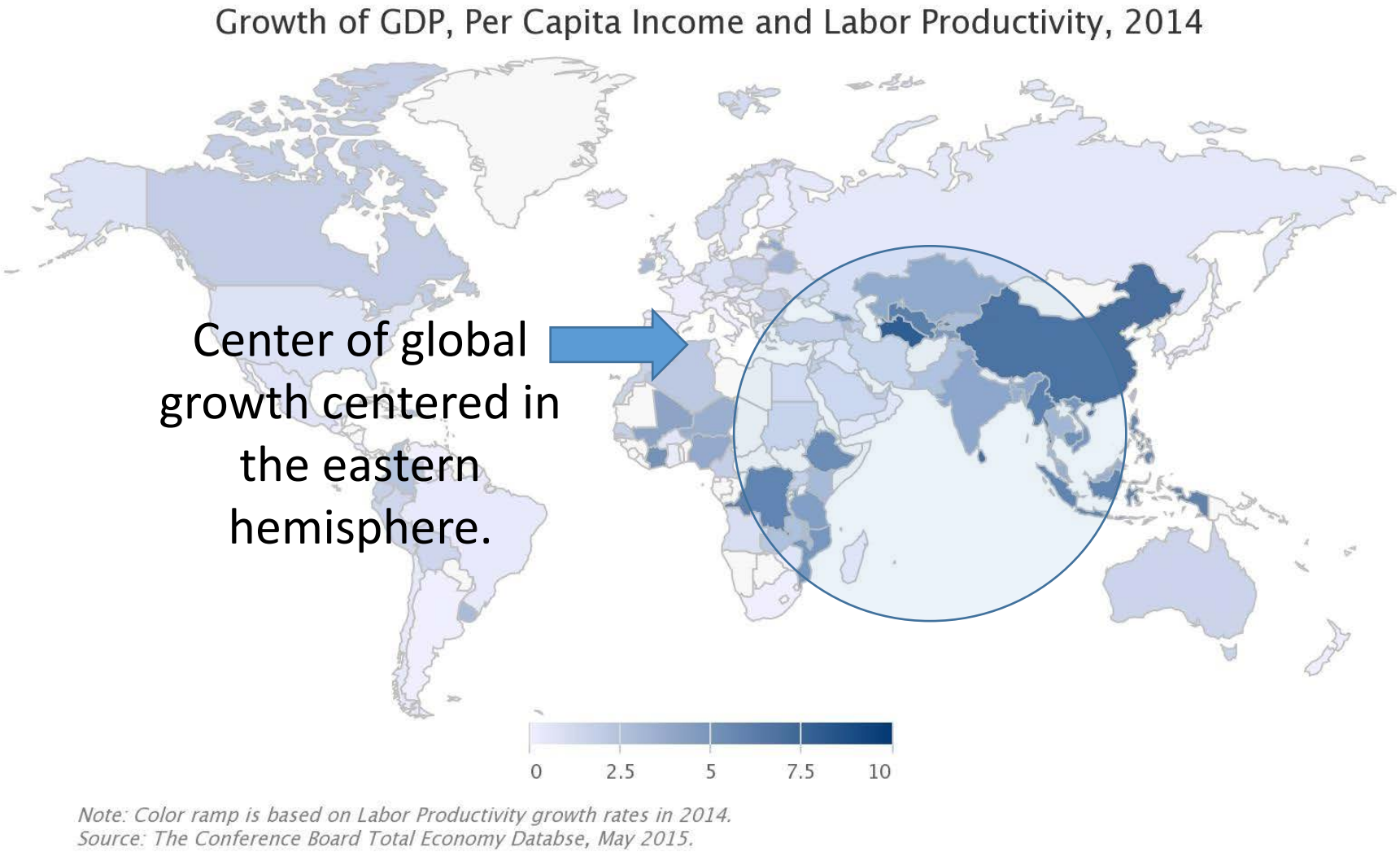
Source: http://www.export.org.uk/blog/wp-content/uploads/2014/07/shutterstock_151227353-1024x681.jpg

World Population Growth



Source: http://www.coolgeography.co.uk/GCSE/AQA/Population/Population%20growth%20graph.bmp

- There was about 1 billion people in 1805, about 3 billion in 1960, and approximately 7.4 billion today.
- The U.N. estimates population will increase to around 11.2 billion in the year 2100.



