NAVAL
POSTGRADUATE
SCHOOL

Optimal Resource Allocation for Preparedness and Recovery of Interdependent Systems

Cameron MacKenzie

Defense Resources Management Institute

Naval Postgraduate School

Monterey, California

WWW.NPS.EDU

NAVAL POSTGRADUATE SCHOOL

Prevention, preparedness, response

Research questions

- What is the optimal allocation of resources pre-disruption (prevention and preparedness) and post-disruption (response and recovery)?
- How should resources be allocated among different industries to help those industries recover?

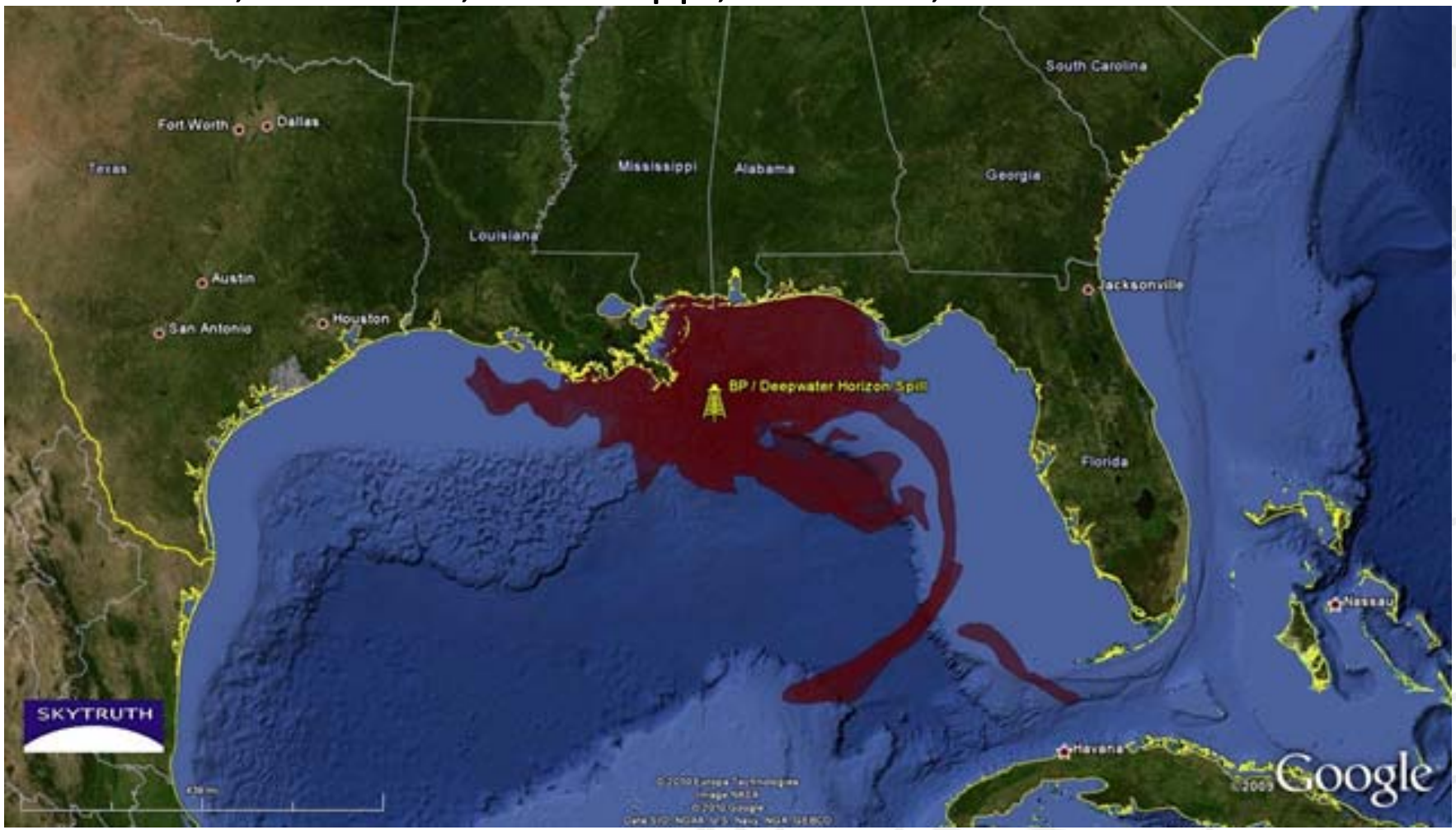
Deepwater Horizon oil spill

Key assumptions

- Objective function minimizes expected economic impact of a disruption
- Preparedness resources reduce chances of disruption
- Response resources reduce economic impact of disruption
  - Allocation to individual industries
  - Allocation to all industries

