Iowa State University
Department of Industrial and Manufacturing Systems Engineering

How I Learned to Stop Worrying and Love Disruptions

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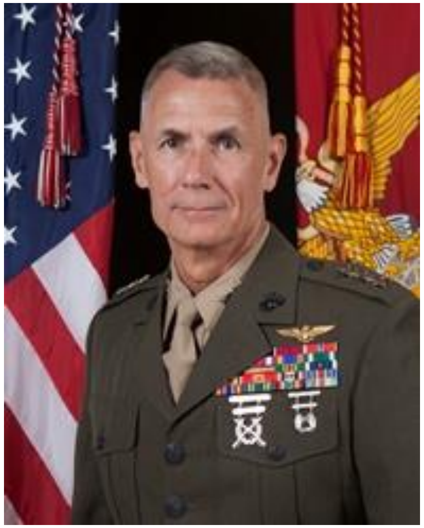
U.S. Marine Forces Reserve



Lt. Gen. Rex McMillian

Evacuate?

- 1,000 Marines on base
- If you wait to order evacuation until 30-40 hours before hurricane, Marines could be stuck in traffic as the rest of New Orleans tries to evacuate
- If no evacuation and hurricane strikes
    - Potential loss of life
    - Potential of city infrastructure disabled
- $300,000 for each day that Marines have evacuated

