



Economics of Technology and the Engineering Career

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Introduction to Economics and Technology

■ Problem

- The central question is how should GOLD members face economic challenges in our modern technology-driven market system?

■ Approach

■ Tools

- The coincidence of technology and economics
- How technology evolves in product markets
- How understanding the market requires embracing irrationality

■ Data

- Employment and economic data analysis
- Experimental data



Technology and Economics



Model of Population Growth

$$\frac{dy}{dt} = R$$

R is the net population growth [number/year]

$$\frac{dy}{dt} = R = ry$$

r is per capita population growth [number/(person/year)]

$$\int_{y_0}^y \frac{dy}{y} = \int_0^t r dt$$

$$\ln\left(\frac{y}{y_0}\right) = rt$$

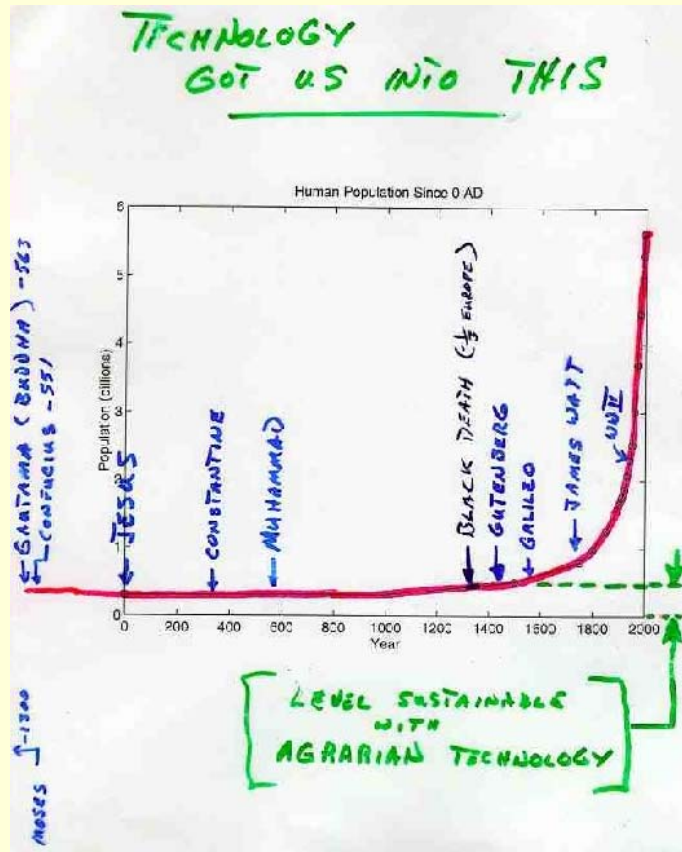
$$y(t) = y_0 e^{rt}$$

Malthus' Law of Growth

- Because Malthus¹ painted a gloomy population prediction of mass starvation, Economics was named "The Dismal Science"
- Technology is the answer, as explained by a Nobel Laureate



Technology as the Solution



Professor Smalley (Rice University), 1996 Nobel Laureate for Chemistry, used a version of Malthus's prediction to promote technology, specifically Nanotechnology²



Redefined Model of Population Growth

$$R = [\ln(K) - \ln(y)]ry \quad K \text{ is the carrying capacity}$$

$$\frac{dy}{dt} = ry \ln\left(\frac{K}{y}\right) \quad \text{Gompertz's ODE, } y < K$$

$$\int_{y_0}^y \frac{dy}{y \ln\left(\frac{y}{K}\right)} = -\int_0^t r dt$$

Let $u = \ln\left(\frac{y}{K}\right)$, then $du = \frac{1}{y}$ and left integrand becomes $\int_{u_0}^u \frac{du}{u} = \ln u - \ln u_0$, so

$$\int_{y_0}^y \frac{dy}{y \ln\left(\frac{y}{K}\right)} = \ln\left[\ln\left(\frac{y}{K}\right)\right] - \ln\left[\ln\left(\frac{y_0}{K}\right)\right] = \ln\left[\frac{\ln\left(\frac{y}{K}\right)}{\ln\left(\frac{y_0}{K}\right)}\right]$$

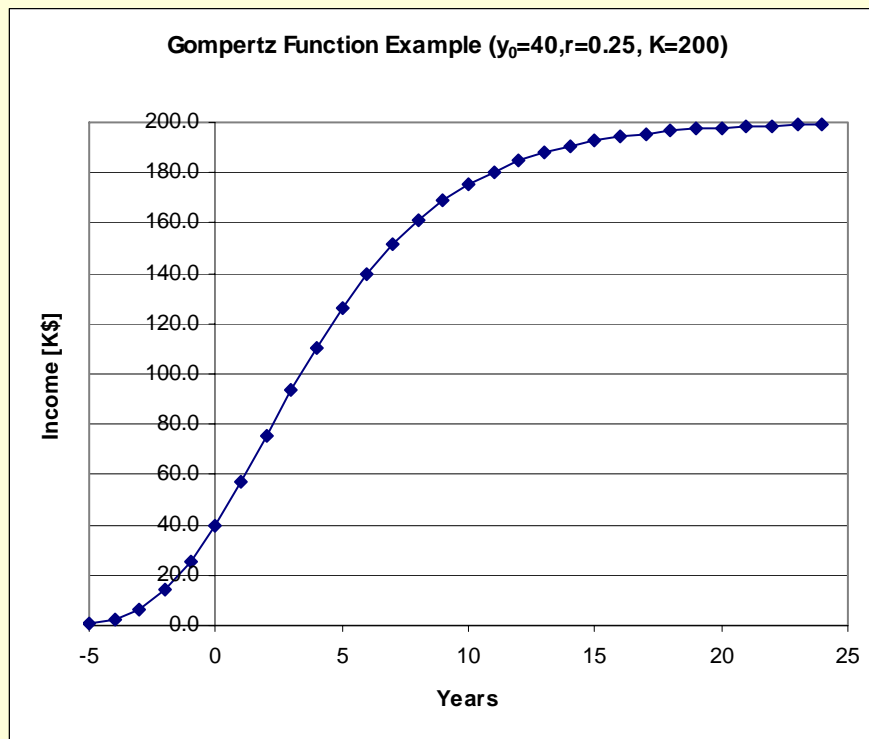
$$\ln\left[\frac{\ln\left(\frac{y}{K}\right)}{\ln\left(\frac{y_0}{K}\right)}\right] = -rt, \quad \text{exponentiating gives } \frac{\ln\left(\frac{y}{K}\right)}{\ln\left(\frac{y_0}{K}\right)} = e^{-rt}$$

