

SPE Distinguished Lecturer Program



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SPE Distinguished Lecture, 2010-2011

Reliability of Expert Judgments and Uncertainty Assessments

Steve Begg

Australian School of Petroleum, University of Adelaide

Centre for Improved Business Performance

SPE Distinguished Lecture, 2010-2011

Reliability of Expert Judgments and Uncertainty Assessments

"All business proceeds on beliefs, or judgments of probabilities, and not on certainties".

Charles W. Eliot

Outline

- The Nature of Uncertainty
- People, Probability and Judgment
- Performance of Industry Experts
- Conclusions



Industry Performance

- **Comments & Observations**

- “Every one of our 10 most important projects failed to generate the desired return.” (Super Major)
- “The actual performance of our key assets wasn’t even within the P_1 to P_{99} range.” (Large Independent)
- “I want your guarantee that we will not spend more than the P_{50} on this project!” (CEO to Manager)
- “a decade of unprofitable growth”; vast majority of projects take longer, cost more and produce less than predicted; 1-in-8 of major offshore are “disasters” (IPA)

The fundamental problem: Industry performance not living up to expectations, or possibilities



The fundamental problem: Industry performance not living up to expectations, or possibilities

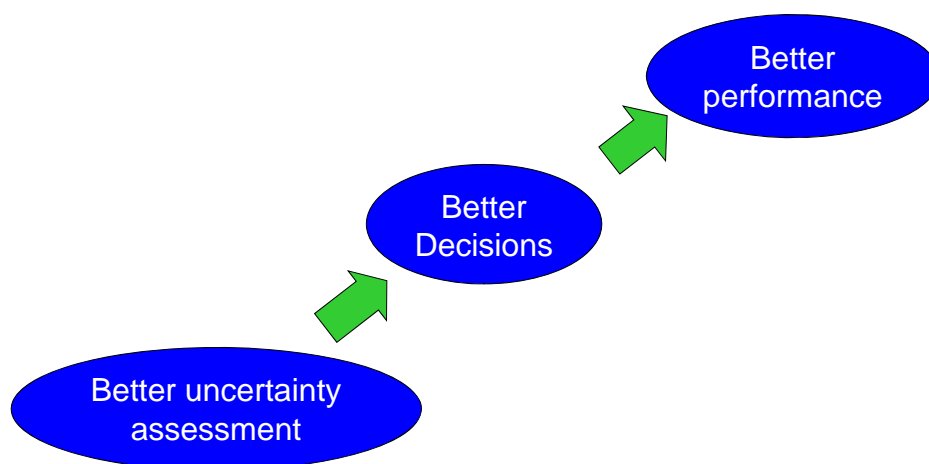
- People tend to grossly under-estimate uncertainty
 - number of uncertain factors and the magnitude of uncertainty
 - complexity of the relationships between them and therefore un-anticipated non-intuitive outcomes)
- Better decision-making, at asset and portfolio levels, first requires *accurate* (= unbiased & appropriate range) uncertainty assessment
- Reduce uncertainty only if
 - it can change a decision (eg Mitigate downside risk and/or capture upside opportunities) AND
 - expected benefit of reduction is less than its cost

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The fundamental problem: Industry performance not living up to expectations, or possibilities



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Probability: The Language of Uncertainty

- **Classical (Theoretical)**

Number of outcomes representing the occurrence of an event
Total number of possible outcomes

- e.g. 30 red balls and 70 green balls in a bag. $P(\text{Red}) = 30\%$

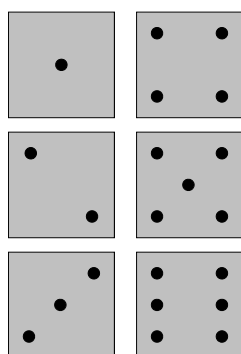
- **Relative Frequency**

- proportion of times an event occurs in the long run
- can be ESTIMATED from sample data ASSUMING identical events
e.g. 15 out of 20 wells drilled were dry holes. $P(\text{Dry}) = 75\%$
- More accurate with greater sample size. May not apply to future.

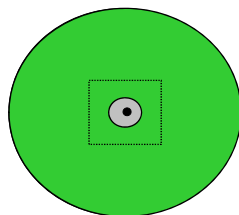
- **Subjective**

- Personal degree of belief of the likelihood of a future event occurring (or of the unknown outcome of a past event)
- May be based on some past similar / analogous occurrences

Uncertainty: not knowing if a statement is true or not



Throw a die and hide top face.
What is the probability of a 3? $1/6$



Now you get information.

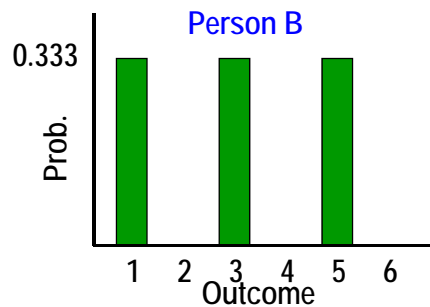
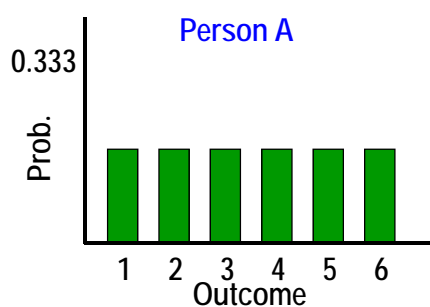
Has the top face changed? **No**
Has the probability of a 3 changed? **Yes!**
What is the probability of a 3 now? $1/3$

**Uncertainty is a function of what you know.
There is no "right" uncertainty (or PDF)!**

Uncertainty is in OUR heads – it's a function of our state of knowledge

Its not a feature of the "system". A consequence:

Different people can, legitimately, hold different views about the uncertainty of an unknown quantity



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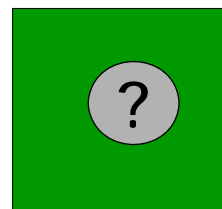
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Uncertainty is in YOUR head: What's it worth to know more?