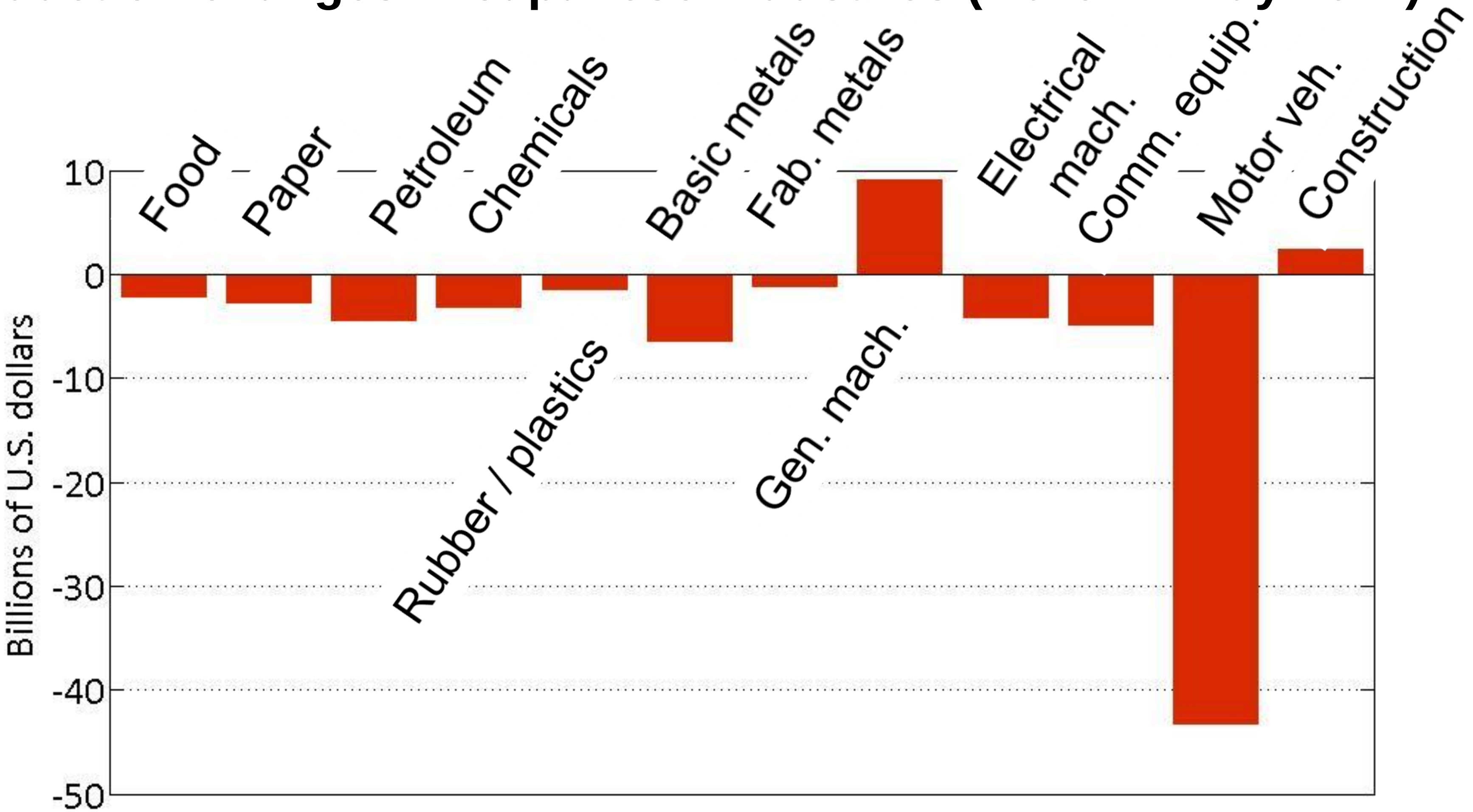
Questions for risk analysis

1. What can go wrong?
2. How likely is to go wrong?
3. What are the consequences?

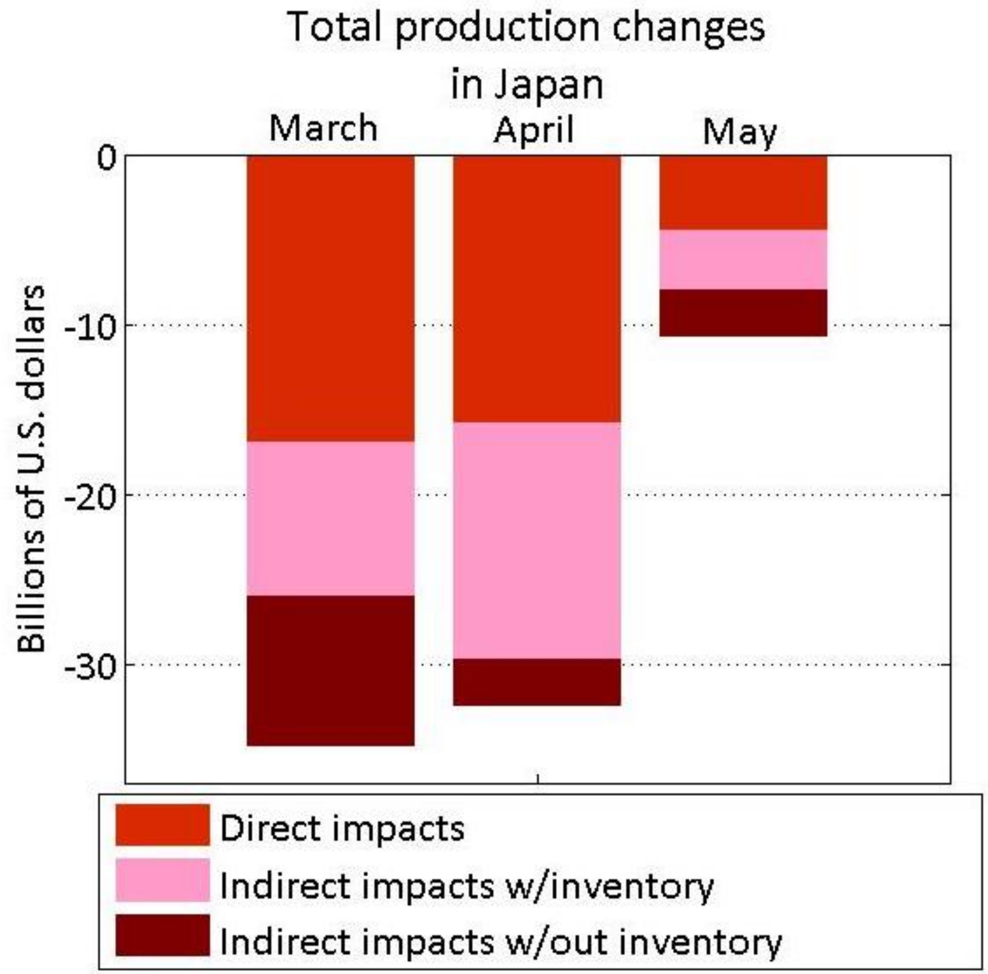
Interdependent ecomony

Economic impacts of Japanese earthquake and tsunami

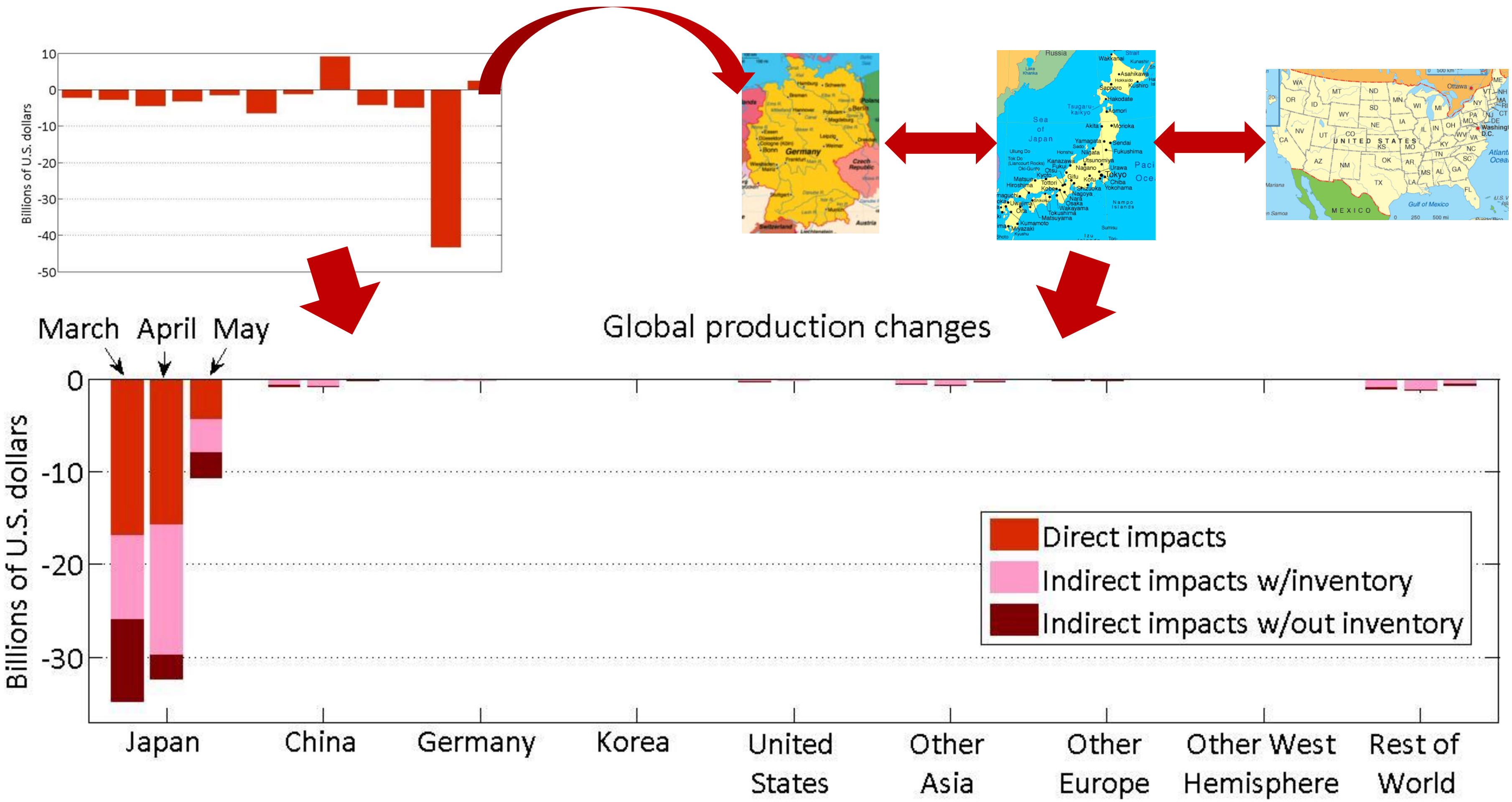
Production changes in Japanese industries (March – May 2011)



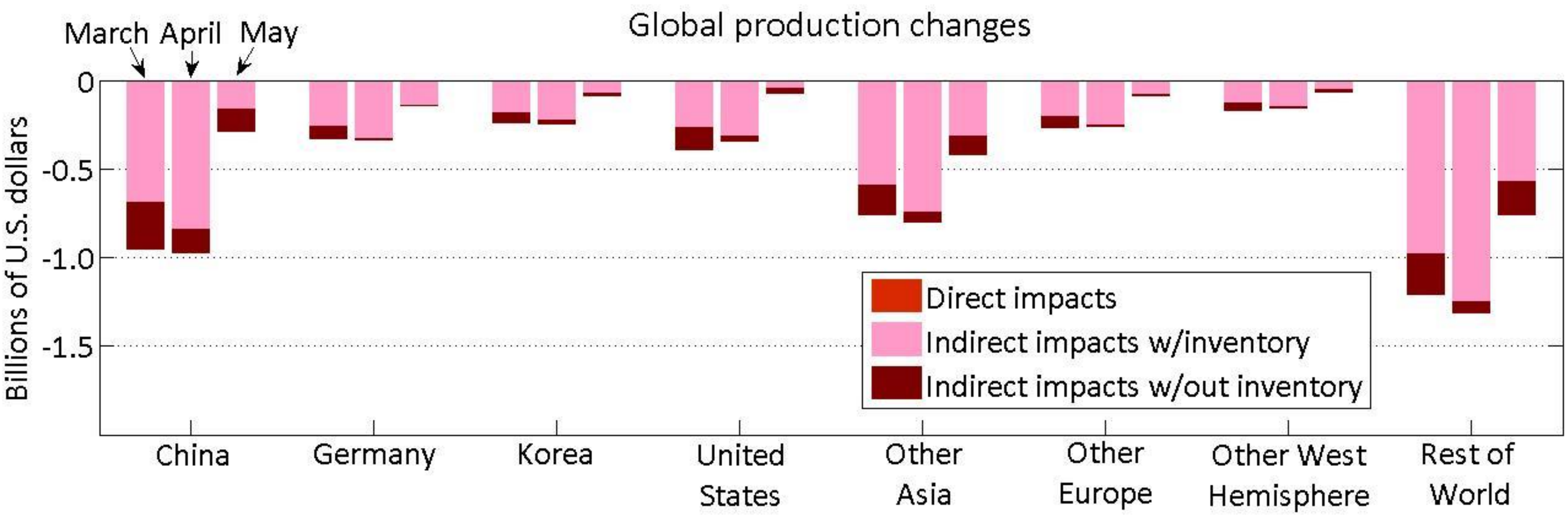
Economic impacts of Japanese earthquake and tsunami



