Tech performance and adoption

Includes notes on:

Final projects, library research
Diffusion/adoption decisions
Financial analysis including option value
Tech life cycles and performance over time.

Roger Bohn

May 2017

- Final Paper and Presentation (40%): Final projects will analyze a situations where the nature of jobs and work has changed or will change. Your analysis can be mainly retrospective; explaining and analyzing how work evolved, and why. Alternatively, it can be prospective: current situation and analyzing likely future developments. Discuss both the technical requirements that must be met for change, and how the work system itself changes.
- The goal is to provide an in-depth analysis of a situation where the nature of work may change as a result of new technology. Projects must consider both the work and the technology. How can automation enhance the product or service?
- Projects can be retrospective or prospective, but must analyze the current state of work and technology in either case.
- You can analyze as a **business case**, a **public policy** issue, or an economic analysis. Economic analysis will require tools not taught in this course.
- A detailed outline and list of sources is due in week 7.
- Final reports should be at most 30 pages in length, excluding appendices.
- **Research sources**: Your project should demonstrate an ability to use a variety of sources and methods, both quantitative and qualitative. Your sources must include at least one of each of the following: interviews with experts, academic books, academic articles, business (trade) press, social science academic articles about the technology, and engineering articles about the technology. Quality of sources is very important. The best sources are generally not available on the open Internet. New technologies are always accompanied by uncertainty and controversy, and much of the material turned up in casual Google searches consists of thinly disguised press releases. Understand the biases, backgrounds, and expertise of all of your sources.

Your actual projects are 80% "techno glory." *Visionary, big technical shifts*

- Augmented reality in fashion. Trying on clothes w.o. clerks. (Ashlee + Jennifer)
- Music composition (Julian)
- Autonomous vehicles Keiji; Taxis Bernardo
- Elderly care assistance (Maya)
- 3D modeling in surgery (Keke)

Typical outline: case study

- The technology
  - How it works. How users use it.
  - How will it be better, how worse? For who? How it assists/empowers its users.
  - What is the evolution/breakthrough that makes it possible. (Why not 10 yrs ago?)
- The function if affects (usually not an industry). E.g. delivering
  - What and how it alters the nature of what people do.
  - Financial evaluation
- How it affects larger contexts (eg alters supply chains, ecosystems, business models)
  - Effects on industries that use it, e.g. shift in scale,
  - Long terms effects e.g. skills needed, overall employment levels.
- Timing and risks
  - What segments will make the shift first? (e.g. types of surgery, delivery)
  - What technical problems have to be solved? What business problems?
  - Project a timetable
  - Long term: if this succeeds, where will it go next? (2030)

Other comments about projects

- Have a target audience in mind.
  - Could be quite a narrow audience, e.g. community colleges;
  - The report is also being read by a geek, so don't skimp on technology issues.
- Don't be seduced by flacks and investors. What are contrarian and independent analysts saying? Where are the bodies buried? (Remember Theranos!)

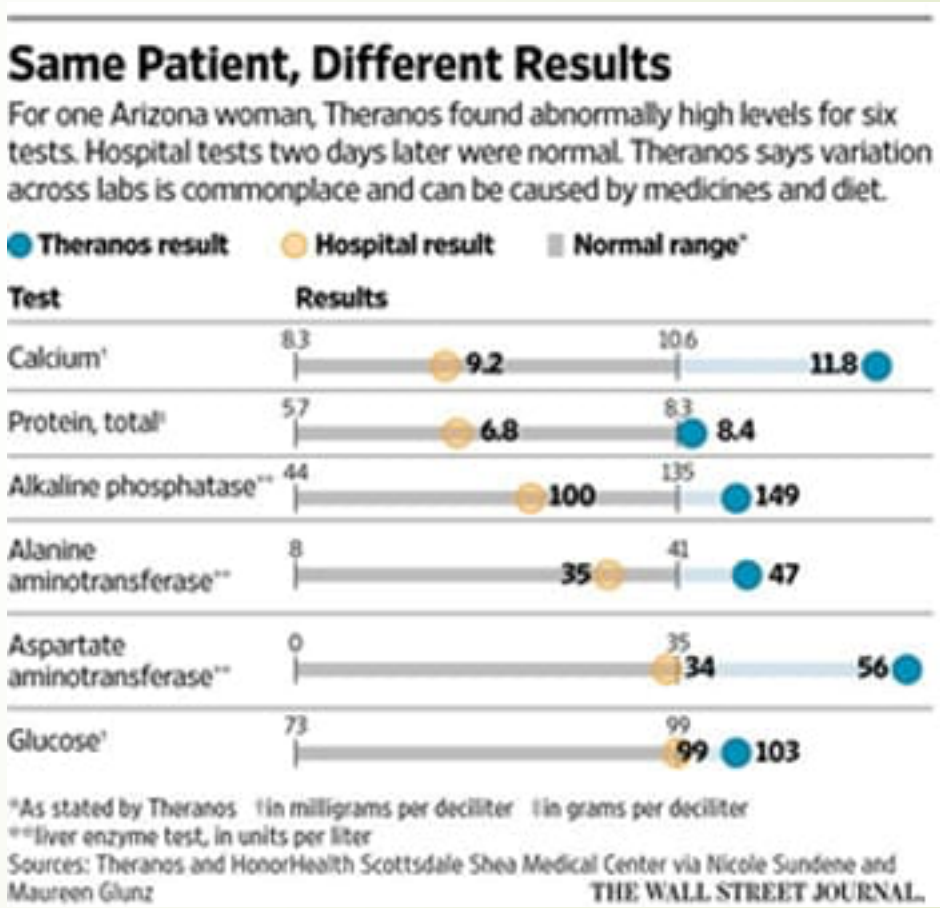
Elizabeth Holmes

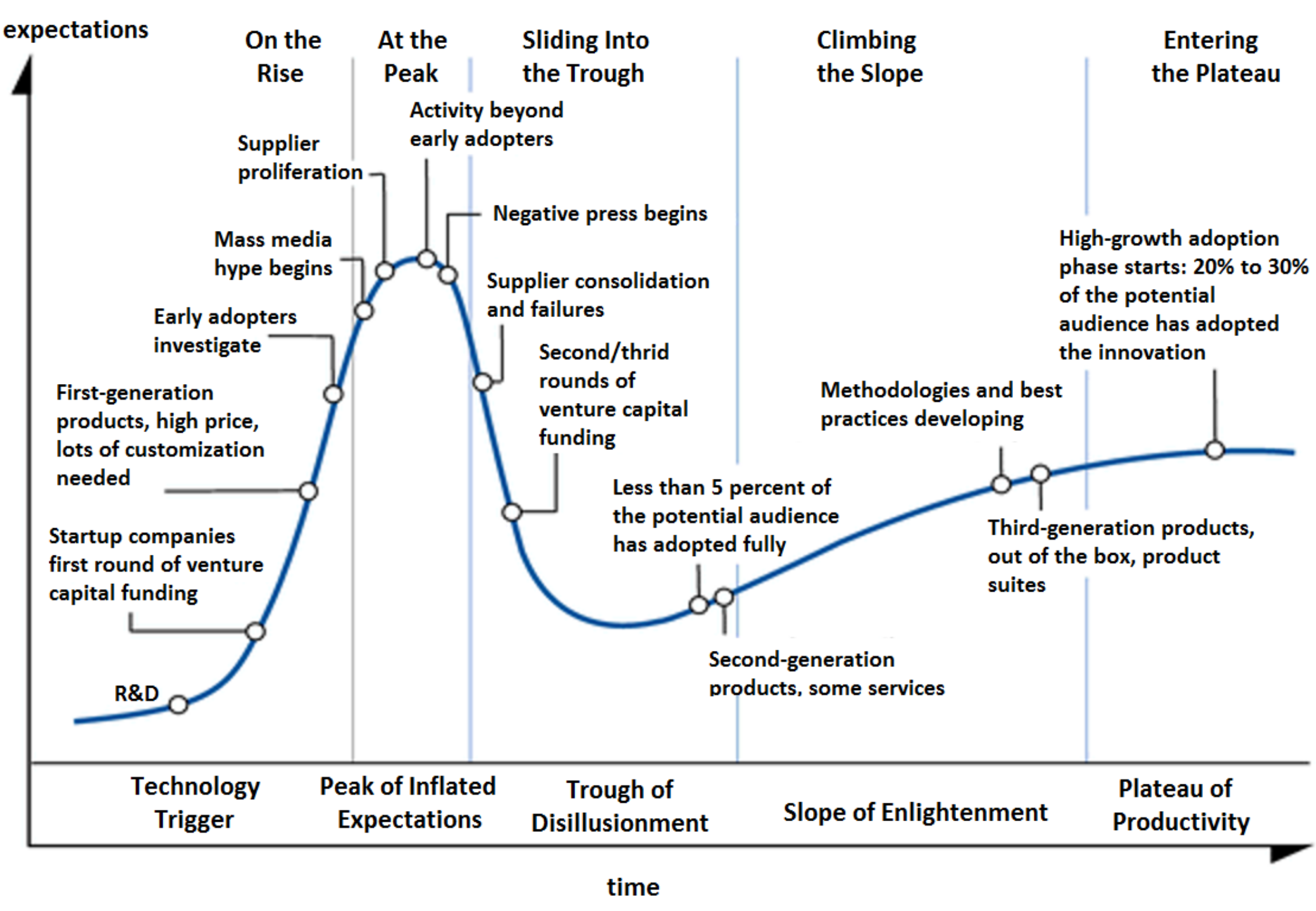
It's hard to overestimate the potential benefit of what Elizabeth Holmes has developed with her tech company Theranos. Blood tests cost hundreds, if not thousands, of dollars. At Theranos, a complete blood count and electrolyte test, taken by a single finger prick, costs $10.17. Her goal? To democratize health care. Turning a blood test into an inexpensive, accessible and even (almost) pleasant experience — rather than an expensive, dreaded and time-consuming procedure — makes people more likely to get tested. As a result, medical problems can be identified earlier, enabling the prevention or effective treatment of diseases ranging from diabetes and heart ailments to cancer.

Holmes, 31, has always been a bit of an outlier. As a child, she studied with a tutor to become fluent in Chinese. She applied for her first patent at 19, a wearable patch to help administer drugs and monitor variables in one's blood while adjusting the dosage as needed. (She currently has 27 U.S. patents in her name.) Since dropping out of

A Revolutionary Piece Of Medical Tech Was A Weird Disaster Built On Lies

The end of disease is the golden chalice of Futurism. So when a company claims to have made a giant leap forward in the field of medicine, we all eagerly perk our ears and listen. That was the case with Theranos, a company that was going to **revolutionize health care**. But the company's founder faced one minor obstacle: Her entire empire was built on a childlike lie.




expectations
On the Rise
At the Peak
Sliding Into the Trough
Climbing the Slope
Entering the Plateau
Activity beyond early adopters
Supplier proliferation
Negative press begins
Mass media hype begins
Supplier consolidation and failures
Early adopters investigate
Second/thrid rounds of venture capital funding
First-generation products, high price, lots of customization needed
Methodologies and best practices developing
High-growth adoption phase starts: 20% to 30% of the potential audience has adopted the innovation
Less than 5 percent of the potential audience has adopted fully
Startup companies first round of venture capital funding
Third-generation products, out of the box, product suites
R&D
Second-generation products, some services
Technology Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time

AUG 21, 2016 @ 12:38 PM 74,859 The Little Black Book of Billionaire Sec

Gartner Hype Cycle For Emerging Technologies, 2016 Adds Blockchain & Machine Learning For First Time