Another consequence:

Information might have value by virtue of its ability to change probabilities

- Betting Game
 - Win \$100 if it is a 3.
 - Lose \$10 if it is not
- How much is it worth to look at (get information about) the centre?

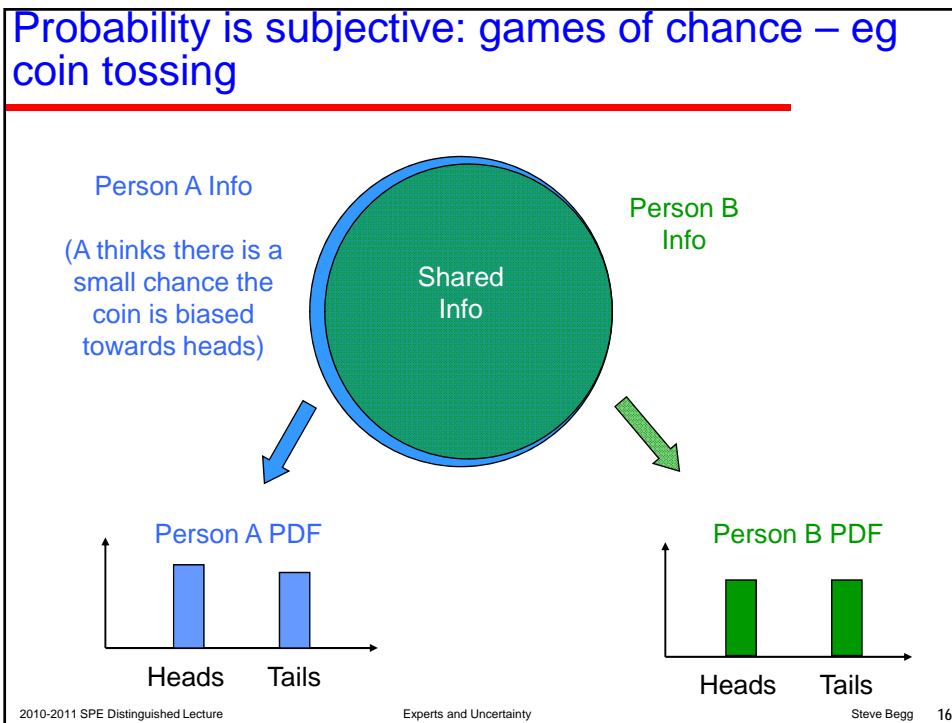
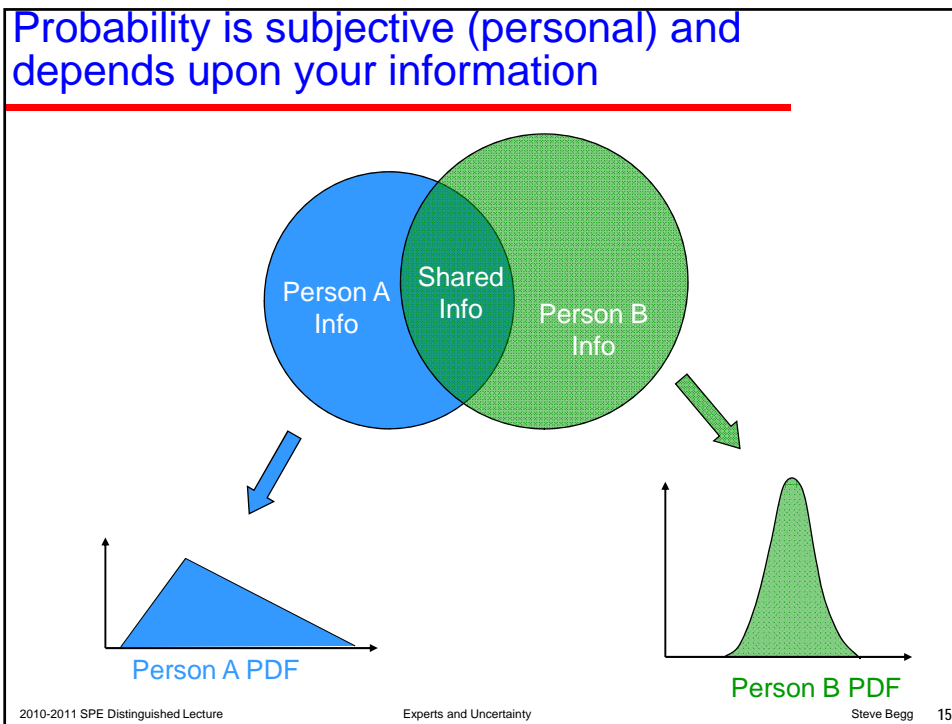


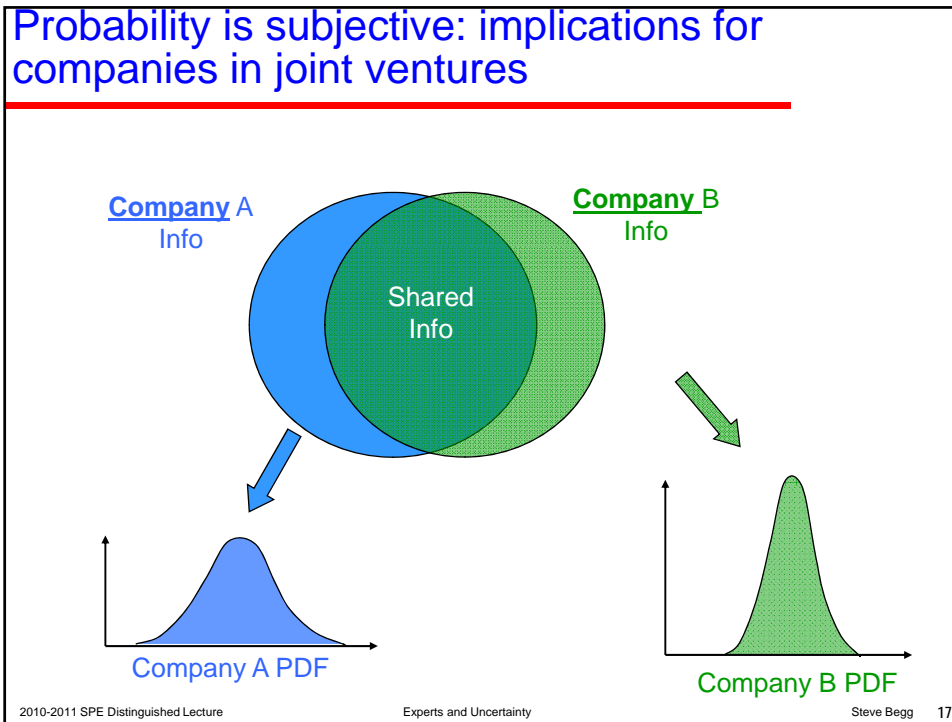
Corollary: you might change your mind on whether to bet or not as a result of getting new information