International economic impacts of Japanese earthquake and tsunami



International economic impacts of Japanese earthquake and tsunami

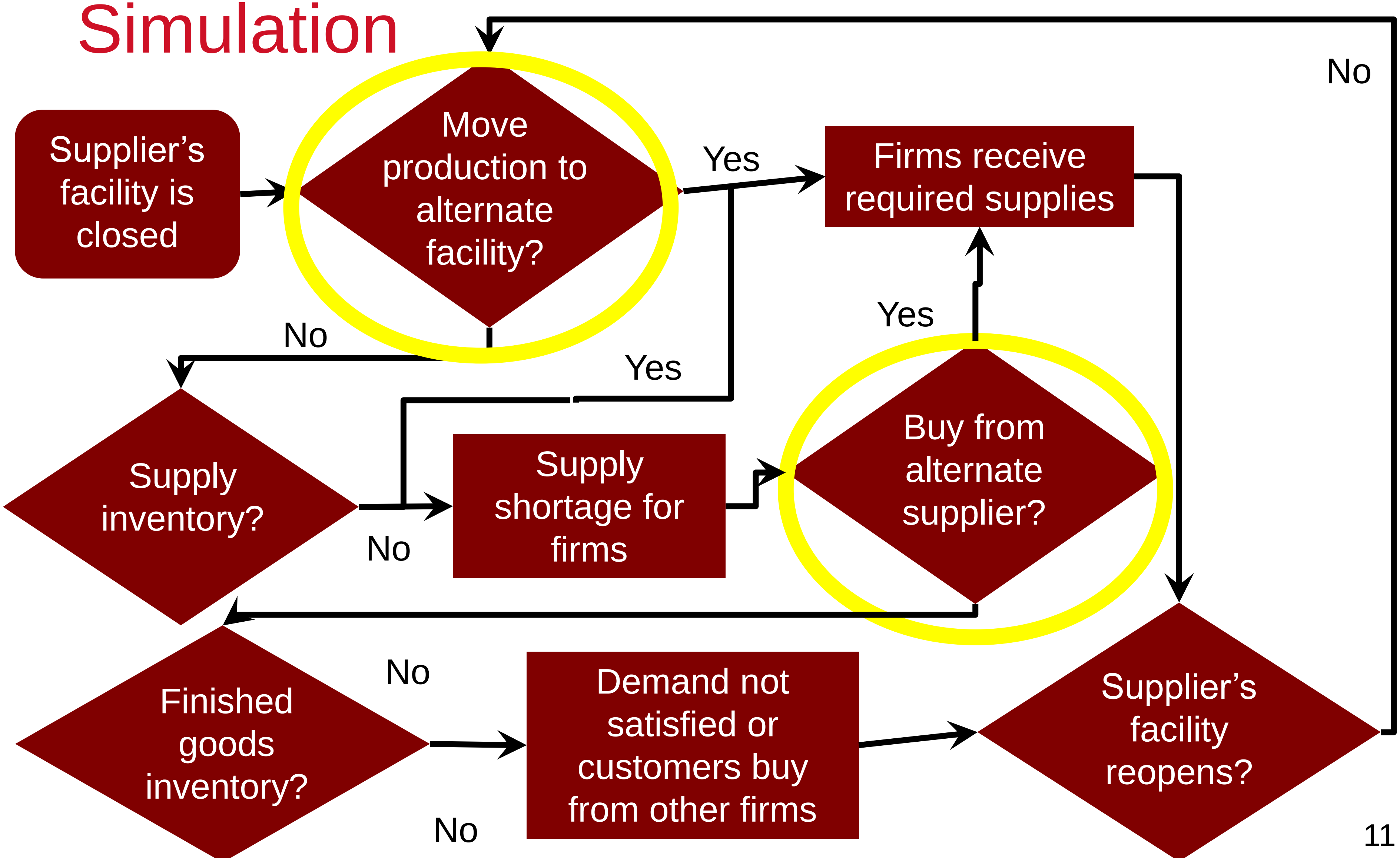


Economic input-output models

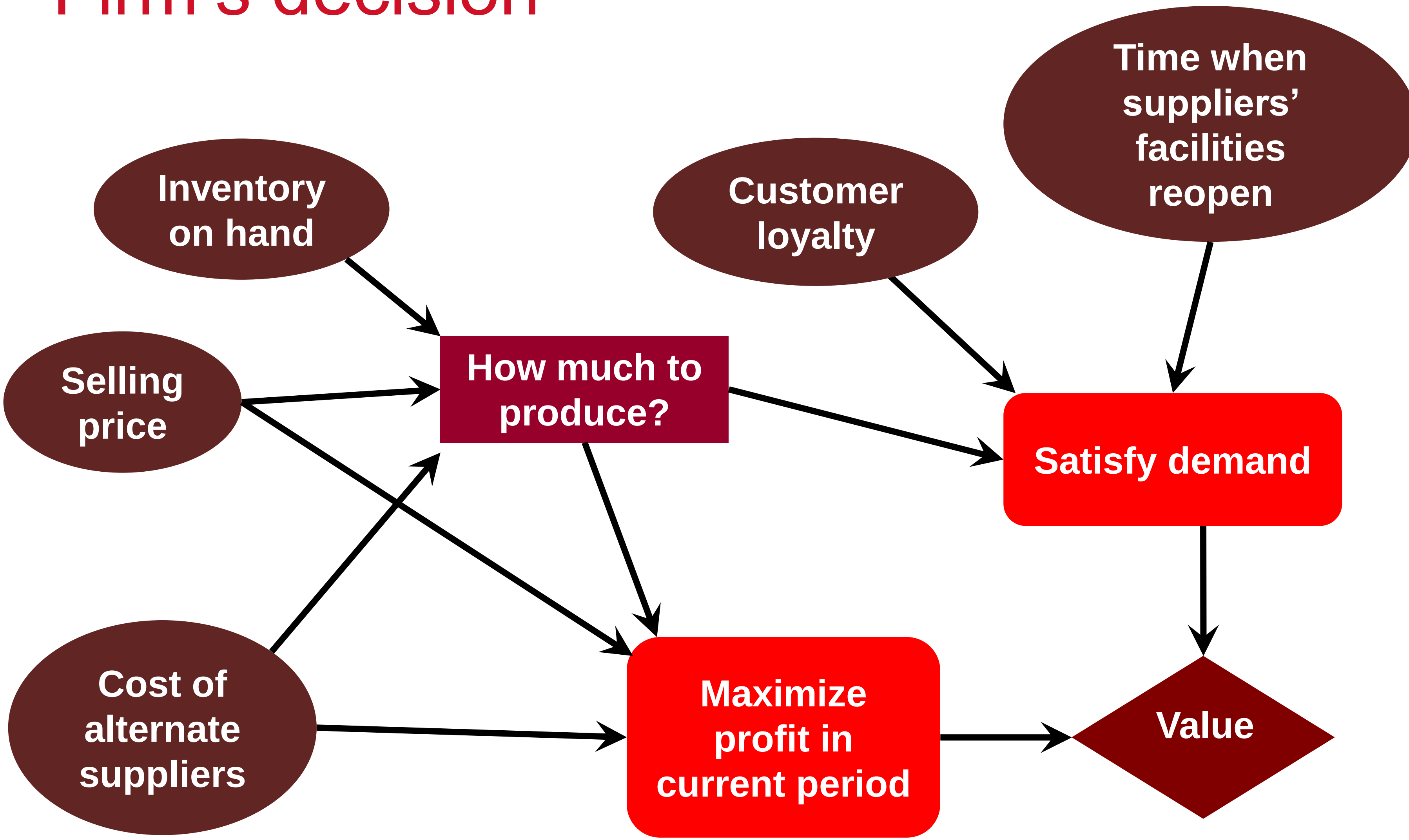
- Comprehensive study of economic consequences from disruptions (both historical and hypothetical)
- Better models of how industries behave during a disruption
- Better dynamic economic model