Louis Columbus, CONTRIBUTOR

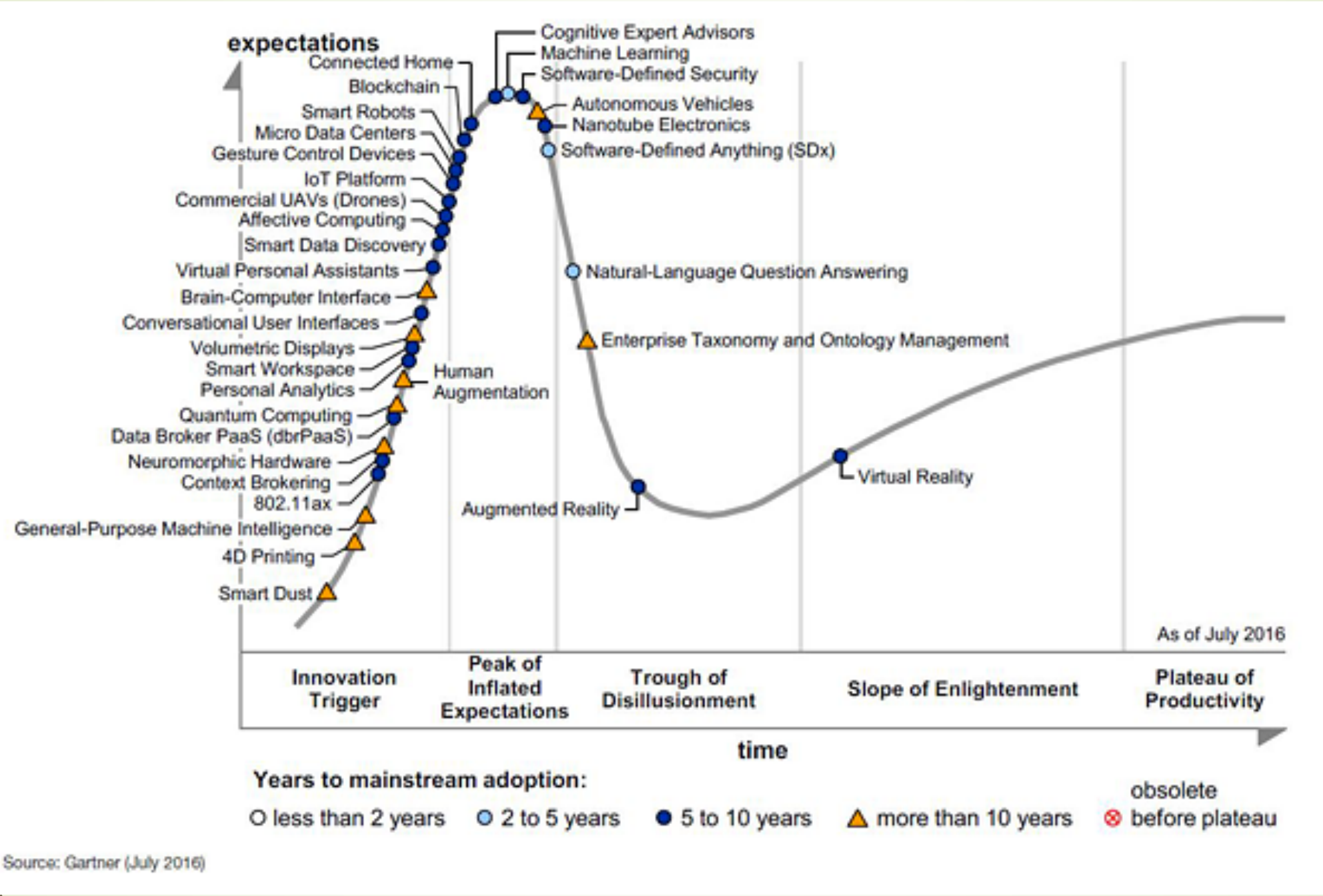
I cover CRM, Cloud Computing, ERP and Enterprise Software FULL BIO

Opinions expressed by Forbes Contributors are their own.

TWEET THIS

Gartner added 16 new technologies to the Hype Cycle this year, including blockchain, machine learning, general purpose machine intelligence, smart workspace for the first time.

Smart machine technologies will be the most disruptive class of innovations over the next 10 years due to their computational power, scalability in analyzing large-scale data sets, and rapid advances in neural networks.


expectations
Connected Home
Blockchain
Smart Robots
Micro Data Centers
Gesture Control Devices
IoT Platform
Commercial UAVs (Drones)
Affective Computing
Smart Data Discovery
Virtual Personal Assistants
Brain-Computer Interface
Conversational User Interfaces
Volumetric Displays
Smart Workspace
Personal Analytics
Quantum Computing
Data Broker PaaS (dbrPaaS)
Neuromorphic Hardware
Context Brokering
802.11ax
General-Purpose Machine Intelligence
4D Printing
Smart Dust
Cognitive Expert Advisors
Machine Learning
Software-Defined Security
Autonomous Vehicles
Nanotube Electronics
Software-Defined Anything (SDx)
Natural-Language Question Answering
Enterprise Taxonomy and Ontology Management
Human Augmentation
Augmented Reality
Virtual Reality
As of July 2016
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Years to mainstream adoption:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau
Source: Gartner (July 2016)

UCSD library: Adele Barsh abarsh@ucsd.

- Drop-in hours. Wed. @Rady 2N127 12:30-2
  - Also Harold Colson: International
  - Also at econ department. Thursday?
- Go to Web site: Research/subjects/business
  - Lab-to-market
  - Analyst reports
  - Private sources: Investext, IBISWorld
- Turn off pop-up blocker!! Otherwise reset.
- Proquest statistic Insights = Abstract and index to US, NGO, International, state, CES associations
- Investext = Thompson One
  - Screening & Analysis tab /Research
  - How to cite reports: Analyst name.

Lab-to-Market: a Guide to Market Research Resources @ UCSD: Start Here

Librarian on site

Librarian drop-in hours Winter quarter!

Starting Jan. 18
Adele will have on-site hours *Wednesdays*
12:30 - 2 pm

near the Graduate Lounge
(Rm 2N127)

Start Here

This guide will walk you through the most useful UCSD resources for market research. The guide is arranged by tasks, which are the tabs above.

- Business Insights: Global
  This database contains market research reports, industry profiles, company chronologies and industry news. It is a great first place to start when looking for background on an industry, company background and much more.
- Business Source Complete
  BSC is a good alternative starting point for industry overviews, business news and academic articles related to management, marketing, strategy, finance and many other topics. It contains fulltext of key journals like Harvard Business Review, Academy of Management Journal, etc.
- IBISWorld Industry Intelligence
  IBISWorld contains U.S. and global industry market research reports, including a specialized collection of China Industry Reports. It also provides U.S. business

Contact Information

Adele Barsh

Email Me

Contact:
Economics & Business Librarian

UC San Diego Library

Hoover's Company Reports

- Hoover's Company Profiles in Lexis-Nexis Academic
  A simple company search in LNA yields a number of useful results, including our online access to full Hoover's Company Profiles, which contain quick background on companies, their competitors, exceutives and operations.

Associations

Industry associations frequently are useful sources of news about market size and trends within an industry. The easiest way to identify potential publications from these sources is through using ***ProQuest Statistical Insight***.

Search by topic or association name (if known).

Private Sources: Analysts, Pre-packaged Risk Analysis

These resources cover background on industries or companies from a risk analysis perspective.

- IBISWorld Industry Intelligence
  IBISWorld contains U.S. and global industry market research reports, including a specialized collection of China Industry Reports. It also provides U.S. business risk ratings, and selected economic and demographic data. IBISWorld's market analysis includes industry overviews, performance and outlook, competitive and regulatory environment, major competitors, operational conditions and key statistics. The U.S. risk reports discuss market risk, including industry life cycle, growth potential, economic sensitivity, etc. Contents are downloadable as full reports or selected elements, such as SWOT analyses, statistical tables and graphs.
- Investext Plus
  This database specializes in analyst research reports on companies, industries, and countries prepared by analysts at leading investment banks, brokerage houses, and trade associations. Its strength is investment reports on public companies.
- Global Market Inform
  The GMID presents ies, industries and countries that focus on consume s include details about market segmentation, leading companies, industry forecasts, consumer spending and attititudes, and economic and business trends.
- Global Insight

Internet Explorer Only

Scanning Your Regulatory Environment? Think Newsletters

Lexis-Nexis Academic has nearly 1000 fulltext online newletters that provide constantly-updated analysis about the regulatory environment of business and Washington policy making. This timely content is uncovered simply by doing a News search on the LNA home page.

You also may limit your search specifically to these newsletters by path: Sources > Browse Sources > News > Newsletters or doing a title search in Find Soures, if you know the title you want.

Example: Inside Washington Publishers group contains 25+ titles on a range of topics, including – California Energy & Climate Report, Clean Energy Report, Health Exchange Alert, Inside Cal/EPA, Inside EPA Weekly

Follow-up comments

- Industry associations:
  e.g. CEA Consumer Electronics Assoc
- Short-term focus
- Good way to research individual companies for jobs
- Remember to log out of each DB. Please!
  - Qs: total budget
  - Find press releases

New technologies are adopted slowly

- Society level
- Industry level
- Firm level
- Product level
- Public vs. private value
- Value capture in the supply chain

Forecasting Diffusion/ Adoption Curves

Notes for MAS

Roger Bohn

Material from various sources including
mktgweb.wharton.upenn.edu/hutch/RWWI-HDTV.PPT

See also:

