

# Manufacturing: Research, Reinventing, and Revitalizing

## Elements of a Long-Term Economic Growth Strategy

Gregory Tasse  
Senior Economist  
National Institute of Standards and Technology

[tasse@nist.gov](mailto:tasse@nist.gov)

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# The Bottom Line

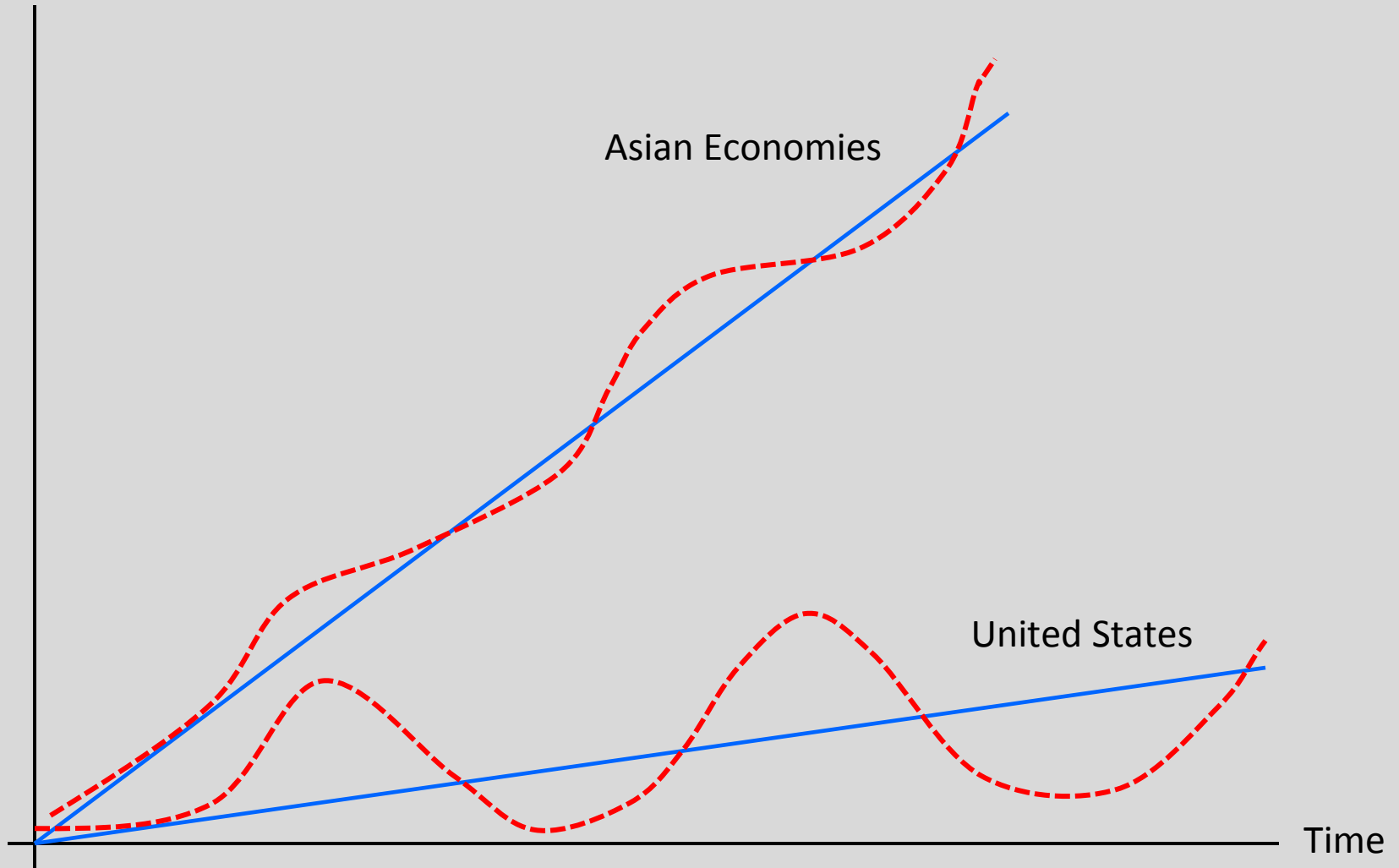
## Major Issues:

- 1) What is the nature of our economic problems — **cyclical** or **structural**?
- 2) Are U.S. economic **growth models** **are outdated**?
- 3) How would new models **change innovation-based growth policies**?
- 4) What do these models say about the current and future **roles for manufacturing**?

Bottom Line: Resolving these issues means **structural changes**, which take **time** and **persistence**

# The Bottom Line

GDP Growth Rate



## Key Economic Concepts:

- Modern manufacturing technologies are **systems**
- These systems are based on **increasingly complex sets of technologies**, which **must be effectively integrated**
- Therefore, **interdependencies exist among industries** that contribute advanced materials, various components, product subsystems, manufacturing systems, and eventually service systems

## Steps in R&D Policy Management:

- (1) Demonstrate **importance** of the policy issue for economic growth
- (2) Identify indicators of **underperformance** at the macroeconomic level
  - ❖ Productivity growth
  - ❖ Trade balances
  - ❖ Corporate profits
  - ❖ Employment and earnings
- (3) Estimate magnitude and composition of **underinvestment**
  - ❖ Specific R&D investment trends
  - ❖ Investment by phase of the R&D cycle
  - ❖ Technology diffusion rates
- (4) Identify **causes** of underinvestment
  - ❖ Excessive technical and/or market risk
  - ❖ Appropriability problems
- (5) Develop/select **policy responses** and management mechanisms
  - ❖ Policy instruments matched with underinvestment phenomena

## Case for a Domestic Manufacturing Technology Strategy

- 1) **Diversification:** Manufacturing contributes **\$1.6 trillion to GDP** and employs **11 million workers**
- 2) Manufacturing accounts for **~70% of US industry R&D** and of **scientists/engineers**
- 3) High-tech workers paid substantially more and **some of most technology-intensive industries** are in manufacturing
- 4) **Majority of trade** is in manufactured products
- 5) High-tech service jobs are growing but are not a panacea
  - a) Increasingly **“tradeable”**
  - b) **30 economies** have policies in place to **promote service exports**

## Service-Sector Dependency

- Service R&D consists largely of **systems integration**
  - High-tech manufacturing **provides large proportion of service industries' technology**
  - **Removed from the S&T establishment**, which inhibits understanding of emerging technological trends
- Bottom Line:
  - Increased **dependence on hardware and software firms** for assessments of technological opportunities and assistance in systems design
  - **Co-location synergies** are significant factor in development and absorption of new technologies by service firms

## Trends in Manufacturing

- Over 50 years (1957-2007), manufacturing's **share of GDP shrunk** from 27% to <12%
- For most of this period (1965-2000), manufacturing employment remained constant at 17 million
- Value of shipments in constant dollars continued to grow due to **productivity growth**
- BUT, in last decade, **3.8 million jobs lost** (2000-08) and **constant-dollar shipments remained flat** (2000-07)

