How to Measure Anything in Innovation

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Introduction

The Biggest Innovation Risk

Question: What is your single biggest risk in Innovation?

Answer: How you measure Innovation.

Introduction

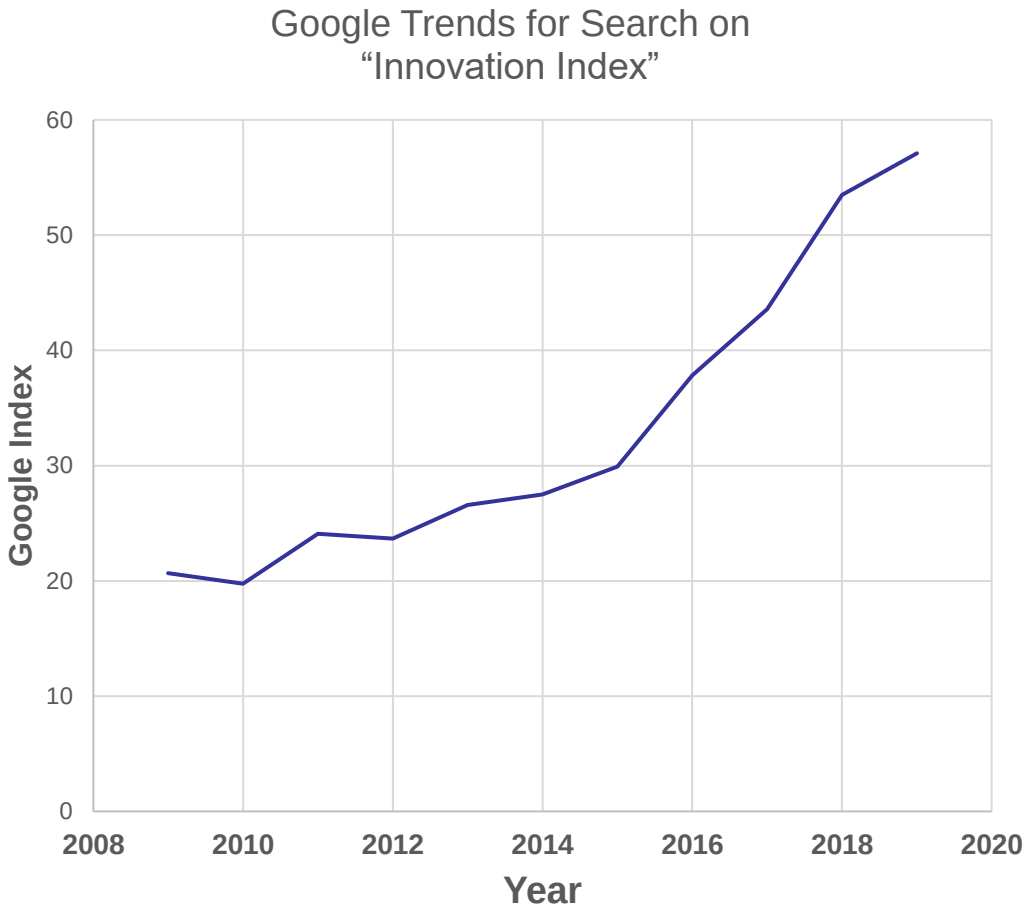
Goals

- A critique of current methods
- The three reasons why innovation may seem immeasurable and why they are illusions
- Ideas for how to frame decisions and – possibly - improve innovation
- Note that some topics are “Takeaways”, others “Aspirational”

Measuring Innovation

Interest in Measuring Innovation

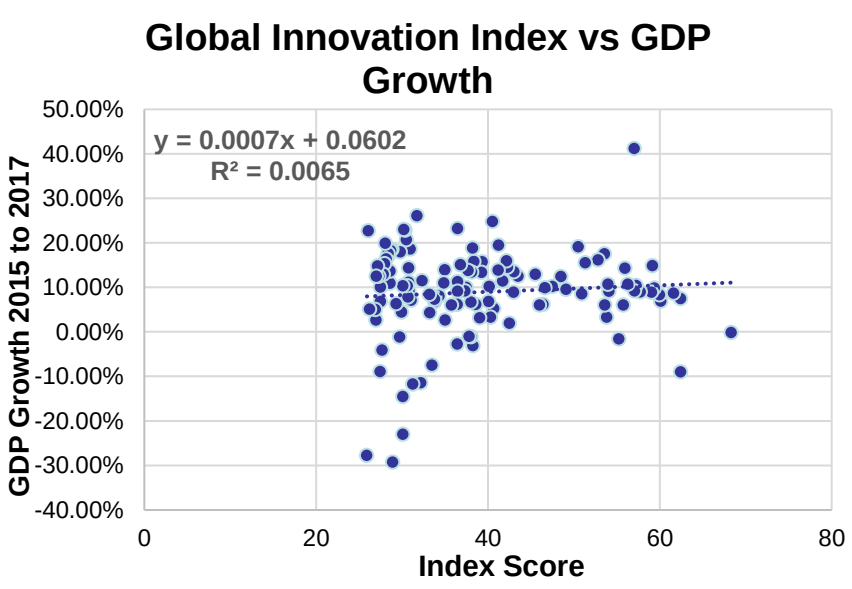
- There is a growing interest in measuring innovation.
- Attempts to measure it include rigorous academic and soft-scoring, self-administered evaluations.
- How can we evaluate these evaluations?

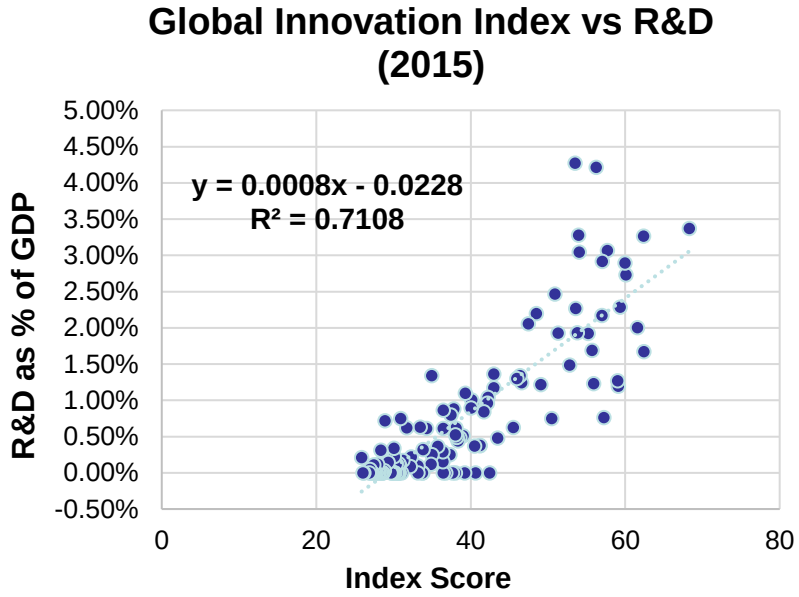


Measuring Innovation

Global Innovation Index

- Various methods to “index” or “score” innovation have no predictive power for performance of any kind.
- Where they do correlate, it is only to *past* performance – that is because past measures are part of the metric.

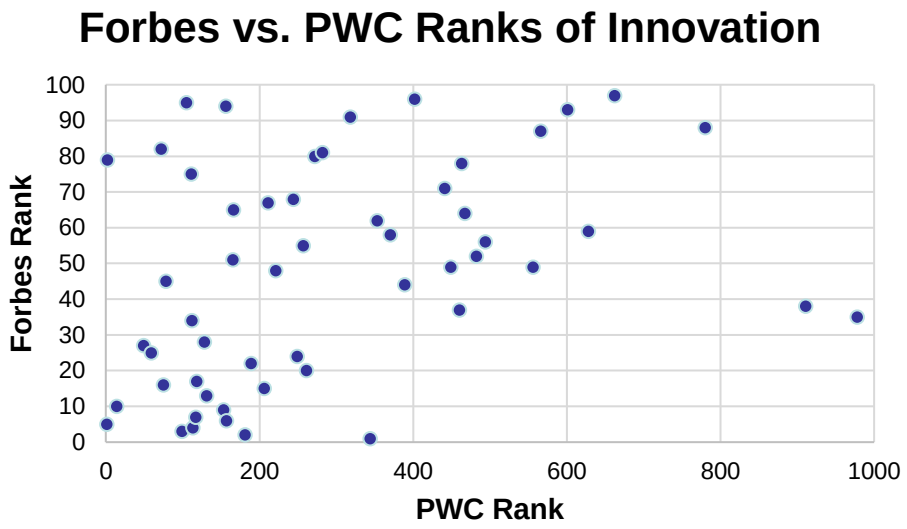




Measuring Innovation

Problems with Corporate Innovation Scores

- Forbes, PWC, A.M. Best and McKenzie* are among the best-known innovation ranking lists and scores for companies.
- Like the GII, there is no relationship to the future financial performance of a company – only past performance.
- They also lack any correlation to each other (see PWC vs Forbes Rank chart).



46 of 100 on the Forbes list don't even make the top 1000 in the PWC ranking.

*McKenzie claims correlations to financial performance, but doesn't provide data to determine if this is predictive

The Three Misconceptions Behind Any Perceived “Immeasurable”

The Illusions of Immeasurability

CONCEPT of Measurement	The definition of measurement itself is widely misunderstood.
OBJECT of Measurement	The thing being measured is not well defined.
METHOD of Measurement	Many procedures of empirical observation are misunderstood.