$$y(t) = Ke^{\ln\left(\frac{y_0}{K}\right)e^{-rt}} \quad \text{The Gompertz equation}$$



Example of Gompertz Equation (in Finance)

- Let y be income [dollars], t time [years], K be limiting income
- And set r at 25% per year ($r = 0.25$)





Technology and Product Evolution

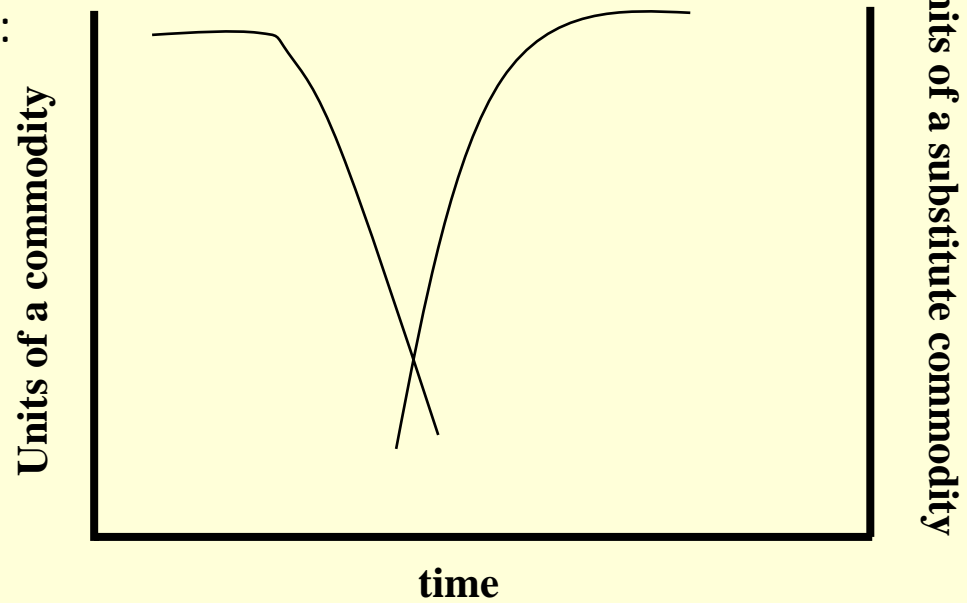


Economics: Technology Shocks and Diffusion

- Technology shocks create business cycles (Kondratieff cycles)³
- It takes time for acceptance of new technology, “diffusion”⁴
- Old technology declines with the rise of the new technology

Examples of Substitute Technologies:

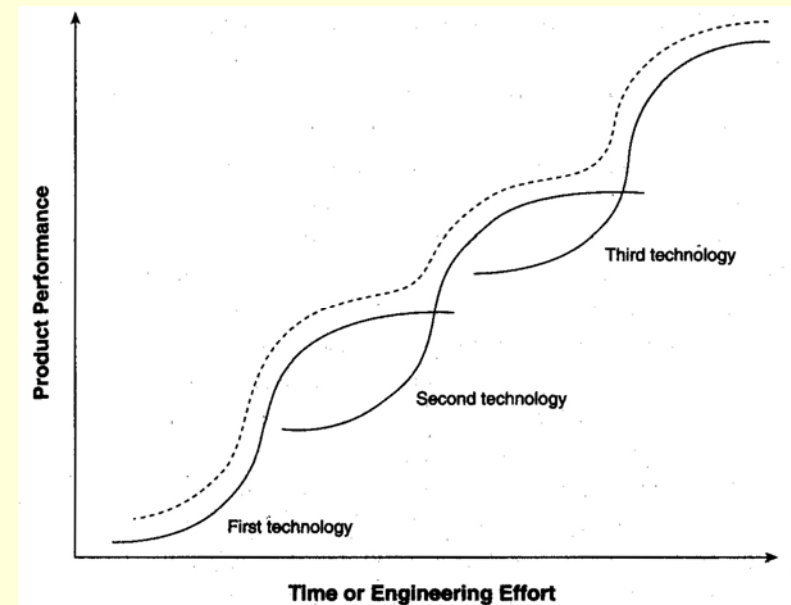
- horses → automobiles
- slide rule → calculator
- floppy → flash memory





Technology Trends (curves within curves)