# Underperformance

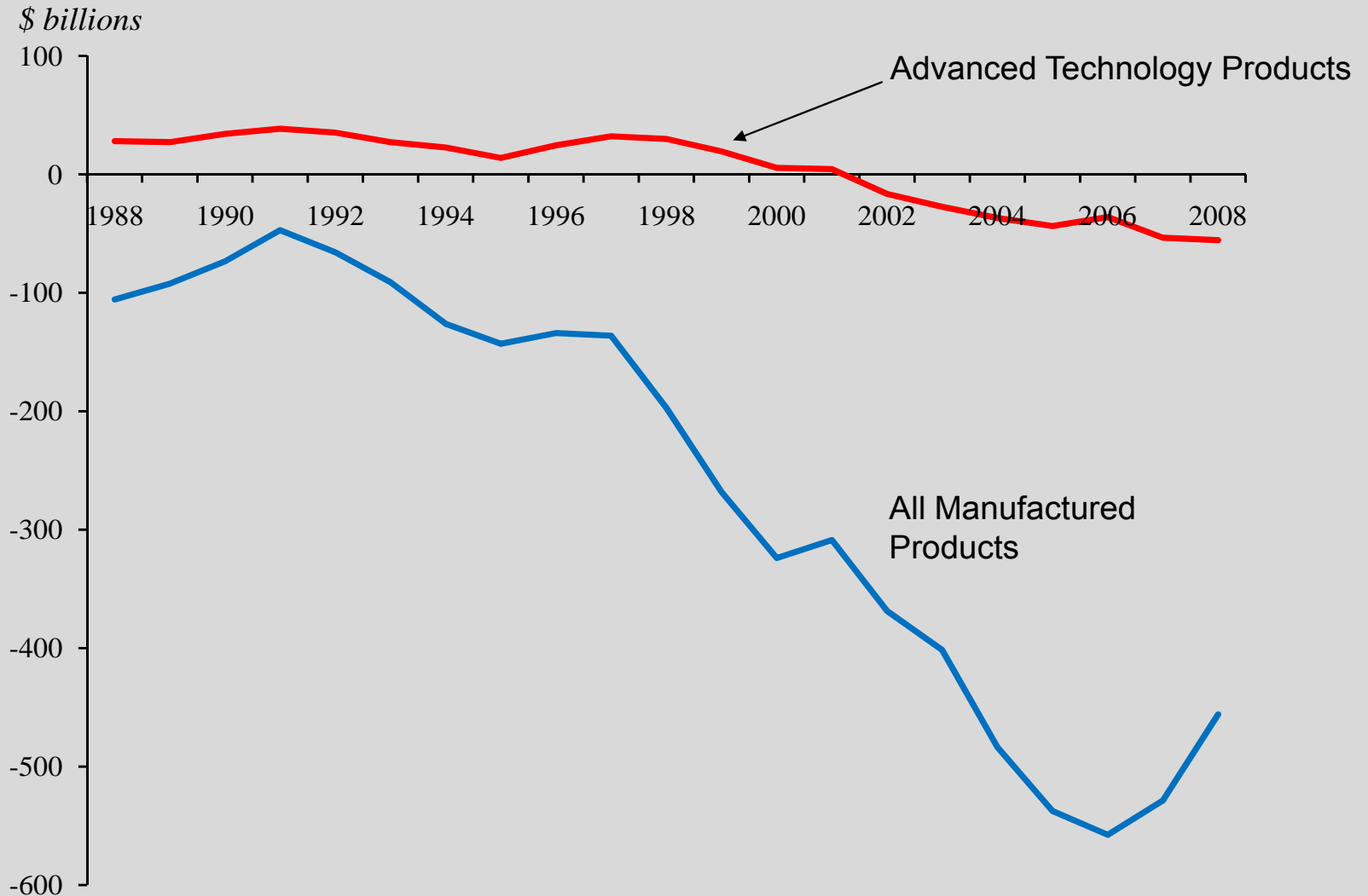
## Relationship Between R&D Intensity and Real Output Growth

Industry (NAICS Code)	Average R&D Intensity, 1999-2006	Percent Change in Real Output, 2001-2006
<b><u>R&amp;D Intensive:</u></b>		
Pharmaceuticals (3254)	10.3	38.3
Semiconductors (3344)	9.8	19.7
Medical Equipment (3391)	8.1	39.2
Computers (3341)	6.3	83.9
	<b>Group Ave: 8.6</b>	<b>Group Ave: 46.8</b>
<b><u>Non-R&amp;D Intensive:</u></b>		
Machinery (333)	3.8	12.3
Electrical Equipment (335)	2.5	-6.3
Plastics & Rubber (326)	2.3	4.6
Fabricated Metals (332)	1.4	7.8
	<b>Group Ave: 2.5</b>	<b>Group Ave: 4.4</b>

## Trends in Manufacturing R&D

- Manufacturing's average R&D intensity (industry-funded R&D/sales) began growing slowly in the mid-1980s from approximately 2.5 percent to the current rate of 3.7 percent
- The increase has been a response to globalization, but
  - More the result of offshoring low R&D-intensive industries than to absolute increases in R&D spending by remaining domestic industries
  - R&D intensity pales compared to truly "R&D-intensive" industries, whose ratios range from 6 to 22 percent
  - Most of the global economy's \$1.1 trillion annual R&D spending is targeting manufacturing technologies
  - U.S. manufacturing firms *increased offshore R&D at three times the rate of domestic R&D spending*
- Government-funded manufacturing R&D increases the sector's R&D intensity from 3.7 to 4.1 percent