Source: https://www.conference-board.org/images/exchange/hc/uploads/v1/TED_Map_May_2015.jpg

Shipping - Size and Specialization

- Waterborne vessels carry international cargoes from ports of supply (exports) to ports of demand (imports).
- Early cargo included fairly uniform types of goods such as food (grain, wine), salt, and lumber.
- Globalization has promoted a complex stream of consumer goods and industrial cargoes.
- As the volume of cargo has grown, economies of scale have driven an increase in vessel and port size (and later terminal size and degree of specialization) to reduce unit cost to the shipper and their consumers.
- There are 3 principal types of cargo ships: dry bulk, liquid bulk, and containerships.

Types of Cargo and Vessels – Dry Bulk Ship

- Dry bulk (grains, ores, gravel, coal) – dry bulk carrier is a merchant ship specially designed to transport unpackaged bulk cargo, such as grains, coal, ore, and cement in its cargo holds.
- Since the first specialized bulk carrier was built in 1852, economic forces have driven their growth in size and sophistication.

Types of Cargo and Vessels – Liquid Bulk Carriers – Tankers

- Liquid bulk carrier moves liquid cargoes including food oils, petroleum, LNG, orange juice and so forth to tank farms or storage facilities.

Types of Cargo and Vessels – Container Ships

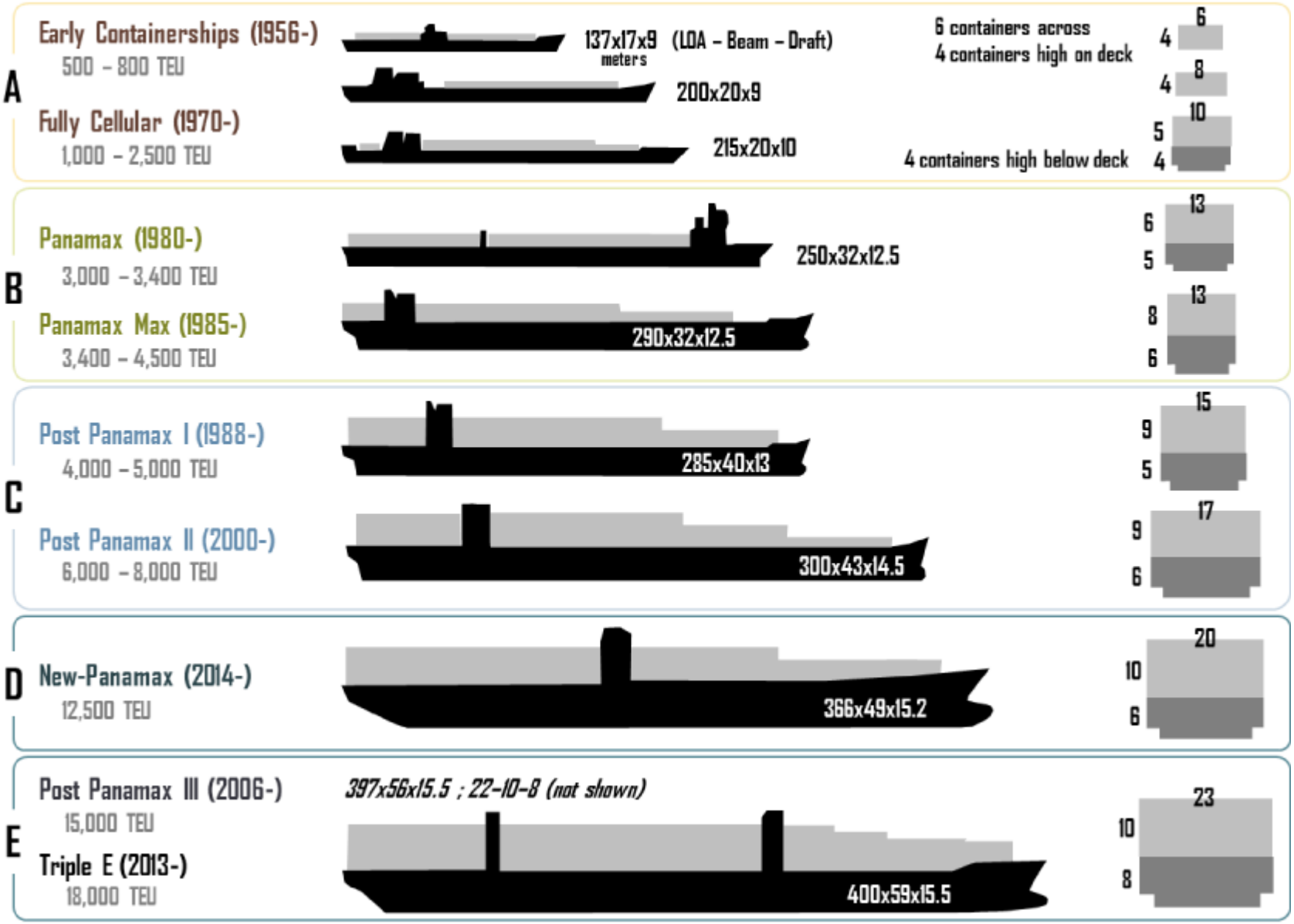
- Container ships are cargo ships that carry all of their load in truck-size intermodal containers -- a technique called “containerization” that started in 1956.
- Container ships are among the largest and common means of commercial intermodal freight transport and now carry approximately 75% of all seagoing, non-bulk cargoes.