The Three Misconceptions Behind Any Perceived “Immeasurable”

The Concept of Measurement

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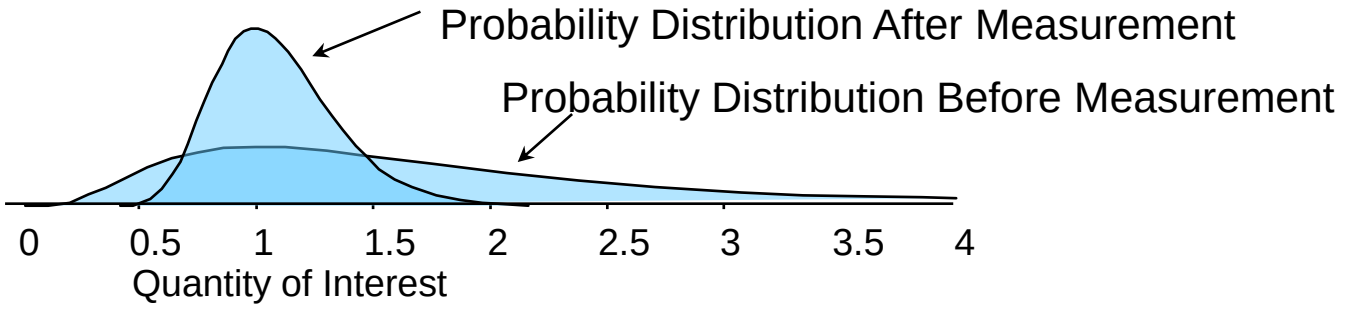
The Concept of Measurement

It’s not a point value

It’s not a point value.

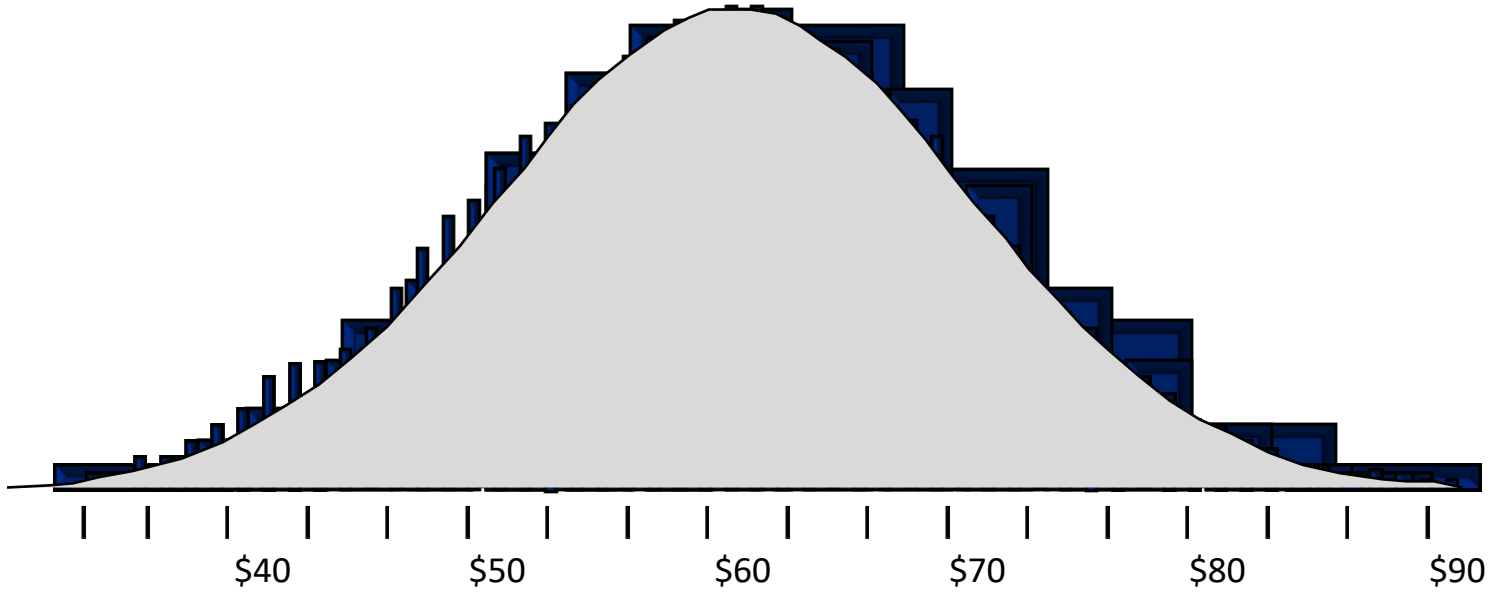
- Measurement: a quantitatively expressed reduction in uncertainty based on observation.
- You can quantify your current uncertainty – additional observations reduce it.
- Even marginal reductions in uncertainty can be extremely valuable.



The Concept of Measurement

Constructing a Distribution

- Uncertainty about “either/or” events are expressed as “discrete” probabilities (e.g. “35%).
- Uncertainty about continuous values can still be thought of as sets of discrete probabilities.



The Concept of Measurement

What the research says about Subject Matter Experts

"Overconfident professionals sincerely believe they have expertise, act as experts and look like experts. You will have to struggle to remind yourself that they may be in the grip of an illusion."

Daniel Kahneman, Psychologist, Economics Nobel

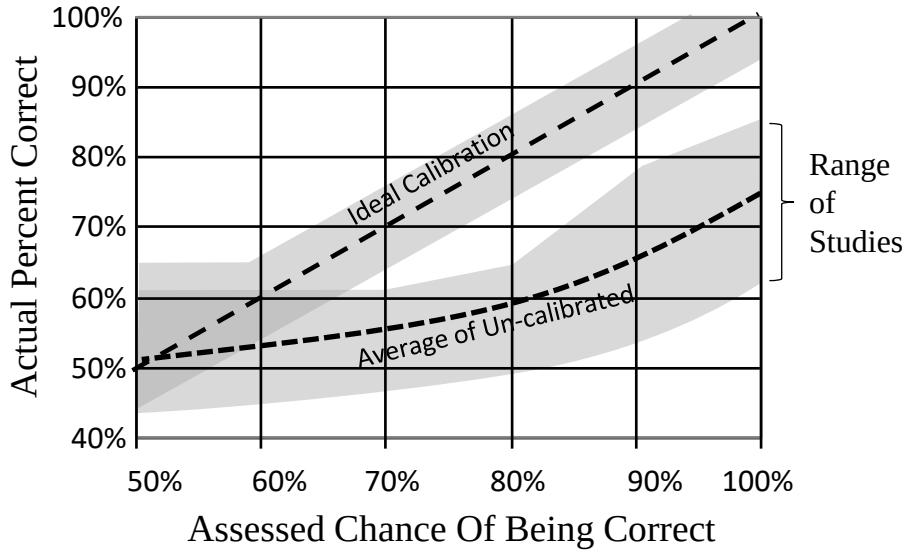
- Decades of studies show that most managers are statistically "overconfident" when assessing their own uncertainty.
- Studies also show that measuring *your own* uncertainty about a quantity is a general skill that can be taught with a ***measurable*** improvement.

The Concept of Measurement

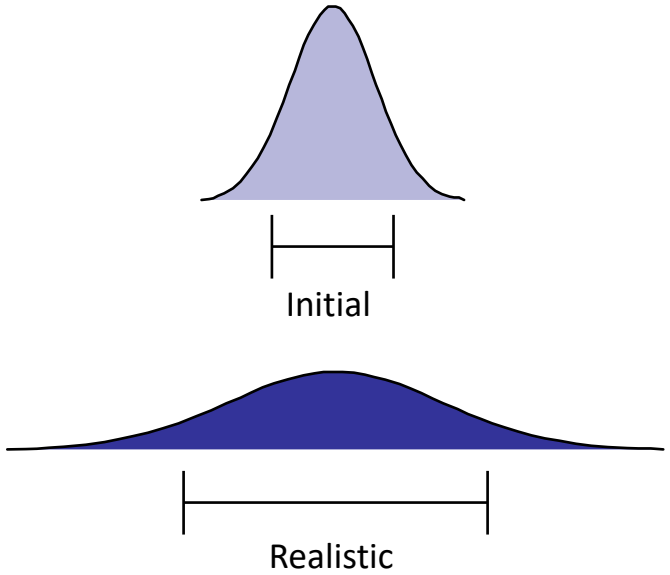
Overconfidence in Ranges

The same training methods apply to the assessment of uncertain ranges for quantities like the duration of a future outage, the records compromised in a future breach, etc.

Binary Events
(It happens or not, like a chance of data breach)



90% Confidence Interval
(For continuous values, like impact)



The Three Misconceptions Behind Any Perceived “Immeasurable”

The Object of Measurement

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The Object of Measurement

The Importance of Defining a Measurement

- If a thing seems like an immeasurable “intangible” it may just be ill-defined.
- Often, if we can define what we mean by a certain “intangible” we find ways to measure it.
- Examples: Brand image, Security, Safety, etc.

The Object of Measurement

Clarifying the Problem

1. Why do you care? (What decision could depend on the outcome of this measurement?)
2. What do you see when you see more of it? (Describe it in terms of observable consequences, then units of measure.)
3. How much do you know about it now?
4. At what point will the value make a difference?
5. How much is additional information worth?