## U.S. Trade Balances for High-Tech vs. All Manufactured Products, 1988-2008

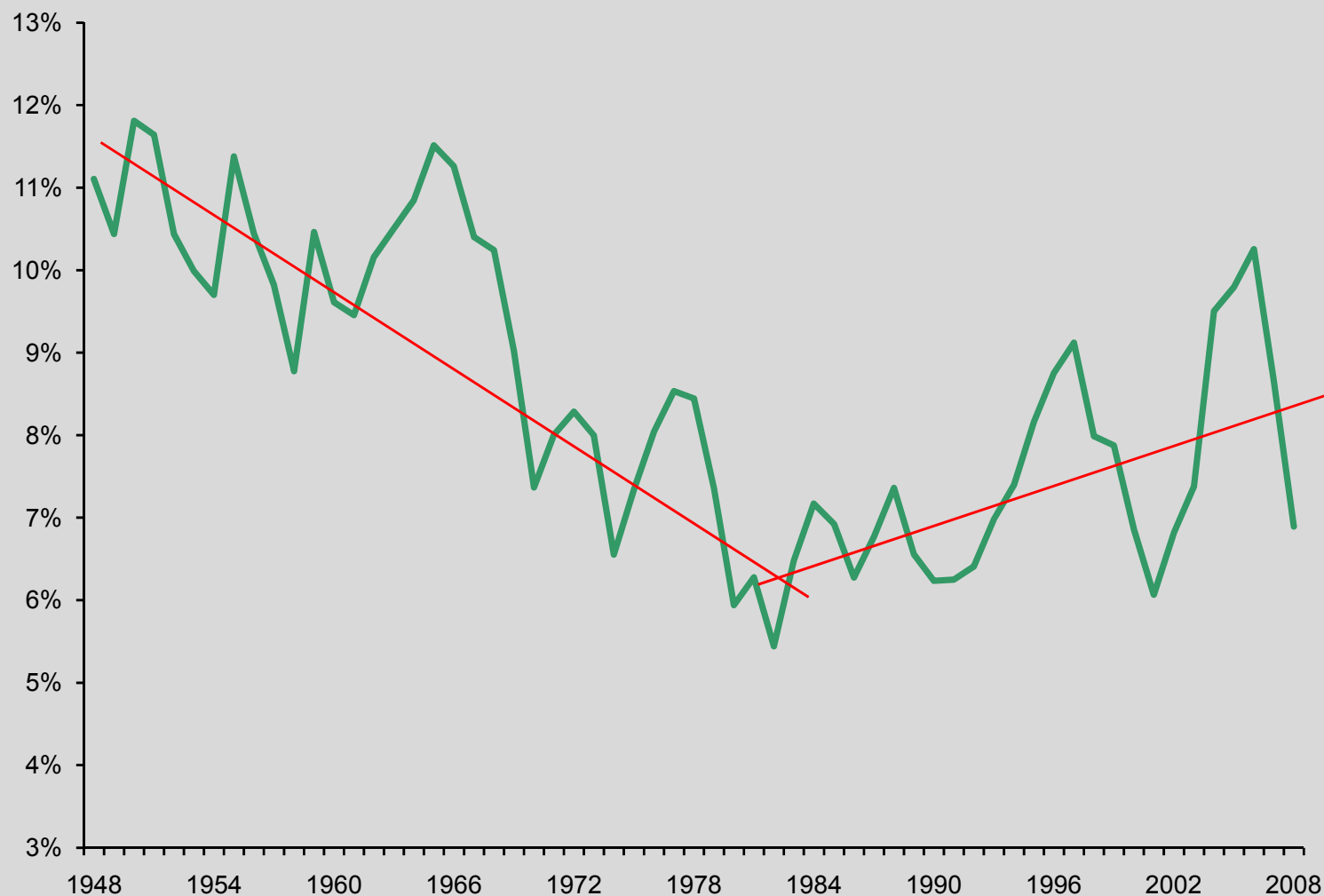


Source: Census Bureau, Foreign Trade Division

## Impacts of Globalization on Domestic Value Added

Industry (NAICS Code)	<u>% Change in Value Added</u>		R&D
	1985–2000	2000–2006	Intensity
U.S. GDP	132.6	34.4	2.6
<hr/>			
Manufacturing (31–33)	92.7	8.7	3.6
Motor vehicles and parts (3361-63)	84.0	-18.0	2.5
Textiles, apparel and leather (313-16)	8.2	-34.7	1.6
Computer & Electronic Products (334)	144.5	-24.7	9.0
Publishing, Including Software (511)	225.1	28.8	17.1
Information & Data Processing (518)	305.4	81.7	8.7
Professional, Scientific & Technical (54)	249.6	37.1	10.0
Health Care (621-23)	194.6	50.4	3.9

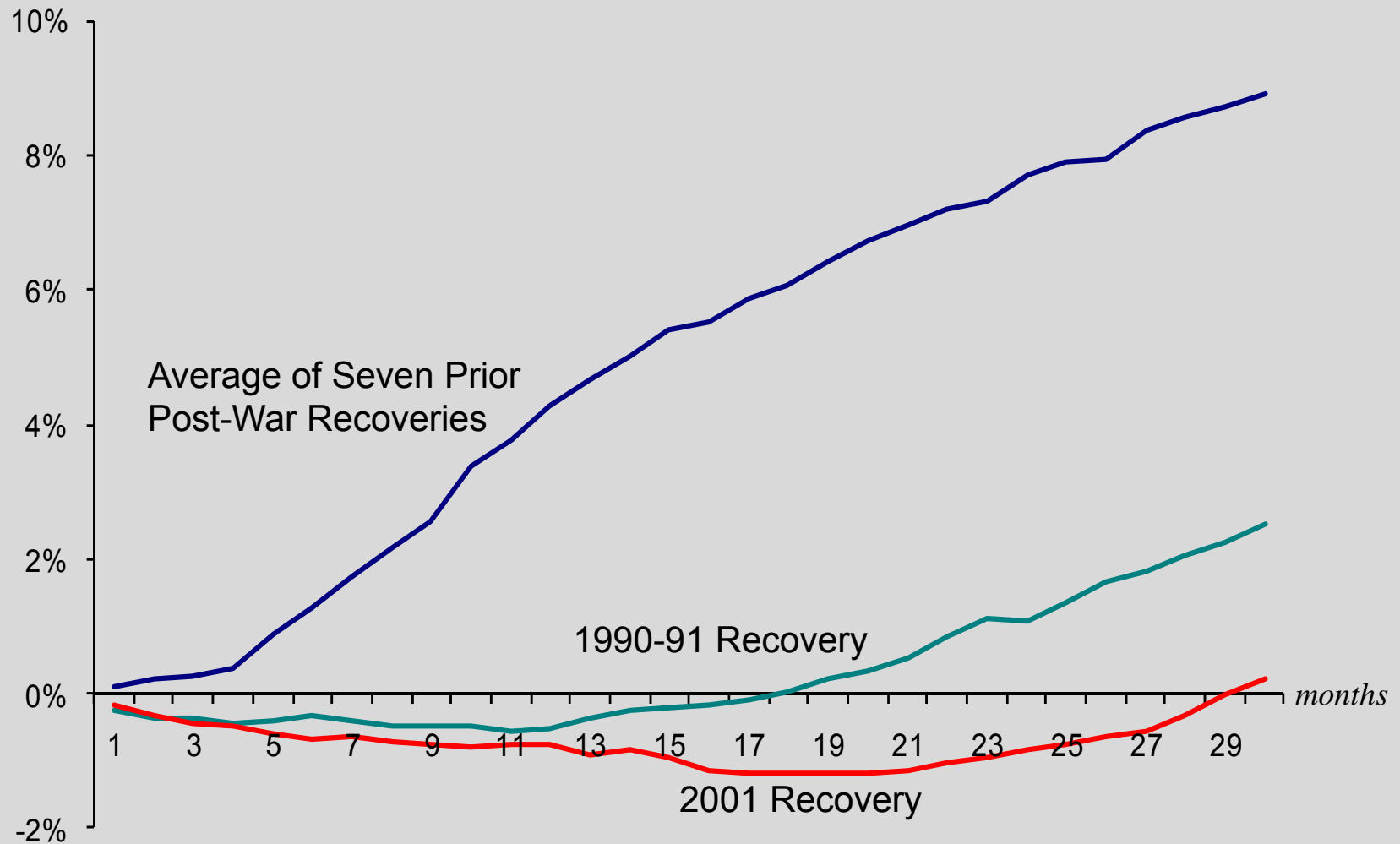
## U.S. Domestic Corporate Profits Before Taxes to GDP, 1948-2008



Source: Bureau of Economic Analysis, NIPA Table 1.14 for corporate profits before taxes (Gross Value Added). Domestic profits exclude receipts by all U.S. corporations and persons of dividends from foreign corporations, U.S. corporations' share of reinvested earnings of their incorporated foreign affiliates, and earnings of unincorporated foreign affiliates net of corresponding payments.