Containership Characteristics

- The fleet owner with the biggest capacity will have the lowest average cost per unit because they can spread their costs across more and larger vessels.
- Variable Costs, labor running the ship and handling cargo, port and harbor fees, and fuel will be reduced on a unit basis for a vessel carrying more cargo.
- Fixed costs, such as capital charges of ownership, insurance, administration, and overhead, are only modestly impacted by vessel size.
- Vessel size continues to grow…

Evolution of Containerships

Source: Ashar and Rodrigue, 2012 (All dimensions are in meters.)



Competitive Container Ports

- Economies of scale forced container ship owners to increase the size of their vessels to carry more cargo - decreasing the unit cost of cargo movement.
- But as ships got larger, terminals had to expand their berths and throughput capacity to handled more cargo.
- Ports have experience fierce competition with other ports and modes for a share of container market.
- Competition among ports constrains the price point and level of quality for services offered.
- When prices get too high or quality too low, users will switch to another service alternative, either a new port or different mode as appropriate.

The Port Market is an Oligopoly.

- A free market with perfect competition emerges when there are a large number of suppliers providing the same or similar goods or services.
- On the other hand, if there is only one supplier then the market is a monopoly.
- Between these extremes is two forms of imperfect competition: monopolistic competition or oligopoly.
- Often regional ports have the characteristics of an oligopoly, which is a state of limited competition where the market is shared by a small number of sellers.
- With few sellers, each oligopolist is likely to be aware of the actions and products of the other competitors.

Competition versus Monopoly

	Perfect Comp	Monopolistic	Oligopoly	Pure Monopoly
NUMBER OF FIRMS IN EACH INDUSTRY	Many	Many	Few (Three or Four)	One
MARKET CONCENTRATION	Low	Low	High	Absolute
TYPE OF PRODUCT	Similar or Identical	Similar or Identical	Similar or Differentiated	Unique (No Substitutes)
AVAILABILITY OF INFORMATION	Much (Product Advertising)	Much (Product Advertising)	Much (Product Advertising)	Some (Product and Institu-tional Advertising)
ENTRY INTO INDUSTRY	Very Easy	Fairly Easy	Difficult	Prohibitive
CONTROL OVER PRICES	None	Little	Some	Complete
EXAMPLE INDUSTRIES	•Agriculture	•Telephone Companies •Airlines	•Automobiles •Breakfast Cereals	•Electric Power •Cable Television

Source: http://isite.lps.org/dhersh/webextras/Mono_Oligopoly.jpg

Port/Terminal Competitive Factors

- Cost of services
- Quality of services
- Total cargo volume throughput
- Availability of new upland and berth capacity
- Hinterland multimodal connectivity
- Perfect competition is unlikely in maritime sector because of many dynamic and confounding factors.
- For example, factors include changing trade routes, global supply and demand volatility, local politics and policies pressures, natural and urban environmental conditions, and locations of manufacturing and consumption zones.