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Uncertainty vs Risk

Uncertainty

Heads or Tails

Risk

Heads or Tails

- A **Risk** (noun!) is one possible consequence of uncertainty. It has a negative connotation, which is "personal" to the D-M
 - an event that has a negative impact on DM's objectives
 - It is specified by **defining the event** and **assessing its probability**,

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Don't take a biased approach to managing consequences of uncertainty

- Risk is only one outcome of uncertainty - so is **Opportunity!**
 - often over-looked – it is a source of **value creation**

```

graph TD
    A[Consequences of Uncertainty] --> B[Risk]
    A --> C[Opportunity]
    B --- B1[Possibility of loss or injury]
    B --- B2[A dangerous element or factor]
    B --- B3[The degree of probability of loss]
    C --- C1[Possibility of exceeding expectations]
    C --- C2[Upside potential]
    C --- C3[A wonderful element or factor]
    
```

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Uncertainty vs Variability

Variability of all sand-body widths

Uncertainty in individual sand-body width

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Uncertainty vs Variability

Variability of all sand-widths

Sand 2

Width

A distribution that describes the variability of a natural phenomenon is not usually appropriate to describe the uncertainty of a single occurrence

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Gambling (probability = repeated outcomes) vs. "Real World" (probability = degree of belief)

```

    graph TD
      UQ[Uncertainty Quantification] --> IPO[1. Identify Possible Outcomes]
      UQ --> APO[2. Assign Probabilities to Outcomes]
      IPO --> AI[All Identified]
      IPO --> SM[Some missed or unknowable]
      APO --> KD[Known Distribution Type]
      APO --> UD[Unknown Distribution Type]
      KD --> KP[Known Parameters]
      UD --> UP[Unknown Parameters]
      AI --- GC[Games of Chance: Classical Prob & Stats]
      SM --- OG[Oil & Gas: Subjective]
  
```

Games of Chance: Classical Prob & Stats

Oil & Gas: Subjective

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Outline

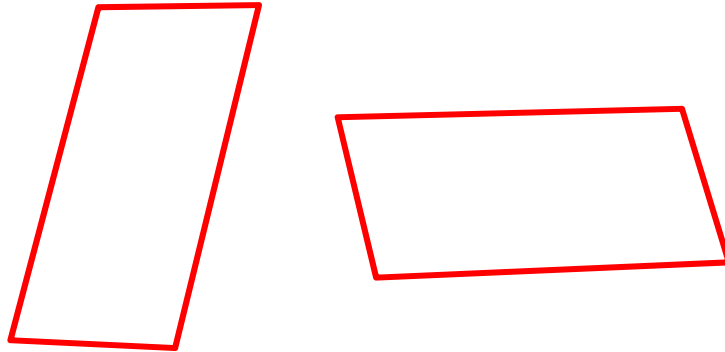
- The Nature of Uncertainty
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Estimate the gray %

Using a scale of 0% (black) to 100% (white) estimate the % gray of squares A and B

*Estimate the aspect ratio



Perceptual Limitations as a Metaphor Cognitive Limitations

- Awareness of illusions, by itself, does not produce a more accurate perception.
- Illusions & cognitive errors therefore, can be extremely difficult to overcome.

Judging likelihoods of events

- Linda is a 31 years old, single, outspoken and very bright. She majored in philosophy. As a student she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

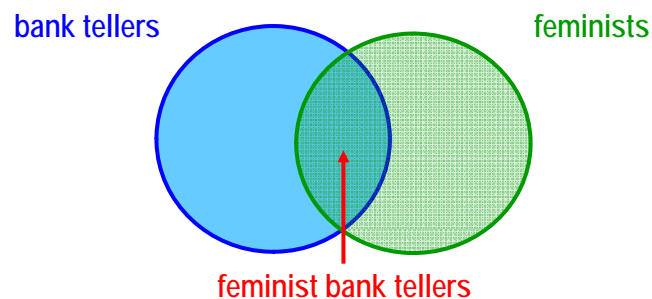
Which is the **more likely** alternative?

- Linda is a bank teller
- Linda is a bank teller and active in the feminist movement.

Answer: _____

*Discussion of Linda Question

- Nearly 90% of respondents choose the second alternative (bank teller *and* active in the feminist movement), even though this is provably *logically incorrect*



Junctions ("ands") are always less likely than stand-alone statements.

Cognitive Illusions

- The description of Linda is **more representative** of a feminist bank teller so people, wrongly, conclude it is **more likely** that she is a feminist and a bank teller
- Kahneman & Tversky (1982)
 - “As the amount of detail in a scenario increases, its probability can only decrease steadily, but its representativeness and hence its apparent likelihood may increase.”
 - “The reliance on representativeness, we believe, is a primary reason for the unwarranted appeal of detailed scenarios and the illusory sense of insight that such constructions often provide.”
- Implications: consider a “rich” description of a reservoir depositional environment

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Count the Passes



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Heuristics, Biases & Uncertainty

- Heuristics

Human beings are not endowed with rational probabilistic thinking and optimal behaviour under uncertainty.