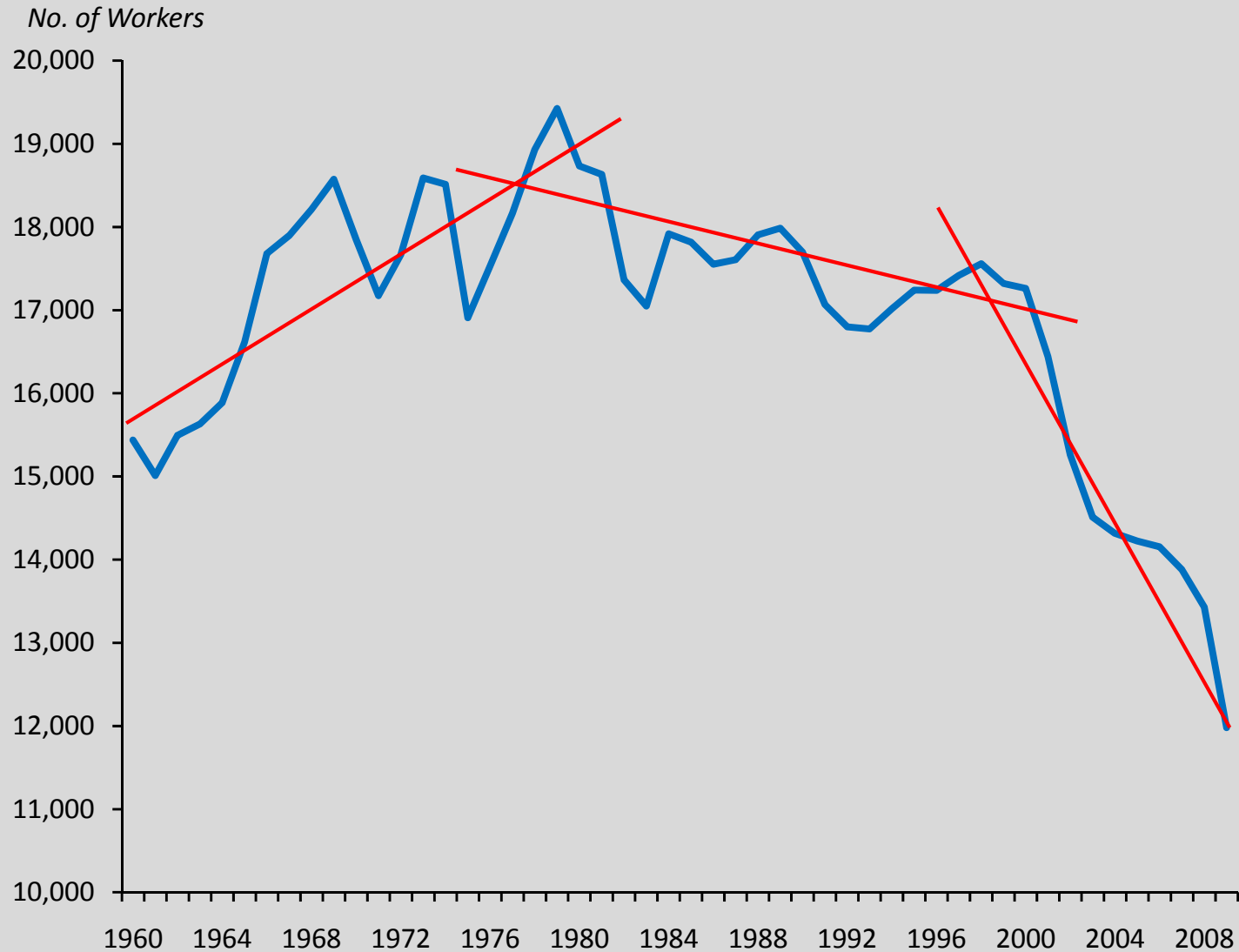
# Underperformance

## Non-Farm Private Sector Employment Growth in Post World-War-II Business Recoveries: Percent Change from Recession Trough



Sources: G. Tassej, *The Technology Imperative*; BLS for employment data; NBER for recession trough dates

## US Manufacturing Employment: 1960–2009



Source: BLS

## Even High-Tech Portion is Impacted: **Semiconductor Devices**

- Status: U.S.-headquartered firms still **account for 48 percent of global sales** and remain technological leaders
- Status: Fabless/Fab-lite firms—evolved out of necessity due to inability to capture economies of scale in manufacturing
- Trend: U.S. domestic share of global semiconductor manufacturing capacity
  - 1980: 42%
  - 1990: 30%
  - 2007: 16%
- Trend: Global 300mm capacity:
  - U.S. share sunk by 50% in the last decade (36% to 18%)
  - 80 percent of new 300mm plants are outside the U.S.
- Trend: **U.S. firms increasing foreign R&D faster than domestic spending**

## Even High-Tech Portion is Impacted: **Printed Circuit Boards**

- Supplies components used in tens of thousands of products
- **U.S. industry shrunk** from \$11 billion to \$4 billion during the 2000s
- Production process
  - Once relatively labor intensive, which led to its offshoring
  - Now highly automated, but **other countries have automated**
- Majority of the global industry remains in Asia **near the next tier in the electronics supply chain (assembly)**

## Poor Technology Life-Cycle Management:

The United States **has been the “first mover” and then lost virtually all market share** in a wide range of materials and product technologies, including

- oxide ceramics
- semiconductor memory devices
- semiconductor production equipment such as steppers
- lithium-ion batteries
- flat panel displays
- robotics
- video cassette recorders
- digital watches
- interactive electronic games

## Industry Structure is a Characteristic of Investment

- R&D is not undertaken in a vacuum
- At a single tier in high-tech supply chain, coordination is required (i.e., horizontal integration—virtual or organizational)
  - Product design and process-technology development
  - Process-technology development and commercial-scale operations
- Vertical distribution of R&D in a supply chain involves greater amounts and types of collaboration

## Co-location Synergies

- Traditional **OEM-led supply chain**
  - OEM conducted majority of R&D and controlled component design
- Increasing pace and complexity of technological change leading to the **“value-stream” supply chain**
  - R&D is **backward distributed**
  - Much more collaboration (**virtual** vertical integration) among the supply chain’s tiers
  - Backward integration of R&D increases need for **“open innovation”**
- **Co-location** essential for **tacit knowledge transfers** in early phases of technology’s development
  - Key issue is **maturity of technology**
- Boeing, Airbus examples of global supply chain management problems

## Typical Process of Offshoring:

1) Manufacturing with **small amount of supporting R&D**

assembly—China

components—Taiwan, Korea

2) Host country gains some R&D experience and **expands R&D infrastructure** to capture synergies **at the relevant tier** in high-tech supply chain

3) Host country then **begins to integrate into design** and into **adjacent tiers** in supply chain to capture higher value added

China—backward to components (from assembly)