Game Theory

- Game theory has emerged over many decades and has been applied in many disciplines including economics, political sciences, biology, computer sciences, security, and even poker.
- Roger Myerson, in 1991, defined game theory as "…the study of mathematical models of conflict and cooperation between intelligent ***rational*** decision-makers."
- In oligopolistic markets where firms must make decisions about pricing, levels of service, and how much to invest in development and expansion, game theory analysis can have direct relevance.

Application of Game Theory

- Since the 1930s, game theory has been used by economists to examine competitive markets.
- When 2 or more businesses compete in a market and have incomplete knowledge about the other's intentions, game theory can be used to predict the outcome of each players' strategic decisions.
- As an oligopolistic environment, port/terminal competitive strategies have been analyzed using game theory since the latter portions of the 1990s.
- Outcomes are uncertain in oligopolistic settings, such as the maritime sector, because of imperfect knowledge regarding strategies and payoffs among parties.

Defining Strategic Outcomes

- The classic example of game theory is the Prisoner's Dilemma, which is a *duopoly* where two prisoners are being questioned over their innocence or guilt regarding a crime.
- Their choices are to confess to the crime or to deny all involvement and hope that their partner does likewise – each strategy having a specific outcome.
- Their choices correspond to some number of years in prison ("payoff") depending the behavior of each, which is unknown until the game is over.

A Player's Strategy

- It is assumed that each player will choose the strategy that is optimal for themselves given the specific strategy taken by the other players.
- A strategy that is always optimal, regardless of the strategy selected by other players, is said to be the dominant strategy – is typically rare in real life.
- When the outcome that occurs is optimal for each player given the action of other players, and a player cannot gain by changing their strategy when holding all the other players' strategies constant, it is called a Nash equilibrium.

Duopoly Competition

Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

What is the optimal strategy for Port A if Port B chooses to develop capacity expansion? If Port A chooses to expand, the payoff is 9. Otherwise, the payoff is 4. The optimal strategy is to expand.

Duopoly Competition

Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

What is the optimal strategy for Port A if Port B chooses not to expand capacity? If Firm A chooses to expand, the payoff is 12. Otherwise, the payoff is 2. Again, the optimal strategy is to expand.

Duopoly Competition

Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

Regardless of what Port B decides to do, the optimal strategy for Port A is to expand its capacity. Hence the dominant strategy for Port A is to expand.

Duopoly Competition

Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

What is the optimal strategy for Port B if Port A chooses to expand? If Port B chooses to expand, its payoff is 6. Otherwise, the payoff is 1. The optimal strategy is to expand its capacity.

Duopoly Competition

Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

What is the optimal strategy for Port B if Port A chooses not to expand? If Port B chooses to expand, the payoff is 9. Otherwise, the payoff is 0. The optimal strategy is to expand, which is also the dominant strategy for Port B.

Duopoly Competition
Example Problem

Port Expansion

		Port B	
		Expand	Don't Expand
Port A	Capacity Expansion	9, 6	12, 1
	Don't Expand	4, 9	2, 0

The dominant strategy for Port A is to expand its capacity, and the dominant strategy for Port B is to expand its capacity.

Nash Equilibrium is for both ports to expand.

Rate Wars of 1870s

"…there was a dim awareness among shipowners that uninhibited competition could be disastrous…"

Type of Steamship of the Atlas Line Service.

Maritime Rate Wars

- Suez Canal was opened in 1869.
- Streamships could use the Canal to shorten the distance to India whereas sailing ships could not because of winds.
- To offset their disadvantage, sailing ship owners reduced their shipping rates.
- Steamship owners met this challenge by cooperating and forming a conference and with greater concessions and a *rate war began*.
- Shipowners decided to cooperate instead of competing their way out of business.

Cooperation vs. Competition

- Cooperation is a business strategy where 2 or more firms work together (sharing mutually agreed upon objectives and policies) for a “win-win” outcome, instead of working separately in competition.
- Oligopolistic sectors usually try not to engage in direct competitive activities with one another (i.e., price cutting or excessive advertising), because it can escalate into a price war or other “lose-lose” outcome.
- Some forms of cooperation violate anti-trust laws and are illegal in certain jurisdictions because they restrict open competition or access to markets or resources by some participants.
- Formation of cartels or price-fixing agreements among market participants are often determined to be illegal and disallowed, although exceptions exist (e.g., OPEC).

