Info-Gap Theory
Concepts and Applications

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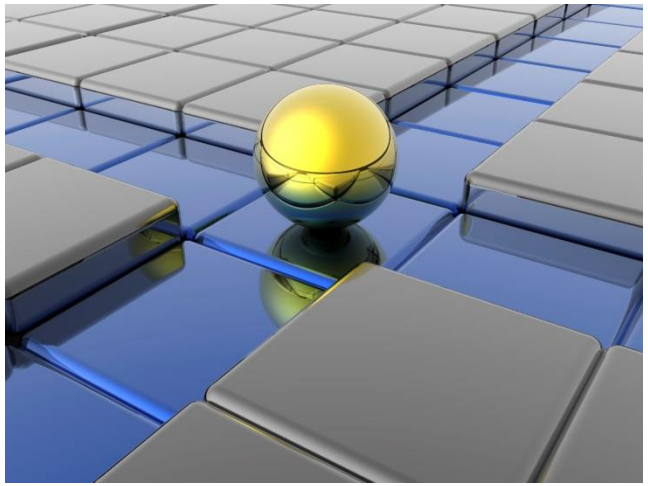


Outline

Risk or Uncertainty?

Probability is powerful, but ignorance is not probabilistic

Uncertainty and the optimization imperative

- Limits of prediction and outcome-optimization
- Robust satisficing

Rural poverty and exploiting natural resources

Risk and Uncertainty

Probabilistic risk

or

Knightian “true uncertainty”

Probabilistic Risk

Consequence	Probability
Drought	Stochastic process
Industrial accident	Actuarial tables
Tsunami	Historical data
Faulty air filters	Quality control data
Deception, scam	Sociological data

Risk is:

- Structured: known event space
- Modeled with probability
- Manageable (but still risky)

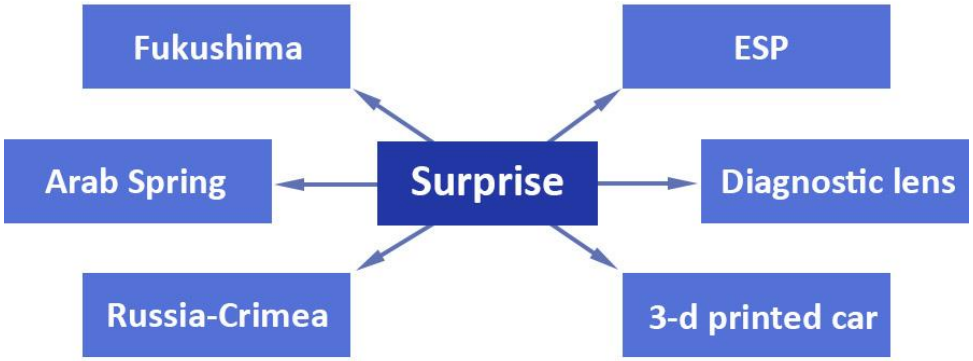
Frank Knight's "true uncertainty"

"The uncertainties which persist … are **uninsurable**

because there is

no objective measure

of the probability".



Wheeler's Island

"We live on an island of knowledge
surrounded by a sea of ignorance.
As our island of knowledge grows,
so does the shore of our ignorance."

John A. Wheeler

Non-probabilistic true uncertainty

D Discovery

- America
- Nuclear fission
- Martians (not yet?)

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

- Printing press: material invention.
- Ecological responsibility: conceptual innovation.
- French revolution: social innovation.

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

S Surprise (Asymmetric uncertainty)

- Ambush
- Competitor's innovation
- Natural catastrophe

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

S Surprise (Asymmetric uncertainty)

What's the next D I or S ???