MacKenzie, C.A., Santos, J.R., & Barker, K. (2014). Measuring changes in international production from a disruption: Case study of the Japanese earthquake and tsunami. *International Journal of Production Economics*, 138(2), 293-302.

Simulation

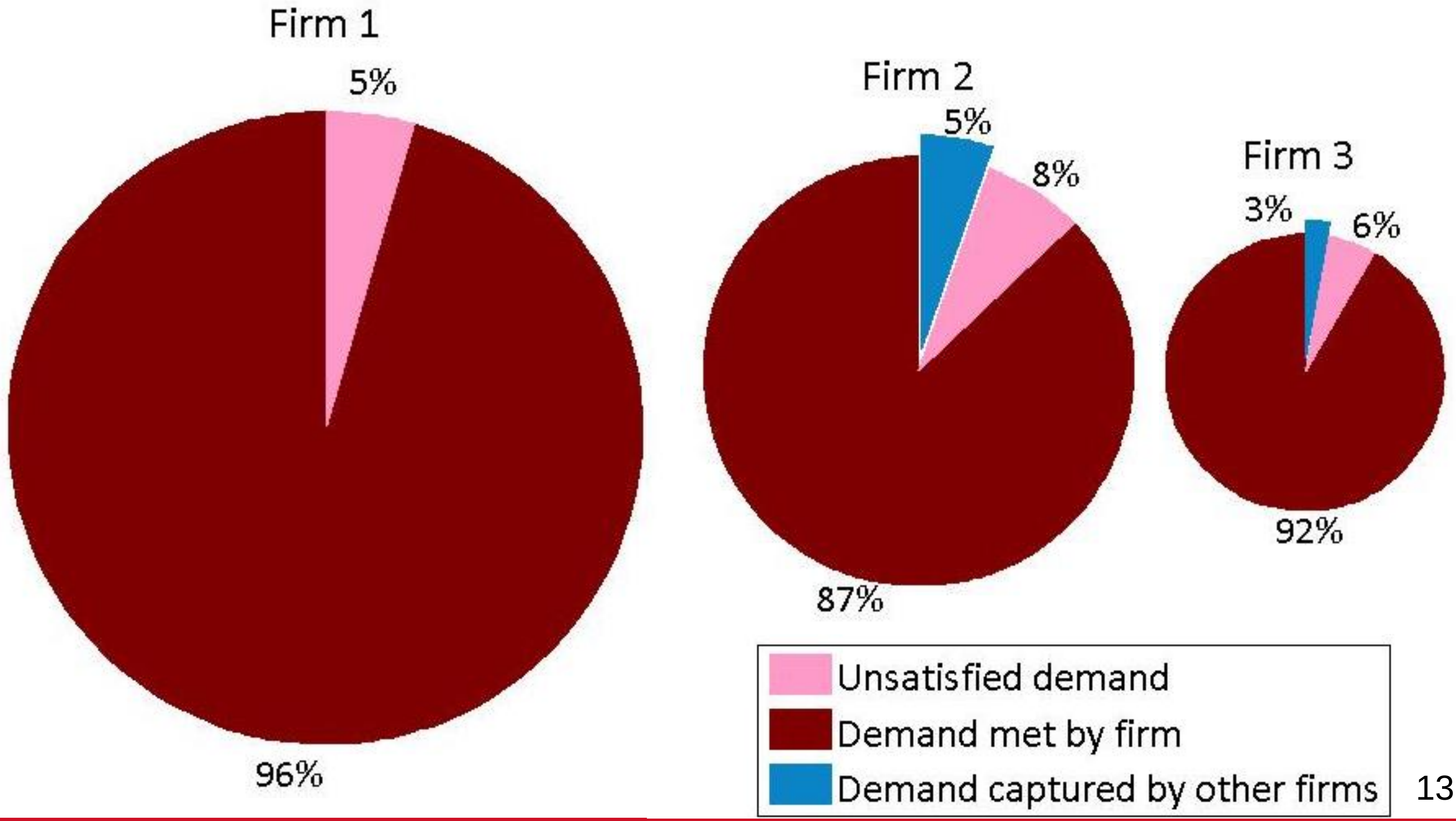

Supplier's facility is closed
Move production to alternate facility?
Yes
Firms receive required supplies
No
Yes
Yes
Supply inventory?
No
Supply shortage for firms
Buy from alternate supplier?
No
Finished goods inventory?
No
Demand not satisfied or customers buy from other firms
Supplier's facility reopens?
No

