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Resource Allocation Decisions with Deep Uncertainty

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INFORMS Annual Conference

November 15, 2016

Deep uncertainty

Levels of uncertainty (Walker et al. 2013)

- Level 4: Enumerate possible outcomes but no likelihoods
- Level 5: What is known is only that we don't know

Uncertain about (Lempert et al. 2003)

1. Appropriate models for interactions of variables
2. Probability distributions
3. Value the desirability of outcomes

Model / structural uncertainty

Walker, W.E., R.J. Lempert, and J.H. Kwakkel, 2013. Deep uncertainty. In *Encyclopedia of Operations Research and Management Science*, S.I. Gass and M.C. Fu, eds. New York: Springer, pp. 395-402.

Lempert, R.J., S.W. Popper, and S.C. Bankes, 2003. *Shaping the Next One Hundred Years: New Methods for Quantitative Long-Term Strategy Analysis*, MR-1626-RPC, Santa Monica: The RAND Corporation.

Models for policy analysis

- Hard to validate
- Need for flexible, adaptive decision support systems
- Policy makers posses various sources of knowledge—difficult to quantify

Solutions to deep uncertainty

- Resistance: plan for the worst case
- Resilience: focus on recovering
- Robustness: perform reasonably well in all circumstances
- Adaptive: change policy if situation changes

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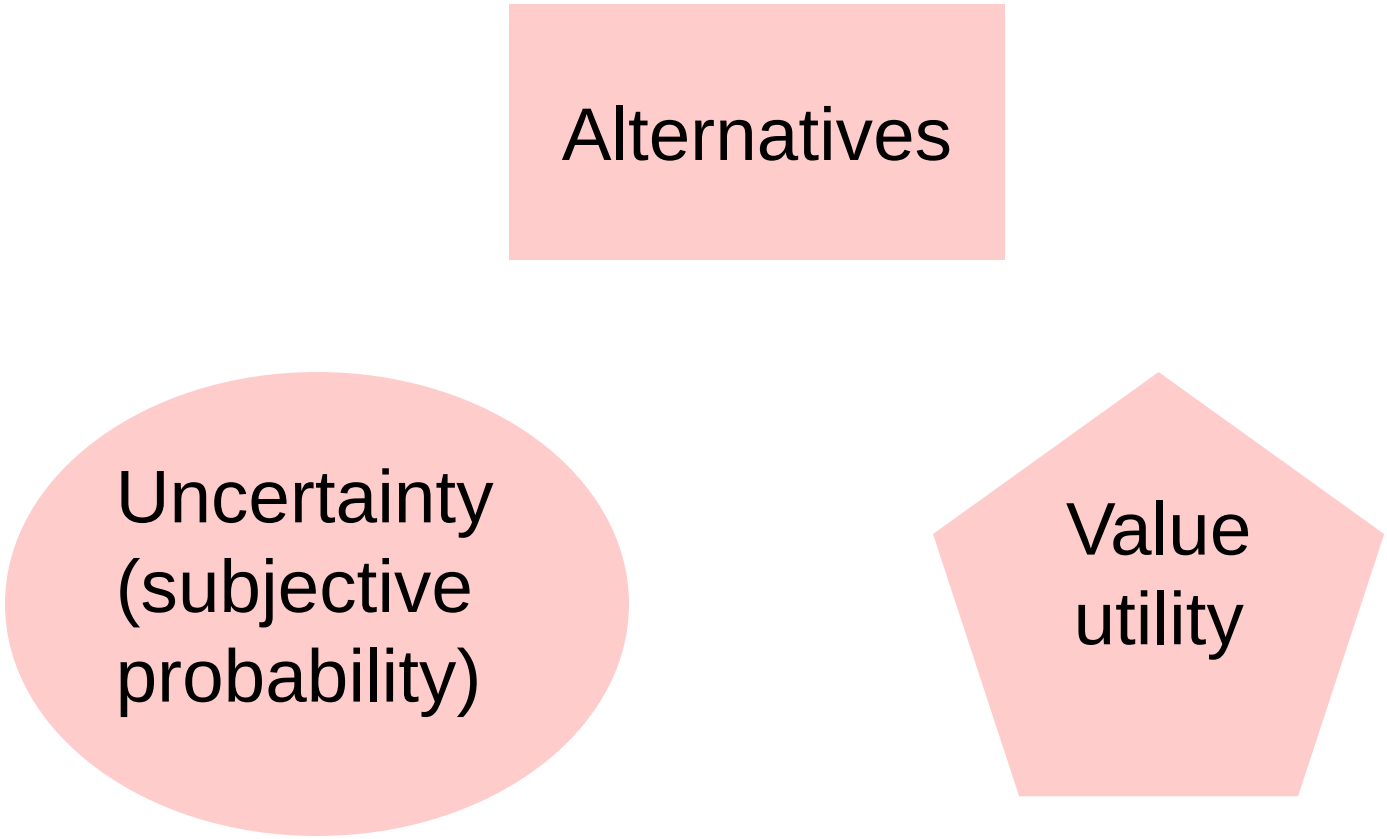
Decision analysis