New Products Management by Crawford & di Benedetto

Rev: April 2016

What we must explain

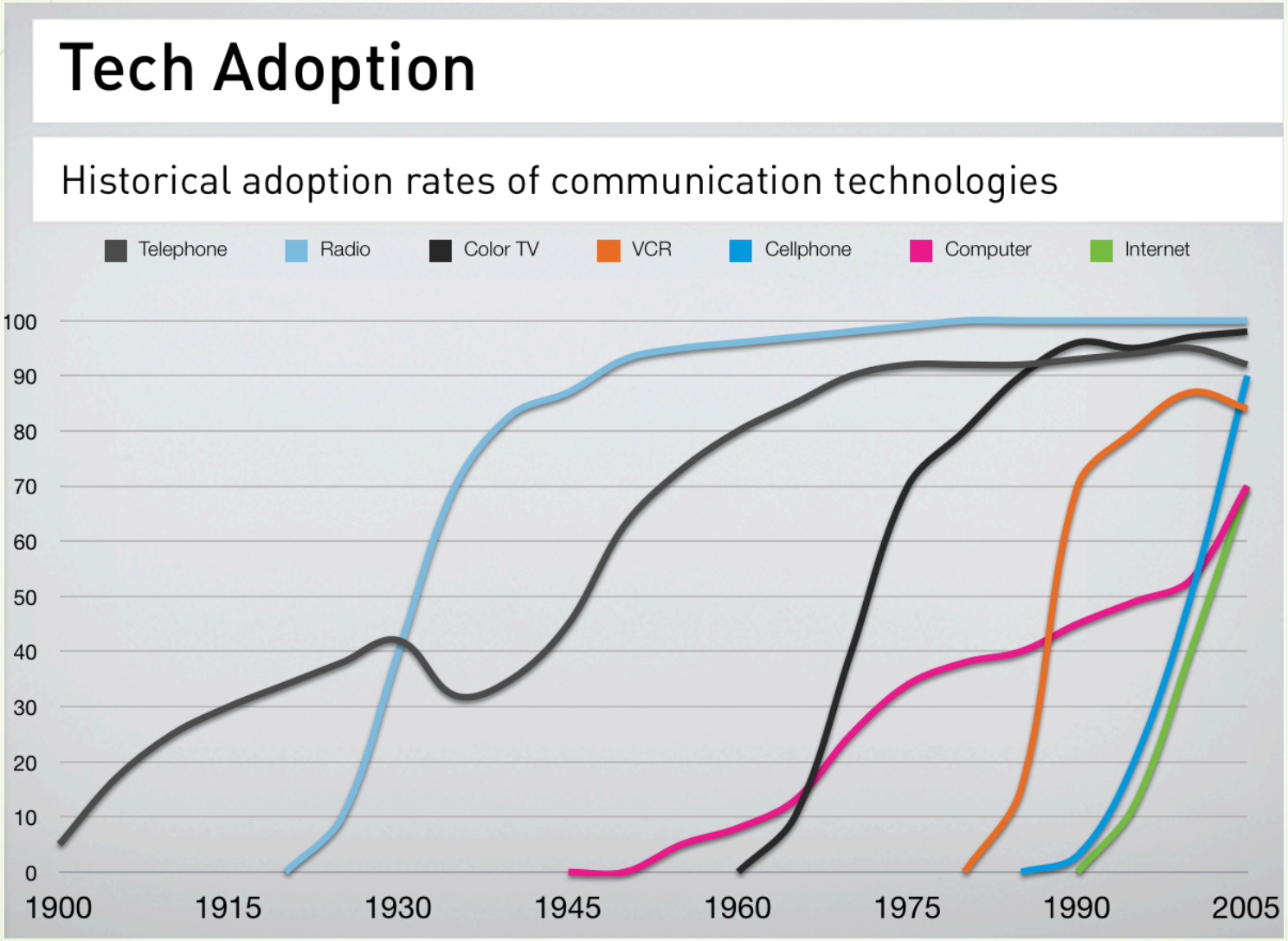
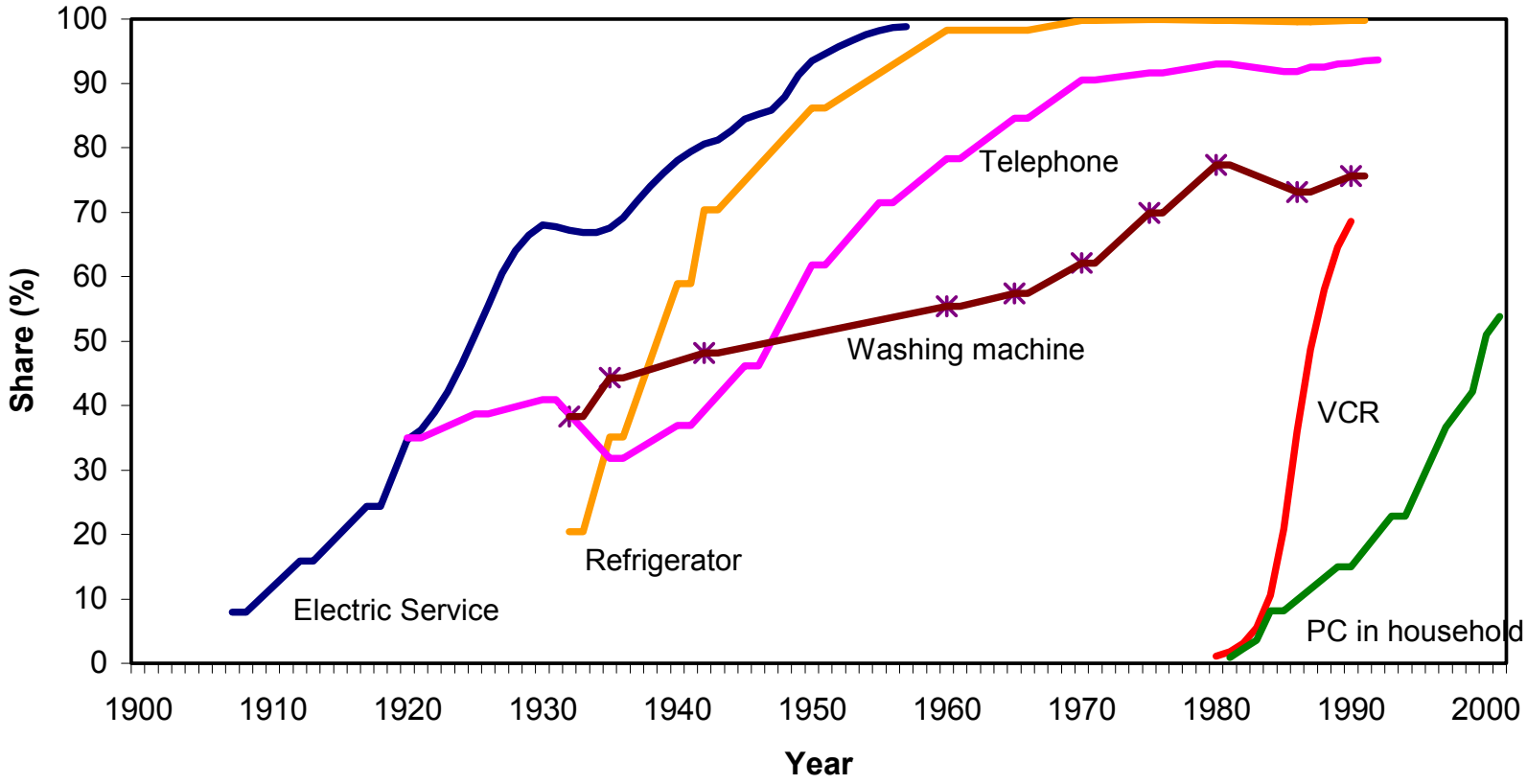
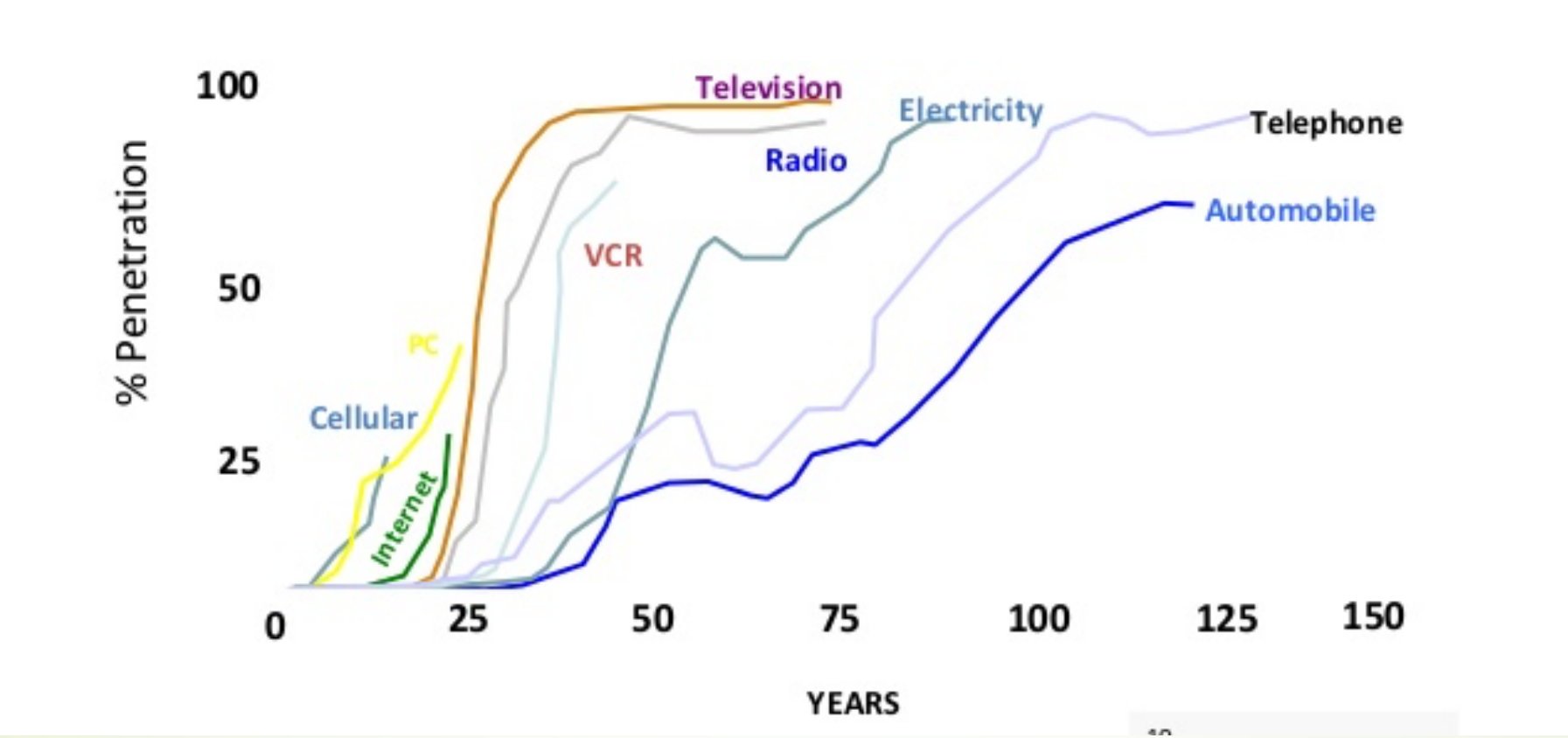


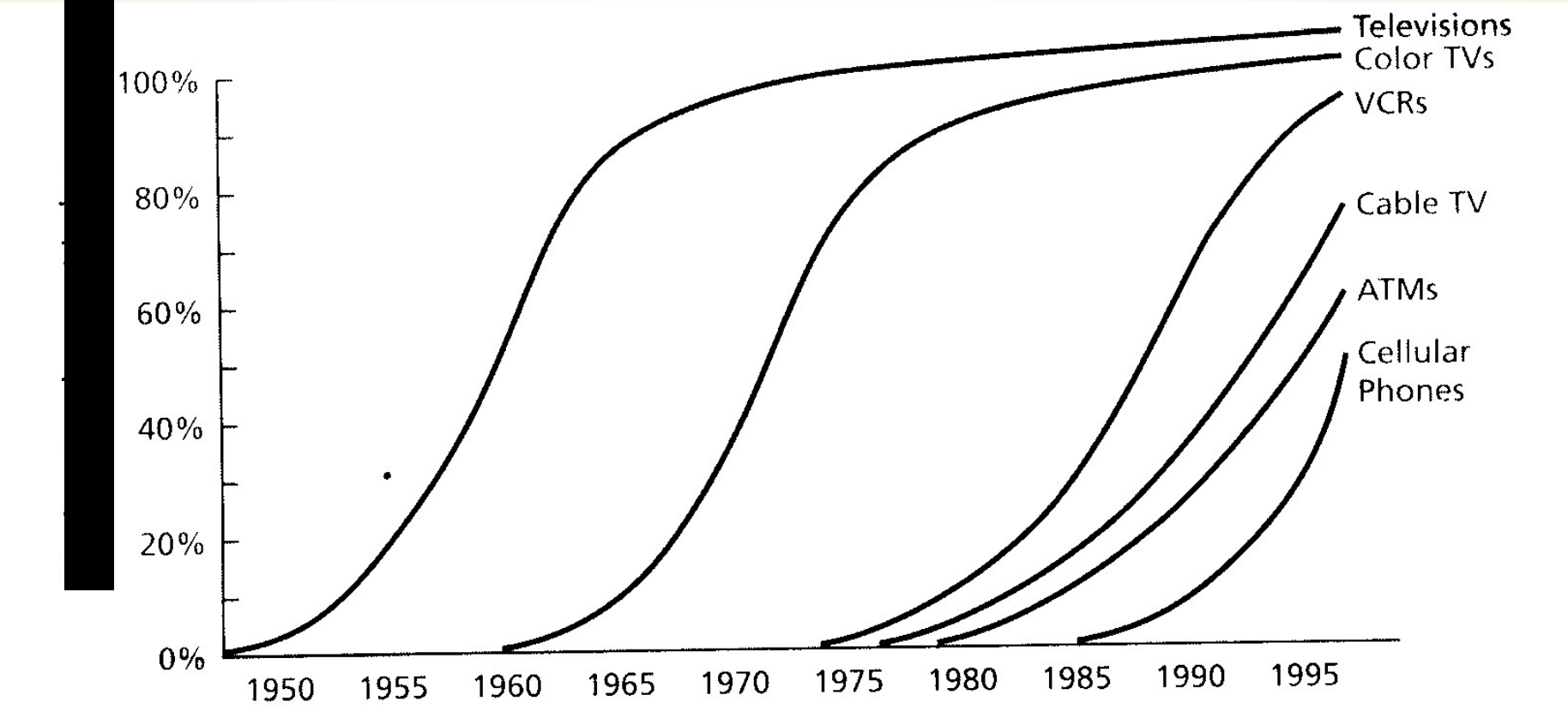
Figure 1
Diffusion Rates in the U.S. for Selected Consumer Products



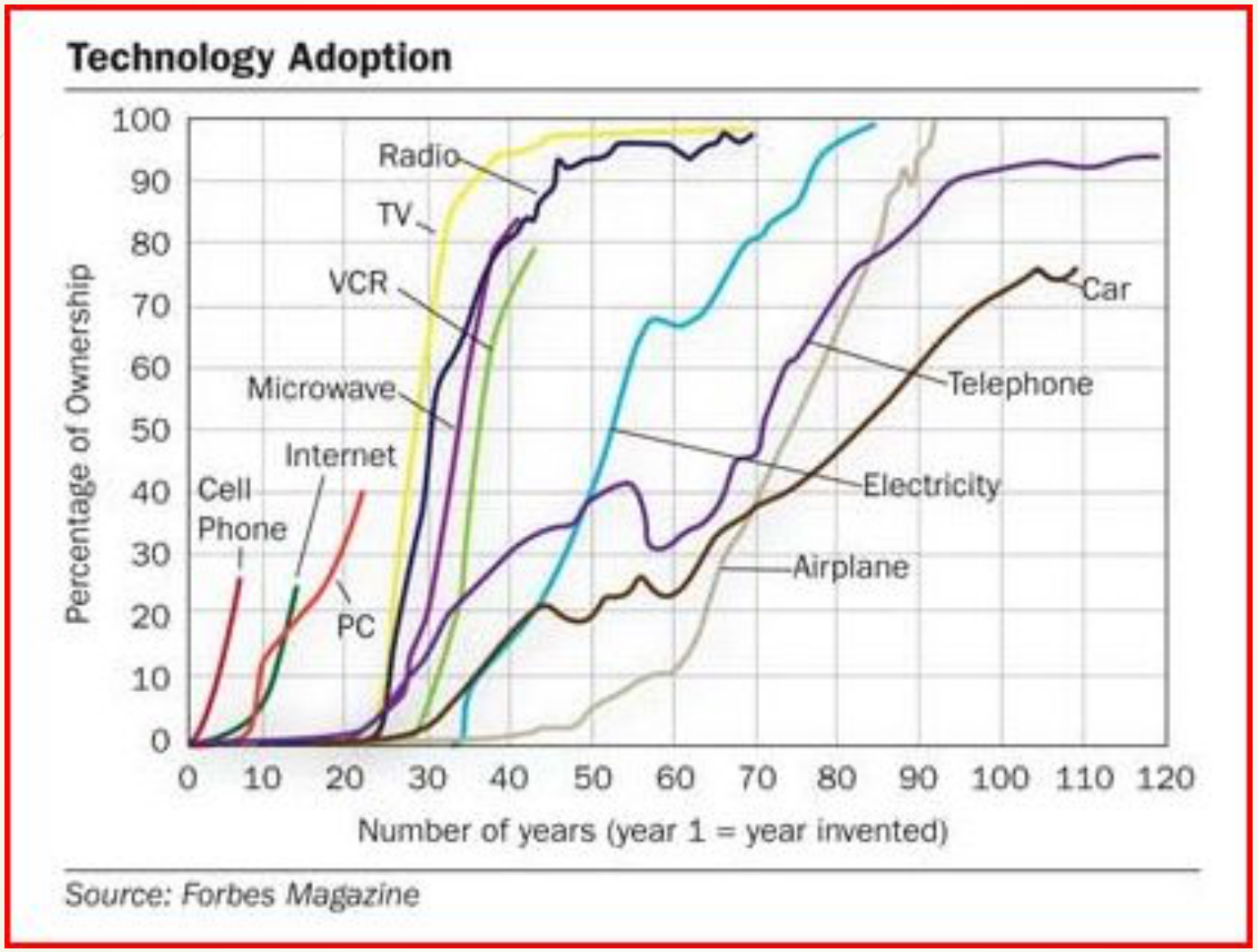
Same idea, different display: Years since invention