Firm’s decision



Simulation results

Average production when suppliers do not move to alternate facility



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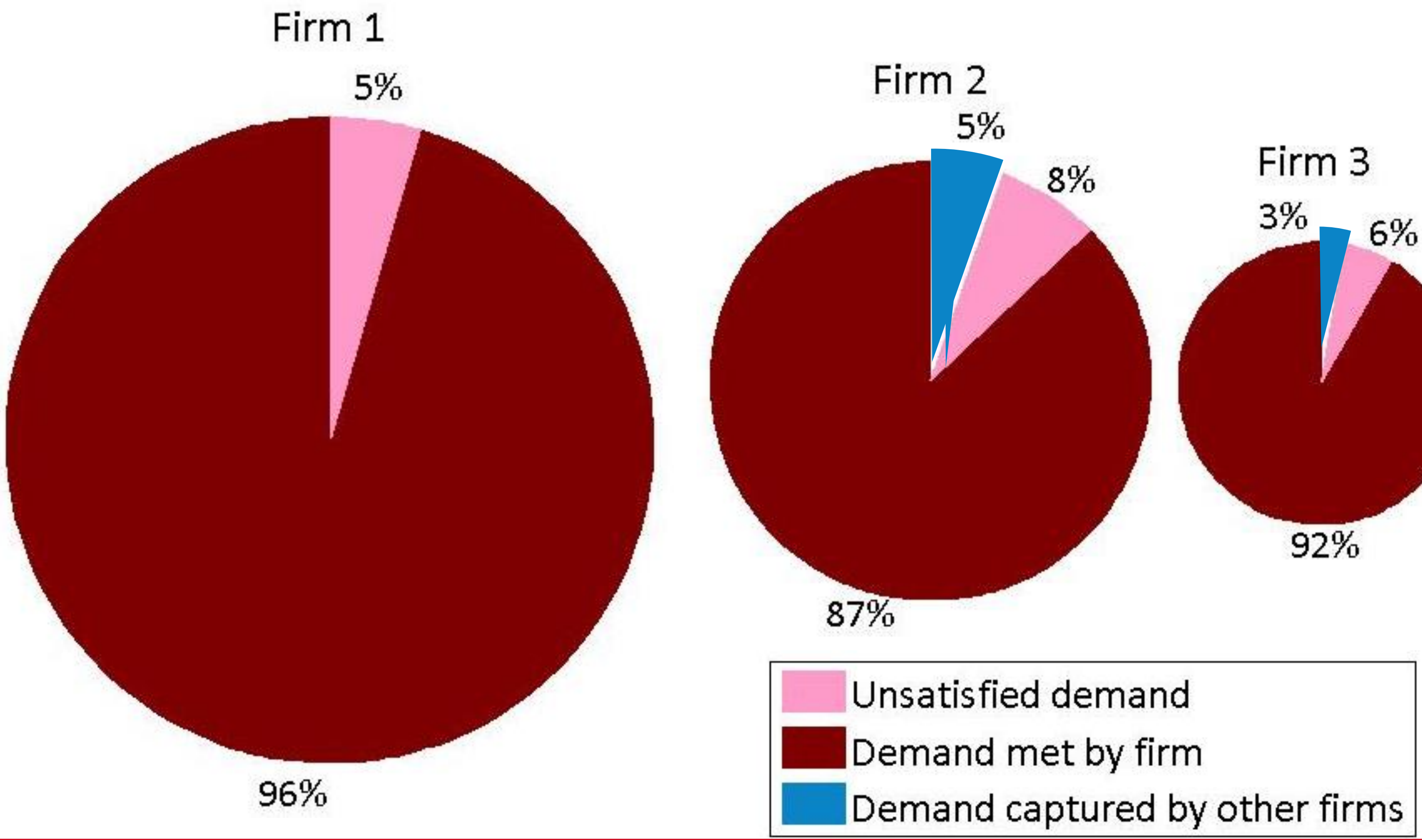

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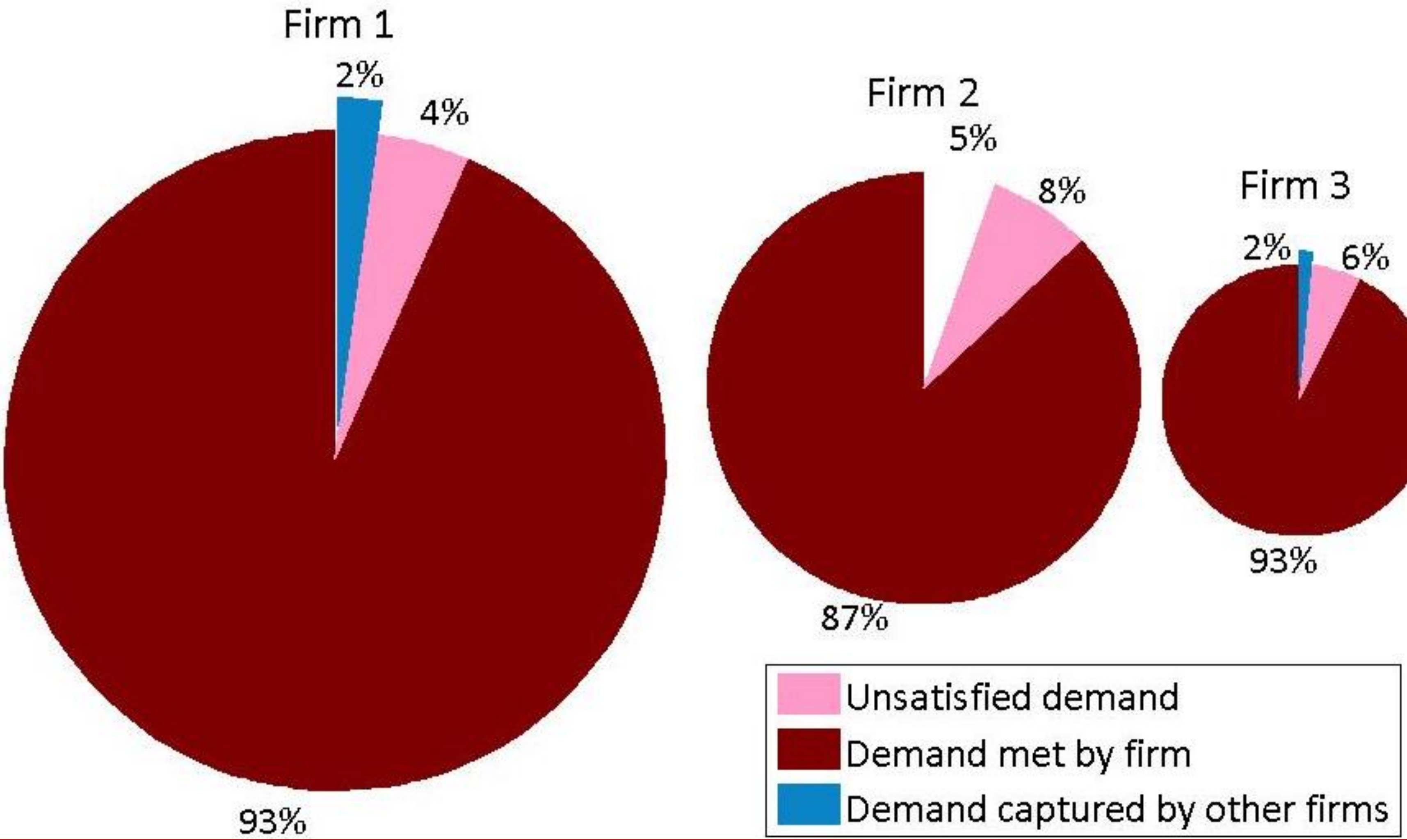