Impacted area

Texas, Louisiana, Mississippi, Alabama, and Florida



Directly impacted industries

Fishing

Real estate

Amusements

Accommodations

Oil and gas

Resource allocation model

Normal production

Interdependent matrix

Increased production if no disruption

$$\min\ p\mathbf{x}^{\mathrm{T}}\mathbf{D}\mathbf{c} - (1-p)g(Z - z_p)$$

Probability of disruption

Vector of direct impacts (proportional)

Effectiveness of preparedness allocation

Probability with no resources

Allocation to prepare

$$\text{subject to } p = \hat{p}\exp(-k_p z_p)$$

Allocation to benefit all industries

Direct impacts with no resources

Allocation to industry

$$c_i = \hat{c}_i \exp(-k_i z_i - k_{General} z_{General})$$

Effectiveness of recovery allocation

$$i = \{Fish, Real\ Estate, Amusements, Accommodations, Oil\}$$

$$z_p + z_{Fish} + z_{RealEstate} + z_{Amuse} + z_{Accom} + z_{oil} + z_{General} \leq Z$$

$$z_p \geq 0,\ z_i \geq 0,\ z_{General} \geq 0$$

Overall budget

Input parameters for oil spill

Preparedness	$k_p = 0.0031$	$\hat{p} = 0.045$
All industries	$k_{General} = 8.6*10^{-5}$	

Industry	k_i (per $1 mil)	$\hat{c}_i$
Fishing	0.074	0.0084
Real estate	0	0.047
Amusements	0.0038	0.21
Accommodations	0.0027	0.16
Oil and gas	0.0057	0.079