Single sector : Cumulative Penetration TV

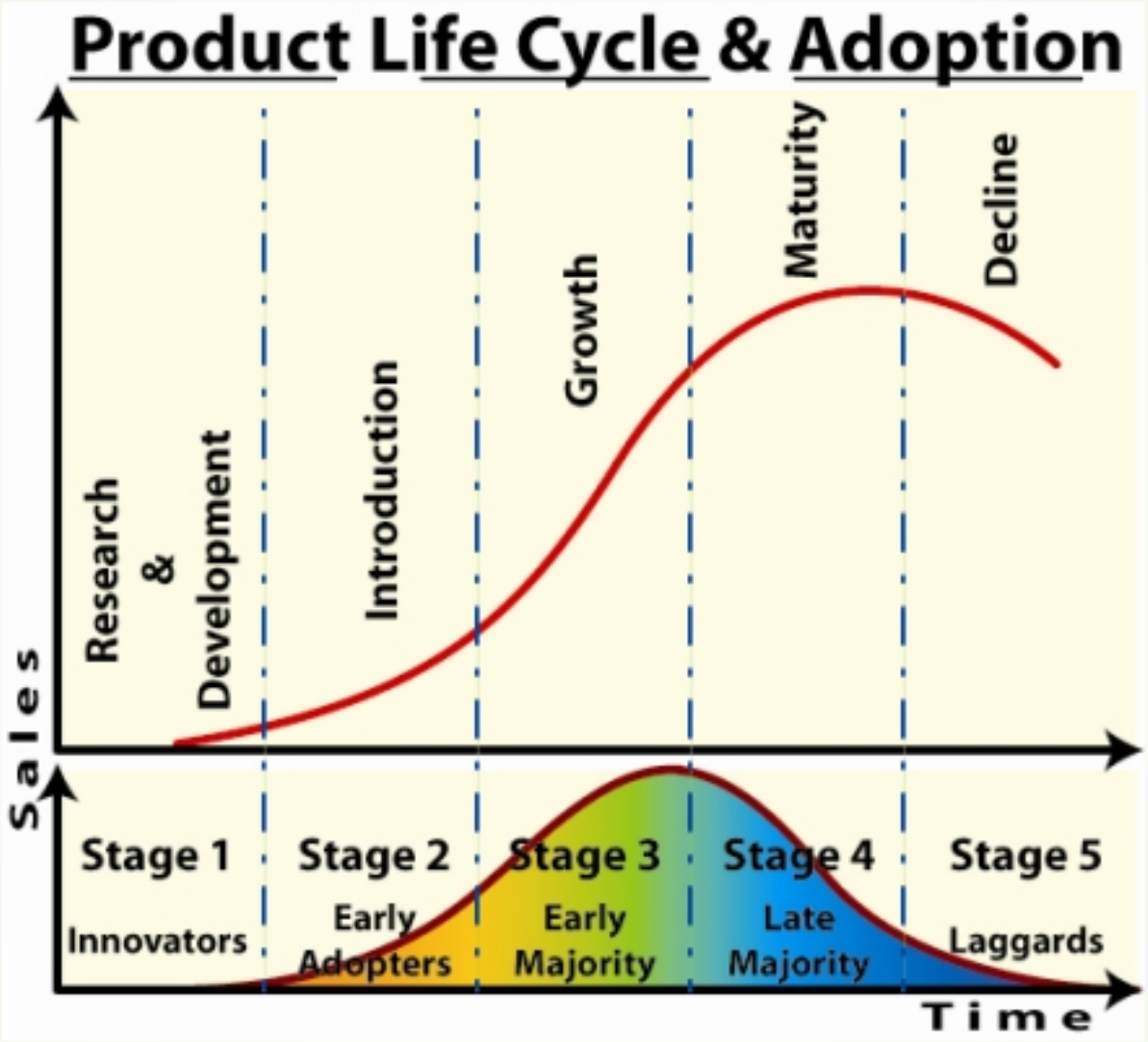


SOURCE: Best (1997), *Market-Based Management*

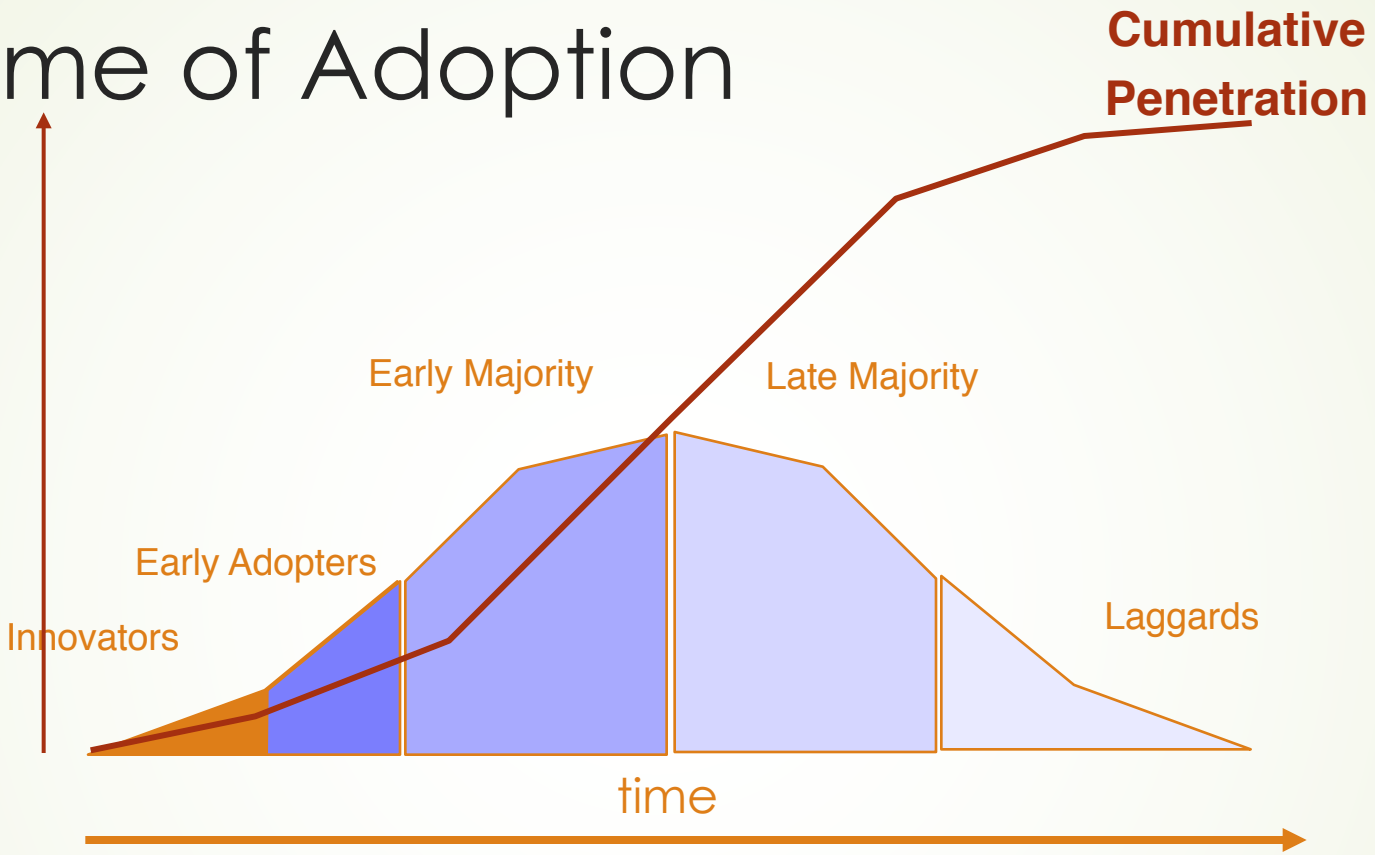

Technology Adoption
Percentage of Ownership
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100 110 120
Number of years (year 1 = year invented)
Radio
TV
VCR
Microwave
Internet
Cell Phone
PC
Car
Telephone
Electricity
Airplane
Source: Forbes Magazine

Four types of models (at least)

- Steady state models: ultimate market share
  - New innovation is not best for all uses
- Dynamic models: adoption over time
  - "Diffusion of innovation"
  - Social level: new type of product
  - Curve-fitting to actual patterns
- Multi-generation models
  - How fast does new tech replace old equivalent?
- Ecosystem models/ networks


Product Life Cycle & Adoption
Research & Development
Introduction
Growth
Maturity
Decline
Sales
Stage 1
Innovators
Stage 2
Early Adopters
Stage 3
Early Majority
Stage 4
Late Majority
Stage 5
Laggards
Time

Time of Adoption



- Everett Rodgers' classic analysis (*The Diffusion of Innovation*, 1962)

2. Diffusion models (population adopting an innovation)

New Adopters = (i.e., first purchases) =
[p + q x (Old Adopters/Population)] x [Population - Old Adopters]

likelihood of "spontaneous" adoption	likelihood of "imitation" or "contagion"	remaining market potential

- Based on models of contagious diseases, Bass (1969) model of diffusion of innovation
- Candidate users get “sick” if they are exposed to existing user, AND the disease jumps
- Candidates = Population – Old adopters
- Exposure rate = old adopters/Population
- Contagion parameter = q = chance to adopt if exposed
- Rate of infection at time t
  = q x (OldAdopters(t) /Pop(t))] x [Pop(t) – OldAdopters(t)]
- Spontaneous adopters (via other channels) at rate p

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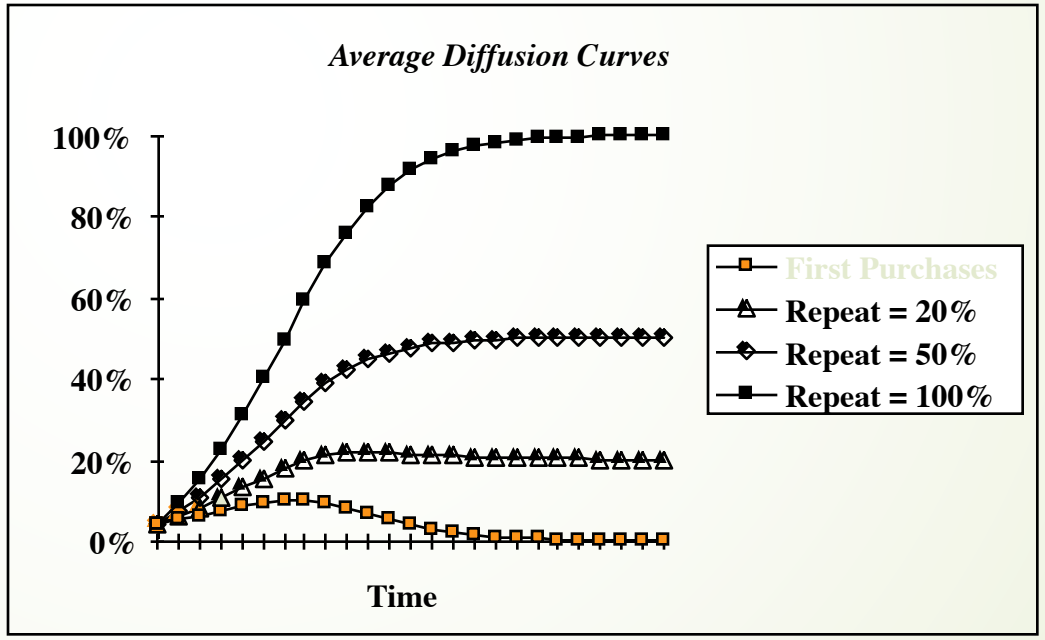
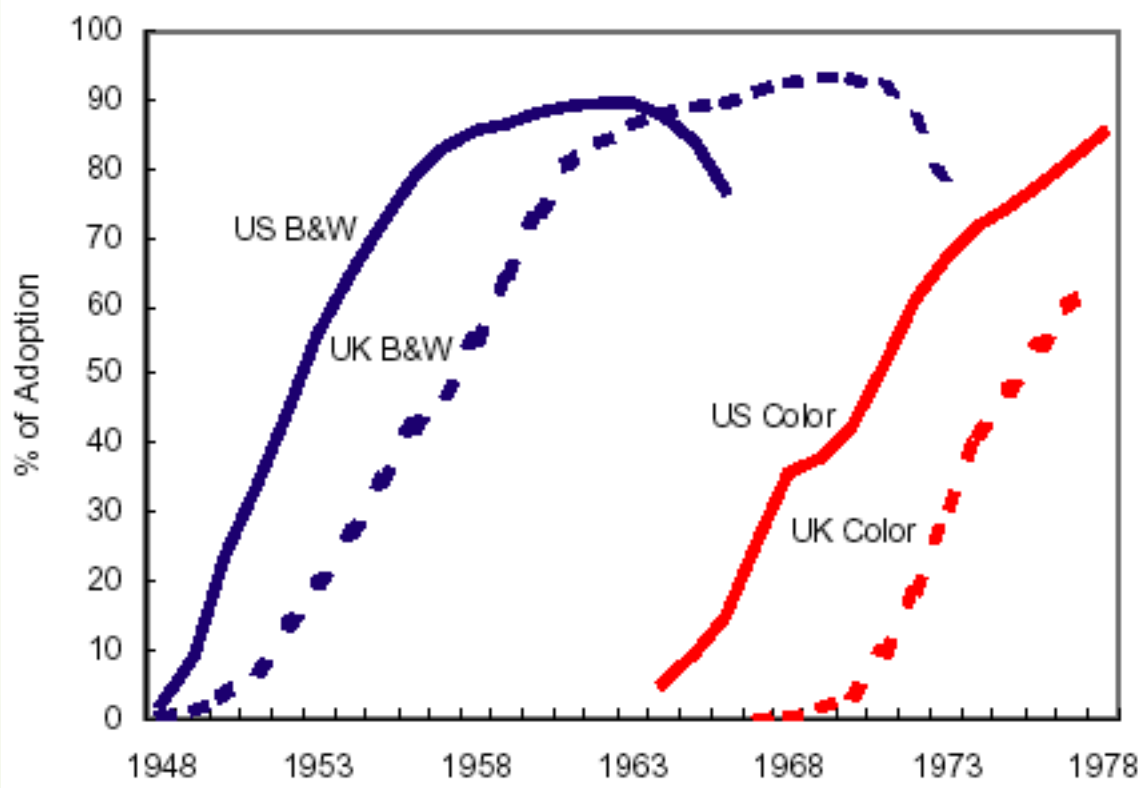
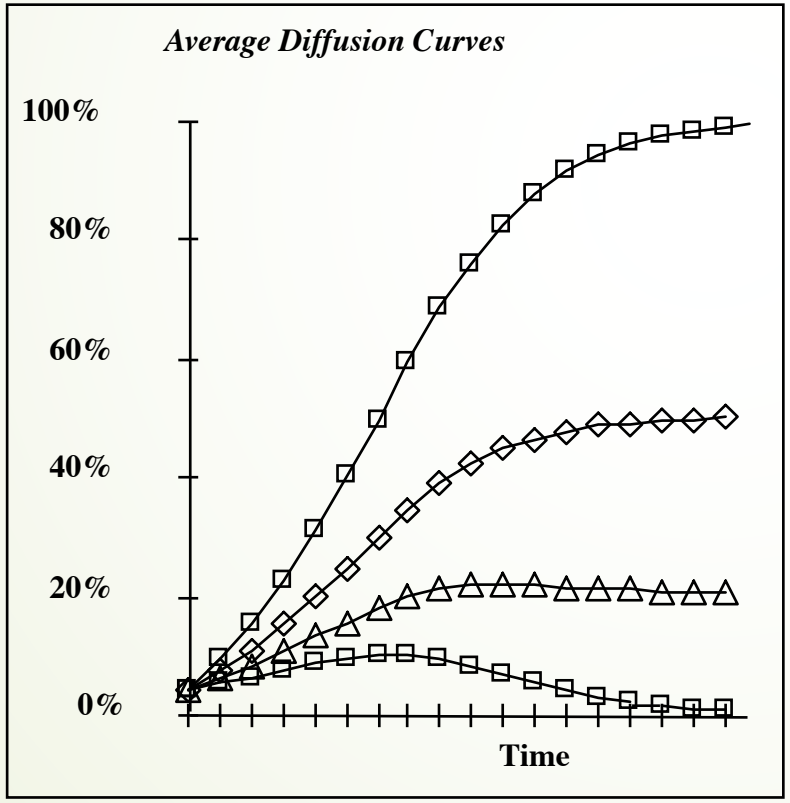