Cooperative vs. Competitive Strategies

Port Pricing Example

		Port B	
		High Price	Low Price
Port A	High Price	**Tacit Collusion**	A matches B
	Low Price	B matches A	**Price War**

Cooperative strategies implemented by port authorities (such as price setting) are seen as malfeasance by regulators; however a port following a price leader (and matching its price) is not strictly illegal but may be seen as a form of tacit collusion.

Other Duopoly Models

- Two static game models are frequently used to study port competitive strategies: Cournot oligopoly model (quantity/price competition model) and Bertrand oligopoly model (price competition model) .
- If capacity and output can be easily changed, Bertrand is a better model of duopoly competition. If output and capacity are difficult to adjust, then the Cournot is generally a better model.
- As the number of firms increases towards infinity, the Cournot model gives the same result as in Bertrand model where price is pushed to marginal cost level, i.e., the market will result in perfect competition.

Summary: Maritime Competition

As an oligopoly, the maritime sector can have several levels of competition between participants. The main competitors include:

- Maritime Sector: Ship/Intra- and Inter-Port
  - Other ports (intra-port)
  - Among terminals at the same port (inter-port)
- Multi-modal Transportation Modes
  - Rail – intermodalism
  - Truck – highway moves
  - Air – time dependent of high value goods
- Severity of competitive pressure is determined by the degree of substitutability among options – in this case other ports or transport modes.

Summary: Game Theory

- When 2 or more businesses compete in a market and have incomplete information about the other's intentions, game theory can be used to predict the outcome of each firm's strategic decisions in the marketplace.
- In oligopolistic markets, like regional port markets, game theory analyses can have direct relevance.
- Currently there is few well-established game models tailored to solving port strategic decision conflicts because of the dynamic nature and complexity of the global maritime freight-transport system.

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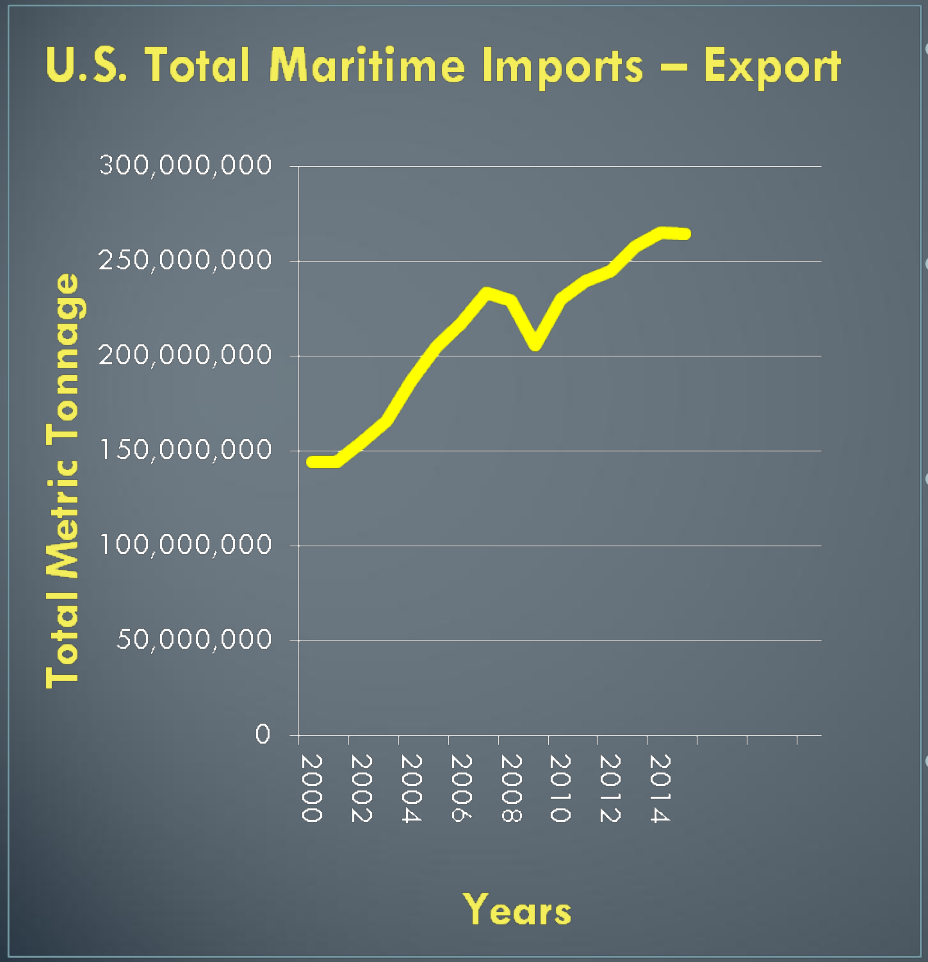
Understanding Regulation and Maritime Cyber

