# Where do High Tech Commercial Innovations Come From?

## Demand and Supply for Technical Knowledge

Frey Lecture,
Duke University Law School
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Lewis M Branscomb,
Harvard University

# High Tech Innovations

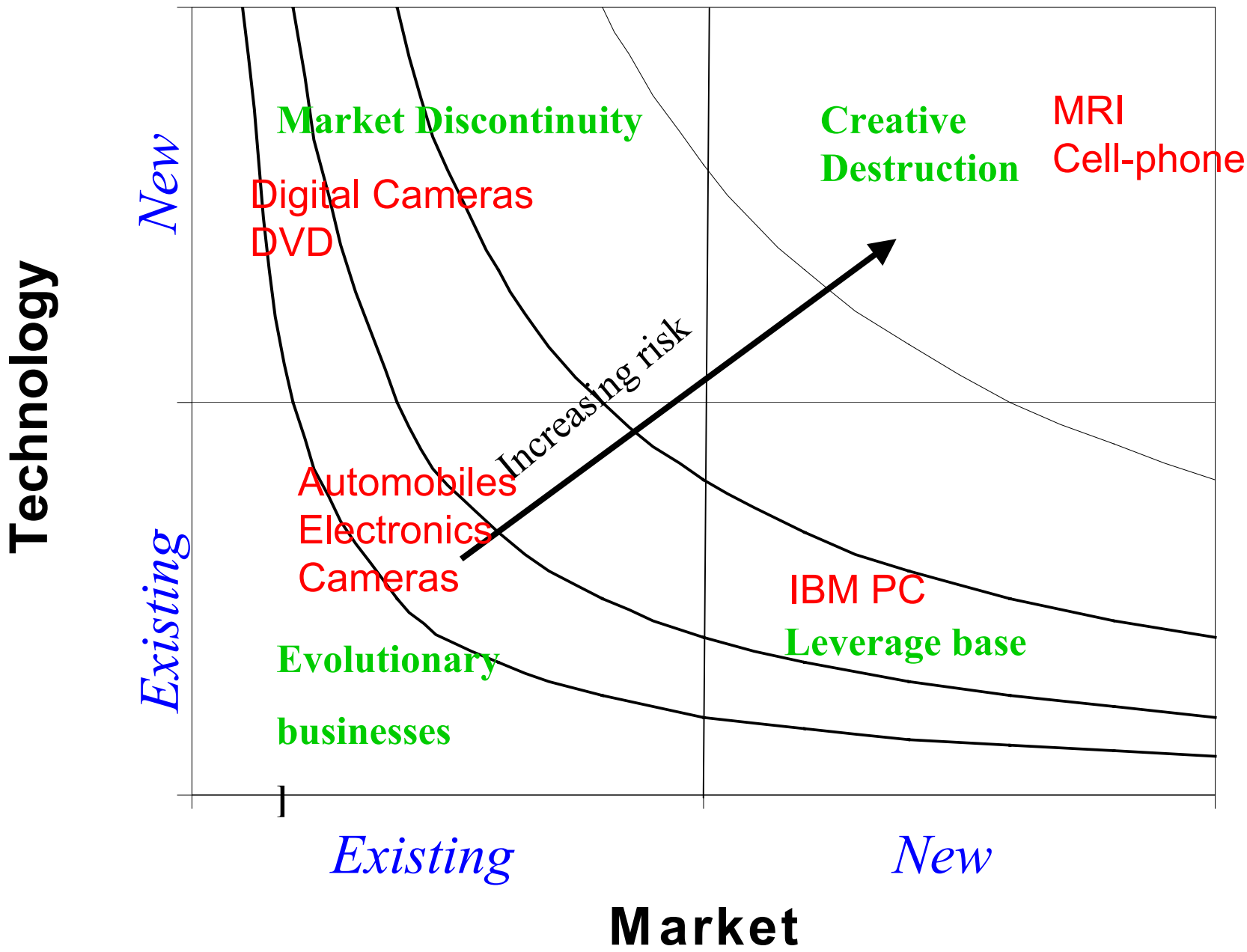
- General agreement that high tech innovation creates new conditions for economic growth
- Innovation begins with a new product or service successfully introduced into the market
- Where do innovations come from? What is the link between scientific research and commercial innovation?