$$\text{Total users}(T) = \Sigma \text{ (new adopters}(t) \text{ x repeat purchasers)}$$

Parameters differ by market

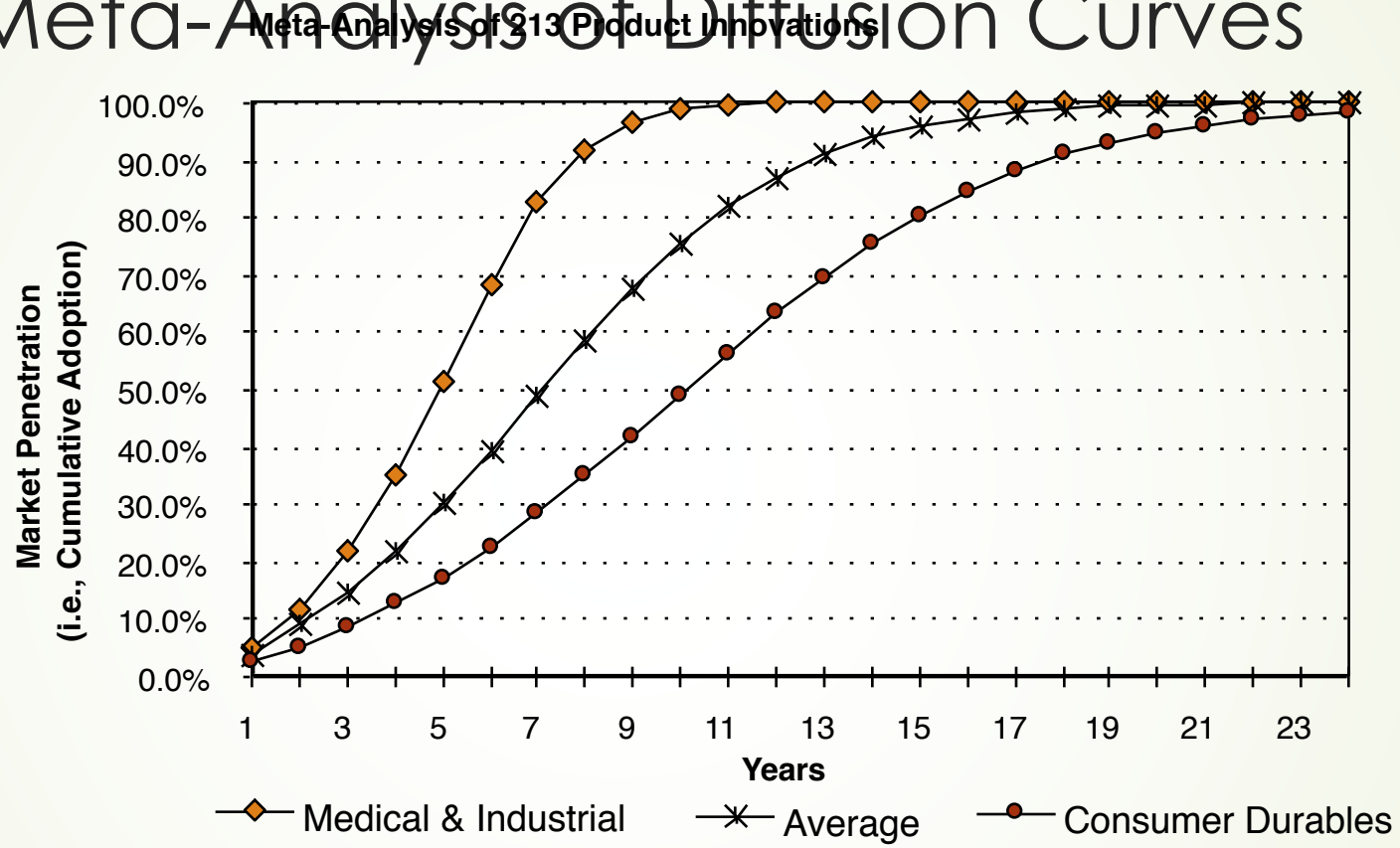


Diffusion is faster when:



1. marketing expenditures are high,
2. competitive activity is high and products use similar technologies
3. the innovation is simple, low risk, easy to observe, easy to try,
4. it is compatible with consumer knowledge and social values,
5. it has a clear relative advantage.

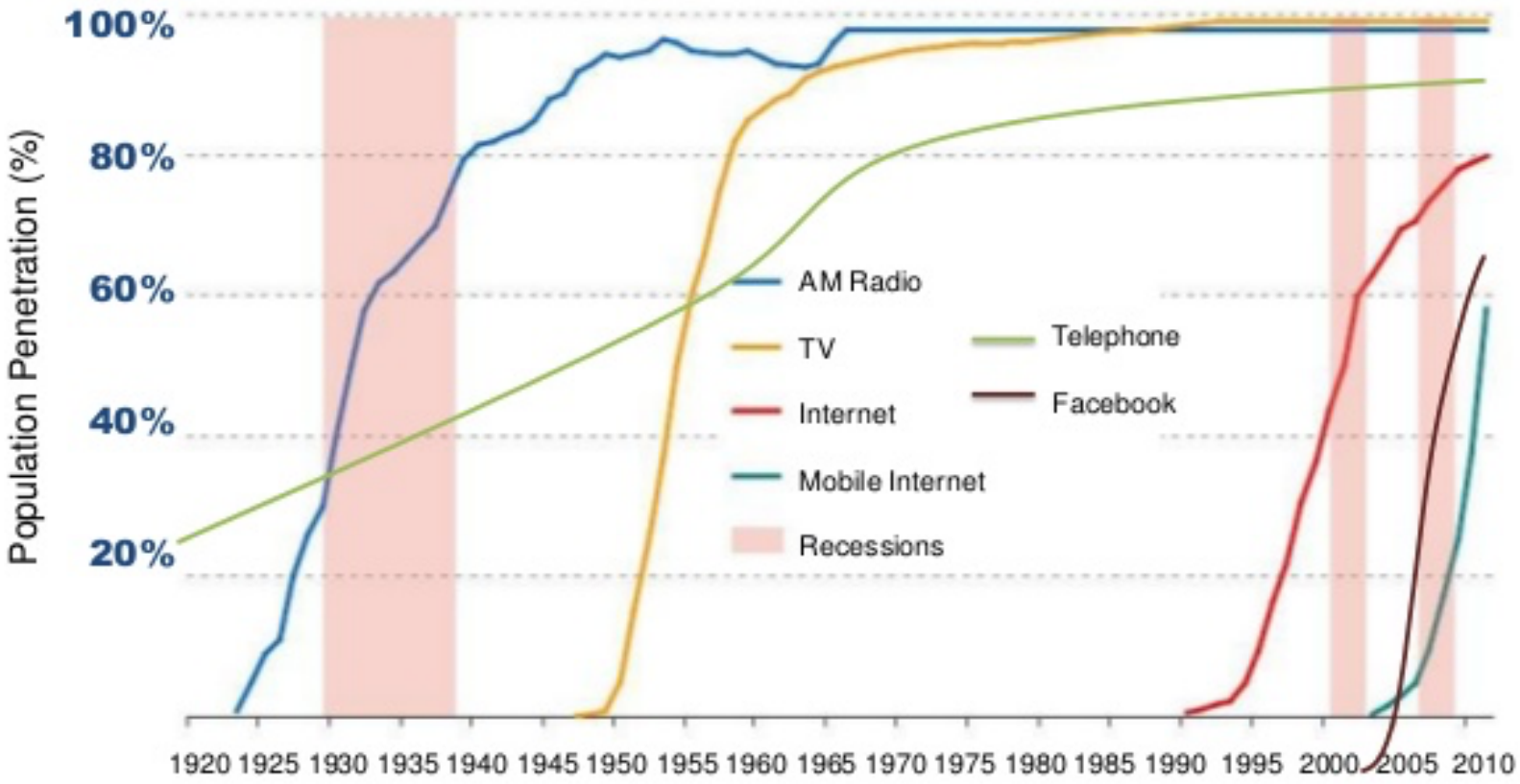
Meta-Analysis of Diffusion Curves

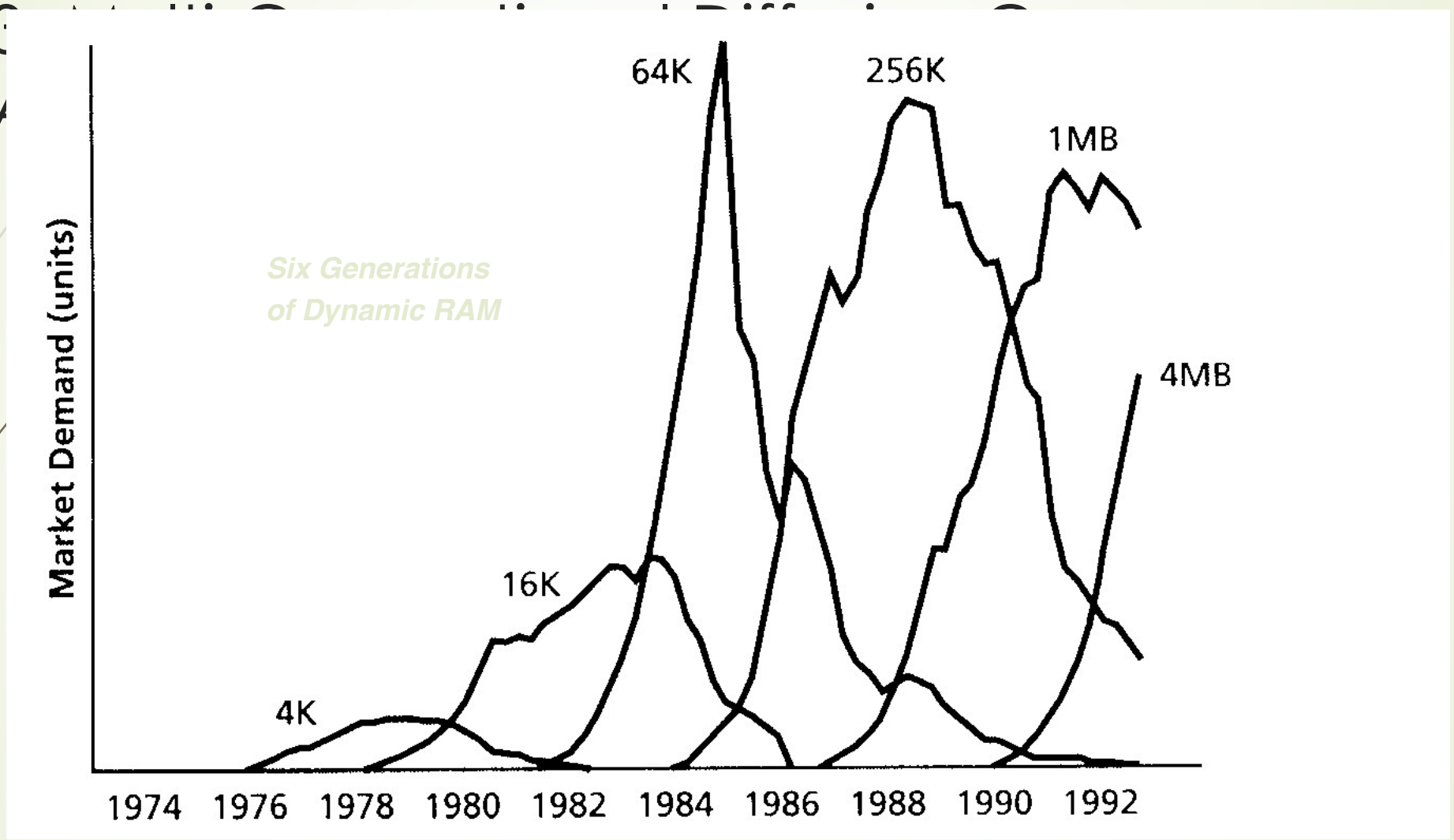


innovation coefficient =	4.6%	3.9%	2.3%
imitation coefficient =	58.5%	30.2%	24.0%
rate =	.16	.11	.07
shape =	.28	.36	.31

SOURCE: Sultan, Farley & Lehmann (1990), *Journal of Marketing Research*

Pace of technology adoption is accelerating





SOURCE: Best (1997), *Market-Based Management*

What drives diffusion/adoption of an innovation ?