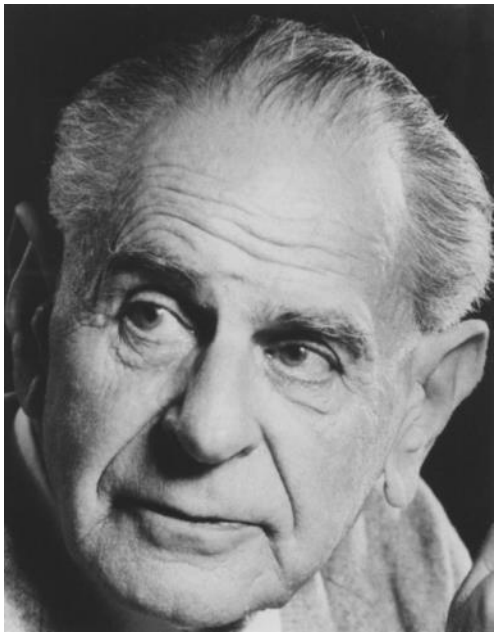
Knightian uncertainty:

- Unstructured: unknown event space.
- Indeterminate: no laws.
- Barely manageable.

Shackle-Popper

Indeterminism

GLS Shackle, 1903-1992



Karl Popper, 1902-1994

Shackle-Popper Indeterminism

Intelligence:

What people **know**, influences how they **behave**.

Discovery:

What will be **discovered tomorrow** can't be **known today**.

Implies

Indeterminism:

Tomorrow's behavior can't be fully modelled today.

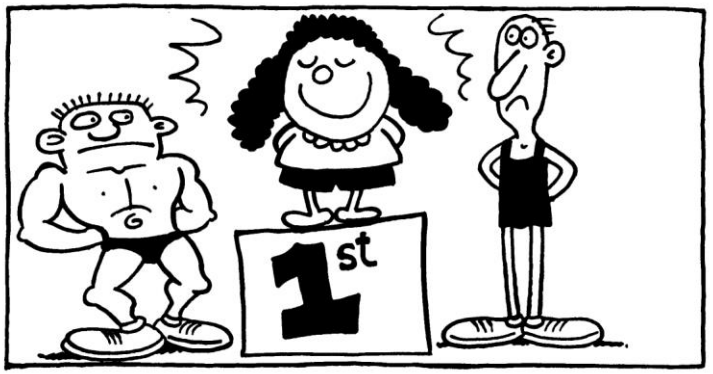
- Info-gaps, indeterminism: **unpredictable.**
- **Ignorance is not probabilistic.**

Uncertainty and the Optimization Imperative

Doing your best:

What does that mean?

- Outcome optimization.
- Procedural optimization.



Implications for decision making:

Robust satisficing.

Doing Your Best

Substantive outcome optimization:

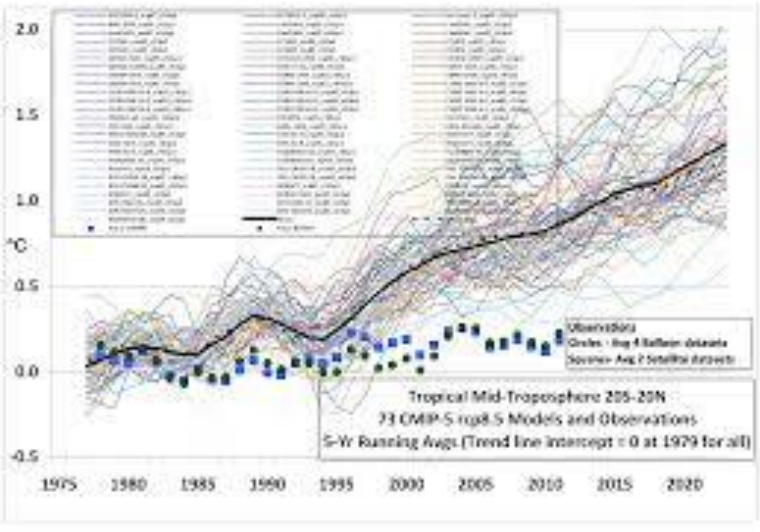
- Predict outcomes of available options.
- Select predicted best option.

Doing Your Best

Substantive outcome optimization.

Useful under risk:

- Structured uncertainty.
- Reliable probabilistic predictions.



Doing Your Best

Substantive outcome optimization:

Useful under risk.

Not useful (irresponsible?) under uncertainty.

- Unstructured uncertainty.
- Unreliable predictions.

Questions

What do we (not) know?

Robustness questions:

- What is an essential outcome?
- How to be robust to surprise?

Opportuneness questions:

- What is a windfall outcome?
- How to exploit opportunities?

How to prioritize decision options?

What are the trade offs?