By Jose Davalos

US Maritime

- Transportation is a key element to any national economy. Without it, a county and its economy would not prosper.
- Since the founding of this nation, maritime transportation has been an integral part of U.S. history.
- The United States as a whole, but particularly its economic strength has come from maritime transportation.
- Today maritime transportation is still as important as when the first vessel arrived & departed America's shores.

Amount of Imports & Export



- In total, the U.S. accounts for approximately 30% of global maritime shipping.
- 78% of all cargo transported in the U.S. can be traced to maritime transportation.
- Total TEU traded throughout the world in 2014 is 255 million TEUs. The U.S. was responsible for 12.4% of that trade.
- Container shipping is one of the most automated systems today.

Cyber Environment

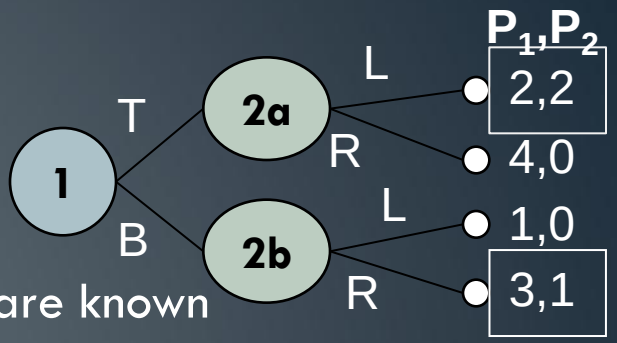
- Executive Order 13636 required that all regulating government agency look into critical infrastructure to improve cyber-security for their respected domain.
- Many aspects of maritime transportation fall under the critical infrastructure requirement.
- It is the Coast Guard's duty to safeguard the maritime industry.
- IT has become an indispensible part of the maritime industry.

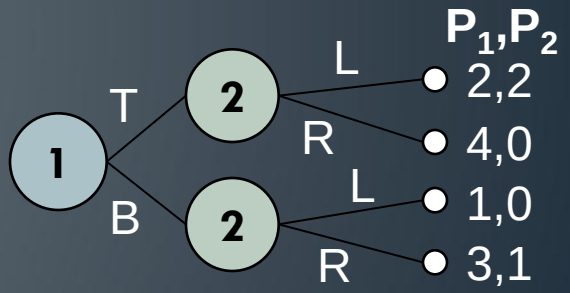
Game Theory in Maritime

- Game theory can be used to determine best approach in countering a cyber threat.
- A cyber scenario using one defender and one attacker would yield a probable outcome.
- However, although the defender may remain the same, the attacker may not.
- Outcomes may not maximize the reduction from a cyber - attack

2 Player Example

- Game tree
  - Establishes ordering of choices
  - Establishes what players know when
  - Leads to enumeration of "pure" strategies
  - Can be solved by pruning if all prior actions are known
- Hidden information
  - Cannot be solved by pruning
  - Can be solved by other means
  - Optimal strategies may be random
- Normal (matrix) form
  - Table of utilities to each player
  - Players assumed to know
    - All strategy options
    - All resulting utilities





P_1,P_2	L	R
T	2,2	4,0
B	1,0	3,1

Issues with multiple entities

- Entities operating in the maritime industry don't all operate in the same manner.
- Many physical facilities' IT system are neither maintained nor administrated at the facility.
- A maritime Cyber – Security breach can occur away from the physical maritime facility and still have the same impact as if the breach occurred with the facility's network.
- The use of game theory becomes very difficult and complex because of the exponential increase in variables.

Collaboration between regulatory Agencies

- Cyber is not limited to just maritime
- Agencies have specific areas of responsibilities, where overlapping jurisdictions becomes an issue.
- Agencies needs to the work together to develop a solution.