– systematic errors that are a result of the use of heuristics

- Our “mental wiring” is just not good when it comes to uncertainty

Bias & error => poor decisions
=> undesirable outcomes

Heuristics, Biases & Uncertainty

- Heuristics

– simple rules of thumb and mental shortcuts

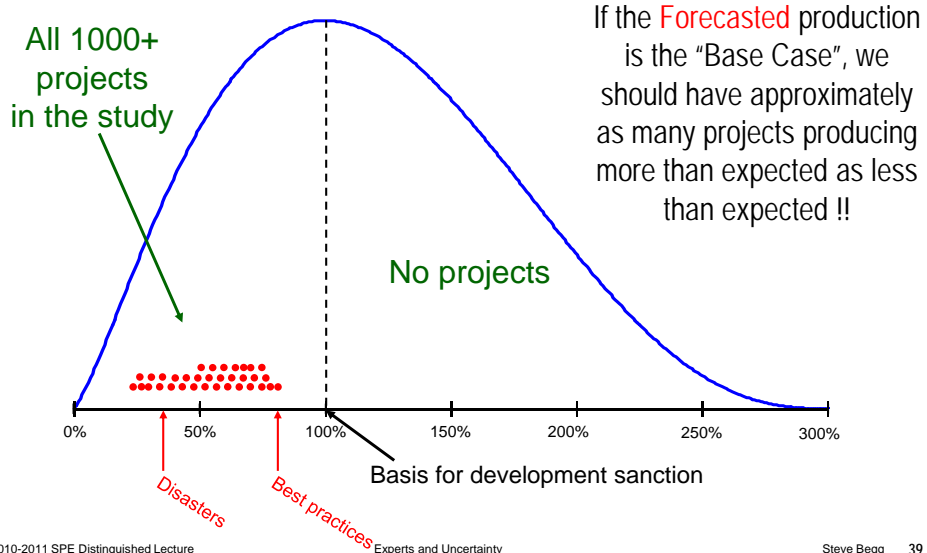
- Biases

– systematic errors that are a result of the use of heuristics

- Our “mental wiring” is just not good when it comes to uncertainty

– Intuition and “gut feel” often significantly wrong

Evidence of Bias: Data from IPA



Outline

- Introduction
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- People, Probability and Judgment
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Assing the ability of experts to assign P10-P90 ranges

← 10% Lower Limit (P10) ← 80% Chance → Upper Limit (P90) → 10%

Question 1 _____

Question 2 _____

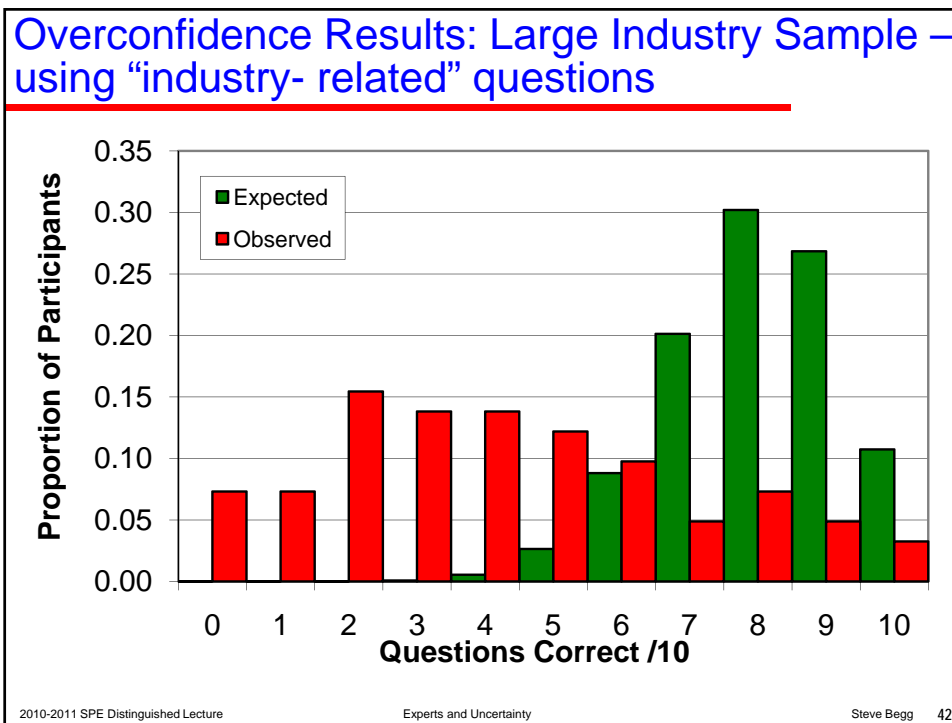
Question 3 _____

etc _____

E.g. What was daily average oil production in the USA in 2003?

Answer: 7,454,000

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Probability Intuition: Assessing co-variation

	<u>Hydro-carbons</u>	
	Present	Absent
<u>Seismic Anomaly</u>	Present	Absent
	16	4
	4	1

- Which cells of the table are needed to determine whether seismic anomalies are associated with hydrocarbons

Upper Left Upper Right Lower Left Lower Right

- According to the data in the table, do seismic anomalies increase the probability of hydrocarbon presence? Yes/No

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Probability Intuition: Assessing co-variation

		Hydrocarbons		
		Present	Absent	Total
Seismic Anomaly	Present	16	4	20
	Absent	4	1	5
	Total	20	5	25