Answers

Robustness answer:

System model
Outcome requirement
Uncertainty model

Robustness function

Prioritized options

Opportuneness answer:

System model
Outcome aspiration
Uncertainty model

Opportuneness function

Prioritized options

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

- Essential goals.
- Worst acceptable outcomes.
- Modest or ambitious.

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

2. Robustness:

- Immunity to ignorance.
- Greatest tolerable error or surprise.

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

2. Robustness: Greatest tolerable error.

Optimize robustness; satisfice goals:

Procedural (not substantive) **optimization.**

Rural poverty & resource use

Rural poverty:

- Low agricultural productivity.
- High mortality/morbidity.
- Resentment and suspicion of government and NGOs.
- Local barons or warlords.

Innovative hi-tech proposal:

- New strains of plants.
- Better irrigation.
- Better fertilizers.
- Mechanization of field work.

Innovation dilemma of poverty

Potential gains of innovative resource exploitation:

- Higher agricultural productivity.
- Higher standard of living.
- Less arduous field work.

Potential losses of innovative resource exploitation:

- Failure of innovative crops, causing starvation.
- Social reorganization and upheaval.
- Rapid population growth, canceling gains (Malthus).

Dilemma: Innovation could be **much better**, or much worse.

How to choose?

Innovation dilemma of poverty

Basic questions:

- What are the **goals**?
- What is our **knowledge**?
- What are the **uncertainties**?

Robustness of an option:

Maximum tolerable uncertainty.

The knowledge-bifurcation. Is your knowledge:

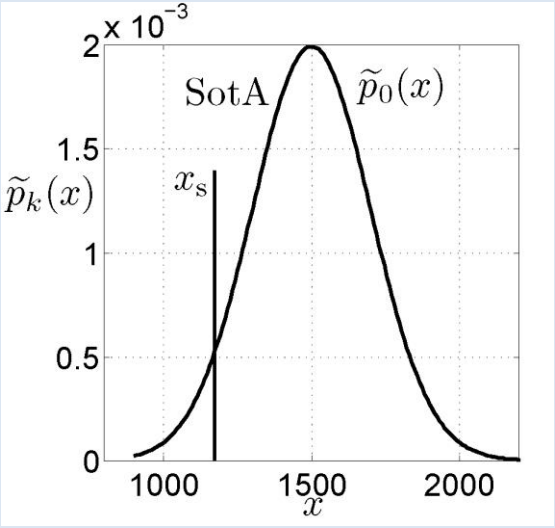
- **Quantitative:** data and equations?
- **Qualitative:** mainly insight and understanding, (perhaps with some numbers)?

We will consider both situations.

Poverty dilemma: quantitative

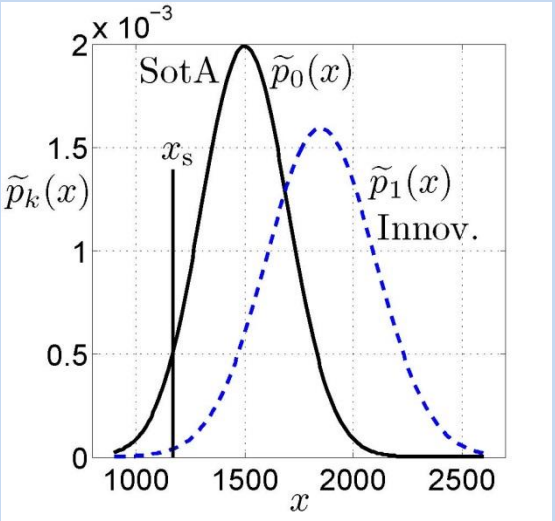
Field study of traditional State of the Art:

- Survival requirement: 1171 kg wheat/ha.
- Probability dist. of productivity **well known**.
- Survival probability: **0.95 (known).**
- Survival catastrophe return-time:
  20 years (known).



Knowledge about innovative option:

- Probability distribution of productivity
  estimated, uncertain.
- Survival probability: **0.9967 (estimate).**
- Survival catastrophe return-time:
  303 years (estimate).

