

# Science, Prediction, and Risk

- What do we mean when we talk of risks?
- How does science help us to understand and manage risks in our lives?
  - How can we tell what to believe?
- Is there something special about risks of running out of energy and water resources in the future?

# What are risks?

- What are the essential things that make something a “risk”?
  - Cost (bad outcome)
  - Uncertainty
- Mathematical form:
  - *Risk = probability × cost*
- How do we measure the probability and cost?

# Science and prediction

- Science can make some predictions with near certainty.
  - Can you think of examples?
- Other predictions are quite uncertain, even with the best science
  - Examples?
- Let's think a bit about what makes a prediction "*scientific*"

# What is science?

- Science as knowledge about the world around us
- Science as a method for studying the world
- Science as a creative activity

*The search for unity in the wild variety of nature*  
—Bronowski

- "Science" as rhetoric:
  - *You can't argue with me because my ideas are scientific and yours aren't*
  - "*Demarcation problem*:" How do we tell real science from nonscience or pseudoscience?
  - "*Boundary work*:" Rhetorical/Political conflict over whose ideas are scientific enough to participate in the discussion

# Science as falsification

- Karl R. Popper (1902-94), 1934
- Inductive reasoning:
  - Observe isolated *facts*
  - Notice patterns
  - Generalize: *hypothesis (general rule)*
  - Unprovable: *There is no rule for inferring from observed events to those not yet observed*  
—Hume, 1739.
- Deductive reasoning:
  - Use hypothesis to make specific predictions
  - If predictions don't occur, hypothesis must be incorrect
  - If predictions do occur, we become more confident
  - Never completely certain

# What this means for science

- This view (Popper's) implies:
  - Science can be right or wrong
  - Nonscience can be right or wrong
  - What's different?
    - Science allows you to make specific predictions
    - Science allows you to test these predictions and disprove incorrect hypotheses (falsifiability)
- Does this fit with your experience of what science is?

# Predicting energy and water shortages

- Can such predictions be scientific?
- What would it mean for them to be scientific?
- Are they falsifiable?
- Can we test them today, or only in the future?
- What is the role of science in understanding the risk of such shortages?

# Trans-science

- What is trans-science?
- Are predictions of energy and water shortages trans-scientific?

# Malthus (1798)

- Population grows exponentially (doubles every 25 years)
  - 1,2,4,8,16,32, ...
- Food production grows linearly
  - 1,2,3,4,5,6, ...
- "In two centuries and a quarter, the population would be to the means of subsistence as 512 to 10; in three centuries as 4096 to 13."
- Same idea put forward by Benjamin Franklin in 1755.
- In fact, the ratio of food to population has not dropped by a factor of 51 in the past 225 years.
- What's missing?
  - Malthus did not consider the role of technology in improving agricultural productivity.
- Do similar problems plague predictions of energy and water shortages?

# Predictions of energy shortages

- 1865: *"It will appear that there is no reasonable prospect of any relief from a future want of the main agent of industry [coal]"*  
—W.S. Jevons
- 1890s, USGS: Little prospect for oil in California or Texas
- 1904: *"The substitution of oil for coal is impossible because oil does not exist in the world in sufficient quantities."*  
—Lord Seldon (1<sup>st</sup> Lord of Admiralty)
- 1914, US Bureau of Mines: 10 years of oil left
- 1939, US Dept. of Interior: 13 years of oil
- 1951, US Dept. of Interior: Again, 13 years
- Frank Notestein: *"We've been running out of oil ever since I was a boy."*

# Science, Probability, and Prediction

- Can we ask how likely future shortages are?
  - What does it mean to ask this?
  - Insurance:
    - How likely is it that your house will be flooded in the coming year?
    - How likely is it that you will be in an auto accident in the coming year?
  - Acts of God: unforeseeable events. Not covered by insurance.
  - What does this mean for our understanding of probability?

# Frequentist vs. Subjectivist

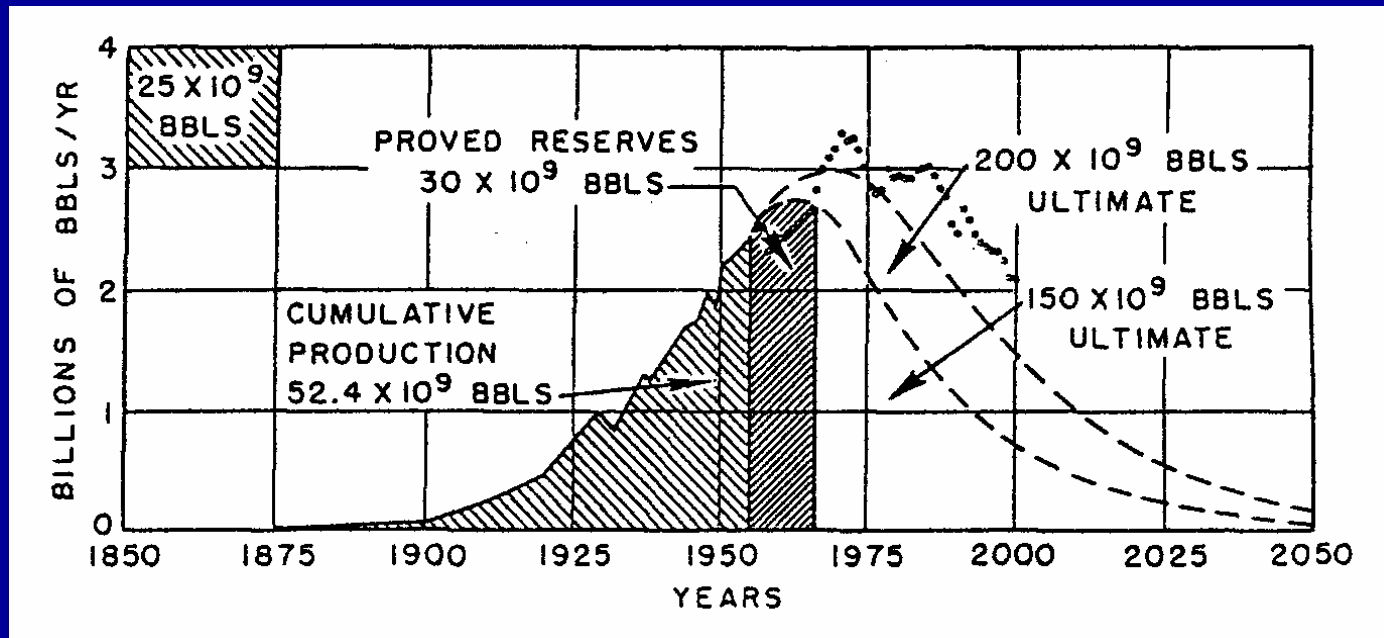
- Frequentist:
  - Probability is only what you can measure/observe
  - Meaningless to ask about probability of an act of God
- Subjectivist:
  - Probability is about our knowledge of the world
  - We can infer probabilities of unprecedented events through "fault trees"
    - Deductions stringing together events with measured probabilities

# Probability and prediction

- How can we treat predictions of future shortages scientifically?
- What obstacles are there?
- Does it help to ask the question differently?

# Hubbert's Peak

- M. King Hubbert, 1956:
  - Oil production in continental US will follow a bell-shaped curve
  - Peak production in 1970
  - Declining production thereafter



# Prediction vs. Observation