- If you can answer the first three, you can usually compute the last two.

The Object of Measurement

The Object: Clarifying Innovation

Is innovation the same as creativity?

"Creativity is subjective, making it hard to measure, as our creative friends assert. Innovation, on the other hand, is completely measurable." Business Insider, April 10, 2013

Just to be clear: everything is measurable. We see no relevant difference.

An interesting quote from a psychologist – in 1964:

"Before creativity research gets completely out of control, some effort must be devoted to definitions of terms. …creativity research will flounder until the measuring instruments and procedures are improved at least to the level of current test theory." Louise Wither Cureton

The Object of Measurement

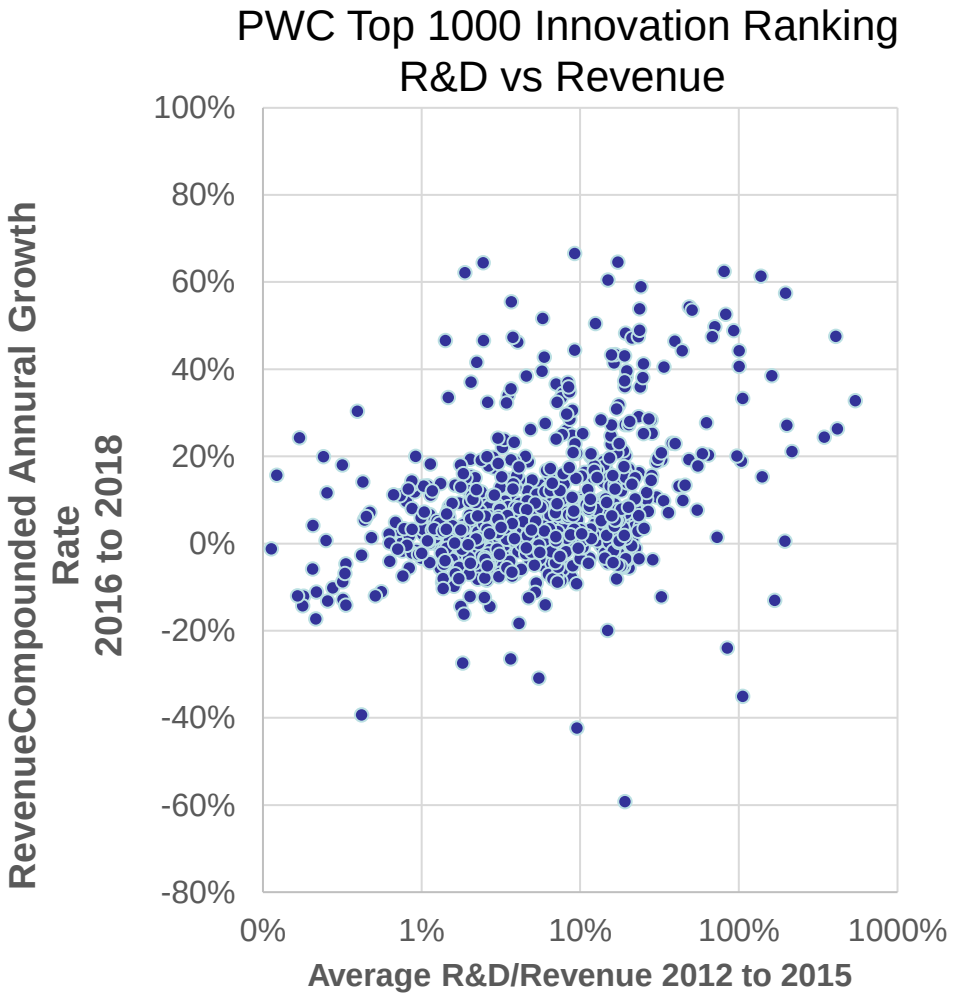
Is Innovation the Same as R&D Spending?

Several studies about innovation are actually studying variations in R&D spending with innovation.

There is faint evidence about a correlation between R&D spend and future financial performance.

Steve Jobs was only slightly exaggerating when he said:

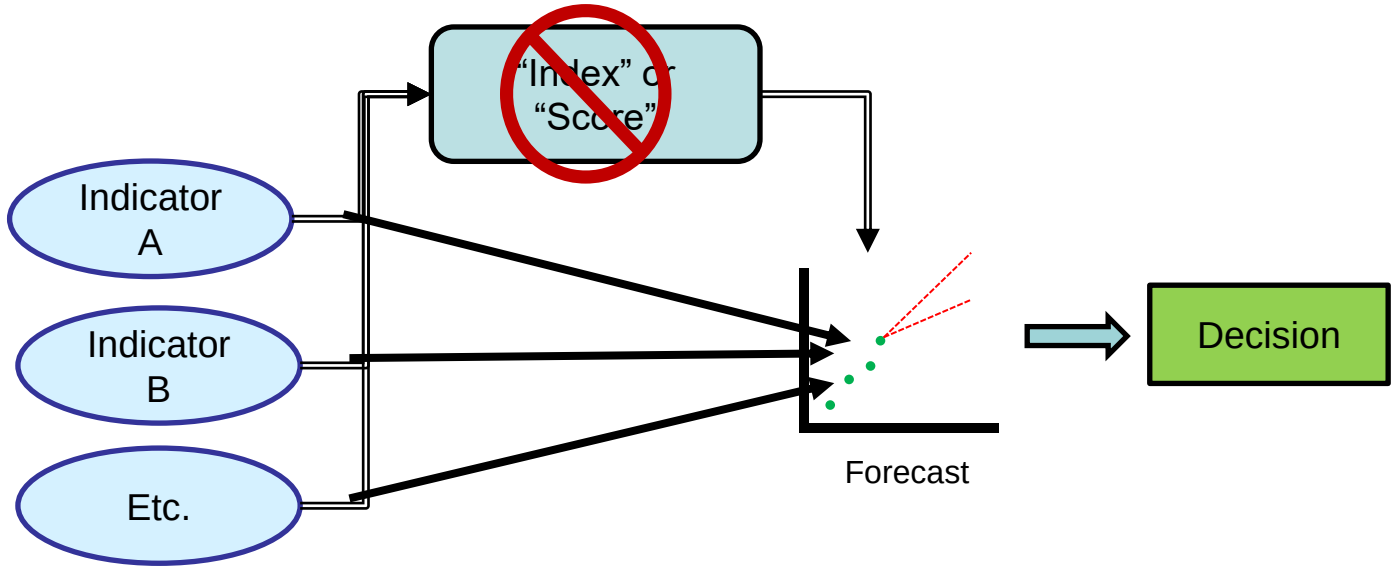
"Innovation has nothing to do with how many R&D dollars you have. When Apple came up with the Mac, IBM was spending at least 100 times more on R&D."



The Object of Measurement

Indices: Information Destroying?

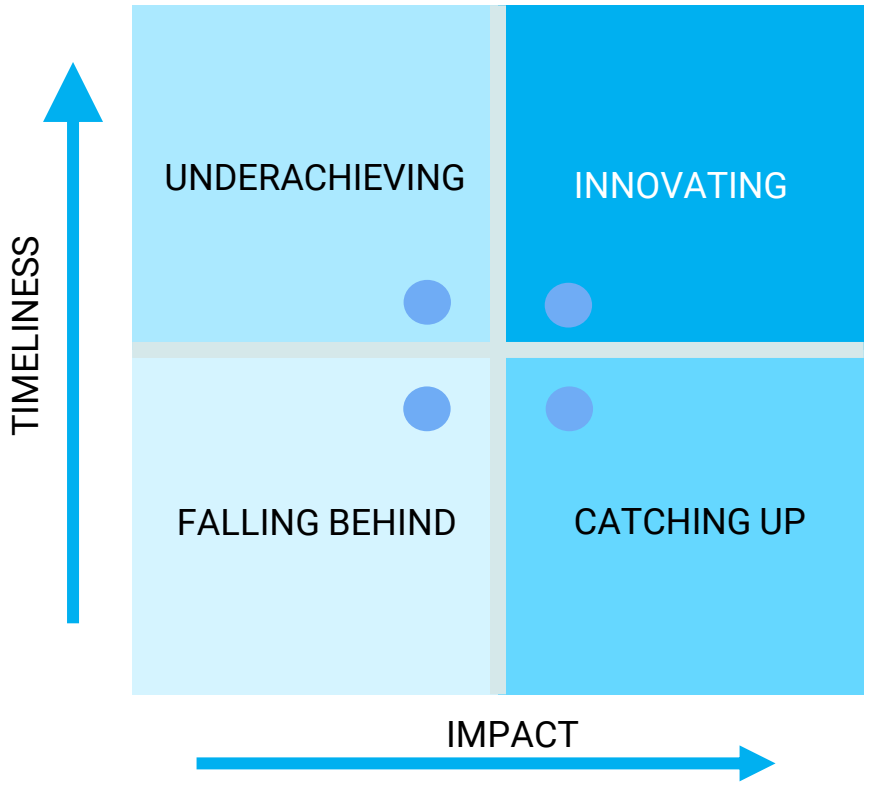
- An index produces a number based on a series of indicators and a formula.
- If it is useful, the index should inform specific decisions by forecasting observable outcomes.
- But if it forecasts observable outcomes, the better solution is to skip the index altogether in the forecasting algorithm.