# Evolutionary versus Radical Innovation

- Almost all GDP growth is due to evolutionary growth of existing markets, services and production processes

- $200 billion in R&D was funded by private industry in 2002
  - Supports a $9,800 billion GDP

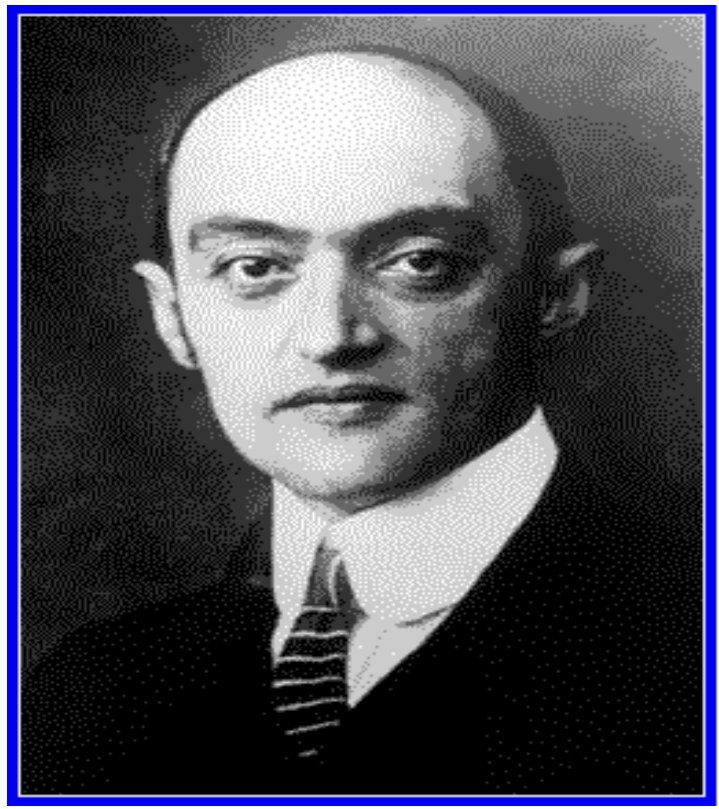
- Of this only about $16 billion funded R&D for radical innovations
  - Producing very modest revenue
  - Total venture capital was $21 billion
  - Only 500 new high tech firms created from universities.


Technology
New
Existing
Market Discontinuity
Digital Cameras
DVD
Creative
Destruction
MRI
Cell-phone
Increasing risk
Automobiles
Electronics
Cameras
IBM PC
Leverage base
Evolutionary
businesses
Existing
New
Market

# Evolutionary versus Radical Innovation: "Creative Destruction"

- "The fundamental impulse that… keeps the capitalist engine in motion comes from the new consumers, goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates."

- "This process of Creative Destruction is the essential fact about capitalism. It is what capitalism consists in and what every capitalist concern has got to live in…."

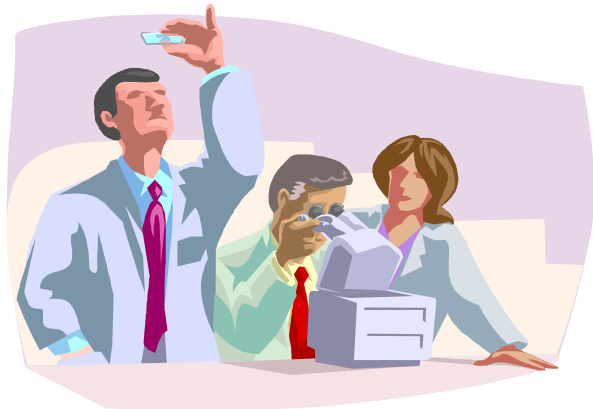


Joseph A. Schumpeter (1883-1950)

J.A. Schumpeter, *Capitalism, Socialism and Democracy*. 1942 [ see pp 82-85 in Harper Press edition of 1975]

# The Chaotic, Creative path from Invention to Innovation

- We think we understand the research and invention enterprise, much of it publicly funded.