- **Spontaneous Adoption**

  Individuals adopt on the basis of their personal needs and marketing activities without regard to cumulative penetration (e.g. VOIP). -- classic marketing

- **Contagion or Imitation***

  Individuals become more likely to adopt the innovation as cumulative penetration increases because their observation of prior adopters and word-of-mouth information is important in their decision making (e.g., personal digital assistants). -- "word of mouth", market pull

- **Direct Network Externalities****

  Individuals become more likely to adopt the innovation as cumulative penetration increases because: the value of the innovation to each adopter increases as the number of adopters increases (e.g., fax machines) -- niche markets; standards battles

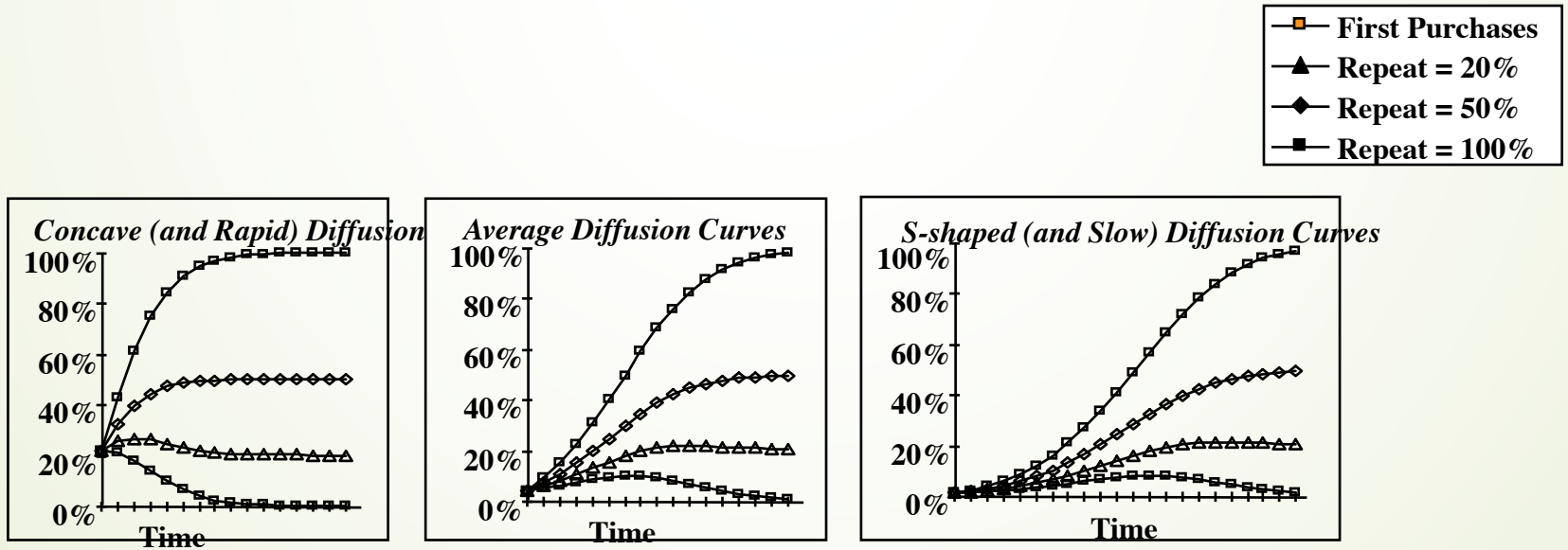
- **Indirect Network Externalities****

  Individuals become more likely to adopt the innovation as cumulative penetration increases because the value of the innovation to the adopter depends on the availability of complementary products and the providers of these products respond to increasing demand (e.g., HDTV; MM PCs; BB internet) -- market to software makers; standards battles

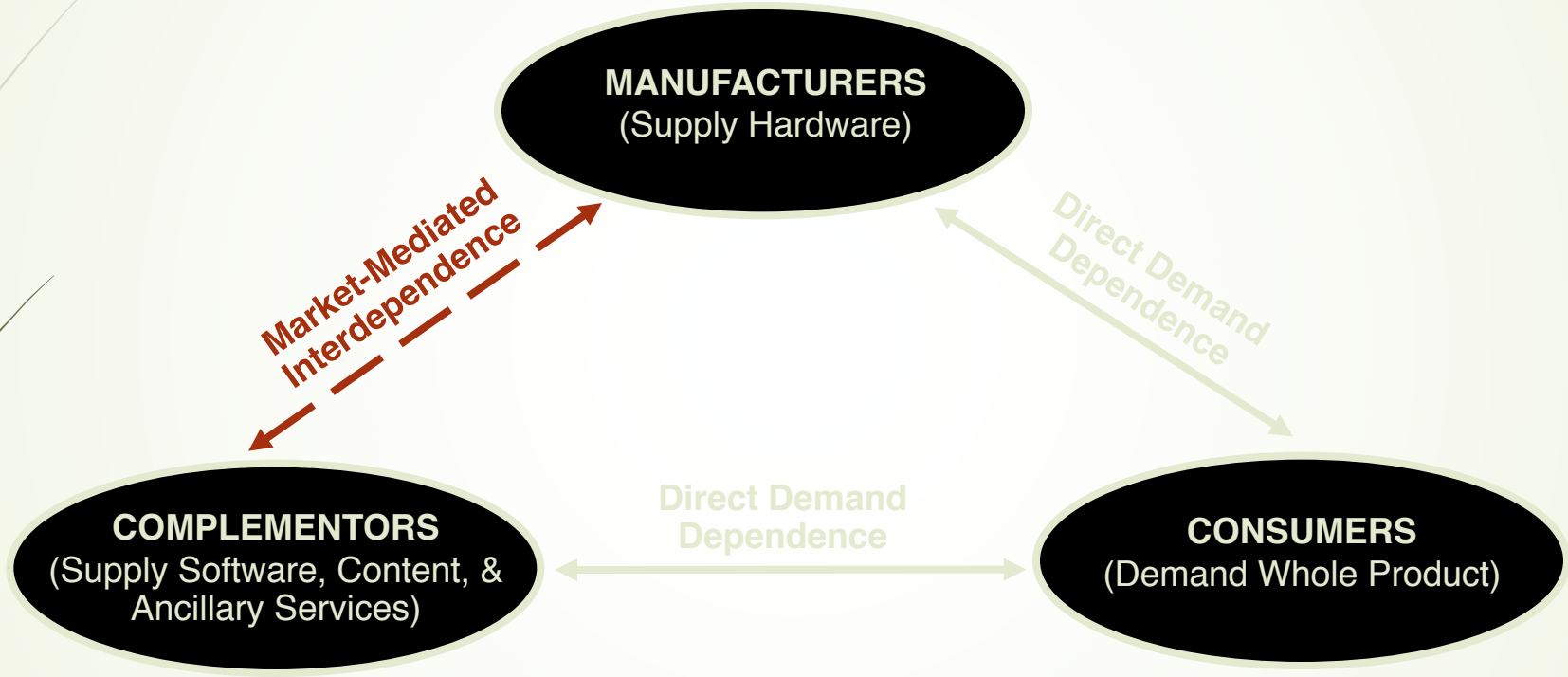
Marketing approach differs for each

HOWEVER, diffusion curves are difficult to predict prior and just after launch

- most products initially show increasing sales
- marketing efforts and trial purchase may cause quick growth regardless of long-run diffusion
- Few data points



Direct and Indirect Network Externalities

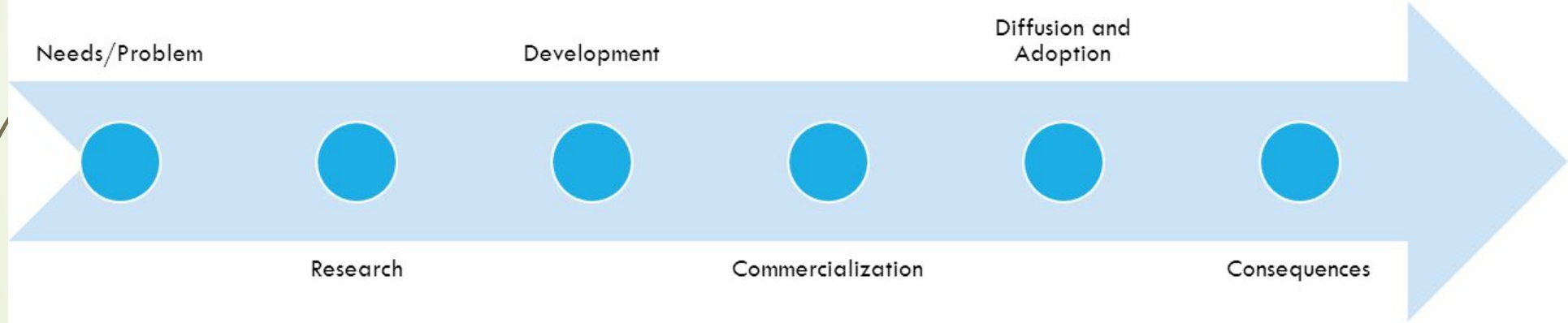


Ecosystems: Indirect Network Externalities

Market	Manufacturers	Complementors	Nature of "Chicken-and-Egg" Problem
DVD Players	DVD hardware manufacturers (Sony, RCA, Philips)	movie studios, video stores	DVD player sales versus movie content and rental title availability
Electric Vehicles	Automobile manufacturers (GM, Ford, Toyota)	gas stations, repair shops	Electric vehicle sales versus availability of charging stations service and spares
Personal Digital Assistants (PDAs)	PDA hardware manufacturers (Apple, 3Com, Casio)	independent software vendors	PDA sales versus availability of PDA software applications
Advanced Photography System (APS)	APS camera/film manufacturers (Nikon, Minolta, Canon)	film processing labs	APS camera/film sales versus availability of APS film processing services
Smart Cards	Smart Card providers (Mondex, Mastercard, Visa)	retailers	Smart card adoption versus card acceptance in retail stores
Paperless Electronic Books	Paperless book hardware manufacturers (Softbook, RocketBook, Everybook)	book publishers	Paperless book adoption versus availability of content for paperless books
Network Computers	Network computer manufacturers (Oracle, IBM, Sun)	third-party Java software programmers	Network computer sales versus Java applications base for network computers
Operating Systems	Operating system vendors (Microsoft, Apple, Sun)	hardware manufacturers, independent software vendors	Operating system installed base versus hardware and software availability
Cable Modems	Cable modem manufacturers (General Instruments, Motorola, 3Com)	cable service providers	Cable modem prices versus cable modem service and content