The Object of Measurement

Defining Innovation

- “The value of an idea lies in the using of it.” – **Thomas A. Edison**
- “It’s not creative unless it sells.” often misattributed to David Ogilvy



The Object of Measurement

The Who/What/Why of Innovation Measurements

What decision you are trying to support is related to whose innovation you are measuring.

Who/What	Why (Decision)
Employees/ Company	Who should I hire? Should I intervene in the team (improve, change, etc.)? Should I change my R&D process?
Customers	Adoption rates of new ideas
Ideas	Should I implement this idea? If not, when should I implement it?
Countries	Should I be based there?

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The Method of Measurement

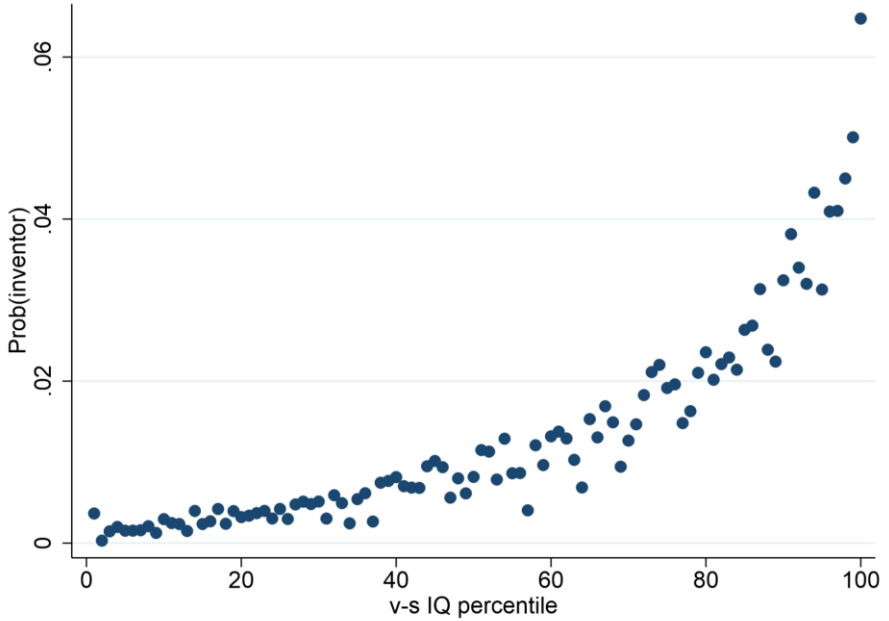
Previous Research on Innovativeness

Diversity: T. Charmorro-Premuzic "Does Diversity Actually Increase Creativity?" *Harvard Business Review*, June 28, 2017.

Patent Quality: J. Lanjouw, M. Schankerman "*Patent Quality And Research Productivity: Measuring Innovation With Multiple Indicators*" *The Economic Journal*, 114 (April), 441-465.

Changing Environments: W. Maddux, A. Galinsky "Cultural borders and mental barriers: The relationship between living abroad and creativity" *Journal of Personality and Social Psychology*, Vol 96(5), May, 2009. pp. 1047-1061.

Reward Systems: D. Slevin "The Innovation Boundary: A Replication with Increased Costs" *Administrative Science Quarterly*, Vol 18 No 1, Mar 1973.



Visual-Spatial IQ: Philippe Aghion, et al "The Social Origins and IQ of Inventors" draft research, February 4, 2018

The Method of Measurement

Having More Data

Potential Indicators of Innovation?

- Patents and "patent quality"
  - Number of patents
  - Number of claims
  - Forward and Backward citations
- The Process
  - Time spent in Ideation/brainstorming
  - Deliberate seeking of outside input
  - Selection rate and basis of "veto"
  - Feasibility testing/Initial development
  - Detailed development
  - Change in technology levels by time
  - Share of R&D which is really just admin
- Indicators for individuals
  - Education
  - Aptitude
  - Past innovation output (patents, etc.)
  - Collaboration behaviors
  - Team surveys
- Portfolio indicators
  - Number of ideas
  - Risk, including Technology horizon

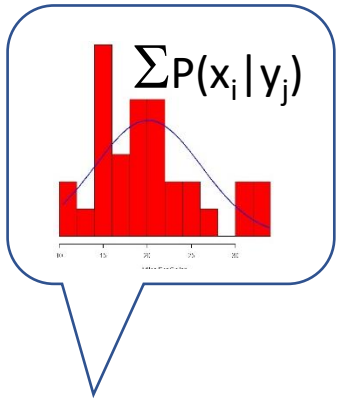
You may already have some indicators of innovation.

Others may be accessible. Simple surveys may capture some of these.

The important issue is to utilize internal variations to see what is correlated to outcomes.

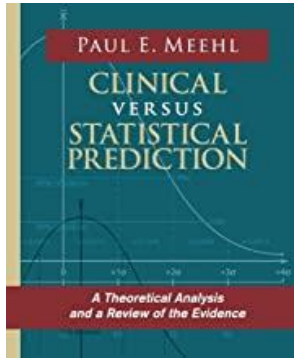
Experts vs. Algorithms

What the research says about statistical methods vs. Subject Matter Experts

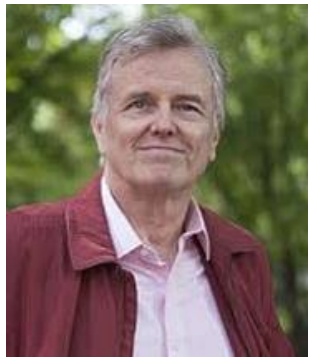


Paul Meehl assessed 150 studies comparing experts to statistical models in many fields (sports, prognosis of liver disease, etc.).

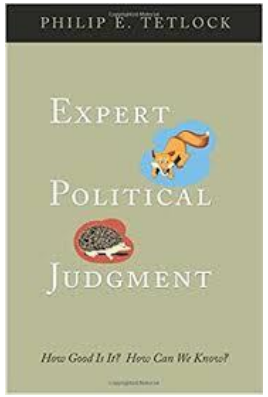
"There is no controversy in social science which shows such a large body of qualitatively diverse studies coming out so uniformly in the same direction as this one."



Philip Tetlock tracked a total of over 82,000 forecasts from 284 experts in a 20-year study covering politics, economics, war, technology trends and more.



"It is impossible to find any domain in which humans clearly outperformed crude extrapolation algorithms, less still sophisticated statistical ones."



The Method of Measurement

The Rule of Succession

Danny Kahneman

A reference class is a population from which you draw observations of events to determine their frequency. Your "reference class" is much larger than you.

You can start by making as few assumptions as possible – your "baseline" uses only your reference class.

Pierre-Simon Laplace
1749-1827

- Laplace's "rule of succession": Given a population of reference class, like company-years, where some number of events occurred:
  - Chance of X (per year, per draw, etc.) =(1+hits)/(2+hits+misses)

The Method of Measurement

Does Customer Research Inform Innovativeness?

- **One View:** When Steve Jobs was asked what market research he did that led to the iPad he said, “None. It’s not the customer’s job to know what they want.”

- **Another View:** There are several examples of ideas that perhaps engineers and entrepreneurs loved, but flopped in the market.

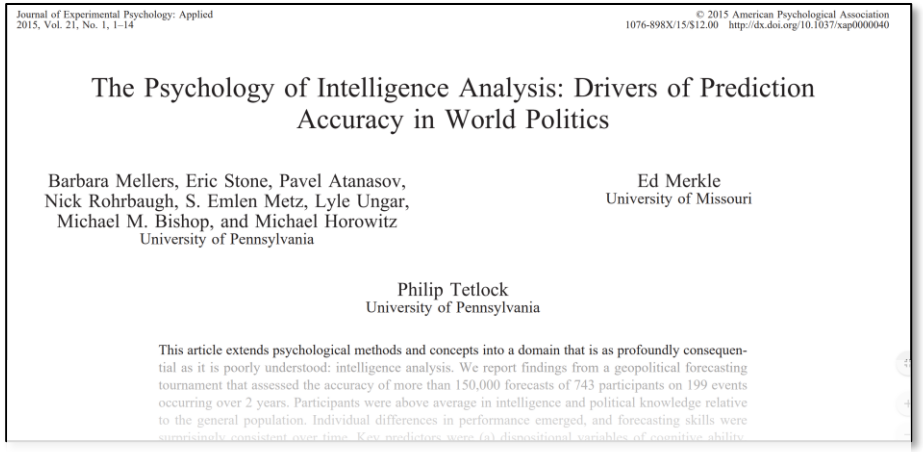
- Either way, observed impact (market adoption, profitability, etc.) is being estimated.

Xybernaut Poma Wearable PC, Xybernaut and Hitachi (2002)

The Method of Measurement

Improving Expert Forecasts

- Tetlock also looked at what improved *forecasting.*
- He tracked 743 individuals who made at least 30 forecasts each over a 2-year period.
- He determined factors that made the biggest difference in the performance of forecasting.



Journal of Experimental Psychology: Applied
2015, Vol. 21, No. 1, 1–14

1076-898X/15/$12.00 http://dx.doi.org/10.1037/xap0000040

The Psychology of Intelligence Analysis: Drivers of Prediction Accuracy in World Politics

Barbara Mellers, Eric Stone, Pavel Atanasov, Nick Rohrbaugh, S. Emlen Metz, Lyle Ungar, Michael M. Bishop, and Michael Horowitz
University of Pennsylvania

Ed Merkle
University of Missouri

Philip Tetlock
University of Pennsylvania

This article extends psychological methods and concepts into a domain that is as profoundly consequential as it is poorly understood: intelligence analysis. We report findings from a geopolitical forecasting tournament that assessed the accuracy of more than 150,000 forecasts of 743 participants on 199 events occurring over 2 years. Participants were above average in intelligence and political knowledge relative to the general population. Individual differences in performance emerged, and forecasting skills were

Probabilistic Training

- Subjects were trained in basic inference methods, using reference classes, and avoiding common errors and biases.