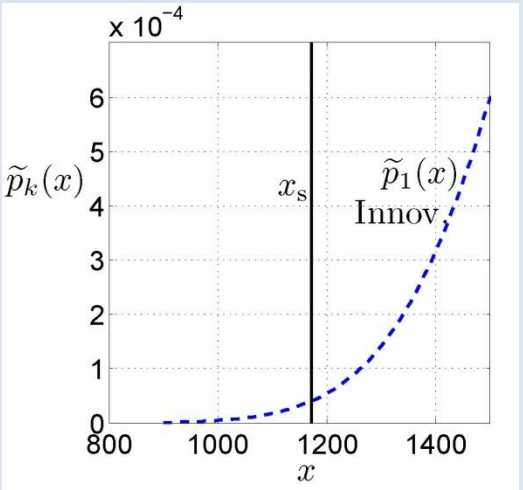


The choice is clear?

Poverty dilemma: quantitative

Uncertainty of innovative option:

- Prob. distribution of productivity: estimated.
- True tail (rare but bad): highly uncertain.
- Survival probability & catastrophe return-time may be **much greater than for SotA**.



Robustness of an option: How much error can we tolerate?

Greatest **uncertainty** at which

current **knowledge** satisfies the survival **requirement**.

Robust prioritization: Innovation or SotA?

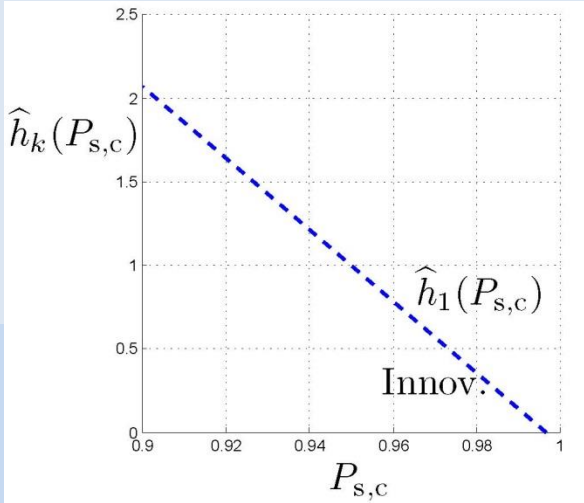
- Maximize robustness, satisfice outcome.
- Don't try to optimize the outcome.

Poverty dilemma: quantitative

Robustness of innovative option:

Pessimist's thm. Trade off:

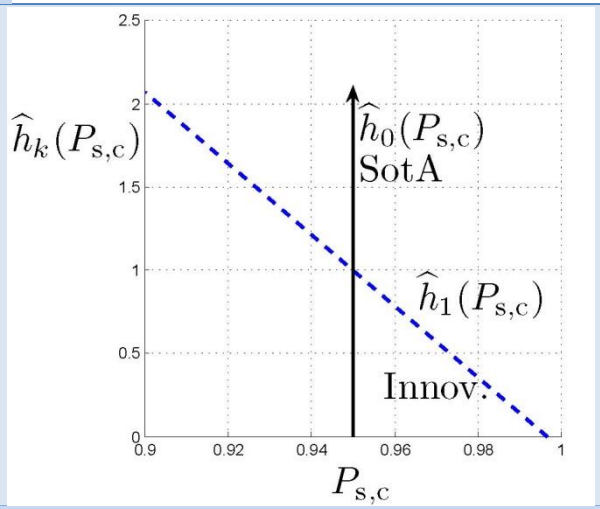
Higher survival prob ⟺ lower robustness



Zeroing: No robustness at estimated survival probability.

Robustness of SotA:

- **Unbounded** for survival probability up to 0.95.
- **Zero** for survival probability above 0.95.