Sequential model of R&D

SIX MAIN STAGES OF THE INNOVATION DEVELOPMENT PROCESS

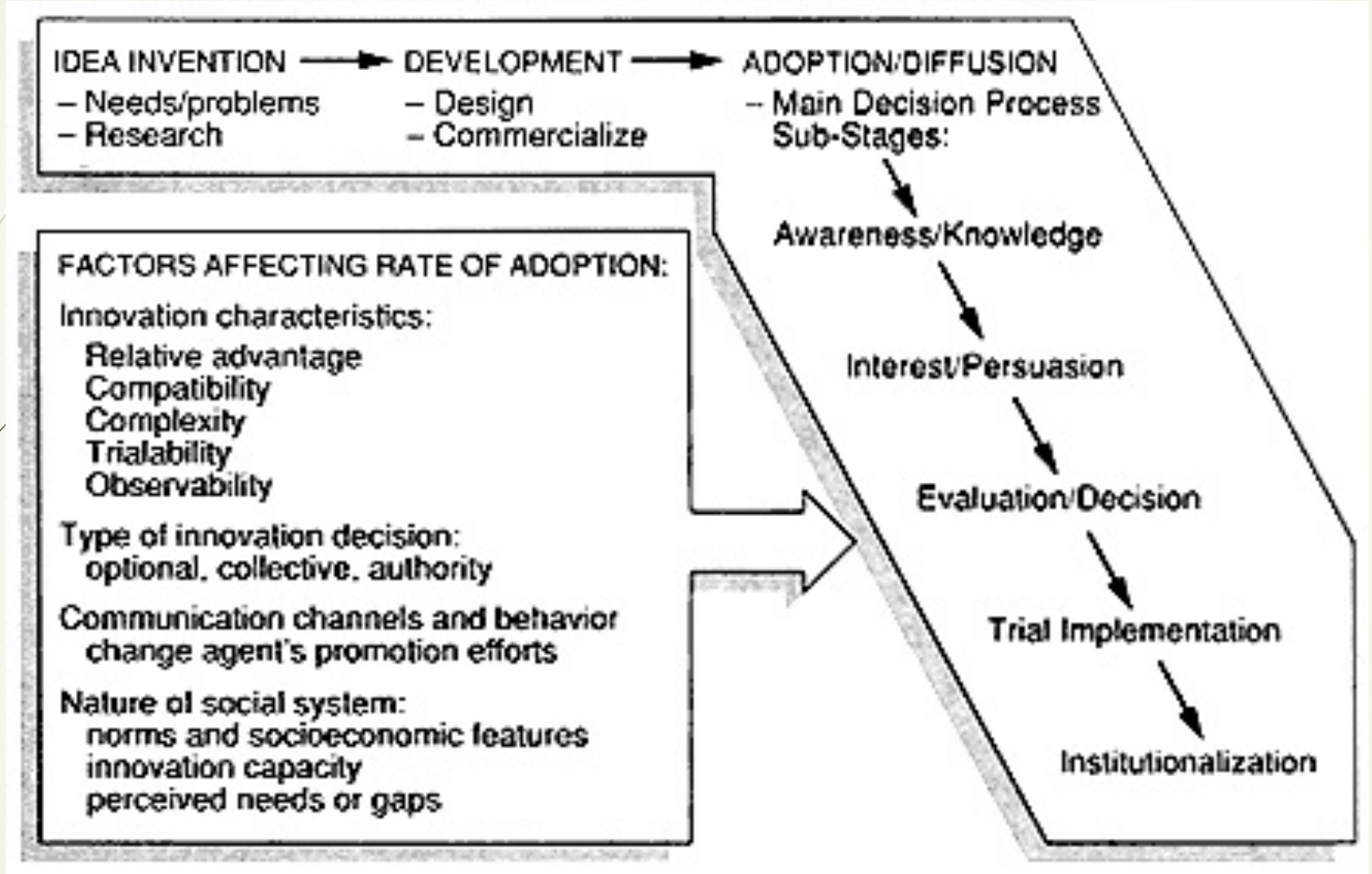


The Innovation Development Process consists of all the decisions, activities, and their impacts that occur from recognition of a need or problem, through research, development, and commercialization of an innovation, through diffusion and adoption of the innovation by users to its consequences

National-Level Perspective

1. Basic Research = Pure science e.g. semiconductor properties
2. Applied Research E.g VLSI processors
3. Product Development e.g. Intel Core Duo
4. Deployment
    1. Manufacturing
    2. Marketing
    3. Distribution
5. Diffusion over time
    1. Ongoing support
6. Obsolescence/replacement

Putting them together



Now shift to the firm level

- Society level
- Industry level
- Firm level
- Product level
- Public vs. private value
- Value capture in the supply chain

Should I go with a new technology?

- Potential consumers = use it?
- Potential business users = buy it, use it
- Potential developers = develop it?
- Incumbents in same industry = adopt it? Fight it?

- What should they consider?
  - Performance
  - Risk of poor performance
  - (Economic) value of this performance
  - Cost of adoption
  - Disruption due to adoption
  - Possible side effects
    - Opposition
    - Regulation
    - Obsolescence = something better may be next

Examples

- Auto safety tech
  - GM = put it in our car?
    - Buy from Delphi? Make it ourselves?
  - Go fast, or go slow? Standard, or optional?
- Auto buyer: consumer or trucking company
  - Will it work? Will my users ever need it? Do I trust it?
  - How much $?
- Microtasks; Capital goods contributors
  - Potential worker: try it? How seriously?
  - Potential employer:
  - Potential platform developer
- New financial instruments
  - Banks
  - Platform developer
  - Merchants
  - Consumers

Out of all these decisions:
Somehow the technology gets adopted.
Or it gets tried, but abandoned.
Or it never gets tried.

3 useful theories
Let's assume rational behavior

- Financial model: will it be profitable?
- Real Option models: I can abandon it.
  - Can I *expand* if it works well?
- Technical life-cycle models:
  Tech performance improves for a while, then levels off

- These 3 models identify the key factors that lead to success or failure. (Most of them.)

The developer's basic decision: Will it be profitable? Outcome distrib?

- Technology development = capital investment decisions

  Invest now, get risky returns later

  Investment = Research + Development + Startup (Factory, tooling) + Marketing

- If successful, make + sell product
  - Cash flow = (wholesale price - variable cost) x Volume – Fixed costs
- Contribution eventually outweighs development cost
  - Net present value calculation: integrate discounted cash flows over time
- All variables are uncertain!
  - Examine different scenarios. Take expected value (weighted average)
  - Discount risky and distant events more.

Decisions of adopters have same structure

- Initial costs to adopt
- Stream of benefits in the future
  - Will the tech work?
  - Will it work *for me?*
- Ongoing costs of use
- All are uncertain

Is the Net Present Value Positive?

- NPV = Discounted sum of expected cash flows
  - Discount rate depends on multiple issues
- Tech Penetration curve ➔ Rate of sales growth
  - Many years of low adoption
  - If/when tech. catches on, competitors enter and drive prices down!
- Technology will improve over time: lower production cost, resist price drops
- How long until cash flows turn positive?

$$\text{Post launch contribution} = \int_0^T \left[\text{Price}(t) \times Volume(t) - Cost(t) \right] e^{-rt}\, dt$$

Net Present Value of tech. < 0 ?!

- Initial costs
  - $50M for tech development
  - $50M for first year of deployment
  - $100M for first 2 years of marketing
- Projected cash flow +$100M/yr in years 4, 5, ….
  - Discount at 10% ➔ $1billion
  - But starts in year 4 so $1B x $.9^3$ = $720 M
- Chance of technical success 40%
  Chance of market success 60% (pessimists not invited)
  - **Chance of overall success = 24%**
- NPV = -50 – 100 – 50 + 100 + 100 + 100…
- Expected NPV = -50 -90 -40 + 24% x $720 = -10

Can we go faster? Develop cheaper?

We *might* get lucky; but it's more likely that things will take *longer* and cost *more*.

- Time sequence
  - Year 1 Develop -50
  - Year 2 Deploy + market -100
  - Year 3 Market and sell -50 (sales – tiny)
  - Year 4 Finally + cash flow +50
  - Years 5 to 20 +50
- One year shorter time to breakeven ➔ + $90M
- Reduce marketing costs ➔ + $50M
- Increase sales volume 10% ➔ + $72M (actually more)
- Increase product life from 20 to 21 years ➔ 50 x $.9^{20}$ = $6M

Real option value

- The NPV calculation ignored two real options:
  - The option of killing the project before spending $200M in startup funds
  - The option of expanding the technology if it works
- Both are very valuable!
- Chance of technical success 40%
  - We find out at the end of year 1. Total spent = $50M
- Chance of market success = 60%.
  - Find out year 2. Total spent = $150 M
- Now expected NPV
  = .6* -50 + .36 * - 100 + .24 * 720 = + $134M
- Invest $50M up front for chance to make $134M

Option value is basis of VC industry; also in large companies if they are sharp

- 50% of VC investments lose everything
- 40% of VC investments break even
- 10% of VC investments win very big

- Large companies:
  accounting system may not capture option value
  But "management judgment" may go ahead anyway.

Company strategies for new tech

- First to market: Big risks, but establish an early market position and reputation
- Fast follower: Let someone else prove the technology *and* market acceptance, then enter and capture market share (Google, AirBNB, etc.)
- Low cost: Enter late, avoid most R&D, price has already fallen. But undercut the early firms; force them to exit
- Hit and run: Arrive early, when prices are high; leave when competition gets tough.
- New markets: Adapt original idea to new markets

Apply these models to corporate *users* of new tech

- It may or may not work well
- Cost to implement immature tech.
- Late adopter strategy: Wait until value of tech is clear and consultants/steal from competitors to get implementation knowledge
- Early adopter strategy: Pay higher cost of adoption, high cost of mistakes. But more + quicker knowledge about the new tech
  - Better knowledge gives many options e.g. specialize, extend, expand
  - "User driven innovation"

These models predict adoption Scurve

- Firms have ranges of parameters
  - Discount rates
  - Assessments of uncertainty
  - Cost structures
  - Ability to develop fast; to adopt fast or cheaply
- Early period: Uncertainty very high.
  - Tech developers start small and slow
    - Option value is lost if jump in too fast
  - Tech buyers adopt only for niche markets
- Middle period: Uncertainty low, benefits clear, but prices are falling. Invest now, or wait until price lower?

Capital stock models of users also gradual drive adoption

- Firms, customers, workers already have a car, a credit card, and a job.
  - "Decision to purchase" comes only at renewal points. Every few years
- If the new tech is demonstrated to be really good (high value, low uncertainty), some users will accelerate write-off of old tech.
- If government will subsidize it, great! (New energy tech.)
- If seller has a big marketing budget

Predicting adoption rates

- This explains adoption rates. Faster adoption if:
  - L ow cost to try new tech
  - Low switching costs
  - Clear value proposition for users
  - Role models demonstrate new tech. Etc.
- When evaluating a new tech:
  - Model value of the tech to several users in different situations
  - Look at main uncertainties, and how long to resolve them.

Decision tree models of options

	One-shot project	Option, if success	Option, if fail
Initial cash (expenditure)	-100M	-20M	-20M
	40%success/ 60% fail		
Stage 2 invest	0	-80M	0
NPV of future cash if success*	+150	+165	NA
NPV of future cash if fail*	+50	NA	0(kill project)
E(NPV) = SUM{P(x) *NPV(x)}	-100 + .4*150 + .6*(50) = -10M	= -100 + 165 = 65	-20
P(this outcome)		40%	60%
Expected NPV whole project	-10M	+27-12 = + 15	
Conclusion: The option to abandon the project after spending only $20M raised the value from -10M to + 15M . So value = $25M .			

Continuous-time real options

- Stock market call option: right to buy stock
  - Fixed exercise price, variable time
  - Black-Scholes formula for valuation
  - Variability raises value of the option
- Product development: success not 0-1
  - Given current information: probability and distribution of cash flows from continuing project
  - Varies over time in Brownian motion
    - Competition, market, technical issues, people
- Model R&D project as call options
  - Each month, pay $ for right to continue
  - If too far underwater, terminate project

Ignoring options leads to systematic distortion

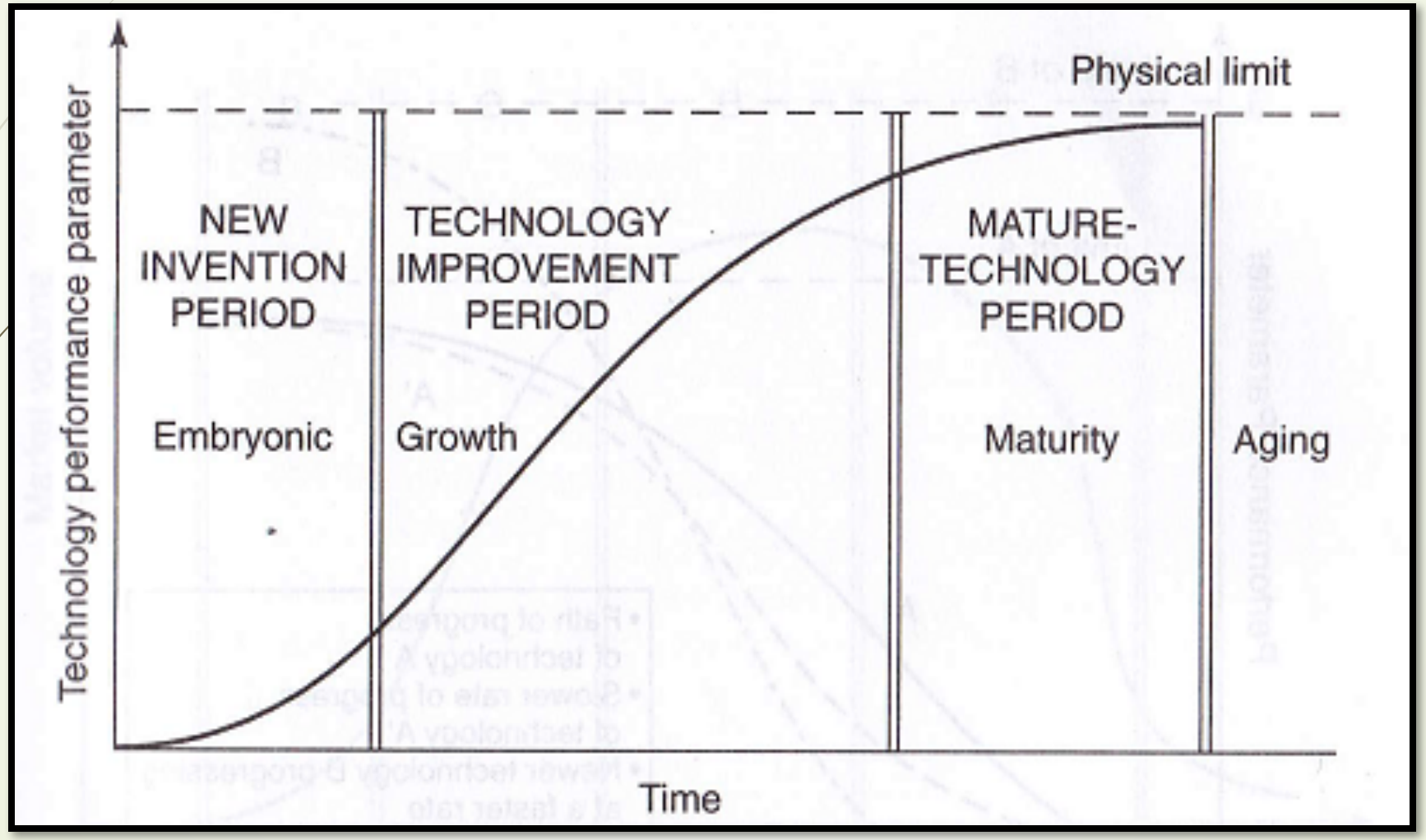
- Options most valuable if payoffs have *high* variance
  - Technology Breakthroughs
  - New markets
- Standard NPV analysis says opposite
  - Higher discount rate for more risky projects
- Platform development also hard to evaluate with NPV
  - First success provides stream of other products
  - Design the first one differently to become platform
- References
  - *Mitchell, G. R. and W. F. Hamilton (1988). "Managing R&D as a Strategic Option." Research-Technology Management* ***31****(3): 15-22.*
  - *Trigeorgis, L. (1996).* Real Options : Managerial Flexibility and Strategy in Resource Allocation.