- Once new technology creates new markets, new inventions come along that are substitutable for the previous technologies; this sequence of inventions can be viewed as a mathematical progression or, more appropriately, as a series of superimposed Gompertz curves
 - In business school jargon, these are called “S curves”
 - Prof. Christensen⁵ pointed out that these cycles defy what managers often think of as “good management” such as the mantra “being close to the customer”





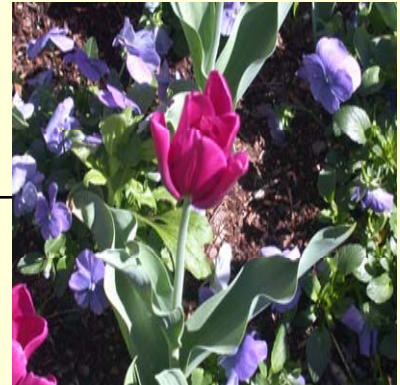
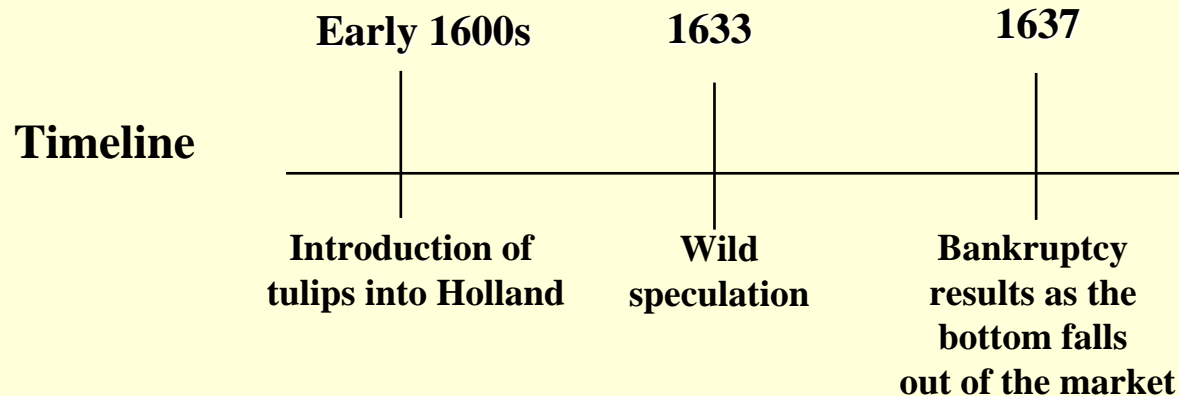
The Influence of Business Cycles on Technical Jobs



Market Psychology: Speculation

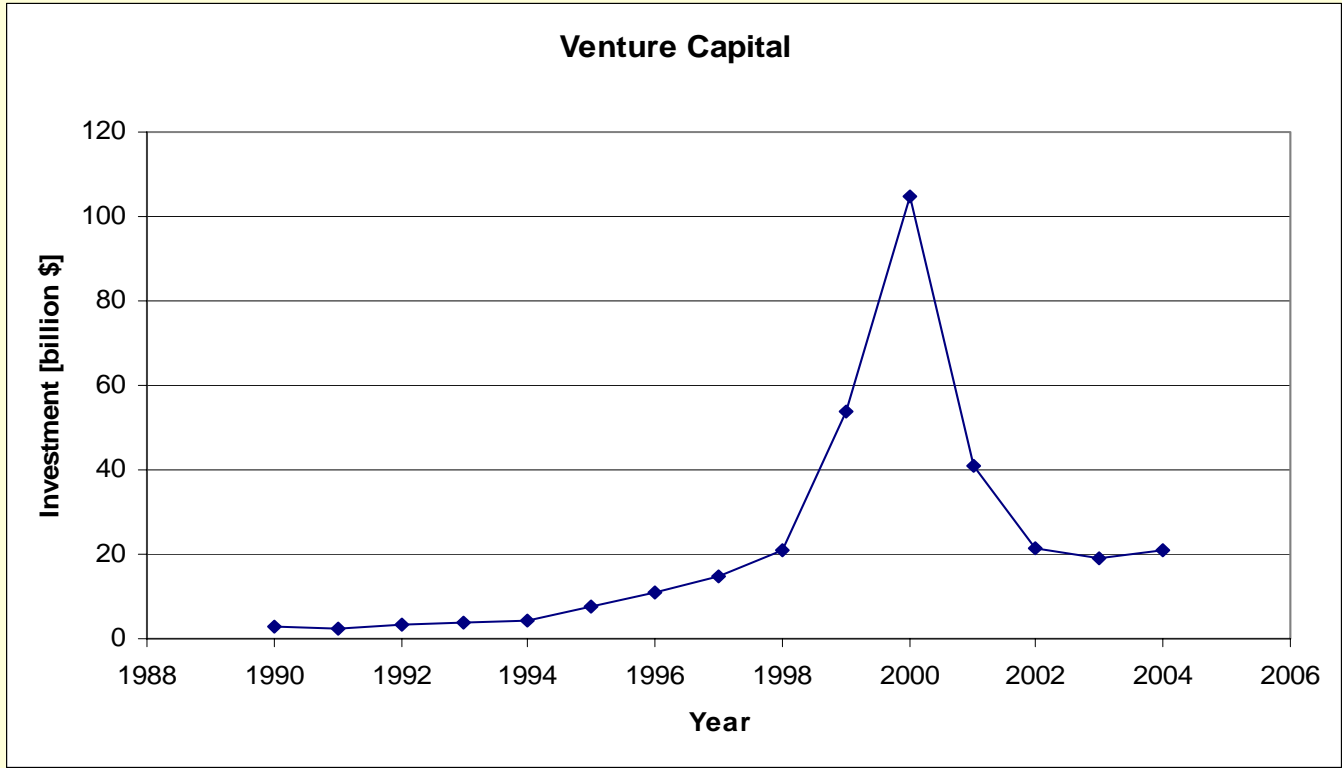
■ Business Speculation

- The boom and bust cycle created by speculation is not studied in engineering school
- An early historical example of speculation is the growth of the tulip trade in Holland at the end of the 17th century⁶
- Recent technology speculation has been captured in “Gartner’s Hype Cycle of Emerging Technology”⁷