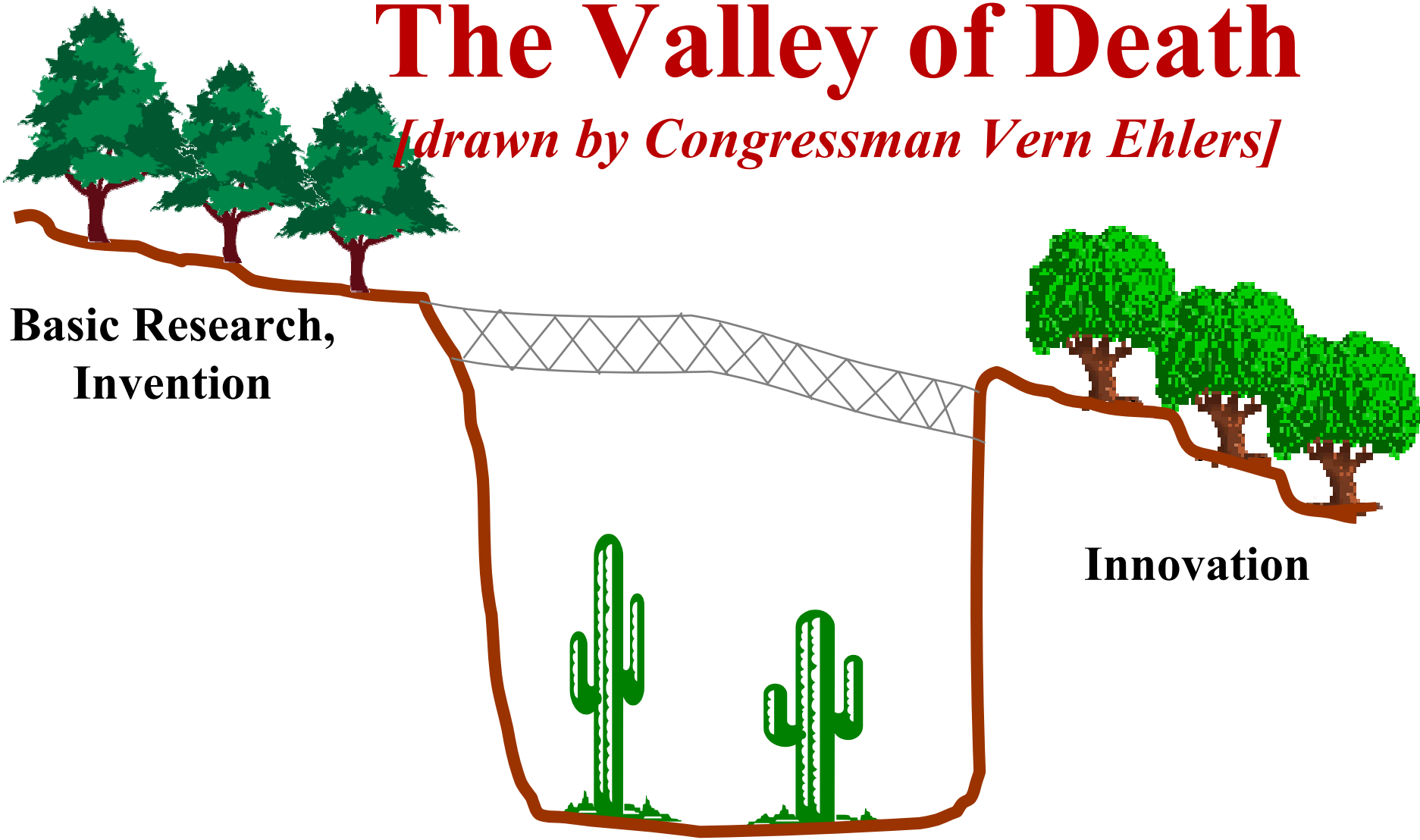


- We think we understand the financial and business world which creates wealth.

- But do we understand what goes in between?