Teams and Belief Updating

- Teams deliberated more and individuals were willing to update beliefs based on new information.

Selecting the Best

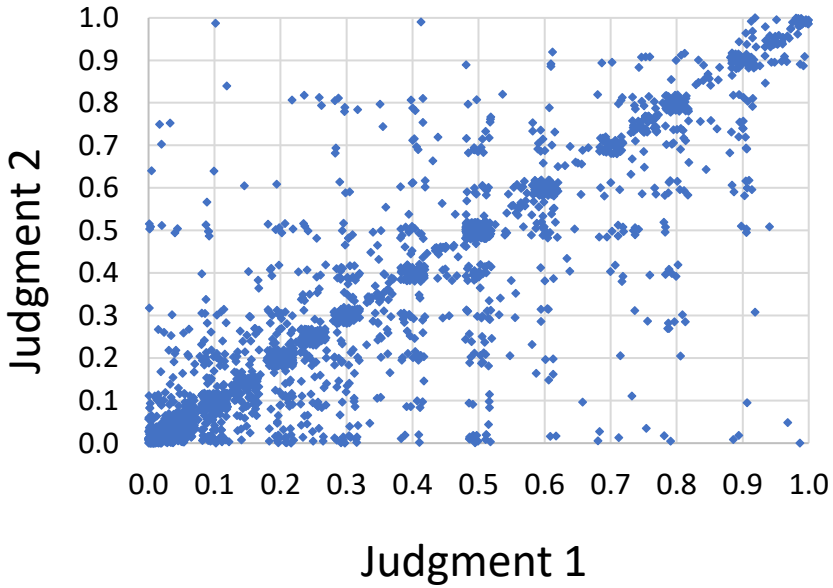
- Brains matter. Both topic expertise and overall IQ were the best predictors of performance.

The Method of Measurement

Calibrating Expert Consistency

- We have gathered estimates of probabilities of various security events from:
  - 48 experts from 4 different industries.
  - Each expert was given descriptive data for over 100 systems.
  - For each system each expert estimated probabilities of six or more different types of security events.
- Total: Over 30,000 individual estimates of probabilities
- These estimates included over 2,000 duplicate scenarios pairs.

Comparison of 1st to 2nd Estimates of Cyber risk judgements by same SME



21% of variation in expert responses are explained by *inconsistency.*

(79% are explained by the actual information they were given)

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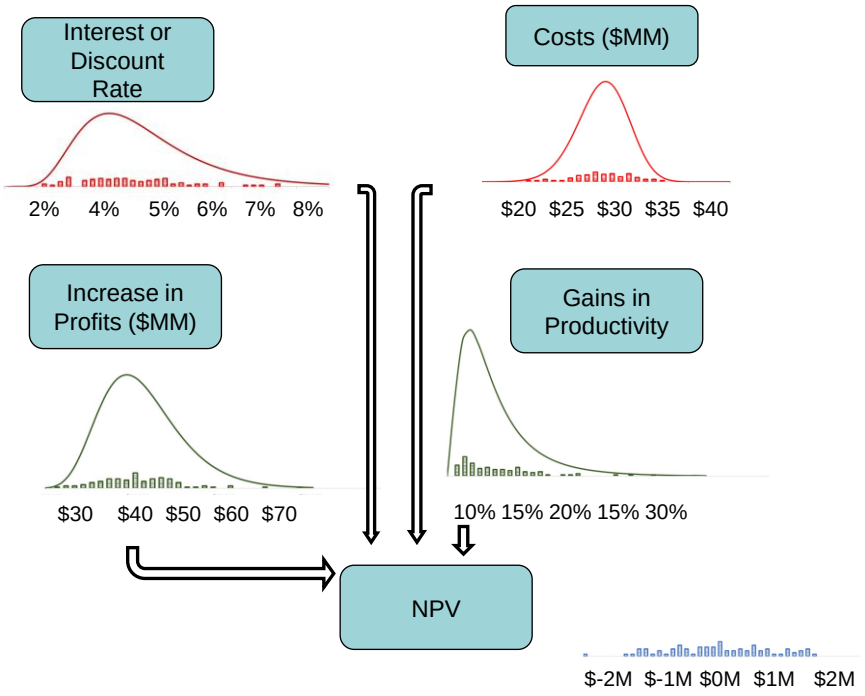
Monte Carlo: How to Model Uncertainty in Decisions



What Published Research Says
(See sources slide for details)

- Psychologists showed that simple decomposition greatly reduces estimation error for estimating the most uncertain variables.
- In the oil industry there is a correlation between the use of quantitative risk analysis methods and financial performance.
- Data at NASA from over 100 space missions showed that Monte Carlo simulations and historical data beat softer methods for estimating cost and schedule risks.

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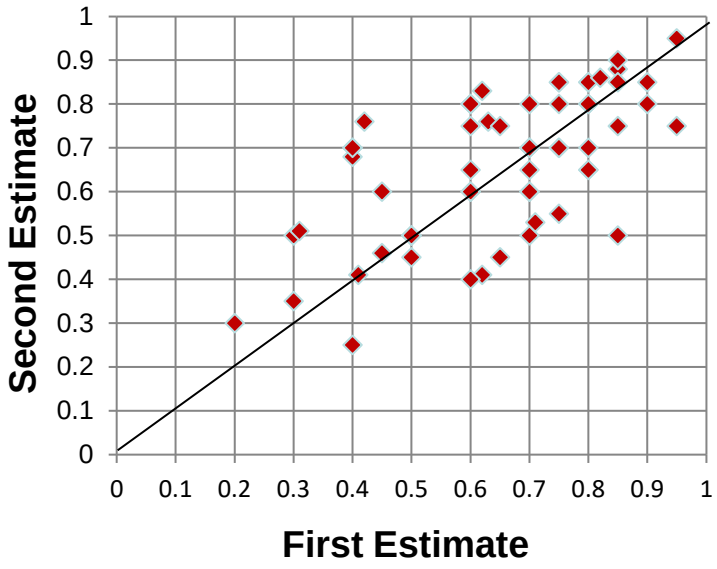
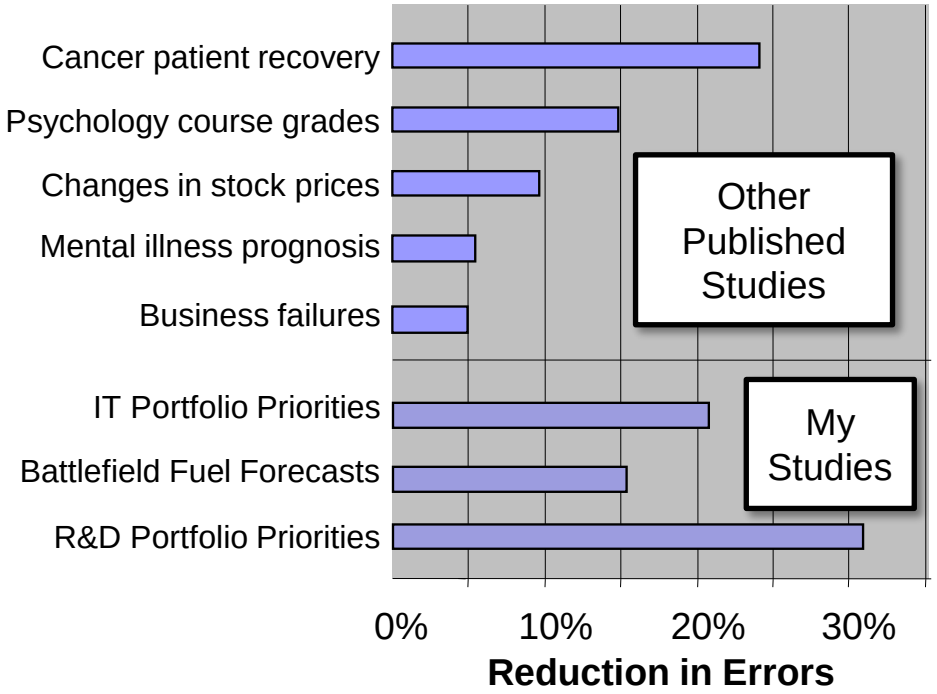
Measuring and Removing Inconsistency

Methods that statistically "smooth" estimates of experts show reduced error in several studies for many different kinds of problems.