Parameter estimation for fishing

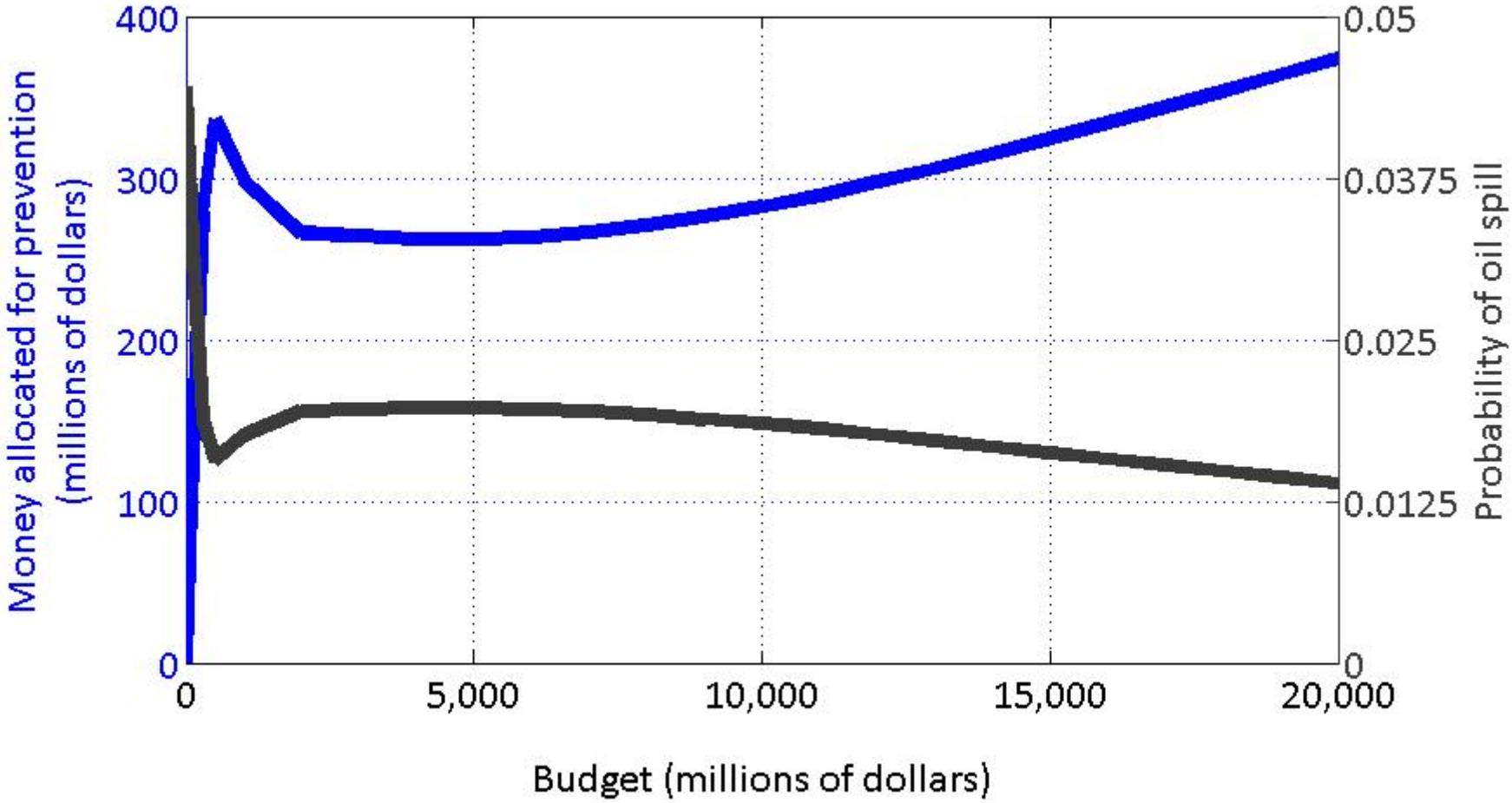
BEA
BUREAU OF ECONOMIC ANALYSIS
U.S. DEPARTMENT OF COMMERCE

NRDC
THE EARTH'S BEST DEFENSE

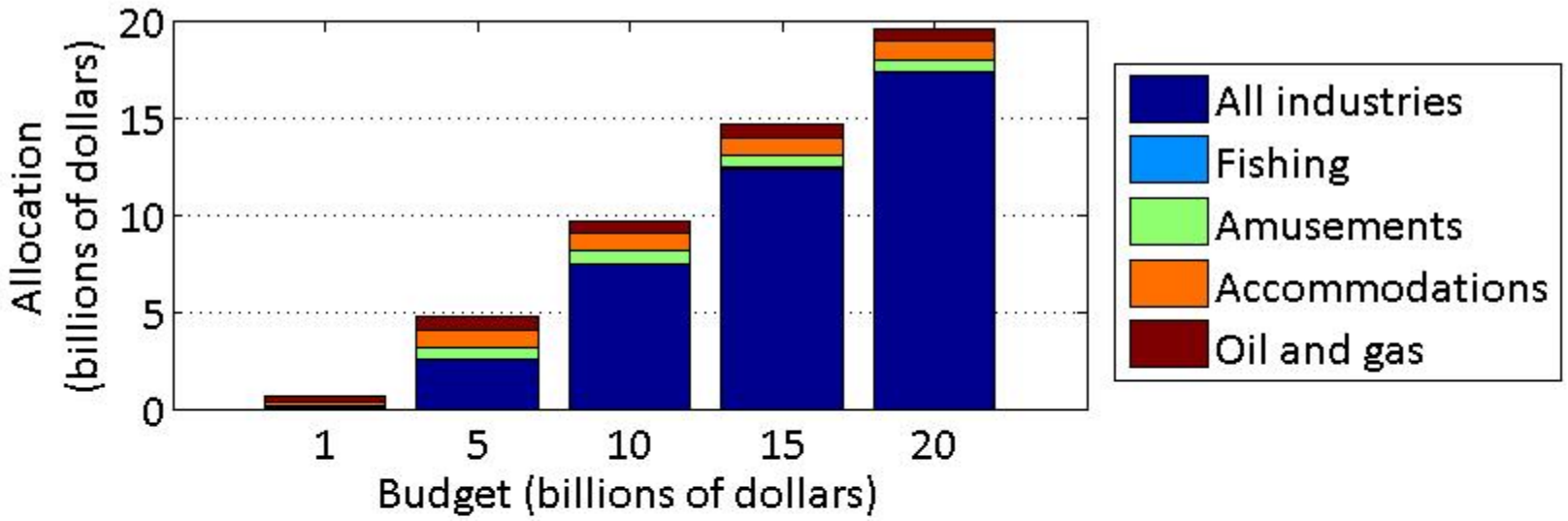
$62 million lost sales from Gulf Coast fishing
→ 0.84% of region's fishing and forestry production