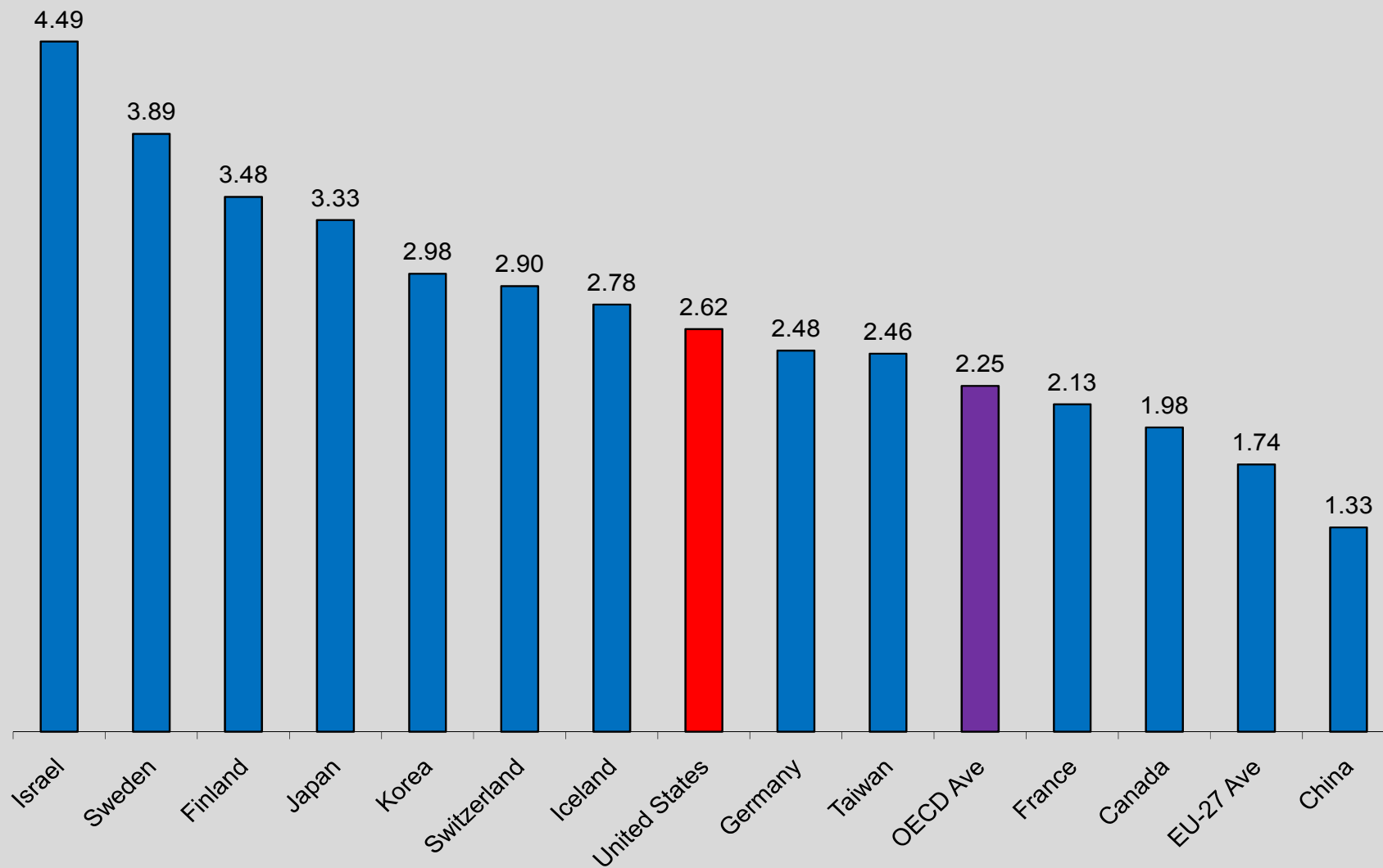
Taiwan—forward to electronic circuits (from components)

Korea—forward to electronic products (from components)

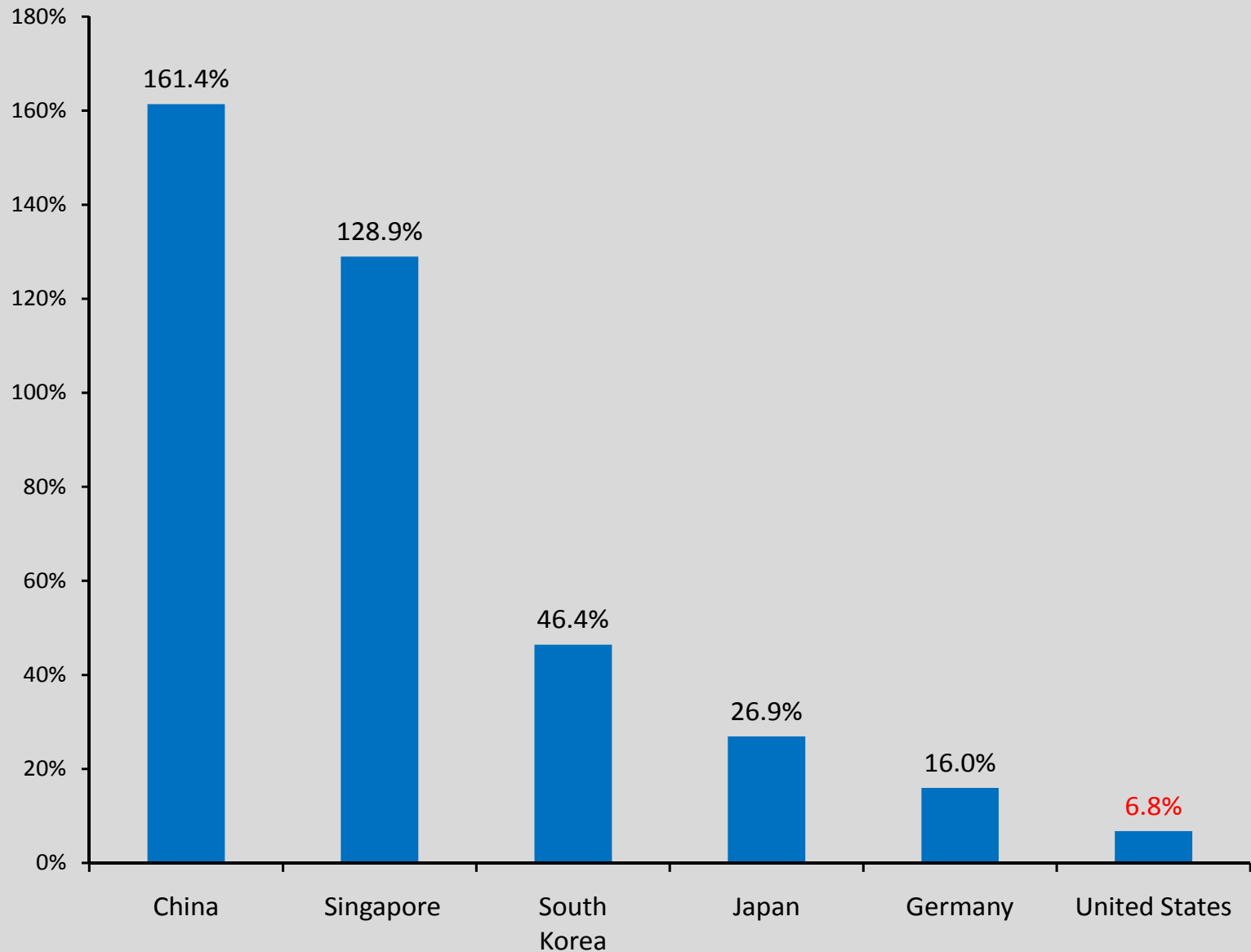
4) Some hosts **eventually begin to integrate forward into services**