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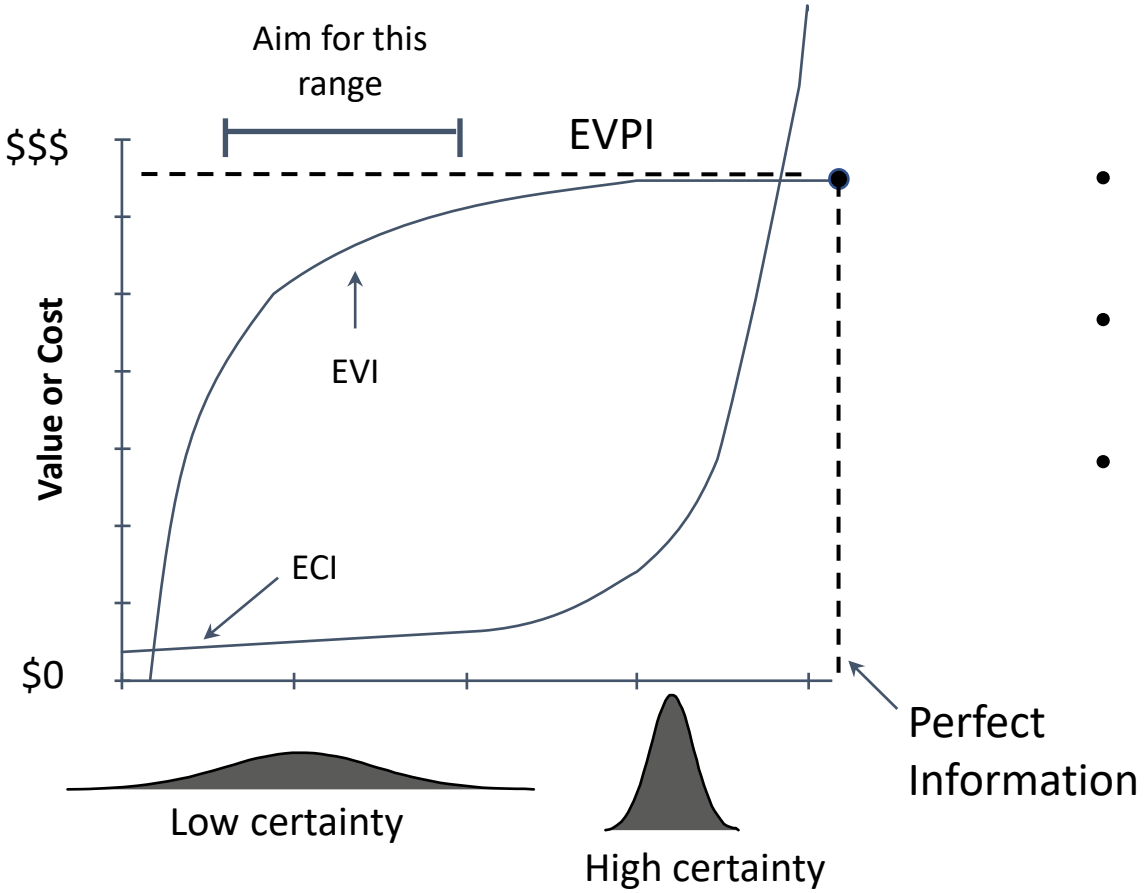
Increasing Value & Cost of Information



- EVPI – Expected Value of Perfect Information
- ECI – Expected Cost of Information
- EVI – Expected Value of Information

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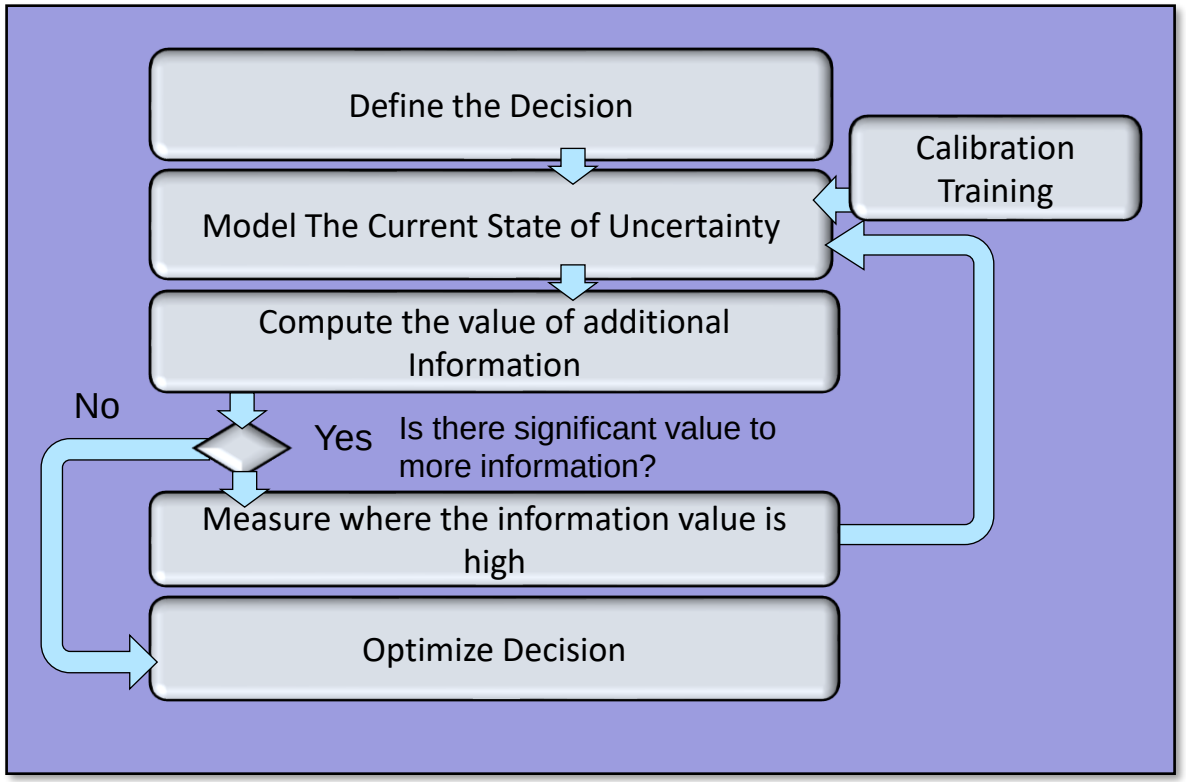
A General Procedure for Measurement

- Measuring Innovation must ultimately support decisions – so let's make that explicit.

- This is a generic decision model for any measurement problem. But the model for the innovation process still has these parts.



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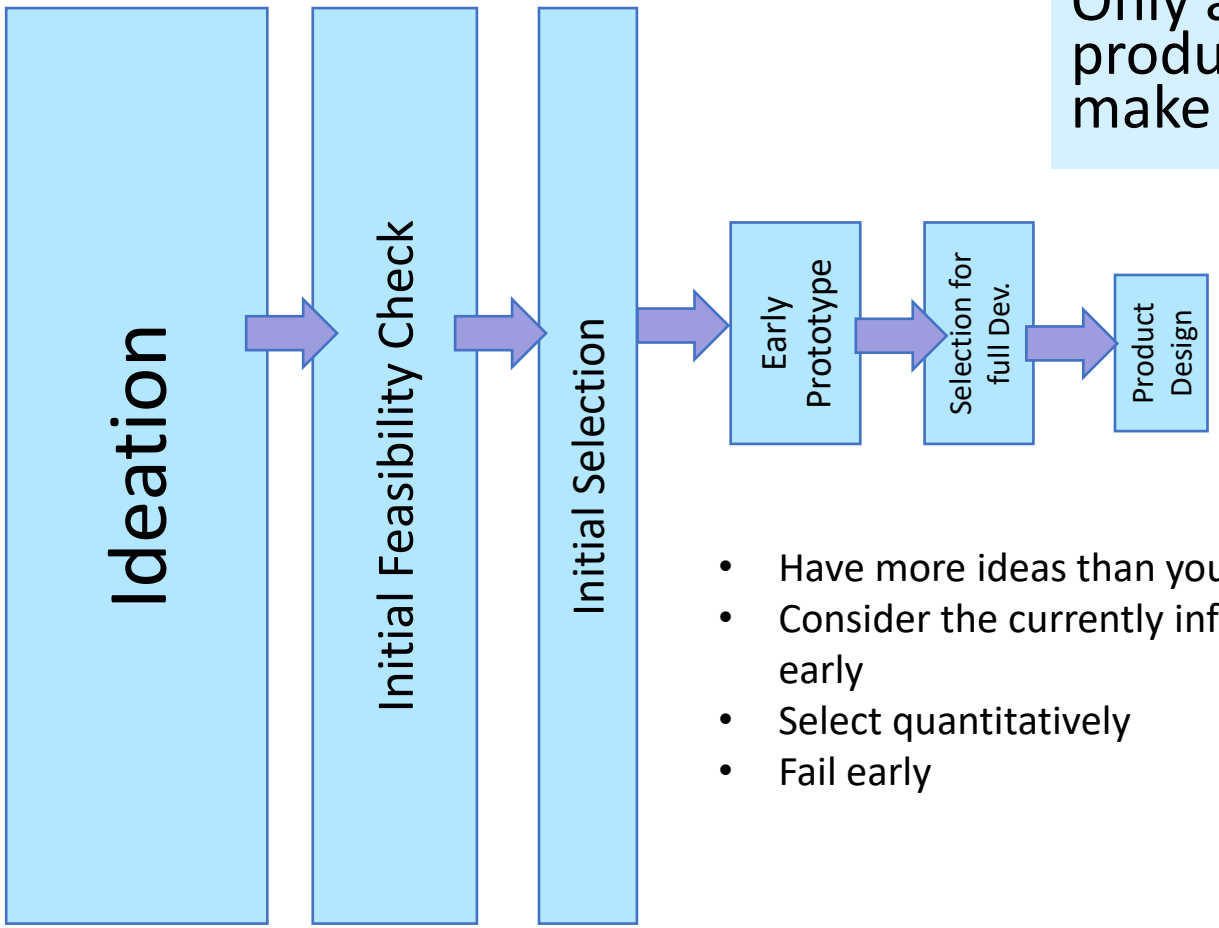
Generate then Filter