# The Valley of Death

*[drawn by Congressman Vern Ehlers]*



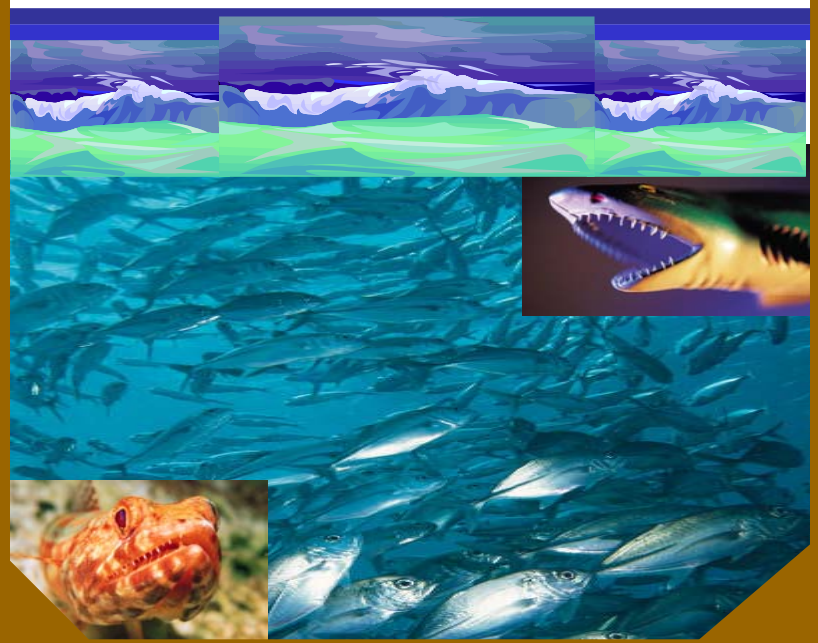

**"Valley of Death"**

LMB 7/3/01

# *The Darwinian Sea*

## *The Struggle of Inventions to Become Innovations*

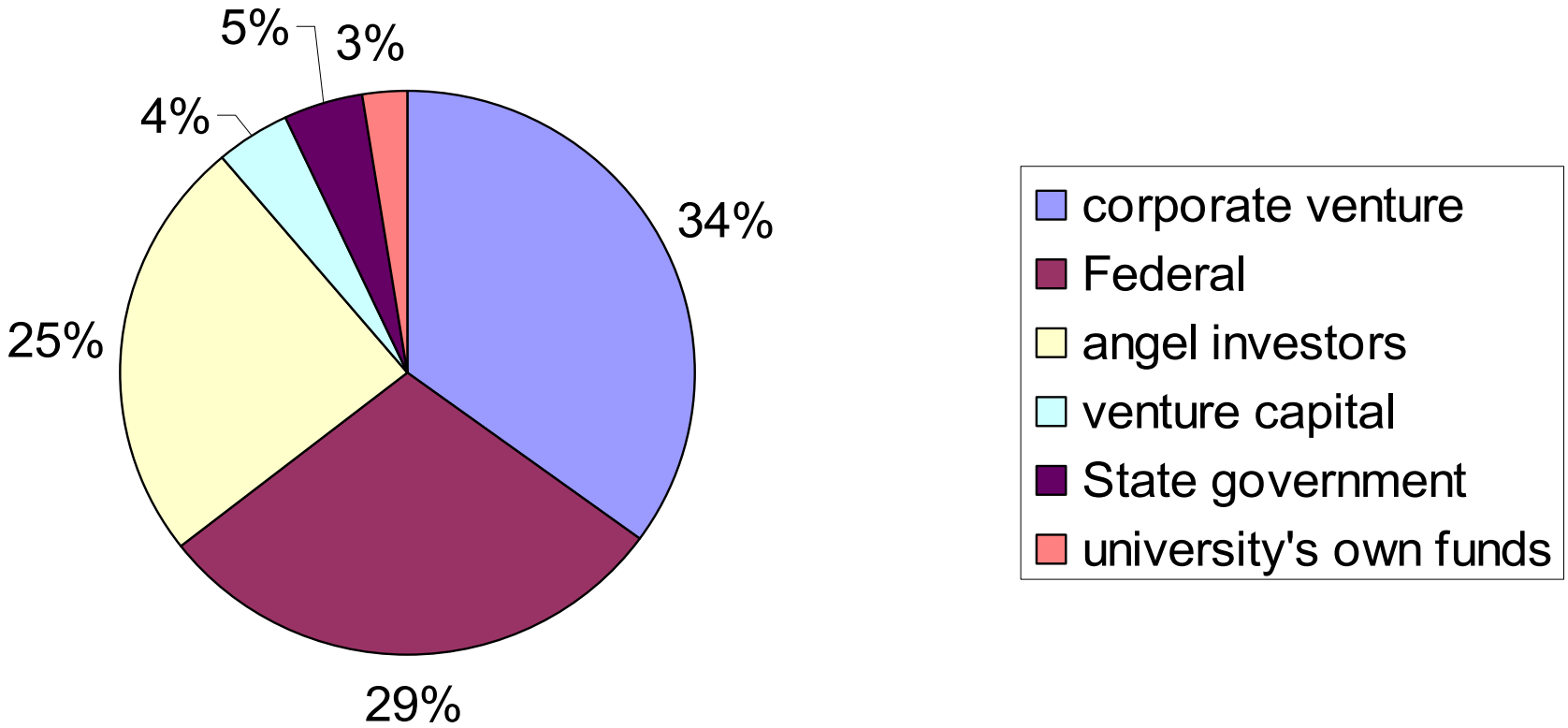
Research & Invention



Innovation: new products new business

"Struggle for Life"in a Sea of Technical and Entrepreneurship Risk

# Average percentage distribution of sources of finance for the invention – innovation transition drawn from high and low estimate models