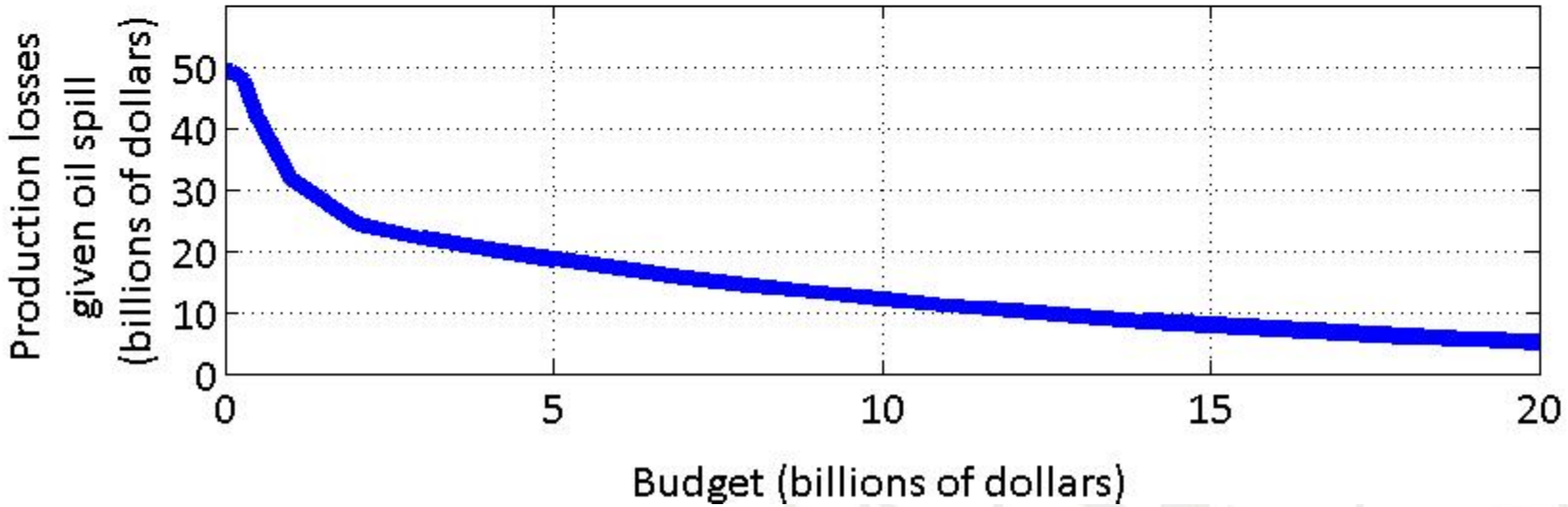
Studies on food safety and impact of positive media stories
→ $792,000 to reduce losses by $40 million