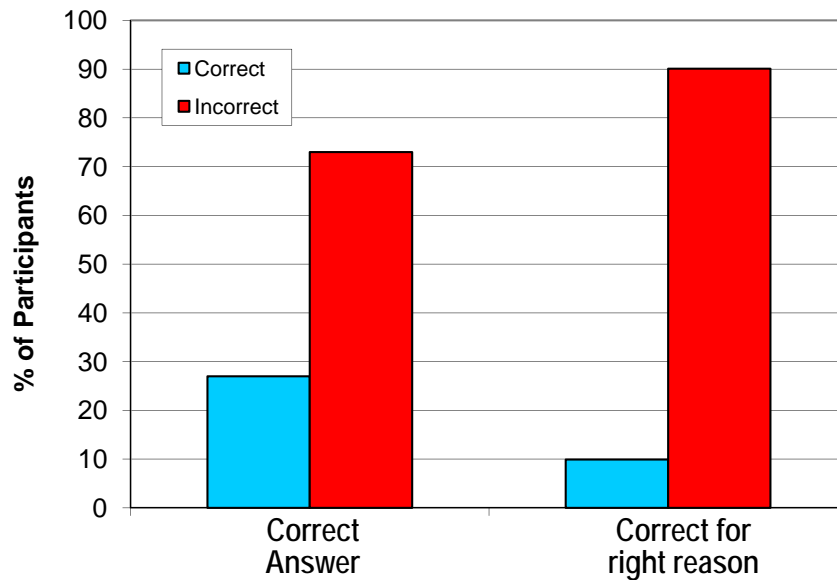
- All 4 pieces on information (cells) are required
- Conditional probabilities of HC presence given the presence/absence of seismic anomaly

$P(\text{HC Present} \mid \text{Anomaly present}) = 16/20 = 80\%$
 $P(\text{HC Present} \mid \text{Anomaly absent}) = 4/5 = 80\%$

- Probability of HC being present is the same, whether or not a seismic anomaly is present – so no information

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Assessing Co-variation (presumed association): Results



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Probability Intuition: Assessing Reliability of Predictors

- Historical estimates suggest one in every 1000 blow-out preventers has serious cracks.
- Suppose x-ray analysis is a very good, but not perfect, detector of these cracks.
 - If a blow-out preventer has cracks, x-rays will **correctly** say it has them 99% of the time
 - If a blow-out preventer does not have cracks, x-rays will **wrongly** say that it has them 2% of the time
- A blow-out preventer has been x-rayed at random and the result was positive!
 - What is your **intuitive assessment** of the chances that it is cracked?

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Probability Intuition: Assessing Reliability of Predictors

- Historical estimates suggest one in every 1000 blow-out preventers has serious cracks.
- Suppose you test a well but not perfectly.

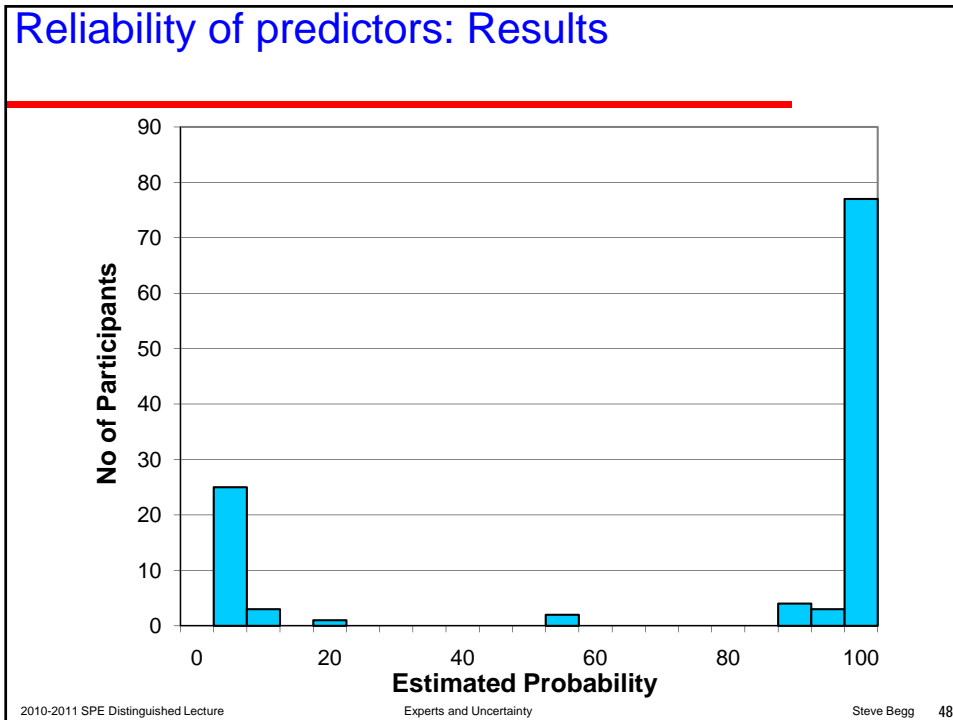
4.7%!

$P(\text{test positive given crack})=99\%$

$P(\text{crack given test positive})=4.7\%$

- A blow-out preventer from a well is tested and the result is positive.
 - What is your **intuitive assessment** of the chances that is cracked?

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Anchoring - Subtle changes in wording of a question can significantly impact responses

Question	Outcome
How long was the movie?	130 min
How short was the movie?	100 min

Question	Outcome
How wide are the channels?	
How narrow are the channels?	