---Branscomb and Auerswald 2003

# Nomenclature

- Basic and applied research are rarely useful distinctions in industry.
- Research [knowledge acquisition] and Innovation [knowledge commercialization] are the key issues
- An Innovation is the successful entry to the market of a novel product, process, or business model.
- An Invention is an Idea or concept for a new product or process.
  [Creating an innovation from an invention is a high risk venture.]
- Radical, high-tech Innovations create new markets with new technology and may destabilize an existing mature industry

# OUTLINE OF TALK

- Background
  - Henry Ergas' Dynamic Model of Innovation
  - Schumpeter's "Creative Destruction"
- Sources and sinks of technical knowledge for commercial innovation
- Relationships between demand for and sources of technical knowledge
- The broken link between research productivity and propensity to innovate.
- Social Capital: trusted networks for innovation

# Vertical vs Horizontal Structures

- Traditionally large firms sought to be self sufficient (vertical) to protect monopoly.

- Now need to accelerate innovation rate leads to outsourcing component and subsystem inventions to SMEs in supply chain.
  - Subcontracts based on performance specifications
  - Supply chain integration may lead to co-development
  - This accelerates technical knowledge diffusion

# Codified vs. Tacit knowledge

- Rapid progress in science since WWII drives codification of knowledge previously tacit.
- This accelerates global diffusion and absorption of practical knowledge
- Sources of useful knowledge are now more diverse.
- Tacit knowledge still key, but focused more on mastery of complex production, product and service systems.

# Model for Science-based Innovation Process

- Good idea but will it work? Critical stage is the technical entrepreneur's ability to reduce his concept to a manufacturable product of known performance characteristics functionally suited to an identified market of sufficient size.

- Do you have the data to convince VC investors? This information is then documented in a business case whose returns on investment, after all risks are included is sufficient to attract $7 million from one or more venture capital companies.

- In simple terms: figuring out how the idea can survive a trip across the Darwinian Sea.

# The sequence from an Idea to a material contribution to a $10T economy

- Idea, based on research, for a new product
- An innovation, initial entry to market
- A viable firm capable of funding its growth from earnings, perhaps an IPO or merger.
- A firm growing to multi-billions in sales leading a new industry.
- One in a thousand, at best, make the sequence.

# Henry Ergas Model of Innovation

- Dynamic model recognizing feedback loops from suppliers, users, providers of complementary assets, government and society large.
  - Generation: [all the steps from conception to innovation]
  - Application: [commercialization – full product line, distribution, customer service, user feedback
  - Verticalization: [Responses from supply chain, providers of complementary assets, user restructuring
  - Diffusion: [Societal adjustments: institutional shifts, training changes, government regulation…]

# Demand function for commercial knowledge

- Strongest demand is for incremental improvements especially in production and business processes
  - **funding market justified, direction driven by customers**

- Next strongest demand comes from customer/end user expectations in rapidly developing, newer, more science-based industries
  - **Funding market justified by subsidized by government research interests, direction driven by competitive opportunities**

- Third is from radical, out-of-core and new firm opportunities
  - **Many originating from or derivative of government-funded research; require angel investor, government, or corporate venture capital funding, direction driven by entrepreneurial vision.**

- Last is general investment in knowledge base to inform technical road maps and guide choices and business decisions
  - **internally funded and direction driven by core competence strategy.**

# Sources of Funding for High Tech Innovations

- For startups and spinouts from corporations
  - Corporate seed venture capital
  - Government programs to encourage innovation
  - Angel investors

# Who sets the performance requirements?

## Visionaries, investors, customers, end-users?

- What the customer wants may not be what the customer needs.
- Small firms often carry burden of testing the viability of meeting those needs in absence of expressed demand.
- Customer wants may not coincide with end-user needs; innovations must satisfy both.