Simulation results

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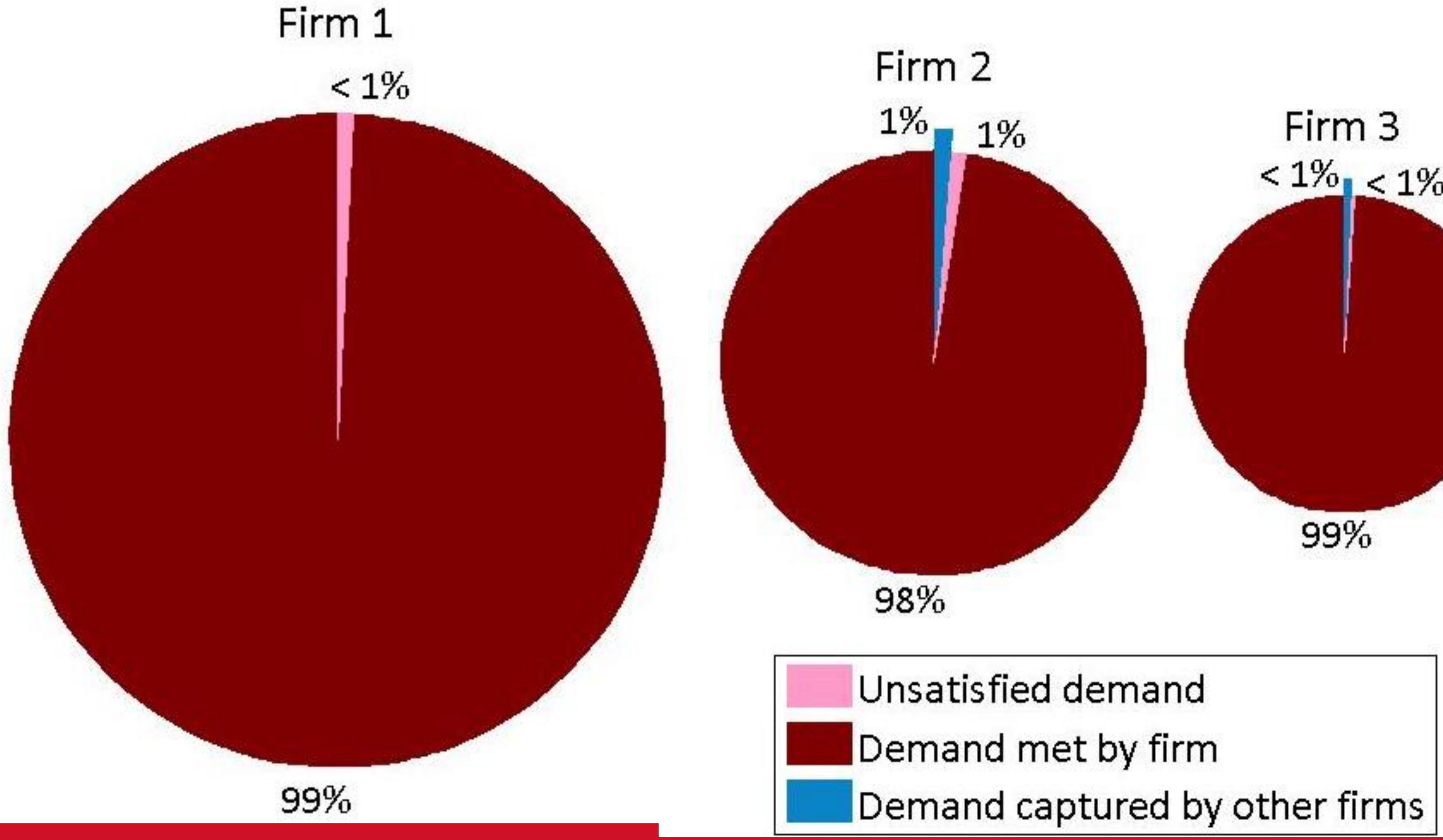


Supply chain risk management

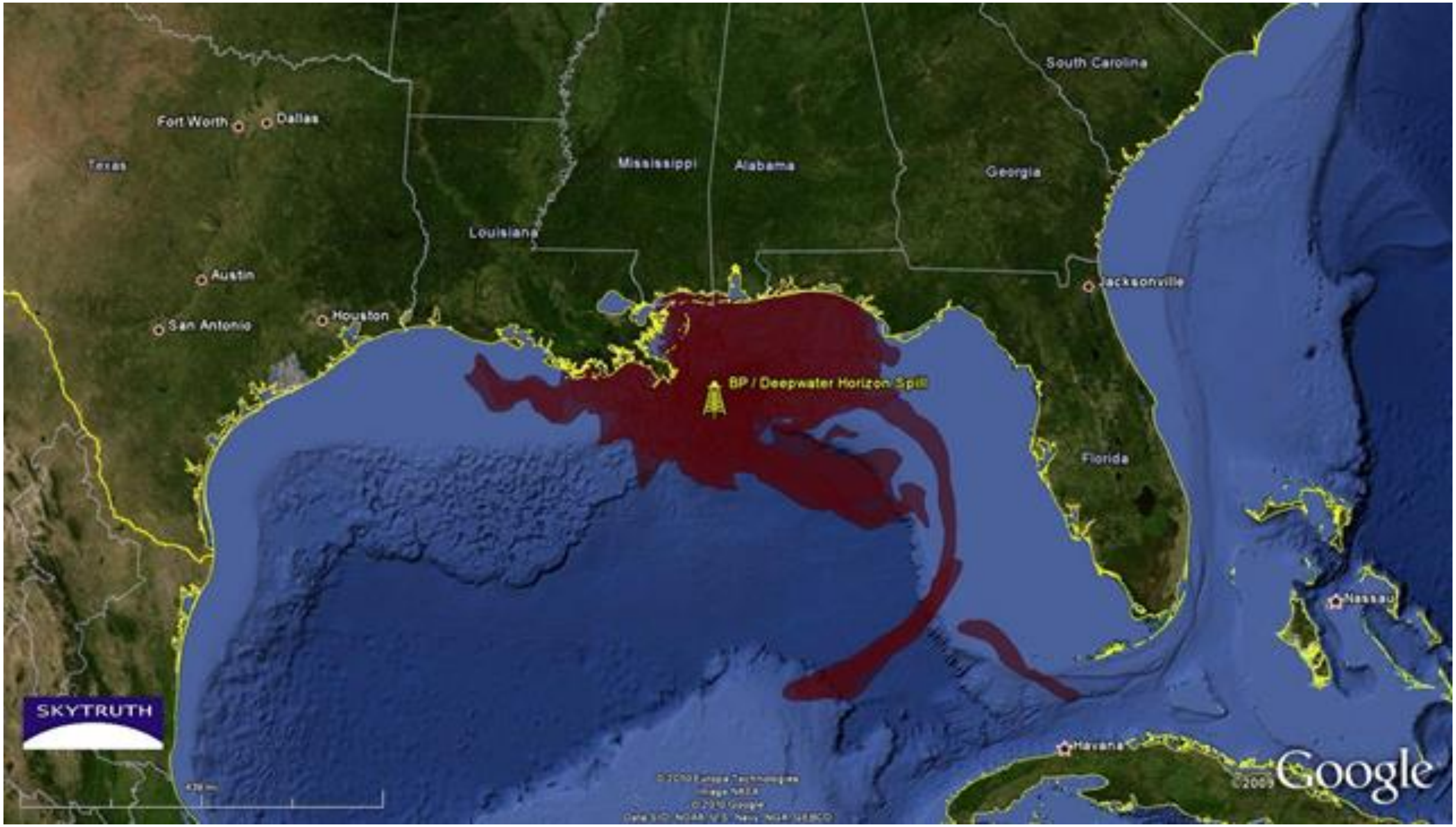
- Mitigating risk of supply chain disruption vs responding to disruption
- More realistic model of company behavior
- Use of game theory for severe supply chain disruptions

MacKenzie, C.A., Barker K., & Santos, J.R. (2014). Modeling a severe supply chain disruption and post-disaster decision making with application to the Japanese earthquake and tsunami. *IIE Transactions*, 46(12), 1243-1260.