5) **Co-location synergies** are captured

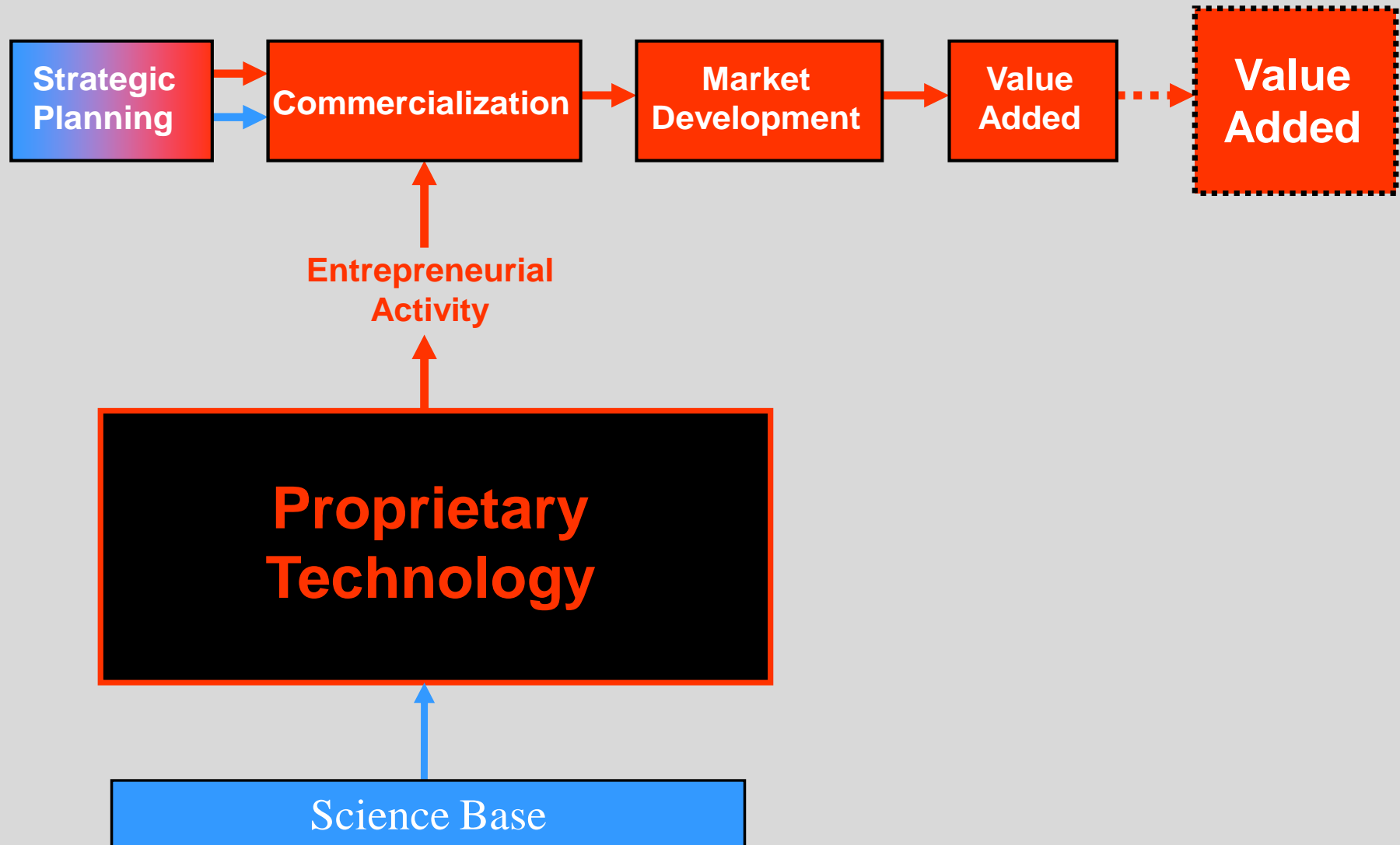
## National R&D Intensities, 2005 Gross R&D Expenditures as a Percentage of GDP



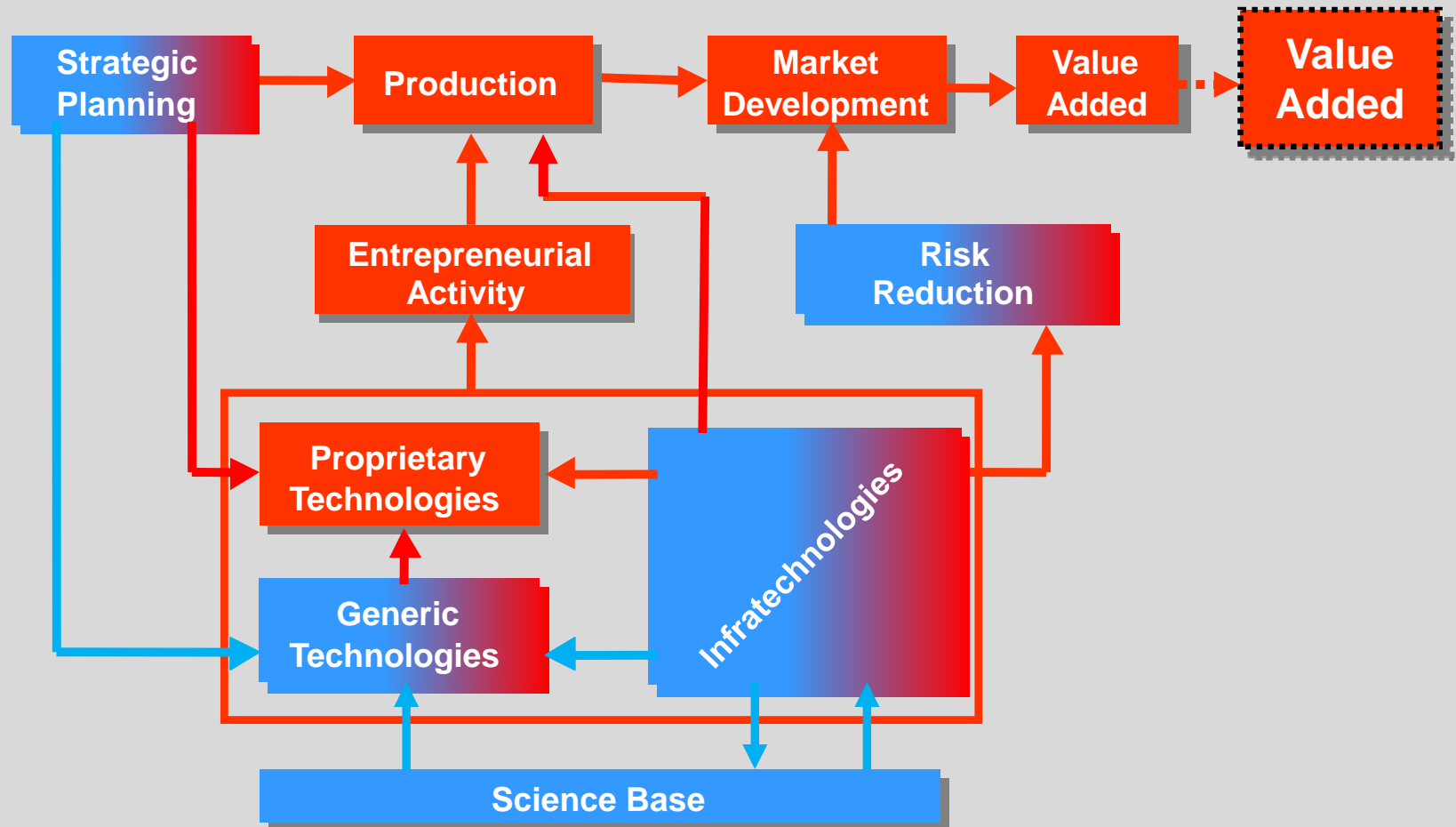
## Change in National R&D Intensity, 1995-2007