Allocation for prevention



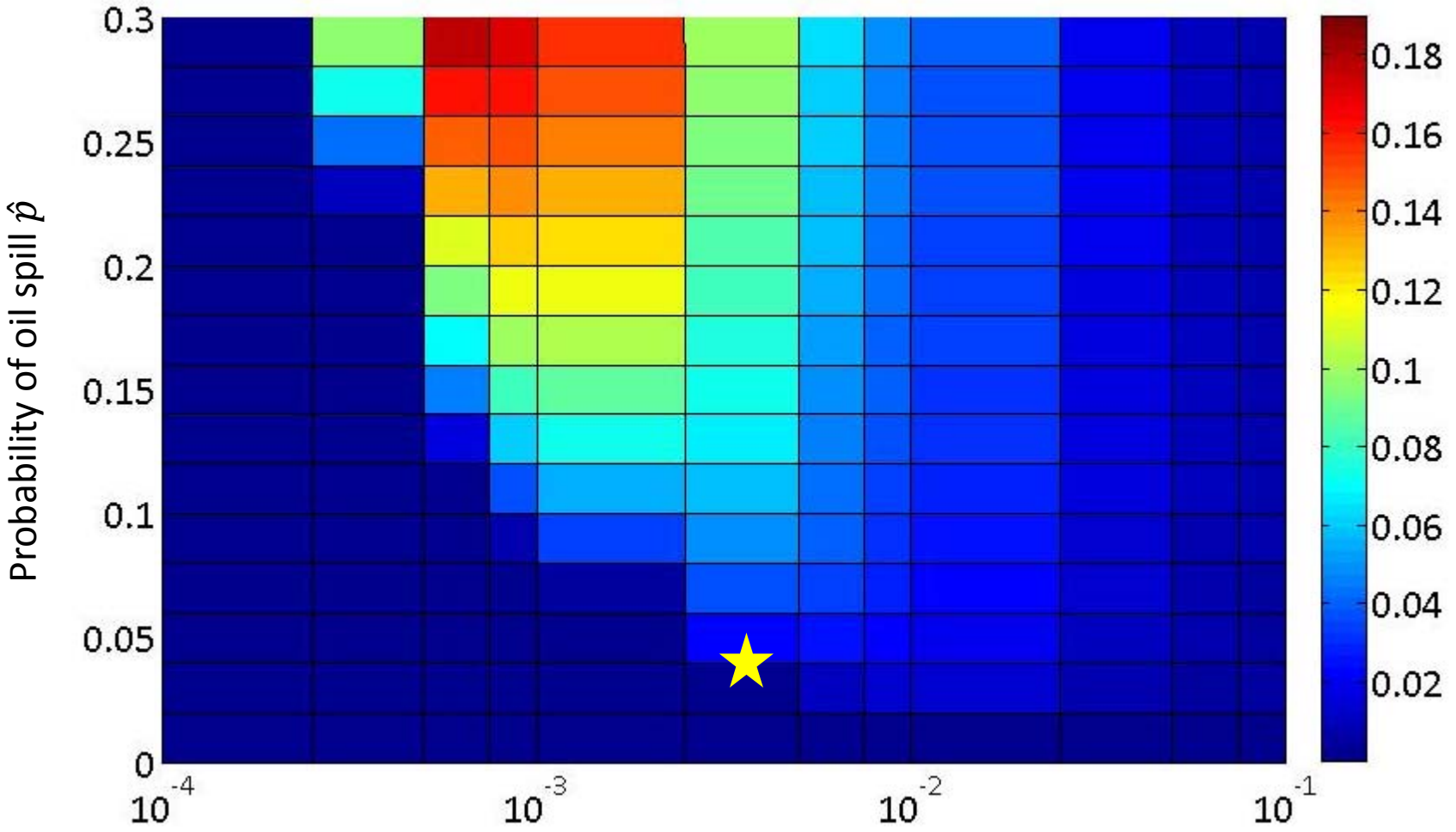
Allocation for response



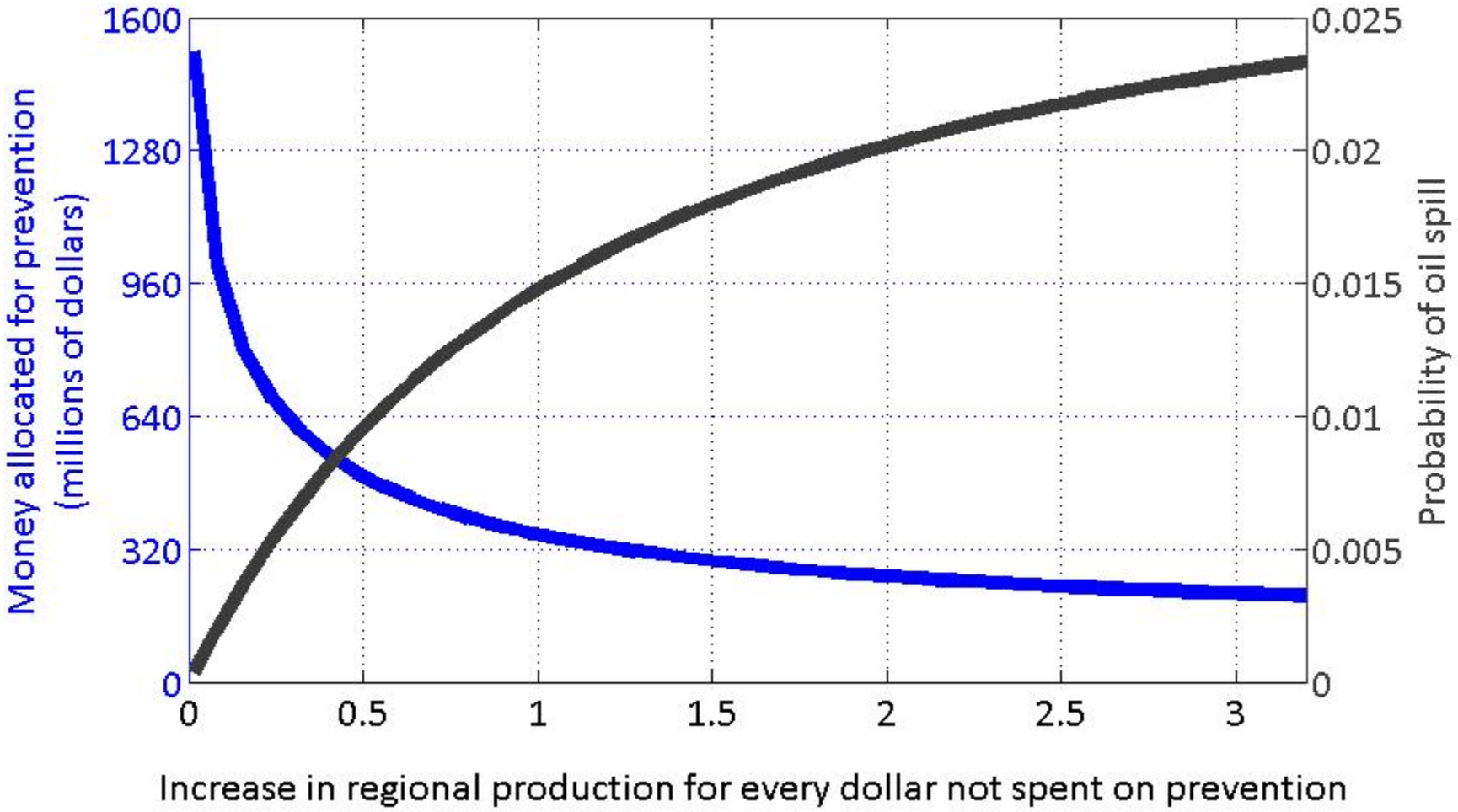


Sensitivity analysis for prevention

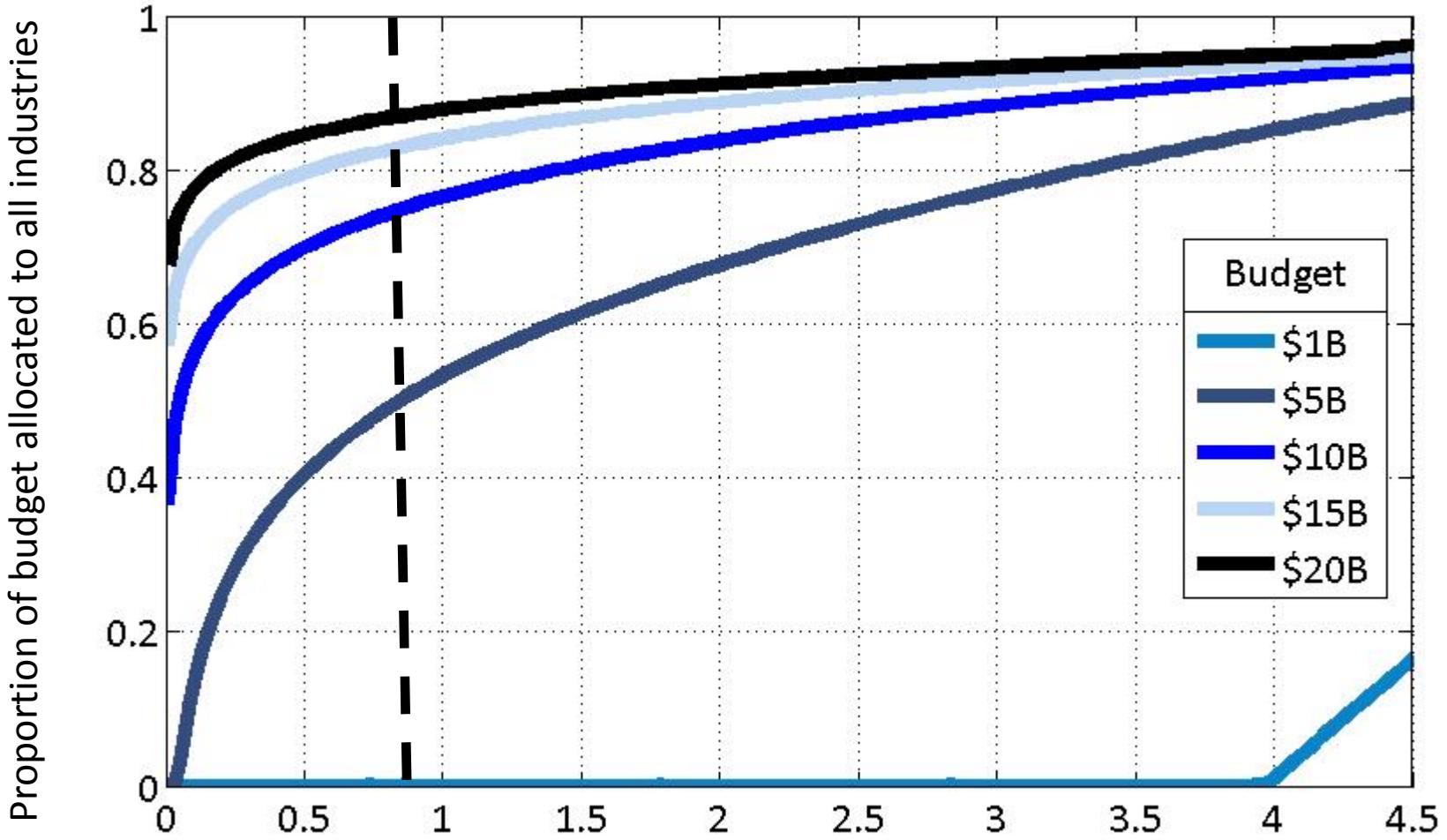
Proportion of $10B budget allocated for preparedness



Sensitivity analysis for $g(Z - z_p)$



Sensitivity analysis for response



Allocation to all industries

$$z_{General} > 0 \text{ if } k_{General} > k^*$$

Overall budget

Allocation to prepare

Column of interdependent matrix

$$\frac{1}{k^*} = \sum_{z_i>0} \frac{1}{k_i} + \left[\frac{\exp(Z - z_p)}{\prod_{z_i>0} (\mathbf{x}^\intercal \mathbf{d}_{*i} \hat{c}_i k_i)^{1/k_i}} \right]^{\left(\sum_{z_i>0} 1/k_i\right)^{-1}} \sum_{z_i=0} \mathbf{x}^\intercal \mathbf{d}_{*i} \hat{c}_i$$

Effectiveness of recovery allocation

Normal production

Direct impacts with no resources

Preliminary conclusions

- Allocating to prevent a disruption may be small compared to allocation to respond
  - Assumptions that prevention reduces chances of disruption
  - Assumption that money not allocated to prevention can increase regional production if no disruption
- Pre-disruption allocation should increase if
  - Preparedness reduces impacts
  - Decision maker is risk averse

Preliminary conclusions

- As budget increases, greater incentive for response allocation to be allocate to benefit all industries versus targeting individual industries
- Future research can include multiple scenarios

Email: camacken@nps.edu