Only about 8% of pharma product that start testing make it to market

- Have more ideas than you have resources to pursue
- Consider the currently infeasible - Don't "veto" too early
- Select quantitatively
- Fail early

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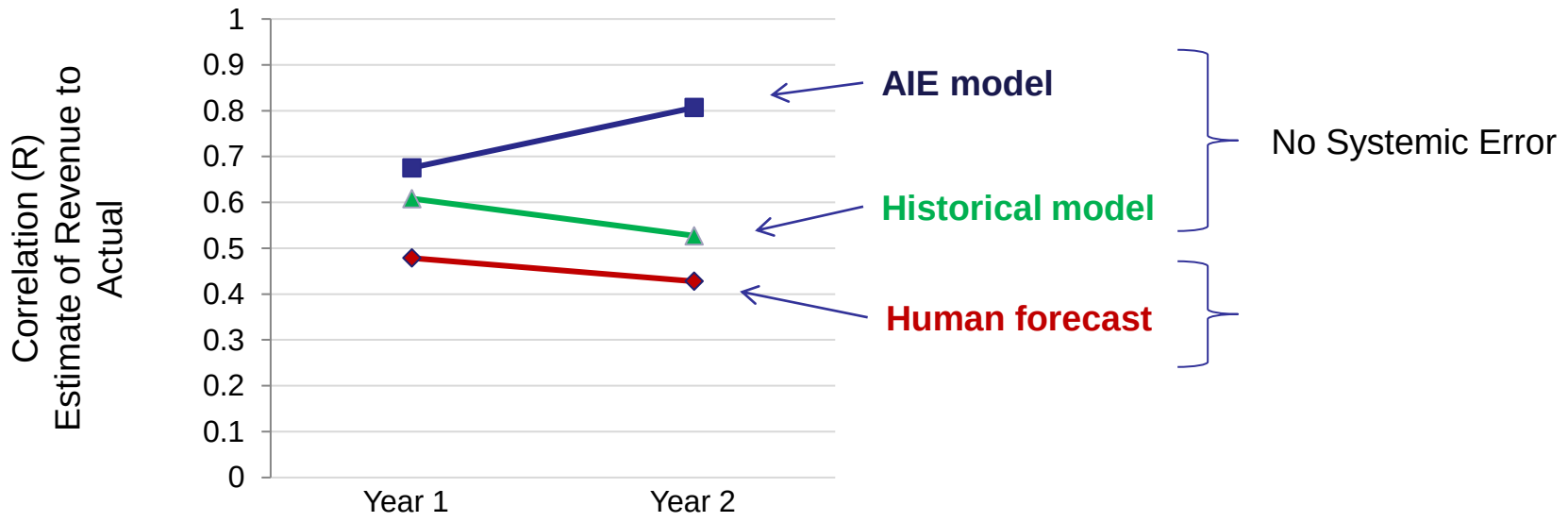
Bad Predictions About Innovations

- **1977:** "There is no reason anyone would want a computer in their home." *Ken Olsen*
- **1981:** *“Cellular phones will absolutely not replace local wire systems.”* — Marty Cooper, inventor.
- **1995:** *"I predict the Internet will soon go spectacularly supernova and in 1996 catastrophically collapse."* — Robert Metcalfe, founder of 3Com.
- **1998:** "By 2005 or so, it will be clear that the Internet's impact on the economy has been no greater than the fax machine's." *Paul Krugman*
- **2005:** *"There's just not that many videos I want to watch."* — Steve Chen, CTO and co-founder of YouTube expressing concerns about his company’s long term viability.
- **2006:** *"Everyone's always asking me when Apple will come out with a cell phone. My answer is, 'Probably never.'"* — David Pogue, The New York Times.
- **2007:** *“There’s no chance that the iPhone is going to get any significant market share.”* — Steve Ballmer, Microsoft CEO.

The Method of Measurement

Case Example for Measuring and Selecting Innovations

- Our client, Life Technologies was forecasting first and second year revenue of new products in the biotech lab equipment industry.
- Their own analysis of our models showed that random error as well as systemic error (constantly overestimating revenue) were reduced.
- Total reduction of error for forecasting revenue was **76%**.



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- Not all R&D expenditure is the same. How much you spend in certain activities and how well you select matter.
- Think about ideation separately from selection, development, and even feasibility assessment. Different teams may be appropriate.
- Premature deselection – dismissals based on overconfident speculation about outcomes - may be a common problem.
- When selection comes, don’t disregard “left field” external developments. Alternative solutions will be developed by competitors – either current or new.

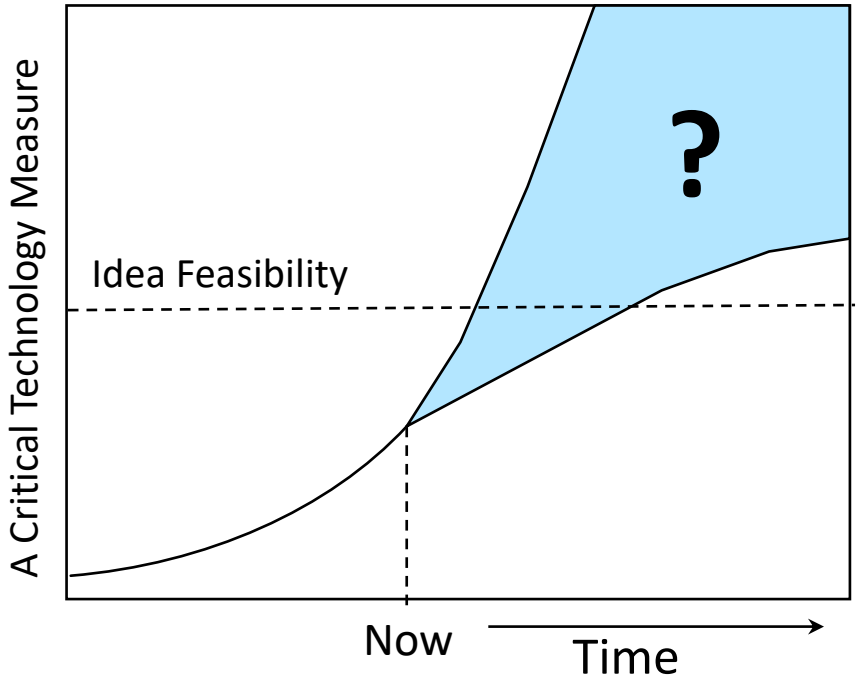
The Method of Measurement

Anticipating Change

"I skate to where the puck is going to be, not to where it has been."*

Wayne Gretzky

- Even though technology change is inevitable it is often not anticipated.
- "Anticipatory Development" may be one method to accelerate the timeliness dimension of innovation.



*Often quoted, poorly sourced, and perhaps frequently overused

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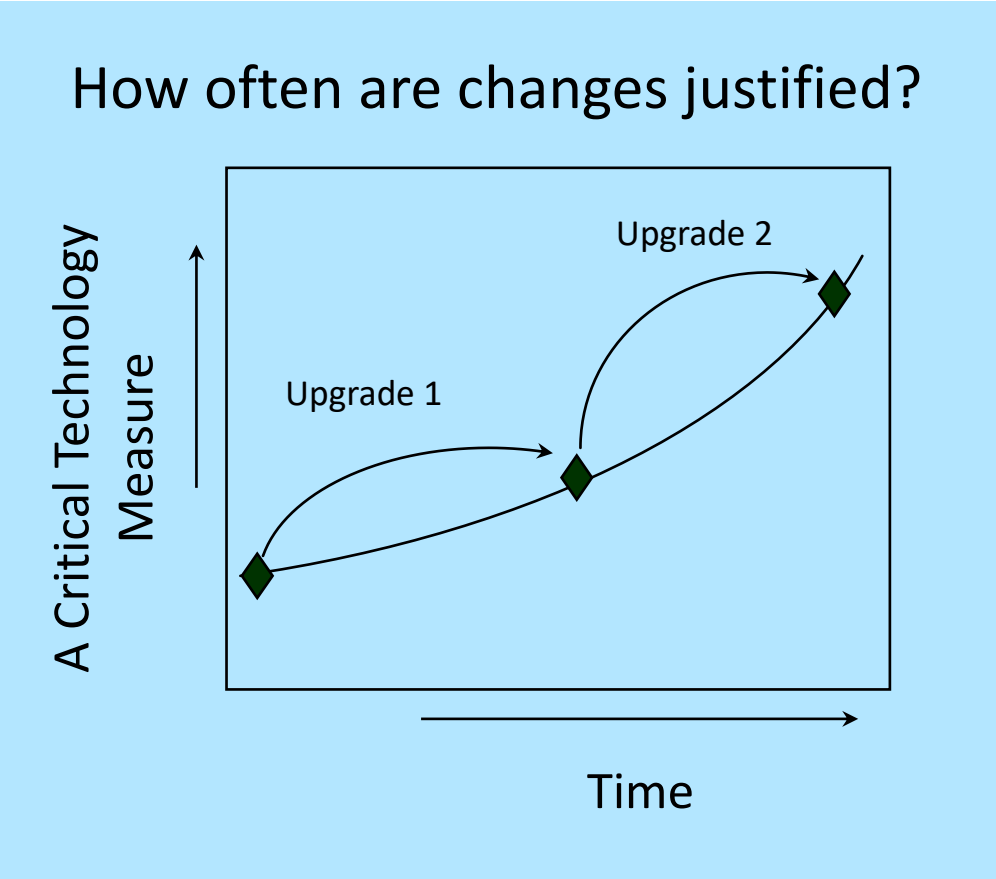
Changing With Technology

- “Technology regret” is the cost of investing too soon.
- Dilemma: Waiting for better, cheaper solutions vs. more immediate benefits of existing solutions
- This can be set up as a type of optimization problem.