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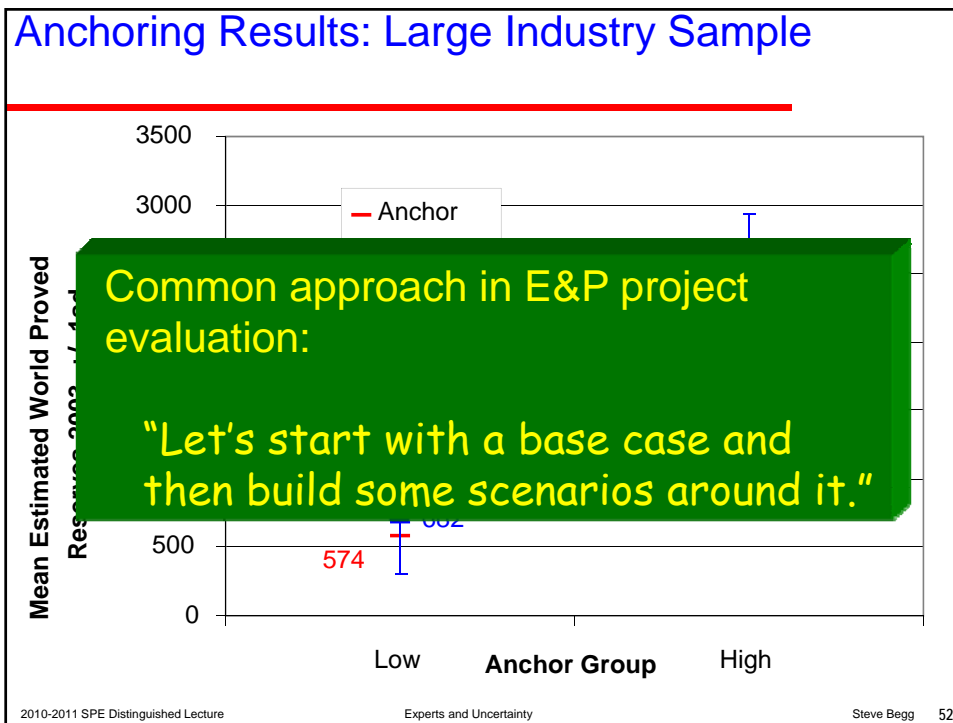
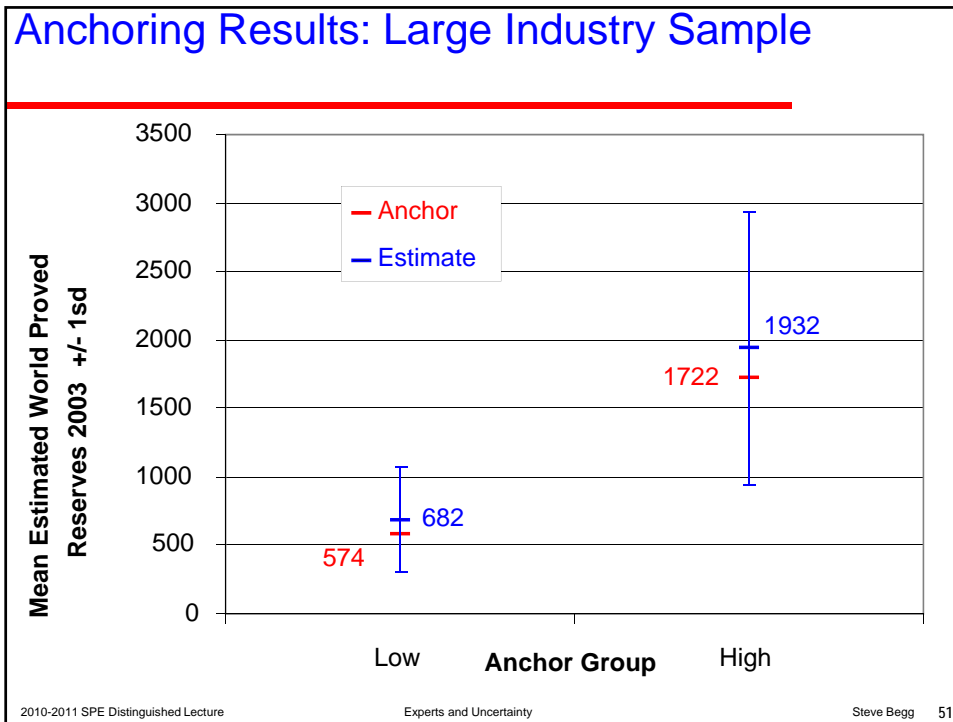
Anchoring Question: Large Industry Sample

- Alternate versions of question with high and low anchors given to two groups
 - **High Anchor Group**: “Were world proved oil reserves in 2003 greater or less than **1721.6** Billion Barrels?”
 - **Low Anchor Group**: “Were world proved oil reserves in 2003 greater or less than **573.9** Billion Barrels?”
- Both groups then asked
 - “What is your best estimate of the world proved oil reserves in 2003?”

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Unpacking

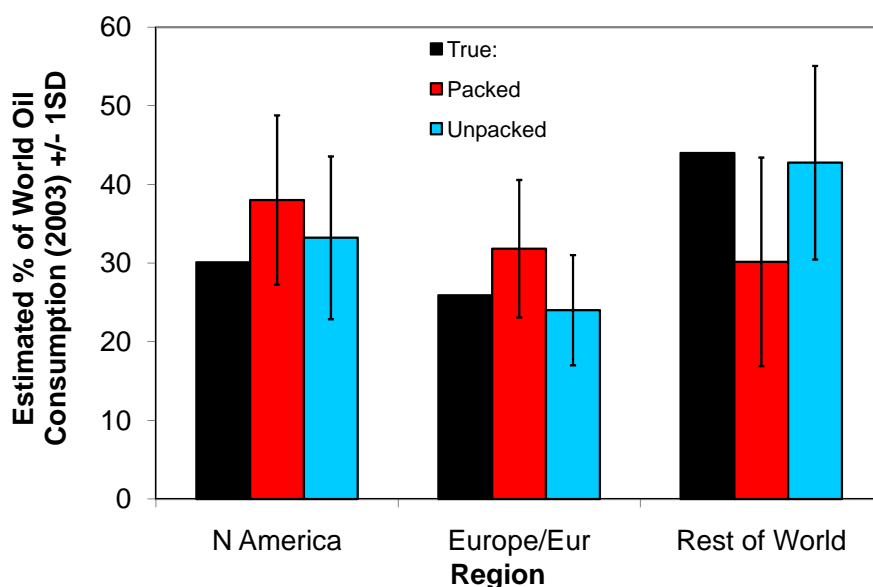
- Unpacking Question (RoW Packed)
 - “What % of world oil consumption is accounted for by each of the following regions: **North America**, **Europe/Eurasia** and **the Rest of the World**?”
- Unpacking Question (RoW Unpacked)
 - “What % of world oil consumption is accounted for by each of the following regions: **North America**, **Europe/Eurasia**, **South and Central America**, **Middle East**, **Africa**, **Asia Pacific** and **the Rest of the World**?”.