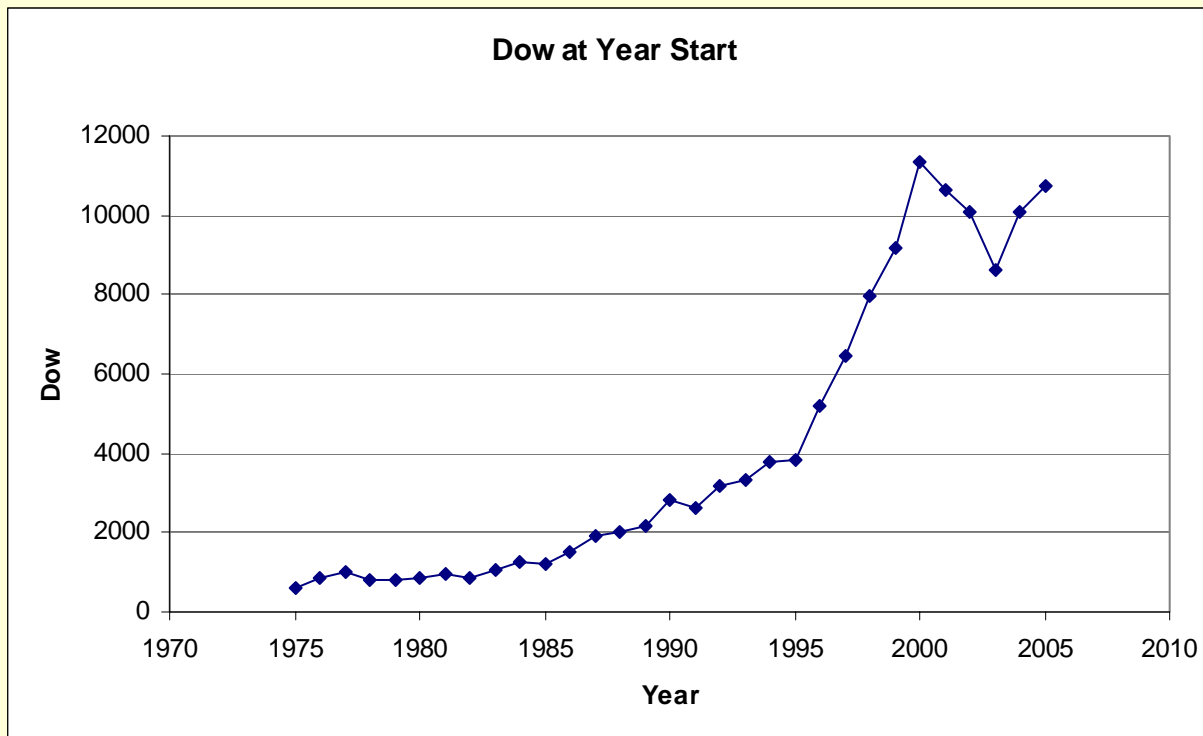
Venture Capital Investment



Internet bubble 1998 to 2000⁸



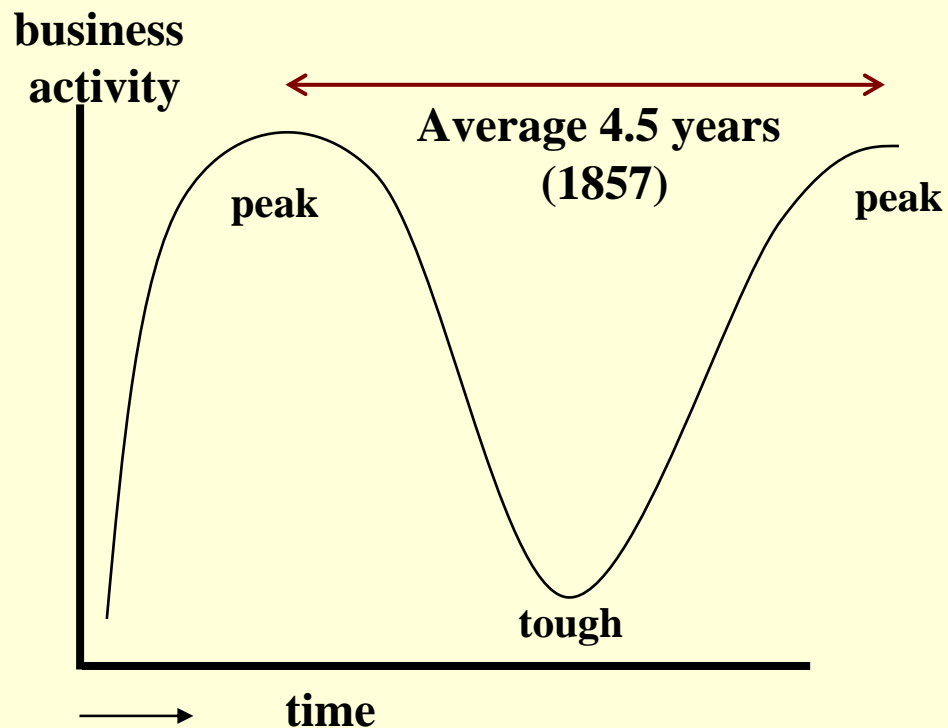
The Dow Jones Average



The Dow reflects the boom-bust of the internet bubble; the Dow had been almost monotonic for decades until 2000