Proposed solution

- Accounts for different types of uncertainty
  - Parameters
  - Functions
  - Risk attitudes
- Returns an interval as solution (rather than a point solution)

Proposed solution

- Objective: minimize $f(x)$
- Several competing objective functions: $f_1(x), f_2(x), \ldots, f_N(x)$
- x is continuous decision variable

$$\text{maximize} \quad b - a$$

interval width

$$\text{subject to} \quad f_i(x) \leq \alpha_i \quad \text{for } a \leq x \leq b$$

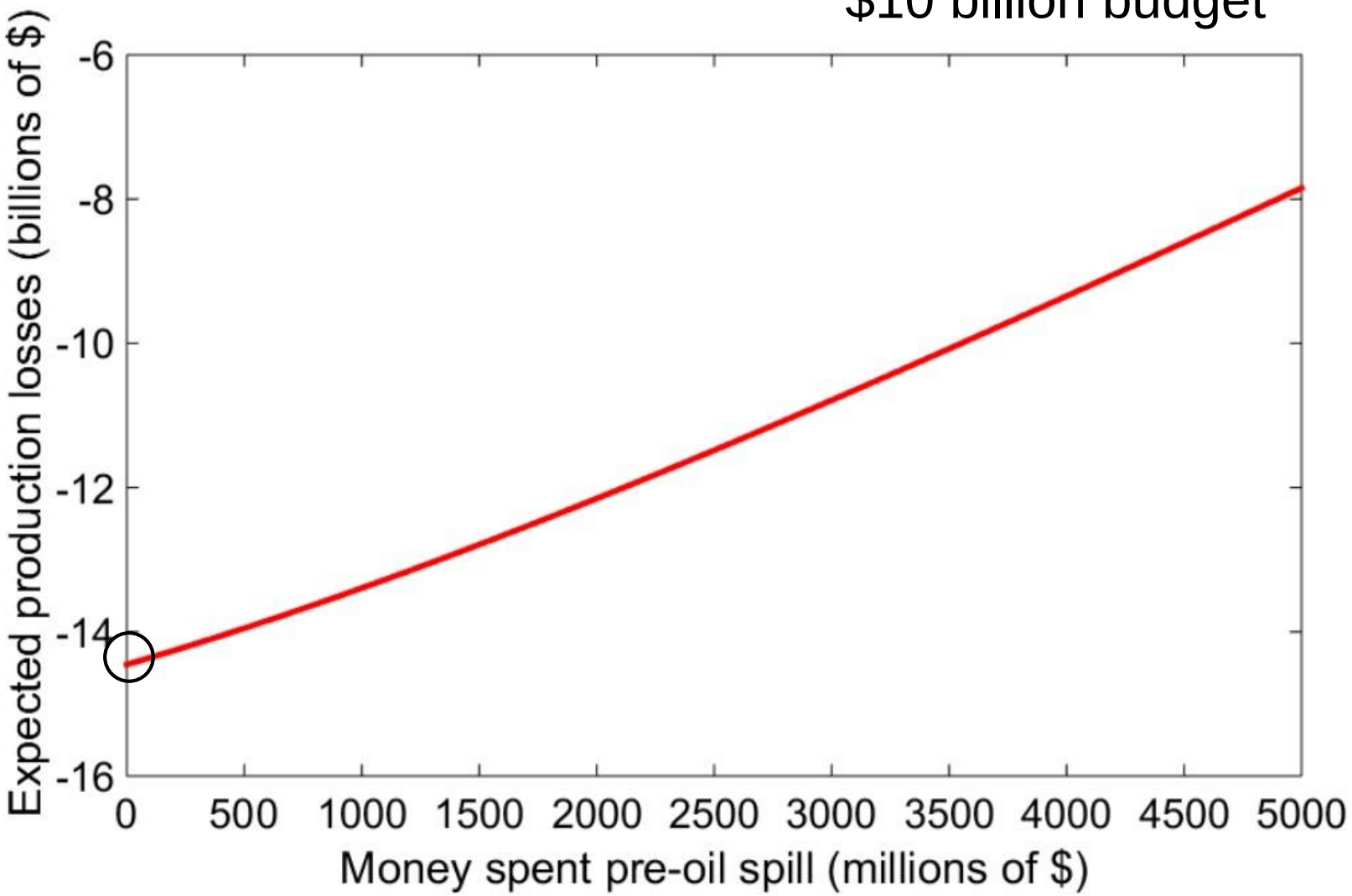
acceptable threshold

Oil spill prevention and preparedness

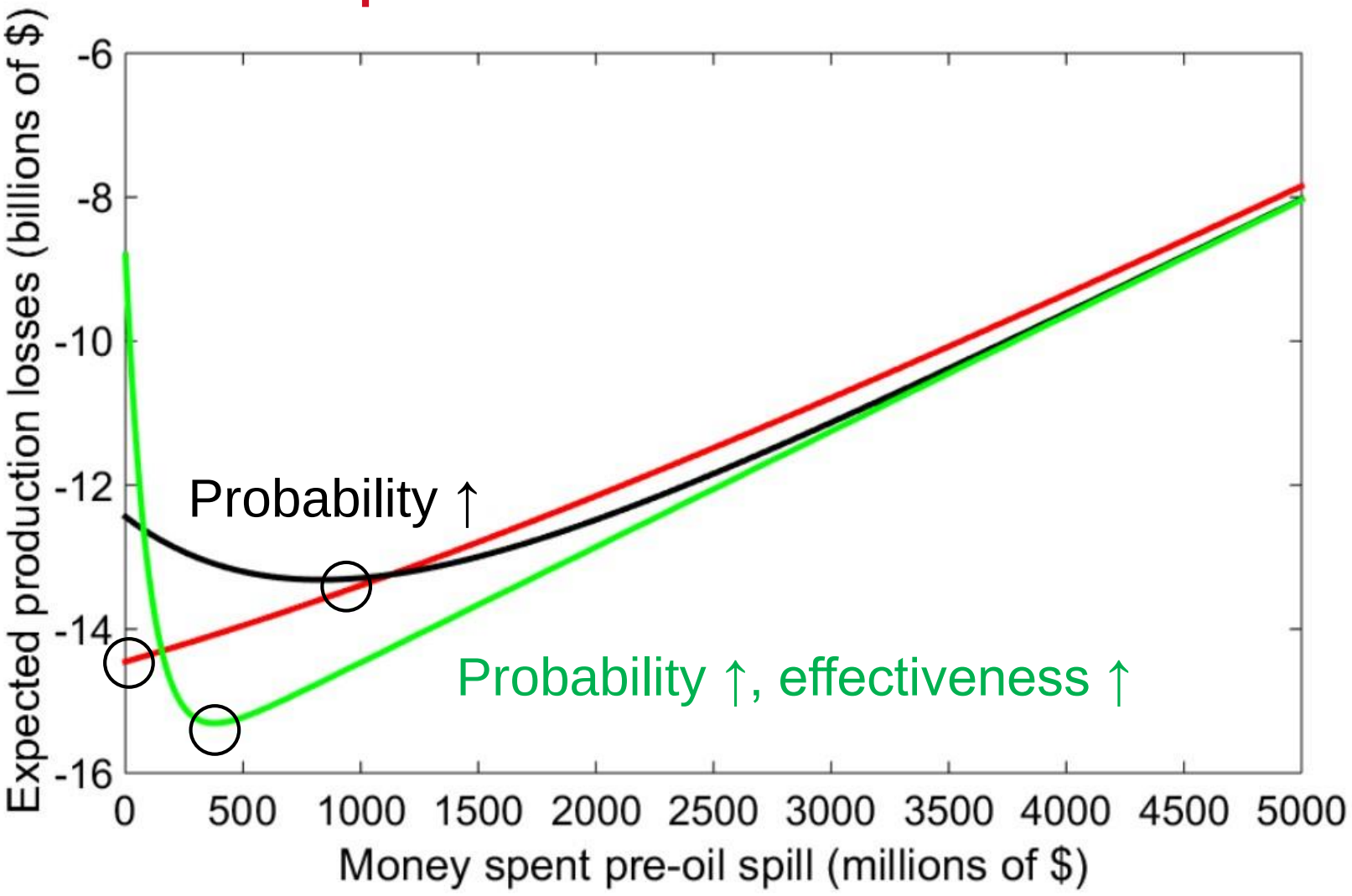
- How much money to prevent and prepare for an oil spill?
- Money that is not spent pre-disruption
  - Response and recovery if spill occurs
  - Other priorities if spill does not occur
- Objective
  - Minimize expected production losses (oil spill)
  - Maximize expected production gains (other priorities)