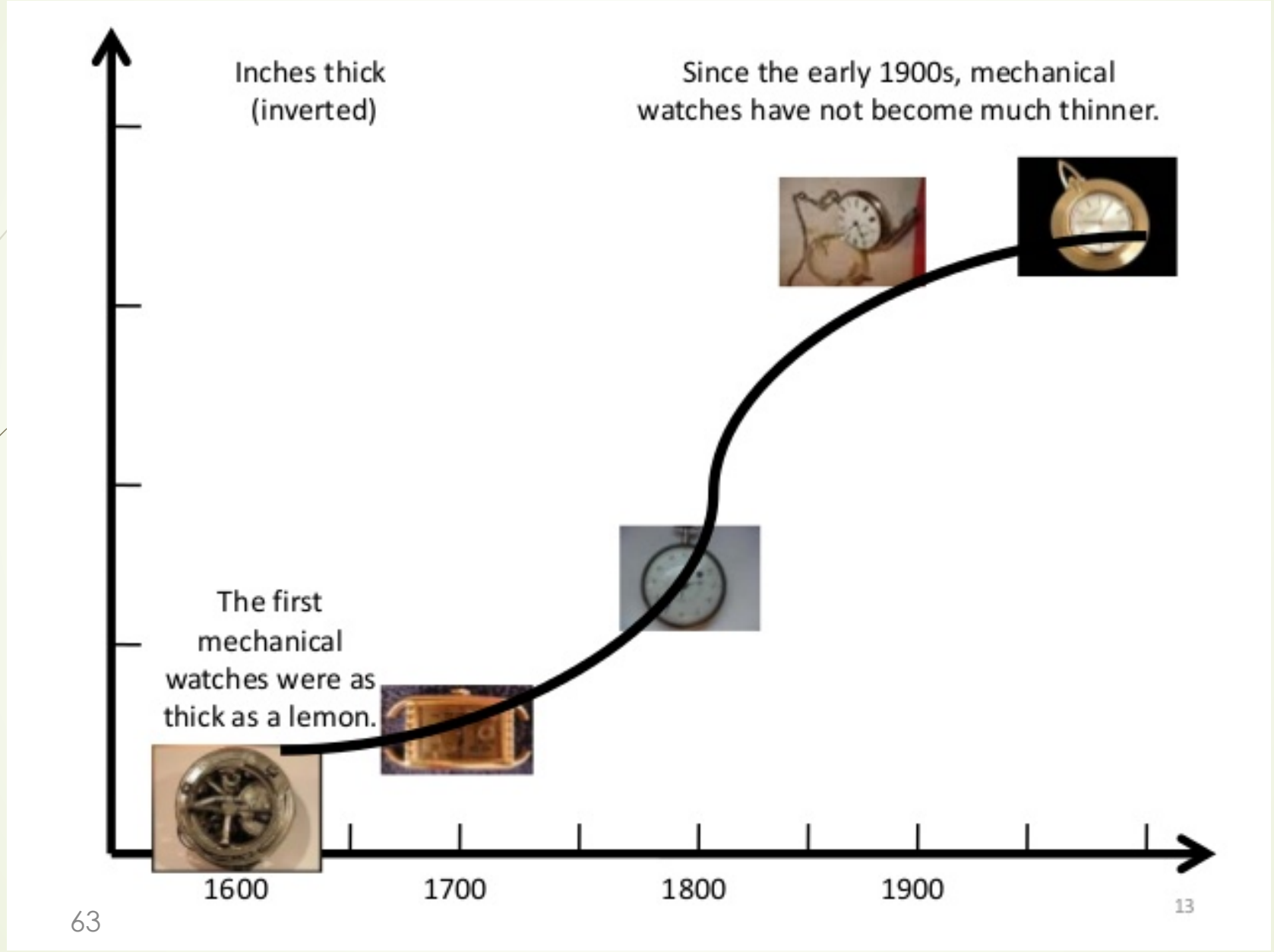
Technology Life Cycles
S performance curves

Technology Performance over time

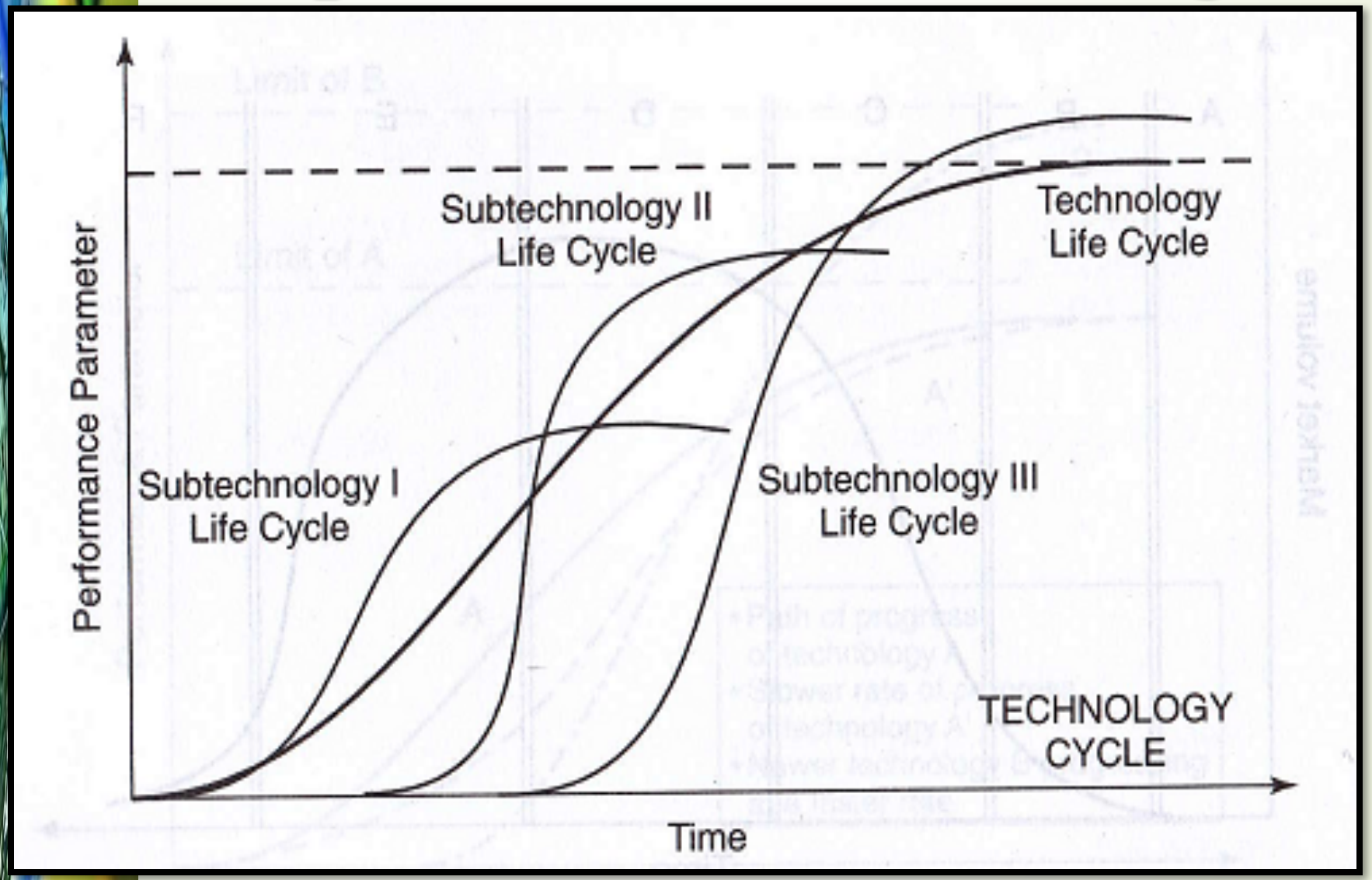
- Moore's Law: Technology always gets better
  - At a constant exponential rate
- Moore's Law required increasing investments
- Each new performance increment took more R&D
- It worked because user demand grew with performance
- Unit demand grew faster than unit price fell
  - Revenue = Price x Quantity increased for decades
- The world *wanted* all the new transistors (double every 2 years), and better performance.

Technical Performance also follows S curve

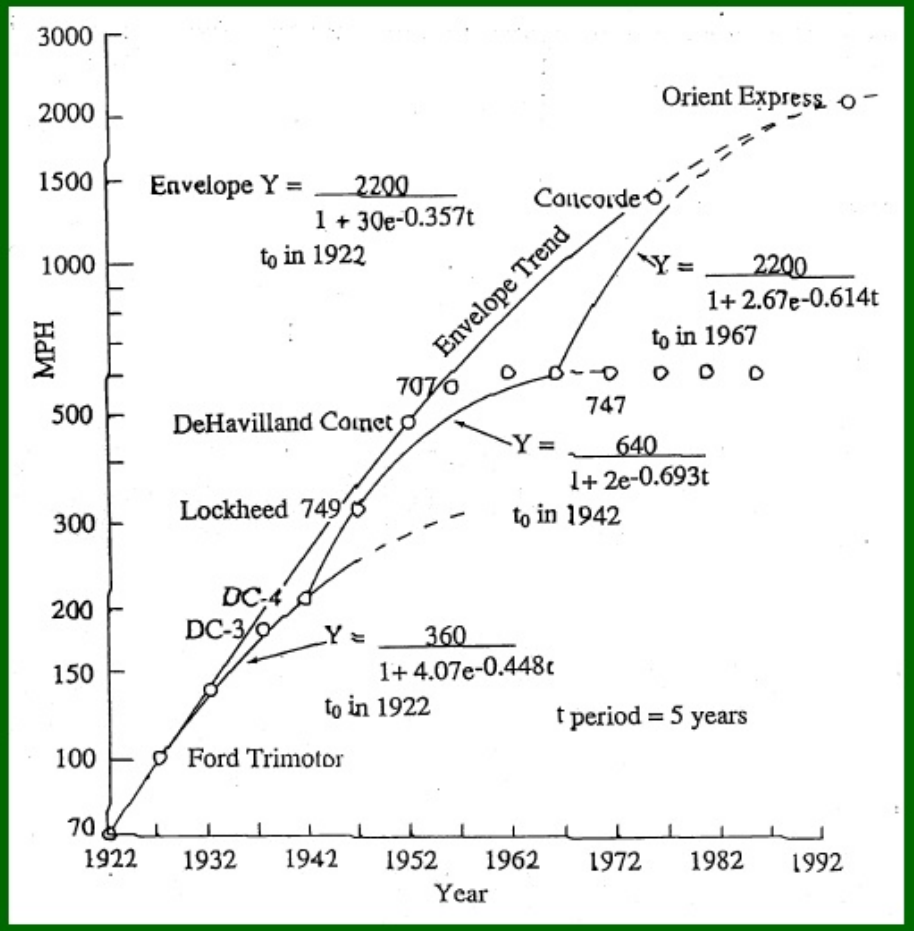



Inches thick
(inverted)
Since the early 1900s, mechanical watches have not become much thinner.
The first mechanical watches were as thick as a lemon.
1600
1700
1800
1900
13

Multiple-Generation Technologies



Envelope Curve



Source: TFI 1983

Conclusions

- Variety of technical models for different aspects of tech change
- No integrated model
- Study ones most relevant to your technology's issues.