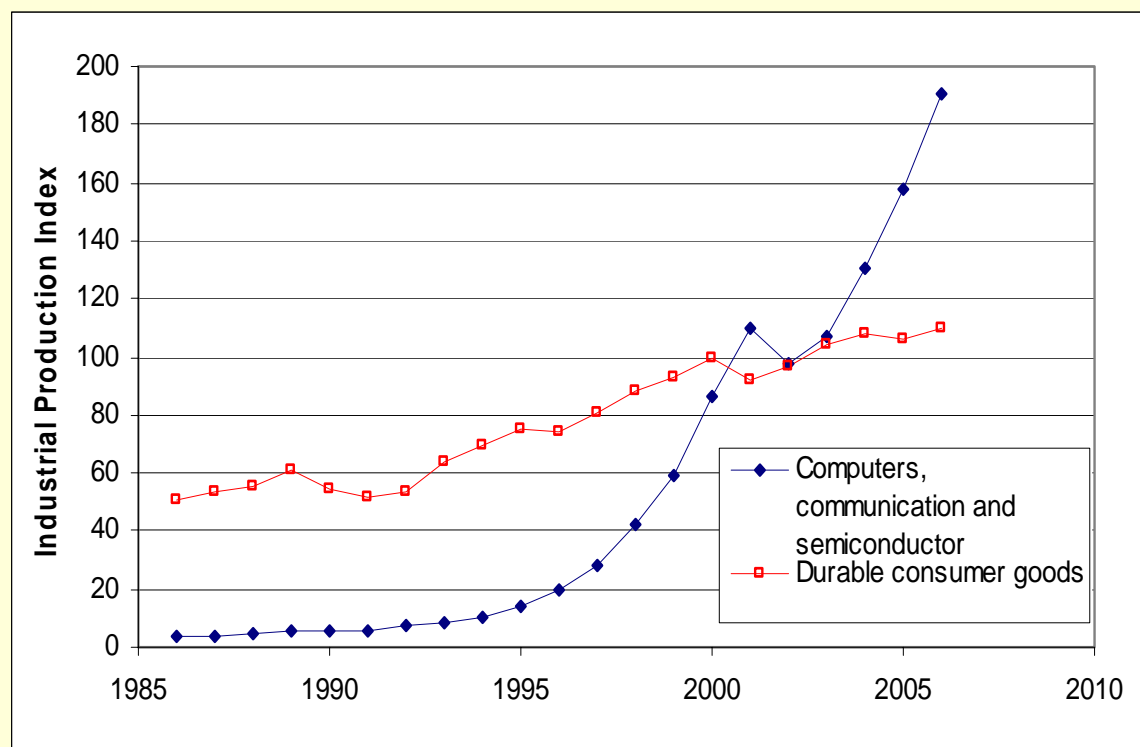
Business Cycles



- There have been 32 business cycles in the U.S. since 1854 and 10 business cycles since WWII⁹
- In 2003, EE unemployment reached 6.7% due to a downturn in the business cycle¹⁰