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Unpacking Question Results



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Availability and Vividness Bias – Seeing What We Believe

- The tendency people have to base estimates of frequencies (probabilities) on the most readily available, recent and vivid information they can remember
 - how many events of a particular type are *available* to memory
 - more available events are judged more likely
- Memory is limited to 7 “chunks”



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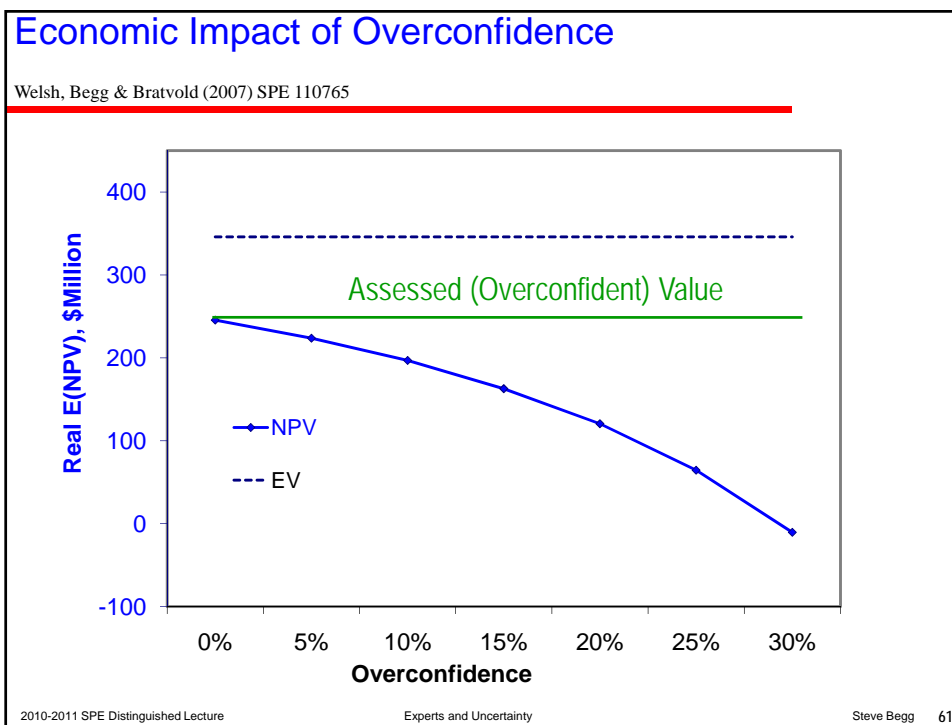
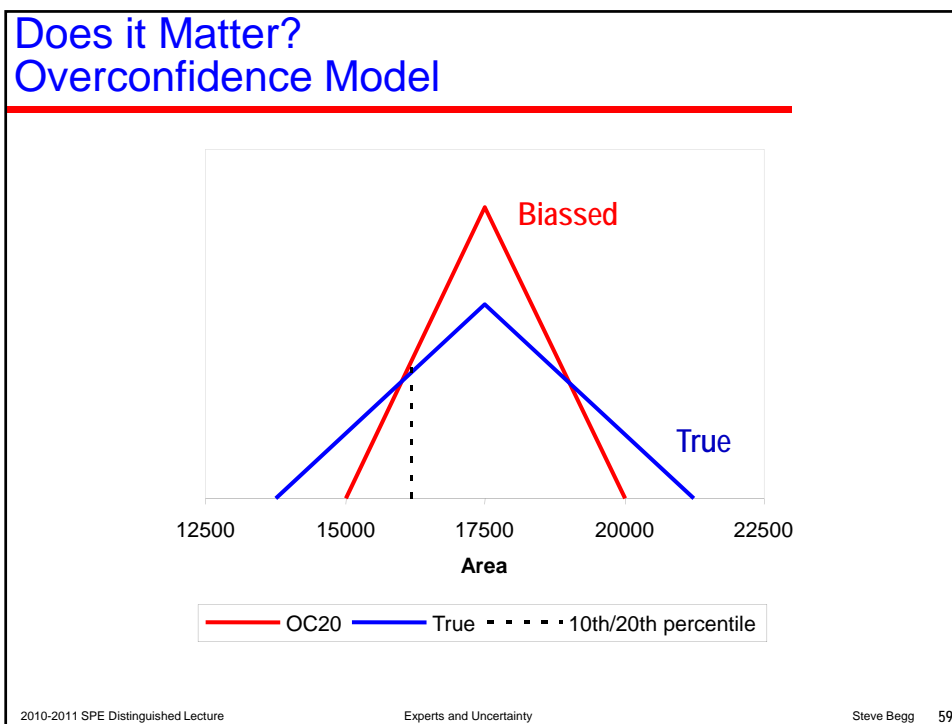
Bias from the Availability Heuristic & Saliency

- Tversky and Kahneman (1974)
 - “decision makers assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind.”
- Managers conducting performance appraisals:
 - Working from memory, vivid instances of an employee’s behaviour (either positive or negative) will be most easily recalled from memory and will appear more numerous than more commonplace instances.
 - Managers give more weight to performance during the three months prior to the evaluation than to the previous nine months of the evaluation period.

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Risk Aversion and Incentives

- Your track record hasn't been too good recently. You can recommend one of two investments. Which one?