## “Black Box” Model of a Technology-Based Industry



## Economic Model of a Technology-Based Industry



Gregory Tasse, *The Technology Imperative*, 2007; and, “The Disaggregated Technology Production Function: A New Model of Corporate and University Research”, *Research Policy*, 2005.

## Example of the Complexity of Generic Technology Research

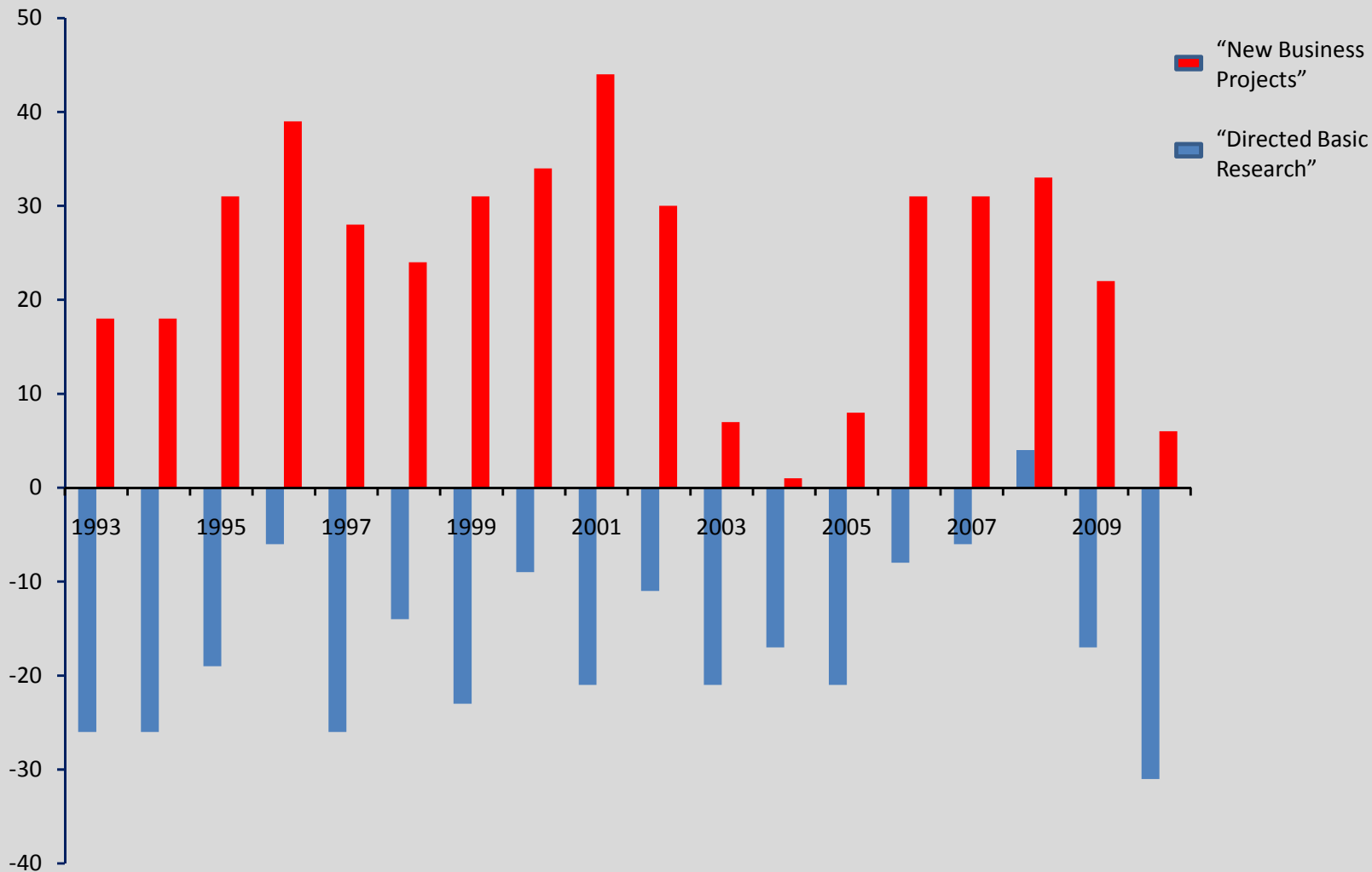
The required elements of the “post-CMOS” or “new logic switch” technology platform based on nanoelectronics (material – process – property concepts) :

- 1) Concepts of new circuit design technologies based on properties of individual molecules
- 2) Generic fabrication methods for radically new classes of materials based on unique electronic properties
- 3) Generic methods for inducing novel compounds to self-assemble into the precise structures needed by new electronic devices and architectures
- 4) Generic methods for interconnecting new devices into circuits