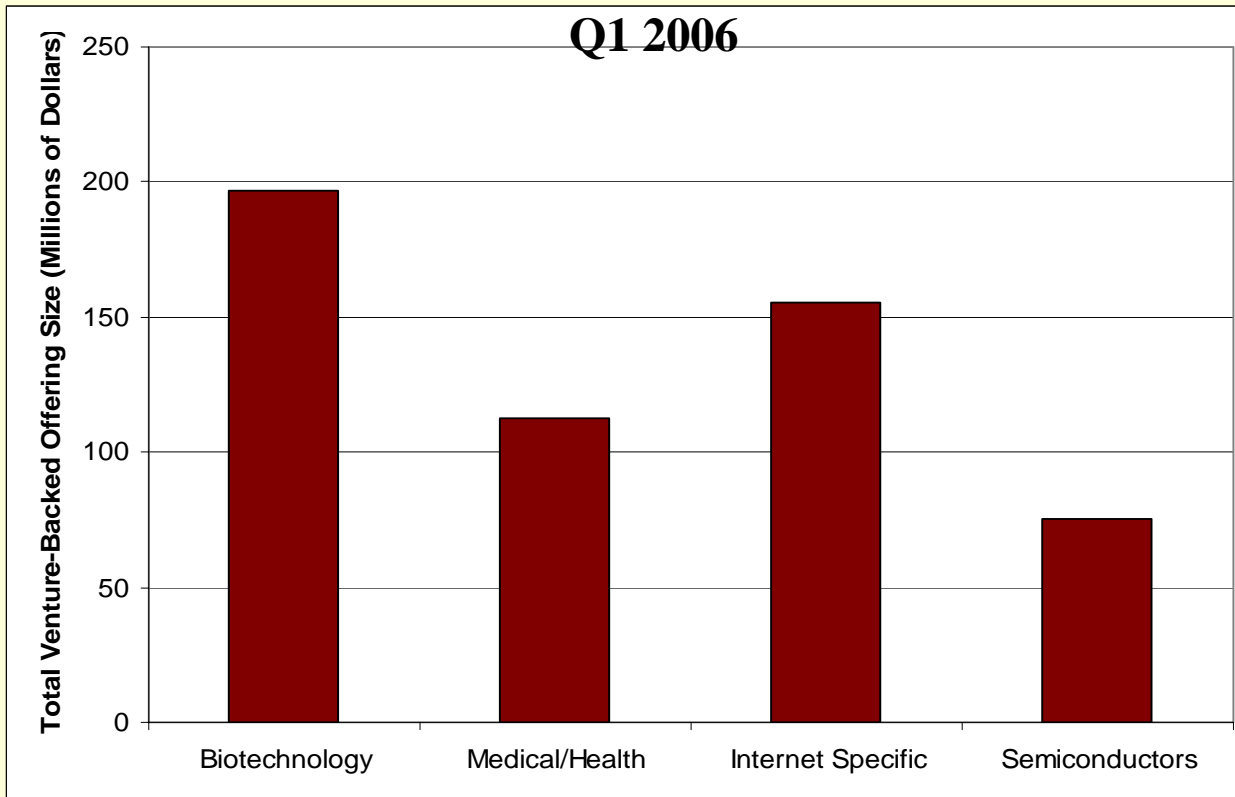
Business Cycles, Leading Indicators



Various indicators can be used to predict the direction of the business cycle; some are more effective than others ¹¹



Areas for Concentrated Venture Capital Spending



Venture Capital Funding Today¹²



Engineering Job Market



Topics in Engineering Salaries

- **Engineering salaries are plotted on the following slide by discipline**
 - The salaries are contrasted to a Family Practice MD which almost overlies the compensation of “executives;” the explanation for the difference in compensation is multifaceted, but one underpinning reason for the difference is the number of medical doctors in private practice
 - However, this is a snapshot in time; may the difference decrease as HMOs become more prevalent?
- **Salary observations related to employer size**
 - Larger employers appear attractive due to the perception of job security; however, there are trade-offs
 - Long term engineering employees in large firms sometimes suffer “salary compression” defined as the narrowing pay differentials between new people and senior people
- **A personal salary history**
 - I am going to be bold and plot my normalized salary history for 30 years



Business Cycle Indicators: Supply Changes

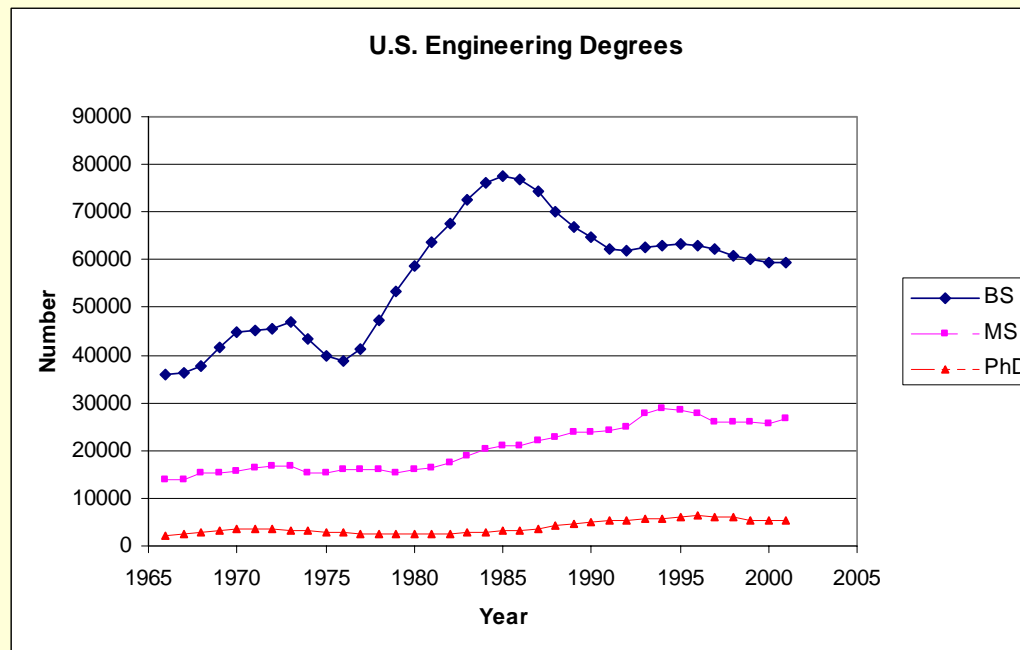
- **The higher the degree of attainment the lower the anticipated unemployment**
 - It is believed that the higher the level the degree of education attainment the less susceptible to changes in the business cycle
 - However, “white collar engineers” are not immune





US Engineering Degrees

- Graduation trends plotted below¹⁴



- The increasing percentage of graduates are foreign nationals and who return home after graduation?
- Will baby boomer retirements create a shortage of engineers?