	P_s	P_f	EV, \$MM
"Safe"	80%	20%	10
"Risky"	10%	90%	20

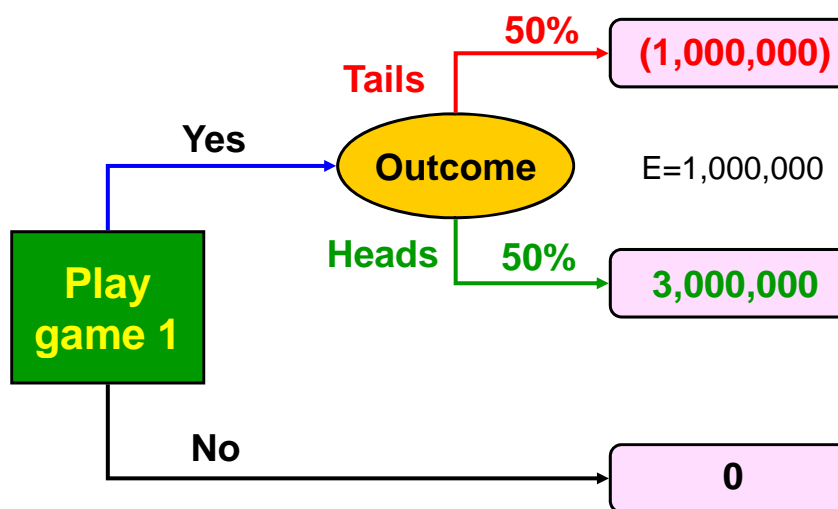
- You should take a corporate (organizational) attitude to risk, not a personal one, and recommend "Risky" based on EV
 - any other choice (being risk-averse or risk-seeking) is **value destroying** (money-losing)
- Most incentive policies, focused on reward by outcome, encourage inappropriate risk-aversion, therefore value loss!

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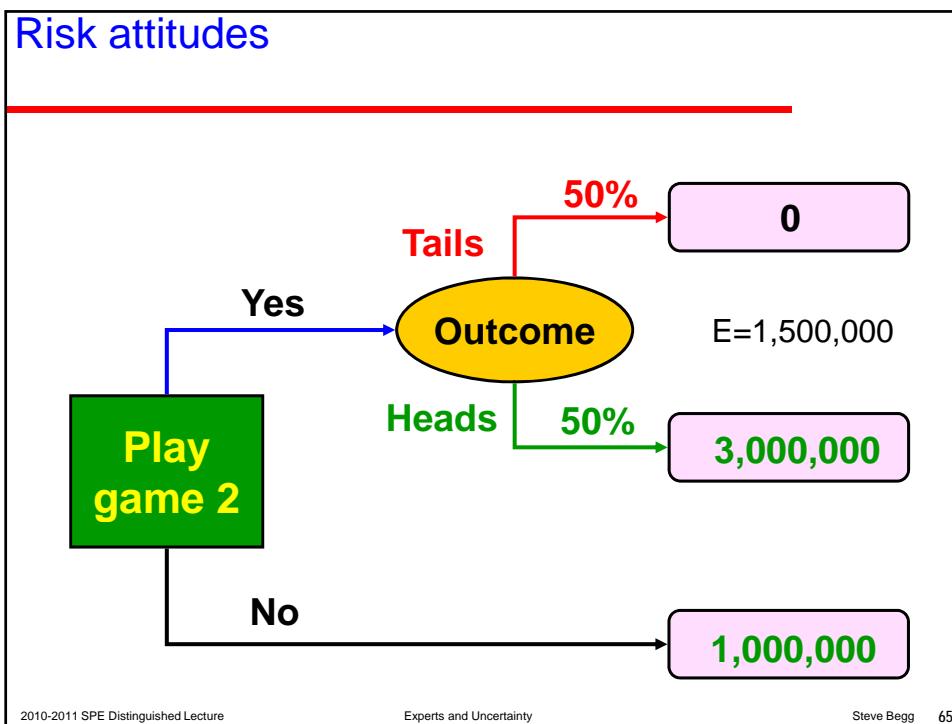
Risk attitudes. Will you play the game?



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Risk Aversion: Consequences

- Expected Value rule is sometimes not followed because its focus on an average outcome ignores
 - the *range* of outcomes and their probabilities (risks)
 - the *consequences* of the outcome
- Risk aversion demonstrably leads to lower returns in the long run (=over many decisions)
 - but can be optimal in some circumstances – when a large part of our wealth is invested in few items
 - Most of us buy insurance
- Reward/penalty mechanisms can create a mis-alignment between organizational and individual attitudes to (tolerance for) risk
 - Leading to *inappropriate* risk-aversion and therefore lower returns
 - Eg “risky” projects not brought forward

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Reasoning under uncertainty = using the rules of probability

- In terms of practical applicability, probability theory is comparable with geometry;
 - both are branches of applied mathematics that are directly linked with the problems of daily life.
- While most people have a natural feel for geometry (at least to some extent), many people clearly have trouble developing a good intuition for probability.
- In no other branch of mathematics is it so easy to make mistakes as in probability theory.
 - Conditional probabilities, and Bayes theorem in particular, are especially difficult

Reasoning under uncertainty = using the rules of probability

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 - In no other branch of mathematics is it so easy to make mistakes as in probability theory.
 - Conditional probabilities, and Bayes theorem in particular, are especially difficult
- “The theory of probabilities is at bottom nothing but common sense reduced to calculus; ...*
- It teaches us to avoid the illusions which often mislead us;***
- ... there is no science more worthy of our contemplations nor a more useful one for admission to our system of public education.”*
- Laplace – Theorie Analytique des Probabilites*

Conclusions

- In our context, uncertainty is a function of what we know about a situation – its in our heads, not a part of the “system”
 - there is no single, “right” probability for an uncertain event
 - variability is not the same thing as uncertainty
- Evolution has not “wired” our brains for a good natural ability to assess uncertainty
 - training helps, but even industry experts, including those whose job it is to deal with uncertainty, are not great
- Do not use intuition to propagate (amalgamate) assessed uncertainties
 - use the rules of probability, or Monte Carlo simulation

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