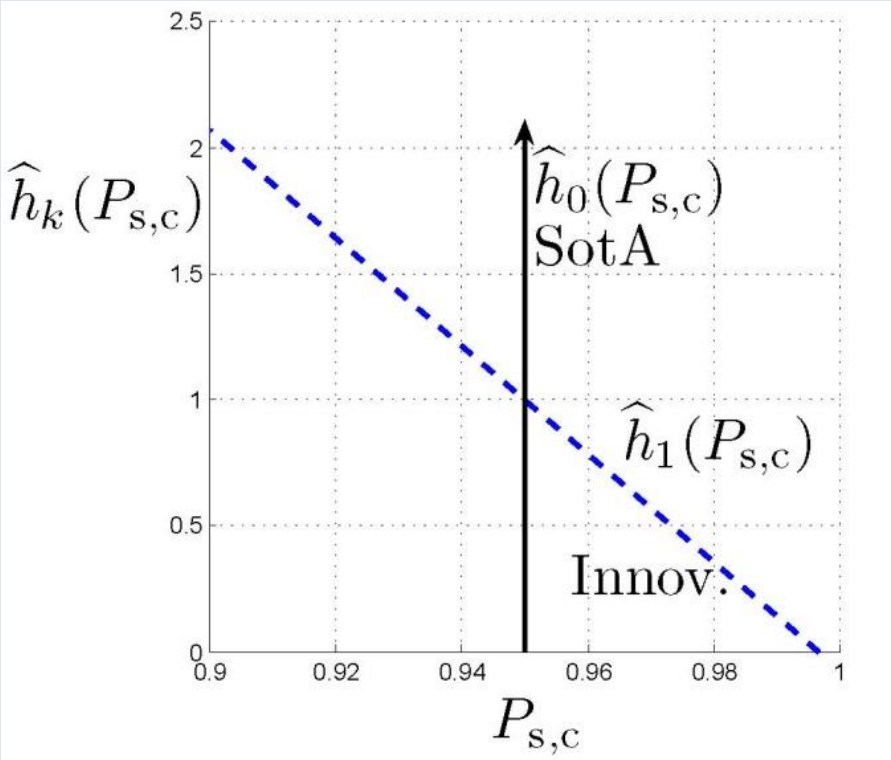


Decision: Choose by robustly satisfying the requirement.

Poverty dilemma: quantitative

Summary of quantitative analysis of innov. dilemma:

- **Zeroing:** no robustness at estimated survival prob.
- **Optimizer's fallacy:** Prioritize by estimates.
- **Trade off:** robustness vs survival probability.
- **Preference reversal:** Resolution of dilemma.



Poverty dilemma: qualitative

Now for the hard part:

Qualitative analysis of robustness.

Robustness:

- We can't evaluate it quantitatively.
- Assess it qualitatively with **proxies for robustness**:
  - **Resilience**: rapid recovery of critical functions.
  - **Redundancy**: multiple alternative solutions.
  - **Flexibility**: rapid modification of tools and methods.
  - **Adaptiveness**: adjust goals and methods online.
  - **Comprehensiveness**: interdisciplinary system-wide coherence.

Poverty dilemma: qualitative

Basic questions:

- What are the **goals**?
- What is our **knowledge**?
- What are the **uncertainties**?

Bernard Amadei: girl water carriers.

- **Goal**: more potable water.
- **Knowledge**: Abundant fuel. Pump tech. Local culture.
- **Uncertainties:**
  - Long-term maintenance? Catastrophe if not.
  - Stable fuel supply?
  - Social response: what happens to the girls?

Poverty dilemma: qualitative

Robust solution:

- **Satisfice** the goal. Don't try to maximize. (Exploit trade off.)
- **Co-design**: local involvement in all stages (comprehensive).
- **Train** locals in pump maintenance (resilience, flexibility).
- **Transition period** of dual supply (redundancy).
- **Long-term contact** for emergency support (adaptiveness).
- **Education** for girls (and boys) (comprehensiveness).
- **Quantitative** analysis where possible.

Poverty dilemma: qualitative

Methodological re-cap:

- **Trade off:** higher ambition = lower robustness.

  Ambitions: Yes. Wishful thinking: No.

- **Zeroing:** Best-estimated outcomes have no robustness.

  Satisfice your goals. **Optimize** your robustness.

  Don't try to maximize the outcome.

- **Preference reversal:** sub-optimal may be more robust.

  Wood burning steam pump more robust to uncertainty than solar electric technology.

Summing Up

Risk or Uncertainty:

- **Probabilistic** risk, **Knightian** uncertainty (info-gaps).
- Shackle-Popper indeterminism.

Substantive outcome optimization:

Useful under risk, not under uncertainty.

Robust satisficing: Optimize robustness; satisfice goals.

- **Procedural** (not substantive) **optimization.**

Opportune windfalling: use propitious uncertainty.

Rural poverty and exploiting natural resources.

Questions?