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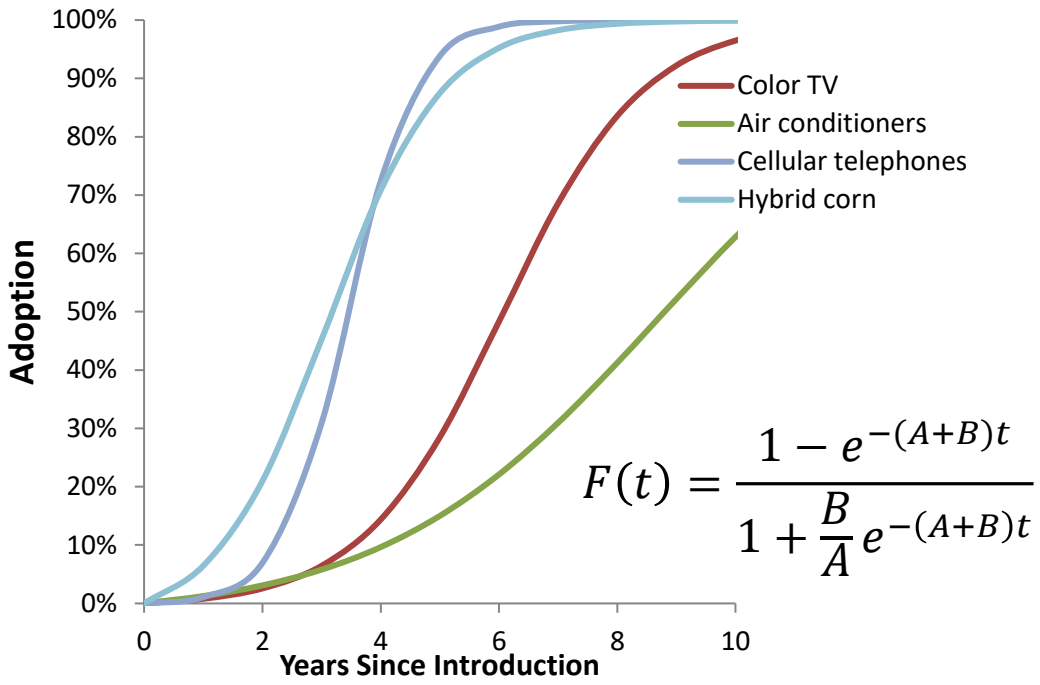
Technology Diffusion

- The market adoption as a function of time since introduction can be modeled with the “Bass Diffusion Model.”
- It uses coefficients for “Innovation” and “Imitation” to fit adoption growth to forecasts or empirical data.
- It is a type of measure of innovation, but in the sense of the willingness to adopt, not the innovativeness of inventors or developers.



$$F(t) = \frac{1 - e^{-(A+B)t}}{1 + \frac{B}{A}e^{-(A+B)t}}$$

t = years since introduction
A = Innovation Coefficient
B = Imitation Coefficient

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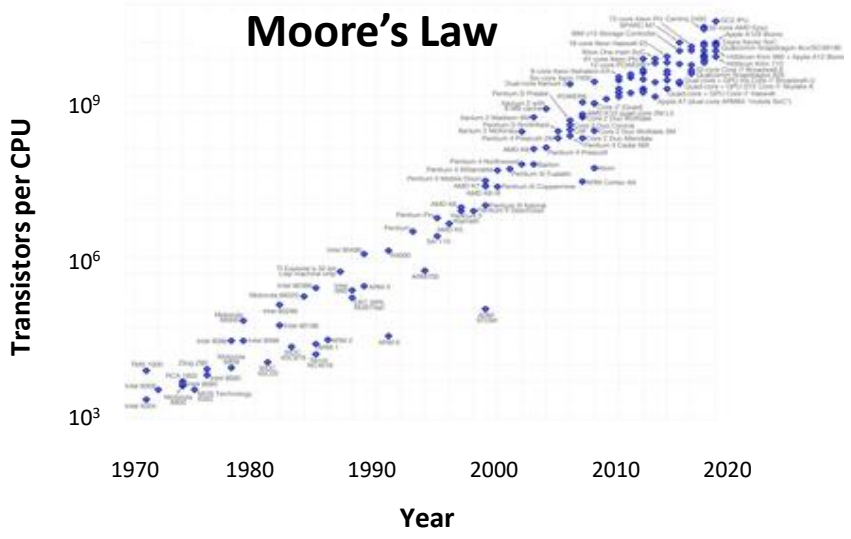
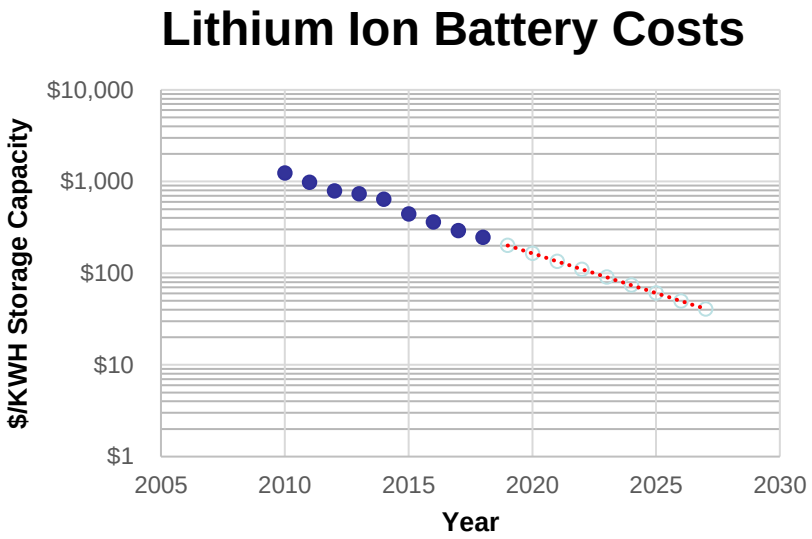
Example: Technology Trends

- Certain technology trends have been very reliable – Moore's Law is only the best known.
- Other consistent trends include: battery energy density, solar cell cost per watt, memory density, bandwidth, population growth, share of population retired, share of population using a technology, tensile strength of materials, etc.



SOURCE: en.wikipedia.org/wiki/Moore%27s_law



SOURCE: about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

The Method of Measurement

Methods: Useful Assumptions

It's Been Measured Before	• Important topics have often been measured already.
You Have More Data Than You Think	• Define a reference class – don't commit the reference class fallacy.
You Need Less Data Than You Think	• Question your intuition about how and whether messy and incomplete data is.

Example Spreadsheets for many of the calculations mentioned can be found at www.howtomeasureanything.com.

Questions?

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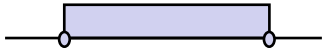
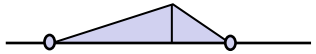
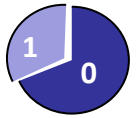
Basic Distributions

Each of these examples can be found on

www.howtomeasureanything.com/cybersecurity

Distributions*	Upper & Lower Bound	Best Estimate
Normal distribution 	Represents the "90% confidence interval"	Always half-way between upper and lower bound
Lognormal distribution 	Represents the "90% confidence interval"; the absolute lower bound of a lognormal is always 0	Always a function of the upper and lower bound
Uniform distribution 	Represents the absolute (100% certain) upper and lower bounds	NA
Triangular distribution 	Represents the absolute (100% certain) upper and lower bounds	Represents the mode; the most likely value
Binary distribution 	NA	Represents the % chance of the event occurring
Beta distribution 	Generates a value between 0 and 1 based on “hits” and “misses”	The mode of a beta is (hits-1)/(hits+misses-2)

*A “●” means a “hard” stop, an “➔” arrow means unbounded

Selected Sources

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- Andreassen, P.” Judgmental extrapolation and market overreaction: On the use and disuse of news” *Journal of Behavioral Decision Making*, vol. 3 iss. 3, pp 153-174, Jul/Sep 1990.
- Williams M. Dennis A., Stam A., Aronson J. “The impact of DSS use and information load on errors and decision quality” *European Journal of Operational Research,* Vol. 176, No. 1, 2007, pp 468-81.
- Knutson et. al. “Nucleus accumbens activation mediates the influence of reward cues on financial risk taking” *NeuroRepor*t, 26 March 2008 - Volume 19 - Issue 5 - pp 509-513.
- A small study presented at Cognitive Neuroscience Society meeting in 2009 by a grad student at U. of Michigan showed that simply being briefly exposed to smiling faces makes people more risk tolerant in betting games.
- Risk preferences show a strong correlation to testosterone levels – which change daily (Sapienza, Zingales, Maestripieri, 2009).
- Recalling past events that involved fear and anger change the perception of risk (Lerner, Keltner, 2001).