Deepwater Horizon oil spill

Impacted area

Texas, Louisiana, Mississippi, Alabama, and Florida



Directly impacted industries

Fishing

Real estate

Amusements

Accommodations

Oil and gas

Resource allocation model

- Allocating resources prior to disruption
  - Reduces probability of disruption
  - Reduces direct impacts if disruption occurs
- Allocating resources after disruption
  - Allocation to all industries helps all industries recover
  - Allocation to individual industry helps just that industry recovery
- Allocation reduces impacts via an exponential function
- Objective: minimize expected economic losses

Parameter estimation for fishing

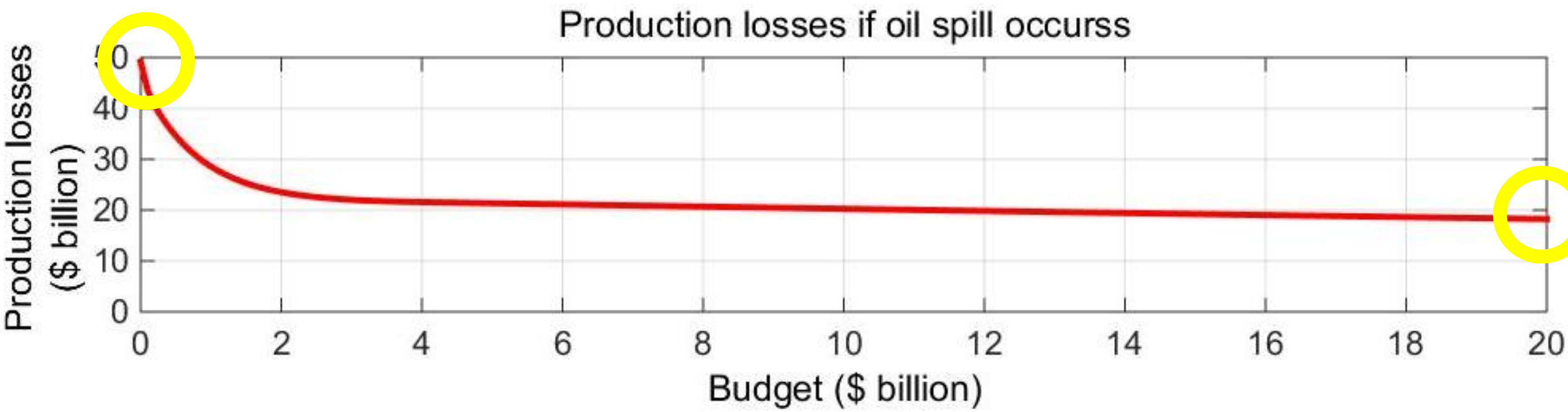
BUREAU OF ECONOMIC ANALYSIS
U.S. DEPARTMENT OF COMMERCE

NRDC
THE EARTH'S BEST DEFENSE

$62 million lost sales from Gulf Coast fishing
→ 0.84% of region's fishing and forestry production (direct impacts)

Studies on food safety and impact of positive media stories
→ $792,000 to reduce losses by $40 million (effectiveness parameter)

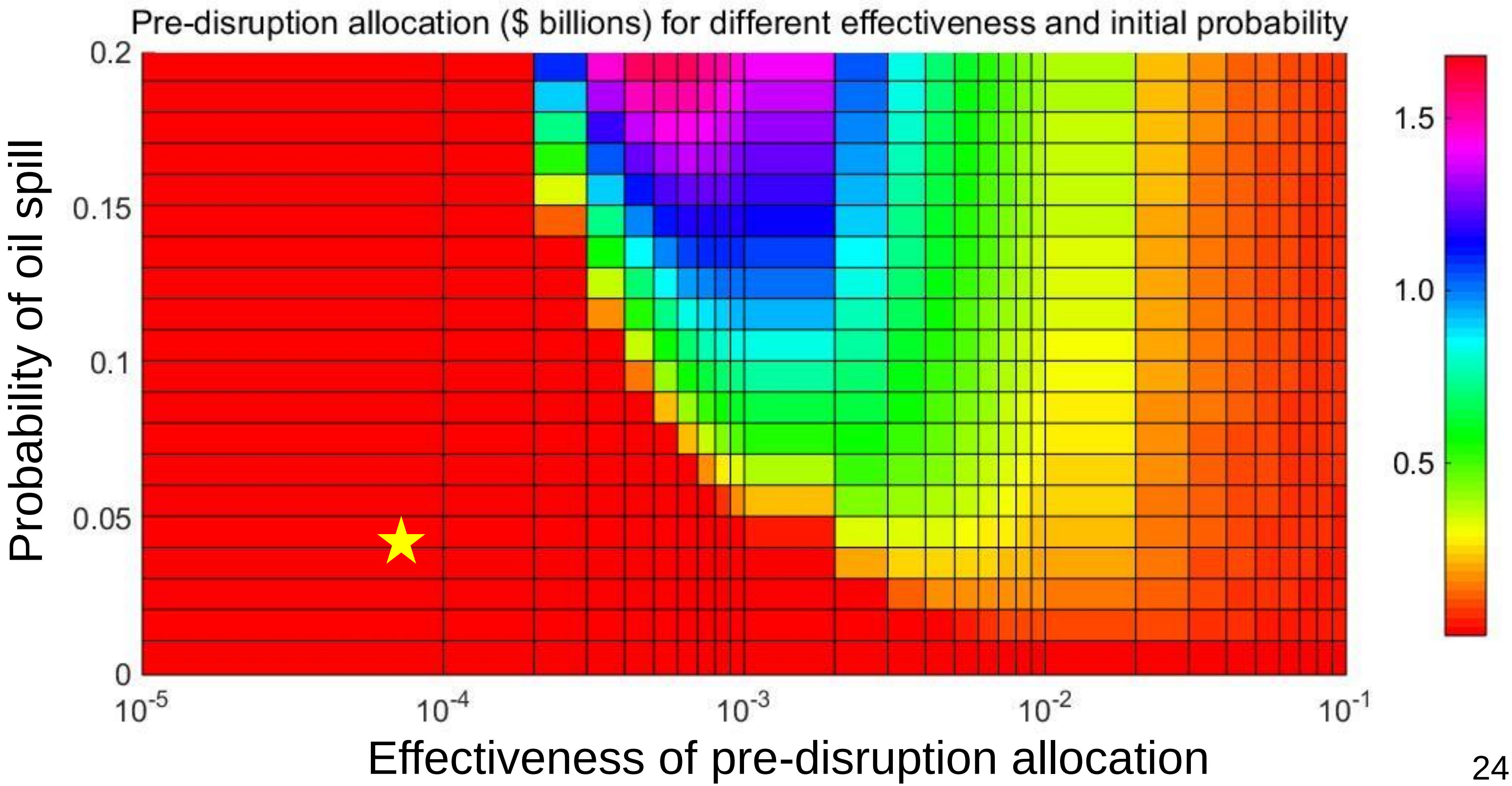
Model results



Industry	Millions of dollars allocated to each industry			
Fishing	0	46	46	46
Real estate	0	0	0	0
Amusements	250	1,209	1,209	1,209
Accommodations	379	1,752	1,752	1,752
Oil and gas	372	1,011	1,011	1,011
All industries	0	981	5,981	15,981
Total budget	**1,000**	**5,000**	**10,000**	**20,000**