Engineering Starting Salaries

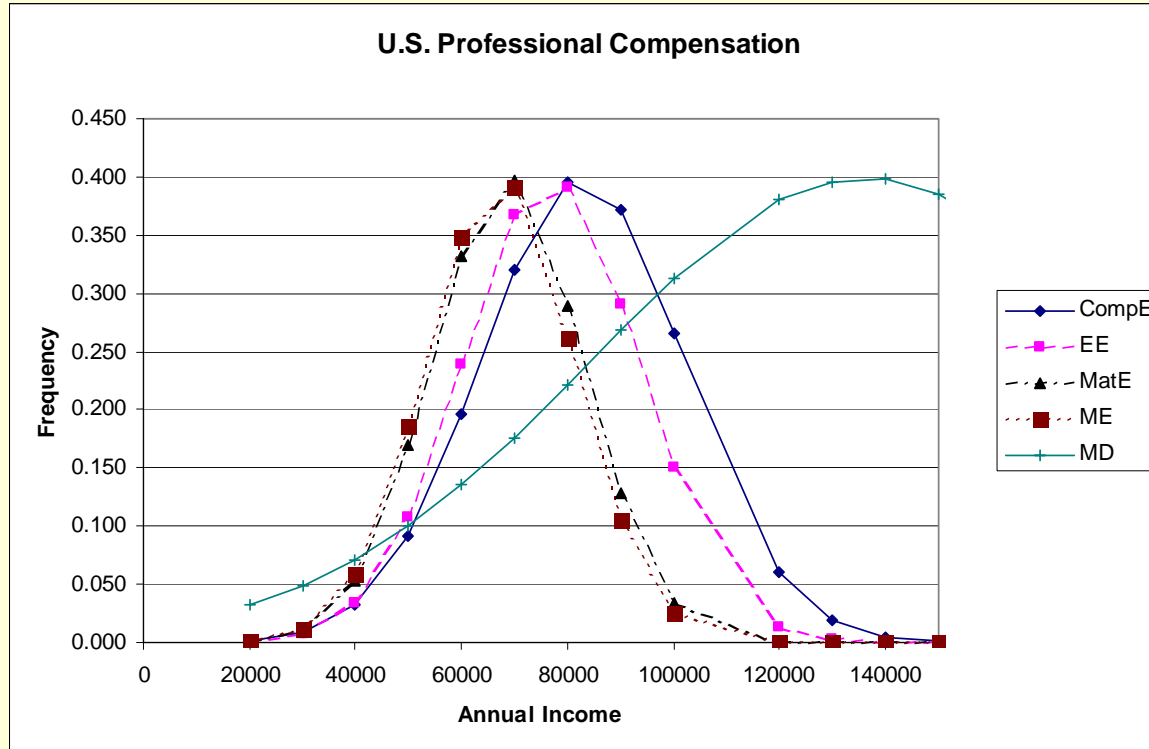
- Salaries decreasing for graduates from 2000 to 2001¹⁵

Engineering Field	Graduation (BS)	
	2000	2001
Aerospace	51	46
Chemical	55	50
Civil	45	44
Electrical	55	51
Mechanical	52	46