## *Relationship between source of demand for technical Knowledge and sources of demand satisfaction*

| DEMAND / SOURCE | Evolution in face of market competition | In-core radical innovation to destabilize market | Out-of-core radical innovation create new market | Sustaining technical lead to support strategy |
|---|---|---|---|---|
| Corporate research | Moderate, usually through process techn. | Moderately strong, but hard to transfer | Very difficult | **Key role for Corporate Research** |
| Business unit R&D | **Primary role** | Difficult, requires strong leadership | N/A | Important for tacit knowledge |
| Outsourcing innovations to supply chain | **Key new strategy in formerly vertical firms** | Useful when linked to firms specialized in new technologies | Weak | Useful only if firms learn from suppliers |
| Collaboration, partnerships, M&A, JVs | Most useful for market expansion and broader product coverage | **Can be a key tool for in-core innovation** [IBM FLAT PANEL] | Weak | Useful only if firms learn from partners |
| New firm creation by spinoff or entrepreneurship | N/A | N/A | **Primary mechanism** | Advanced knowledge is both required and produced |
| Passive and active access to world knowledge | Important for process and product development | Essential for radical innovation | Most essential for out of core innovation | **Key task for corporate Research** |

# Sources of commercial ideas

- Individual entrepreneurs with a commercial vision and a passion for success.
- Universities, spinning out new firms and licensing new inventions.
- Government research commercialized through licenses and joint ventures
- Angel investors and others with novel business model or market opportunity, looking for the technology
- Spin-outs from Corporate Research in large firms

# Universities and high-tech innovations (Y2000)

- 8,500 patents filed by US universities
- $1.26B in royalties to US universities from 4,346 licenses in FY2000.
- 454 spin-off companies from universities
- US universities took equity interest in 56% of those deals --- up 46% from 1999.
- Research universities are now creating their own seed Venture Capital funds

  – Data from Association of University Technology Managers (AUTM) www.autm.net

“Angels” got that name from sponsors of Broadway theatre.

Today some 200,000 private equity investors in high-tech, new ventures.

A tiny fraction of them are high tech Angels creating new companies based on new science for new markets.

Who are they?

Technical entrepreneurs who have “been there, done that” and now nurture new firms to repeat the miracle of high tech innovation.

CAN YOU IDENTIFY THESE FUTURE ENTREPRENEURS WHO LATER BECAME ANGELS?

**BILL GATES; [microsoft]**

**MITCH KAPOR; [lotus]**

**FRED GIBBONS [software pub.]**

# Geographic and Industry sector concentration of innovation investments

- Skew of private investments by business sector:
  - IT, retail, medical & biotech were 76 % of total in ‘99
- Skew of private investment by geography
  - CA, MA, NY, TX  received 67 % of total VC in ’99

# Percent of patents to converted to innovations (1982):

- San Jose (**Silicon Valley**) innovations/patents = **57%**

  (highest among all U.S. metropolitan statistical areas with 100+ patents)
- Boston (MA): 35%
- Cleveland (Ohio): 18%
- Washington DC: 13%
- **Albany/Schenectady/Troy** (New York): **0.3%**

  (lowest among all U.S. metropolitan statistical areas MSAs with 100+ patents)