Sensitivity analysis

$10 billion budget

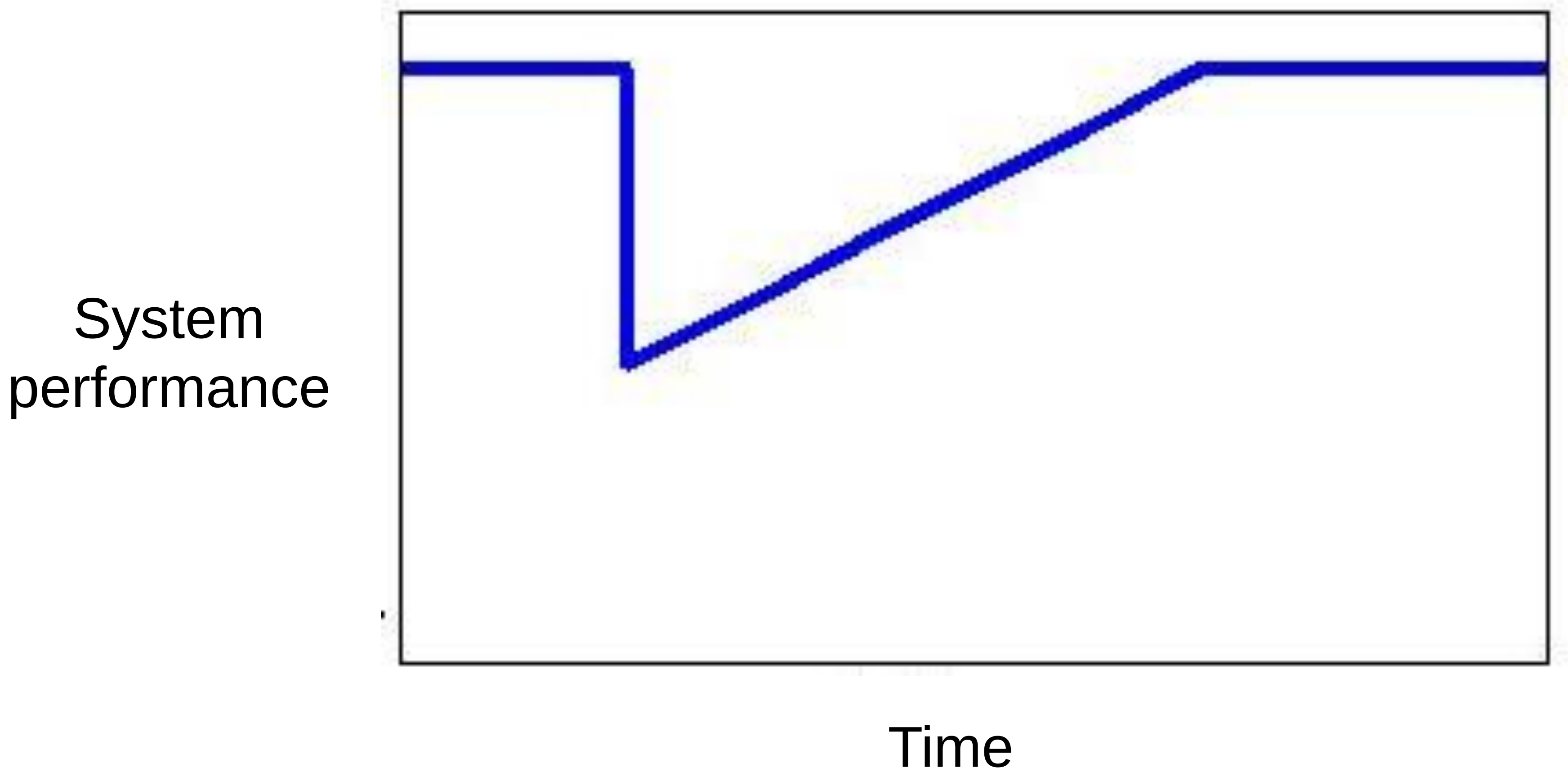


How much should we prepare for disruptions?

- More general model of preventing, preparing for, and responding to disruptions
- Include more uncertainty and multiple consequences
- Dynamic model

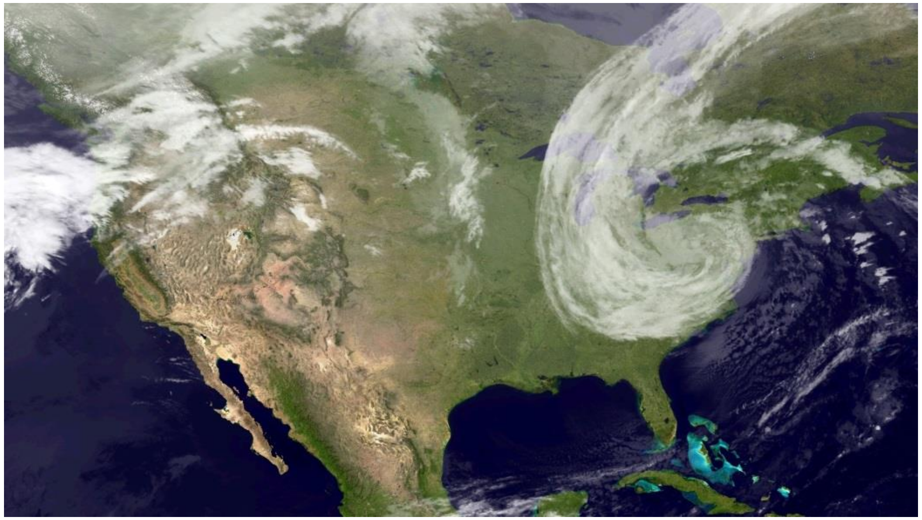
MacKenzie, C.A., Baroud, H., & Barker, K. (2014). Static and dynamic resource allocation models for recovery of interdependent systems: Application to the *Deepwater Horizon* oil spill. In press. DOI: 10.1007/s10479-014-1696-1

Disaster resilience



Superstorm Sandy

- October 2012
  - East coast of the U.S.
  - Second costliest hurricane in U.S. history
- ConEdison Electric Utility
  - 670,000 New York city customers without electricity
  - Approximately 1/5 of ConEdison's customers
  - Duration: 13 days



ConEdison's Post-Sandy Plan

- $1 billion over 4 years to increase resilience of electric power network
- Hardening activities (reduce initial impacts)
  - Trimming trees around power lines
  - Building higher flood plains
  - Backup power for substations
- Restoration activities (reduce time to recovery)
  - Smart-grid technologies
  - Preemptively shutting down steam plants
  - Deploying advance teams before the storm

Consolidated Edison Co. of New York. (2013). Post-Sandy enhancement plan. Orange and Rockland Utilities.

Allocation results

Optimal amount (in millions of dollars) to allocate to reduce initial impacts from a $1 billion budget

	Allocation function	Amt
Certainty	Linear	0
	Expon	1000
	Quadratic	762
	Logarith	648
Uncertainty with inde-pendence	Linear	0
	Expon	1000
	Quadratic	556
	Logarith	494

	Allocation function	Amt
Uncertainty with dependence	Linear	0
	Expon	1000
	Quadratic	840
	Logarith	470
Robust allocation	Linear	0
	Expon	0
	Quadratic	21
	Logarith	286

Resilience

- Apply allocation model to specific projects
- Resources can improve both factors simultaneously
- Incorporating resilience with uncertainty about disruption
- Social, economic factors for resilience

MacKenzie, C.A., & Zobel, C.W. (2015). Allocating resources to enhance resilience, with application to the electric power network. *Risk Analysis*. In press. DOI: 10.1111/risa.12479

My own research hints

- Research what interests you
- Brainstorm early
  - Be familiar with the literature but do not feel like you have to read everything before you start your own research
  - Look for possible extensions at end of journal articles
  - Relax an assumption
- Apply a model used in one area to another area