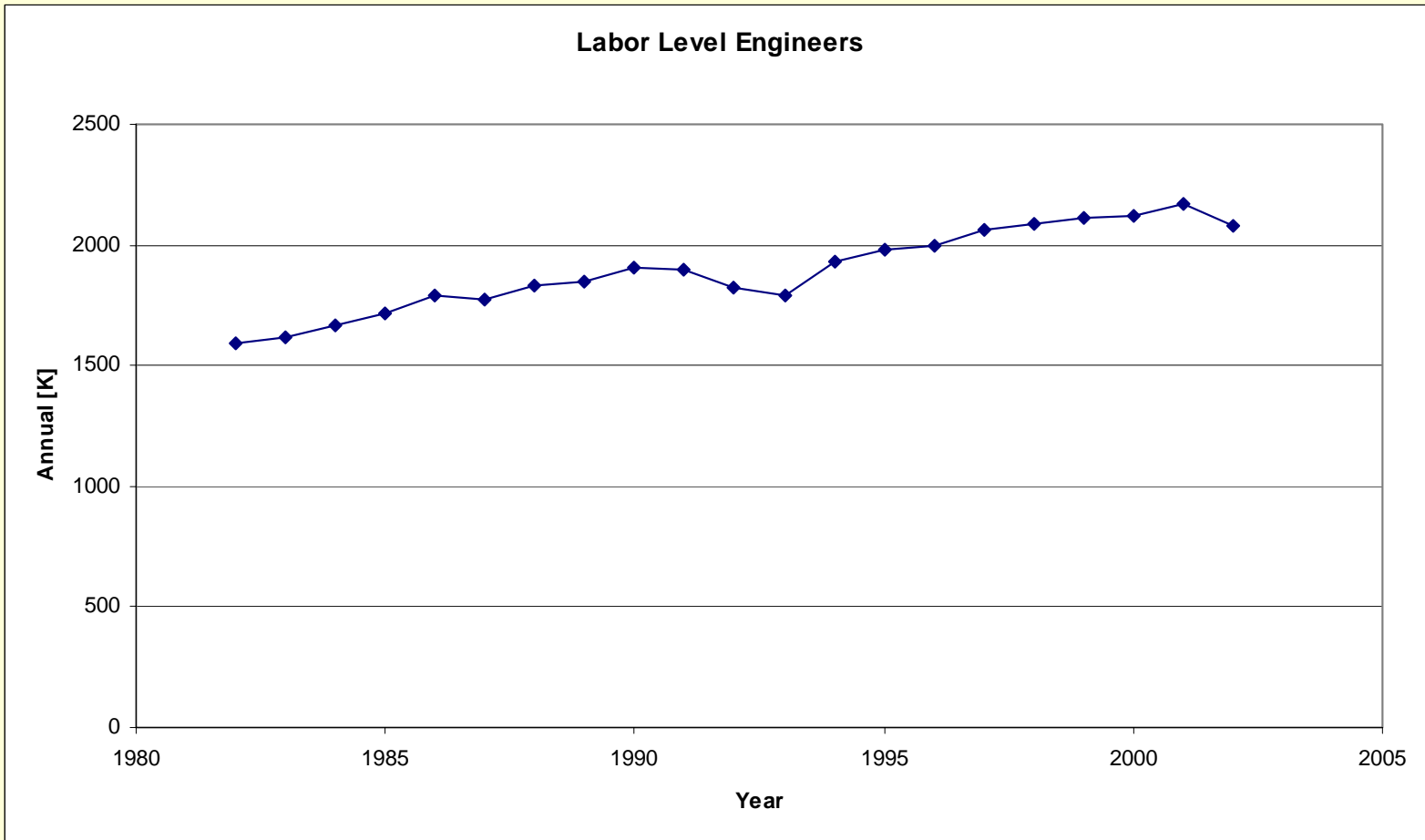
Engineering Wages versus Professional

- A wise man sets expectations consistent with observations¹⁶



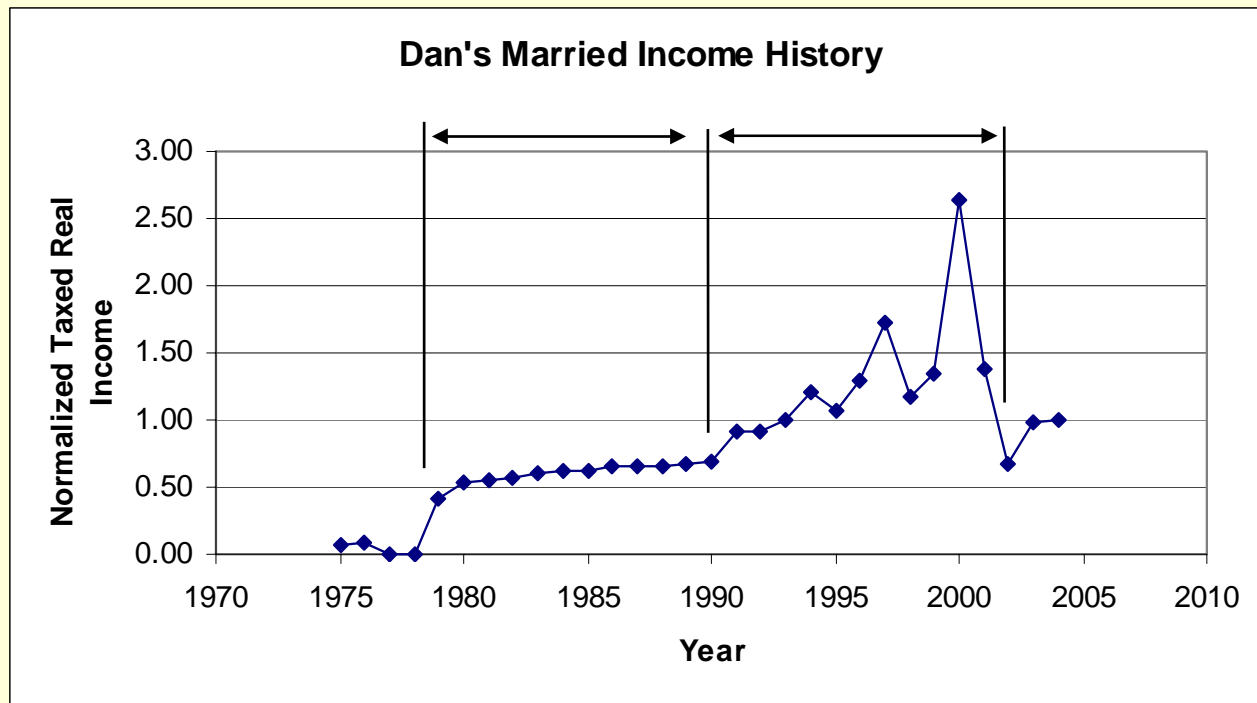


Number of Employed Engineers in US¹⁷





One Person's Story

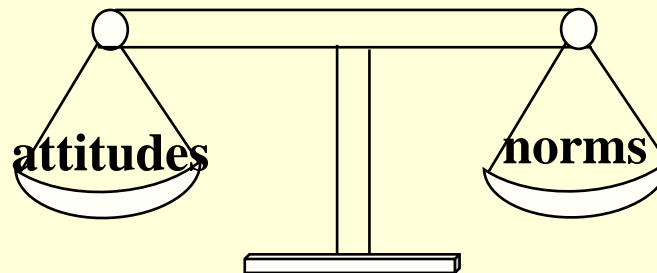


- **Income from taxes for two main employment periods**
 - Defense related electronics and commercial electronics
 - Two different slopes with different volatilities
 - But I'm still married



Psychology of Picking a Career

- **Why do people pick an engineering career over other alternatives?**
 - One reason lies in psychology: People balance their attitudes (beliefs about outcomes) and internalized norms (societal expectations) to determine shape their intentions and, thereby, their behavior
- **What should a reasonable person do in making career decision?**
 - The best simple metric is the one proposed by social scientists: minimization of regret¹⁸





Summary

- A poem by Richard Hodgetts quoted by Norman Augustine before the Committee on Science, Engineering and Public Policy of the US Congress in Oct. 2005¹⁹

*Every morning in Africa a gazelle wakes up.
It knows it must outrun the fastest lion or it will be killed.*

*Every morning in Africa a lion wakes up.
It knows it must outrun the slowest gazelle or it will be starve.*

*It doesn't matter whether you're a lion or gazelle-
when the sun comes up, you'd better be running.*



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