Base case

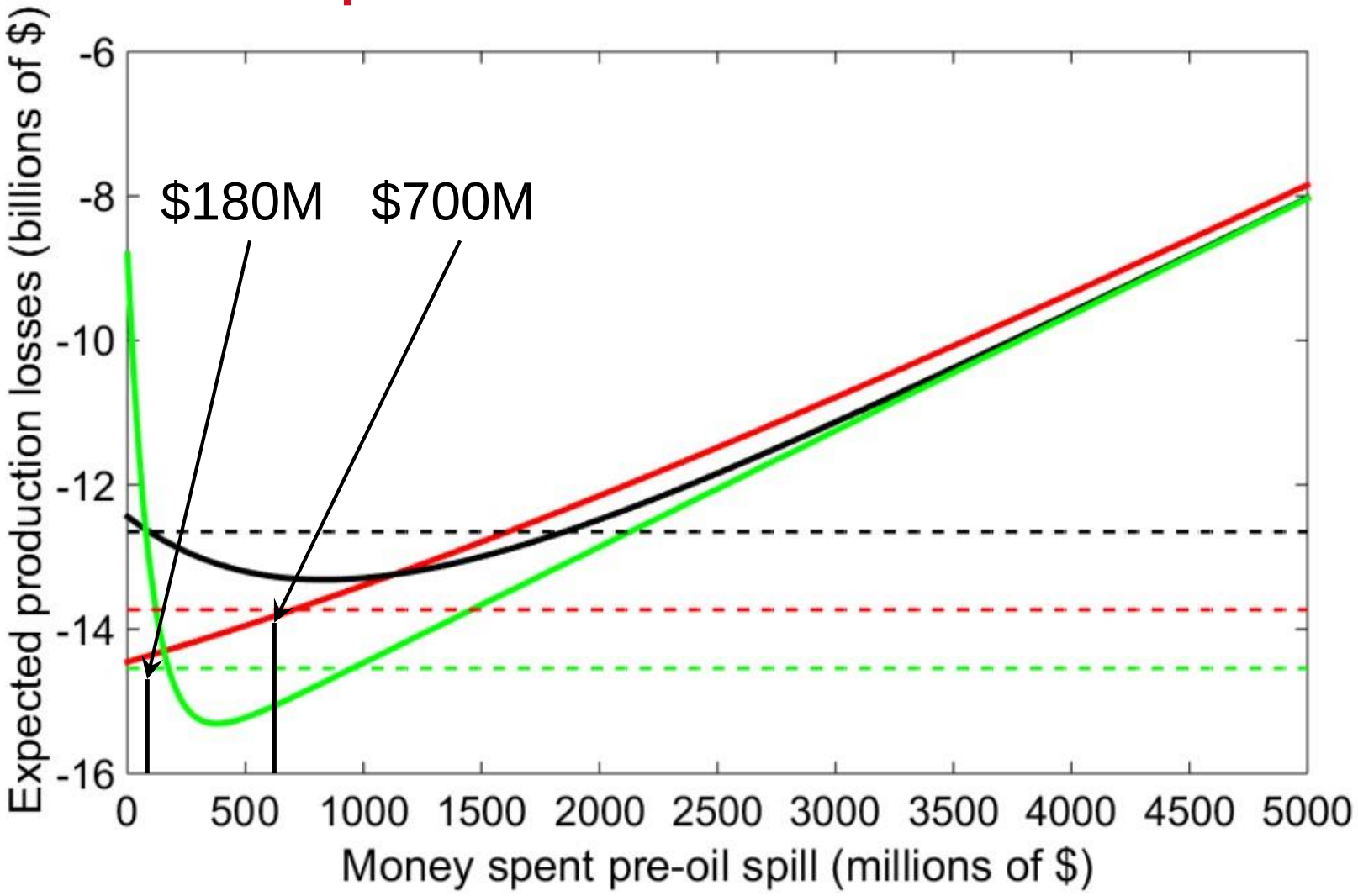
$10 billion budget



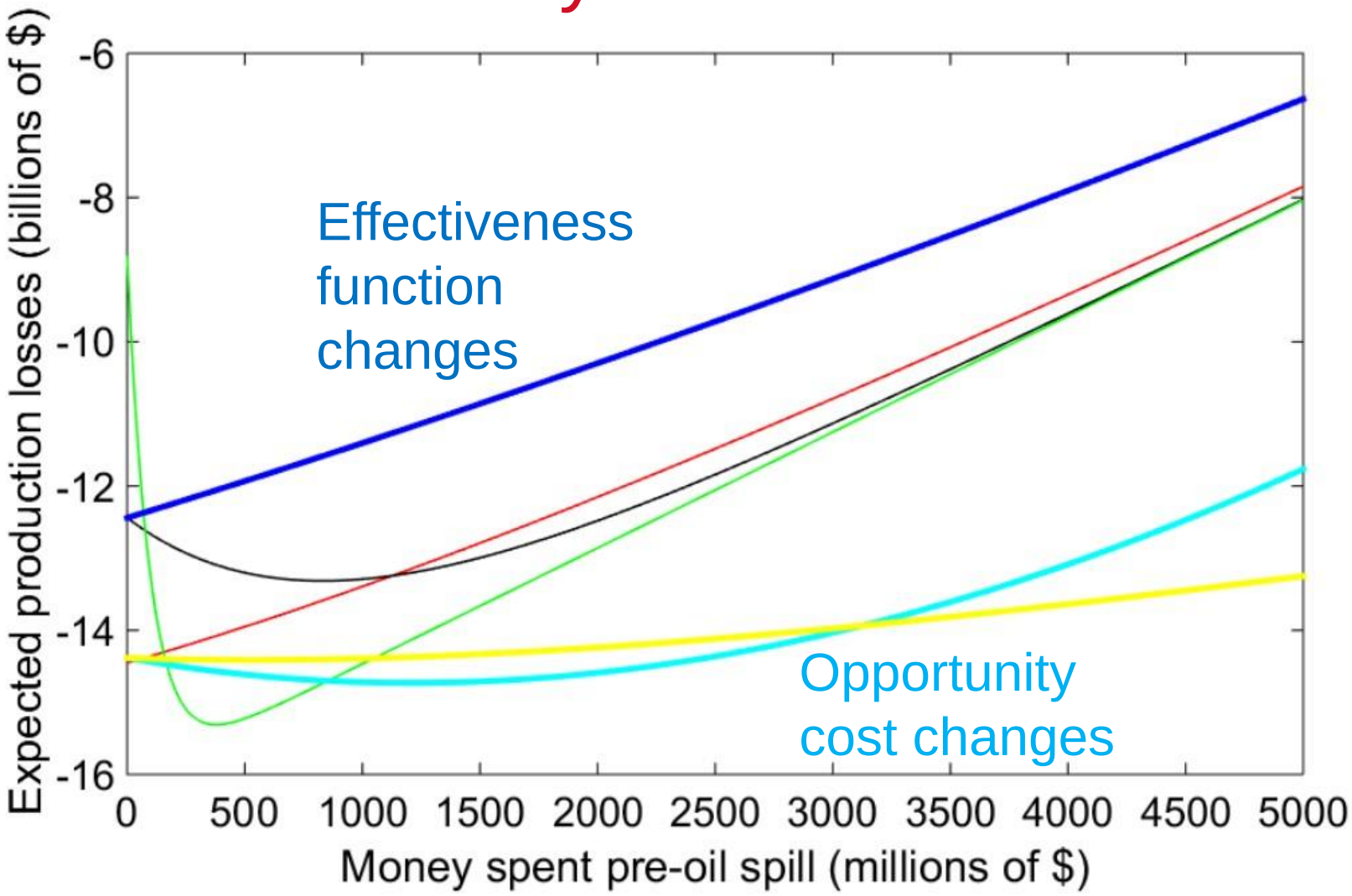
Uncertain parameters



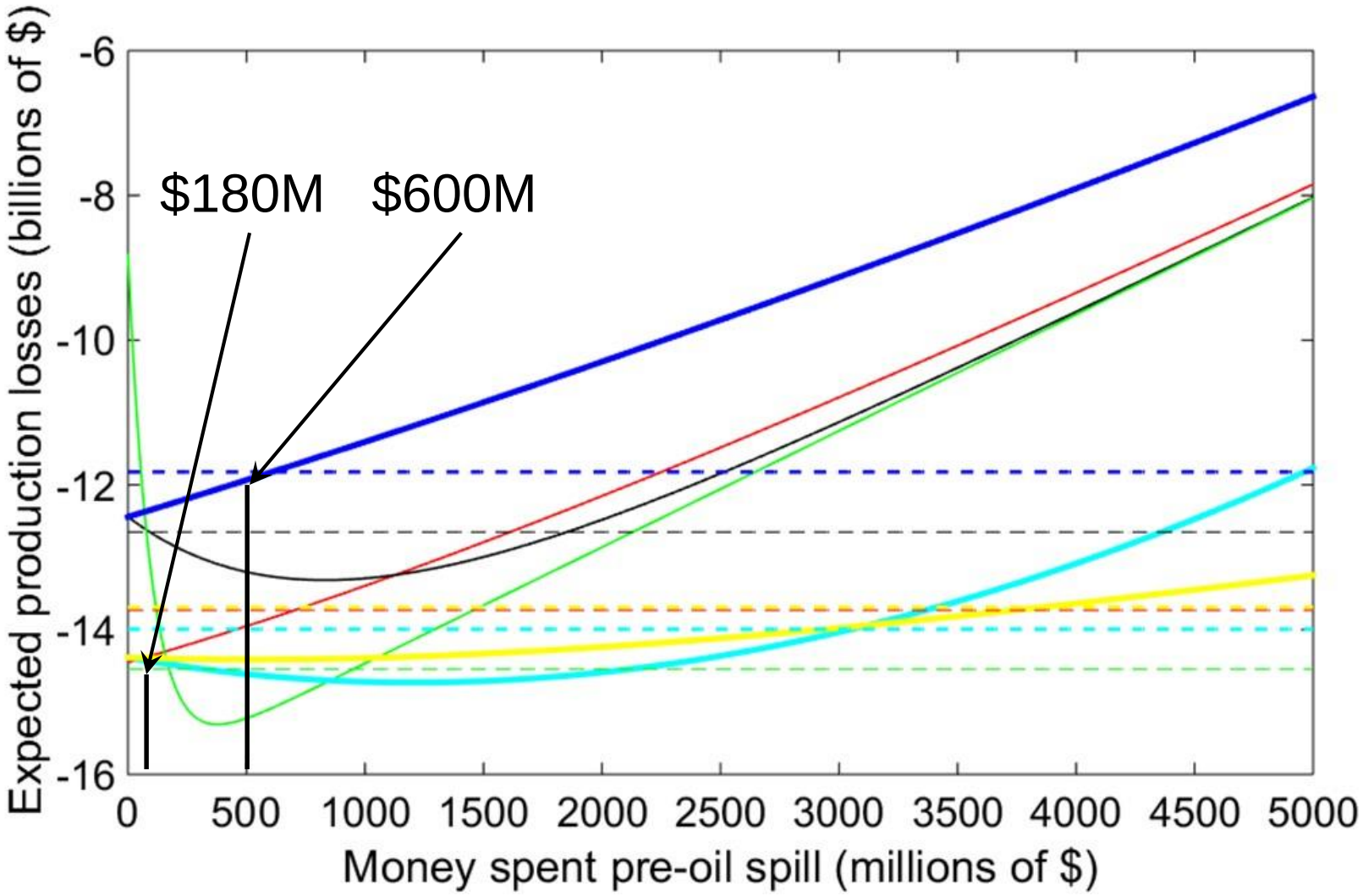
Uncertain parameters



Model uncertainty



Interval recommendation



Changing threshold

Percent of optimal	Minimum	Maximum
97	240	360
96	190	480
95	180	600
94	170	720
94	150	840
92	140	960
91	140	1070
90	130	1190

millions of dollars

Future extensions

- Different risk attitudes (utility functions)
- Add hundreds of models / uncertain parameters → algorithm development
- Multiple decision variables
- Belief that some models are more likely → different thresholds for each objective function

- Interval recommendation gives decision maker flexibility

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