# Geographical concentration of patents and Innovations (U.S. 1982)

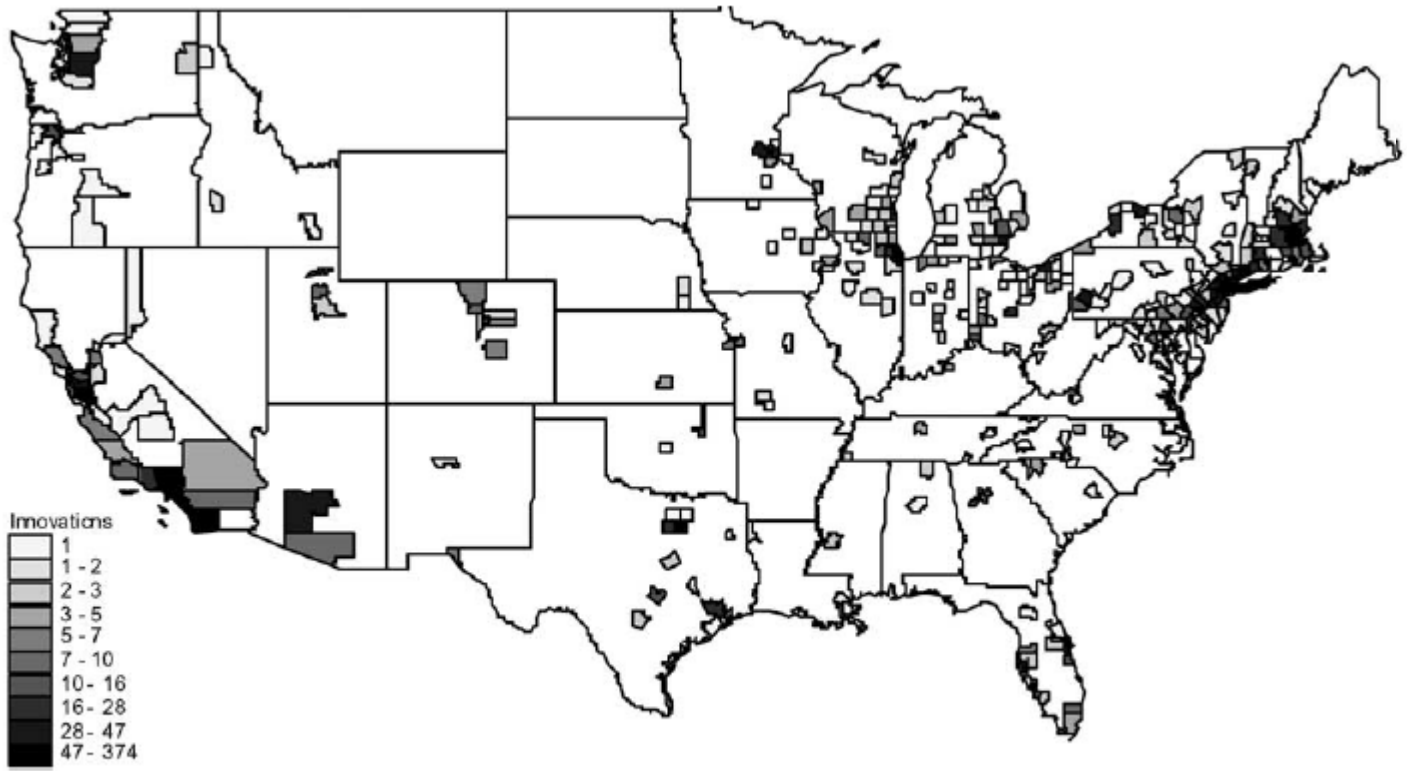



Fig. 1. The spatial distribution of innovations, 1982.

Source (Acs, Anselin, and Varga 2002); “innovation” counts from the U.S. Small Business Administration

# Intellectual Property Law

- Critical constraint on use of commercial knowledge, preserving temporary monopoly. In theory accelerates knowledge diffusion while limiting profitable use.

- Protection is essential to high-risk, high-tech start-ups

- Effect very different in each industry [*], depending on
  - Age and novelty of the technology
  - Breadth of opportunity to invent around patents
  - Size of the firms in the industry
  - Speed to market and regulatory constraints on speed

- There is growing feeling in larger firms that IP protection in US may be growing too slow, too expensive and too strong.

[*] Computer industry is heavily cross-licensed; Biotech industry depends on strong IP protection. Dot.com firms try to protect business models.

# Social Capital: trusted networks for innovation

- Capturing benefits locally
  - Examples of Si Valley & Boston vs. Cleveland & Albany
  - Building on, vs. displacing existing economy
  - 80% of university based startups in same state.
- Using the tools of innovation policy with local government to increase social capital.
- Partnerships and consortia may enhance – or be evidence of -- social capital.
- Richard Florida's discovery of the correlates to a community's innovation potential.

  - Richard Florida, *Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life* – Basic Books 2002

# Communications and Trust

- Technical innovator confident of success but risks failure if nature is not compliant.
- Business executive acts only when assured that risks are manageable.
- Venture capitalists rely on networks of trust and actively manage new firms.
- Success depends on access to networks of trust in the community

# Policy Issues

- How can funding for Early Stage Technology Development be sustained?
  - Should government funded research take ideas closer to “reduction to practice?”
  - Should the Advanced Technology Program be continued?
- Should government attempt to even out the geographical skew in places where innovations are created in large numbers?

# R & D

It’s not the R

It’s not the D

It’s the &