## Examples of Infratechnologies Supporting Nanotechnology

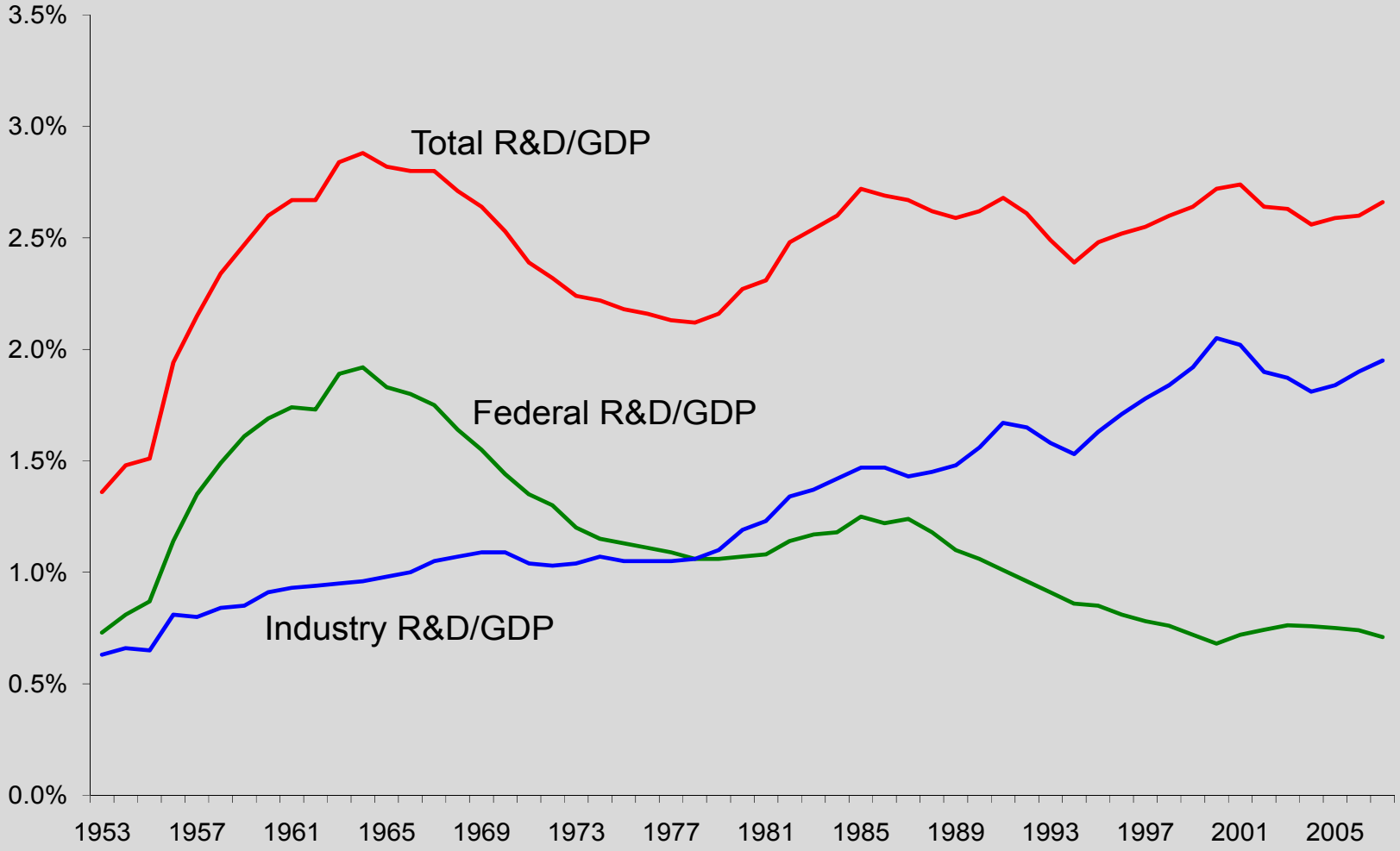
- **Techniques for measuring** the shapes, dimensions, and electrical characteristics of the various molecules making up nanoscale devices
- **Techniques for manipulating and measuring** the spin of individual electrons
- **Scientific and engineering data for characterizing** the fundamental physical behavior and long-term reliability of new nanoelectronic materials

## Trends in Short-Term vs. Long-Term US Industry R&D, 1993-2010



Source: Industrial Research Institute's annual surveys and calculation of "Sea Change Indices". A Sea Change Index is calculated by subtracting the percent of respondents reporting a planned decrease in the particular category of R&D spending from the percent planning an increase of greater than 5 percent. Sample size and respondents vary from year to year.

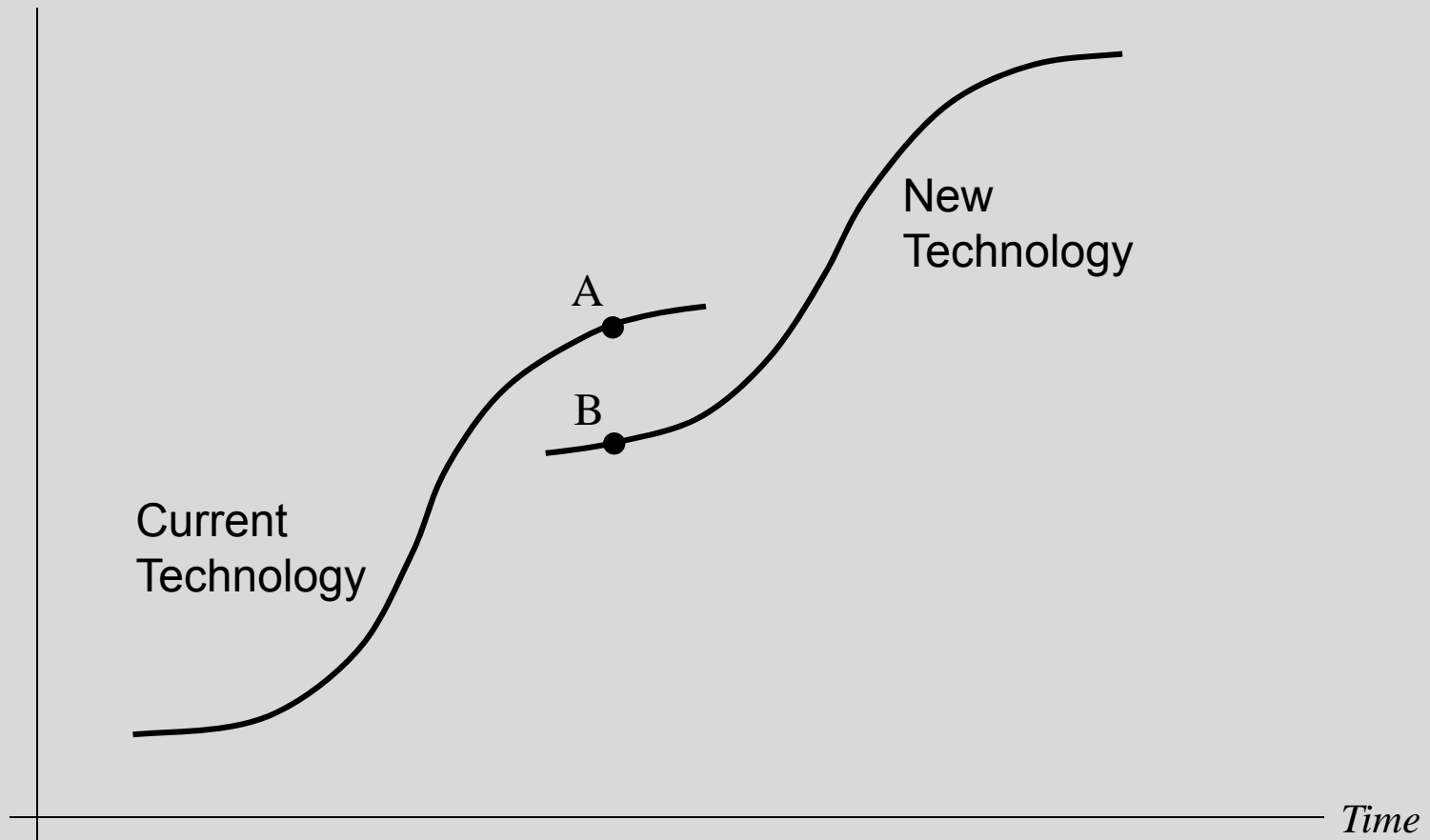
## R&D Intensity: Funding as a Share of GDP, 1953-2007



Source: National Science Foundation

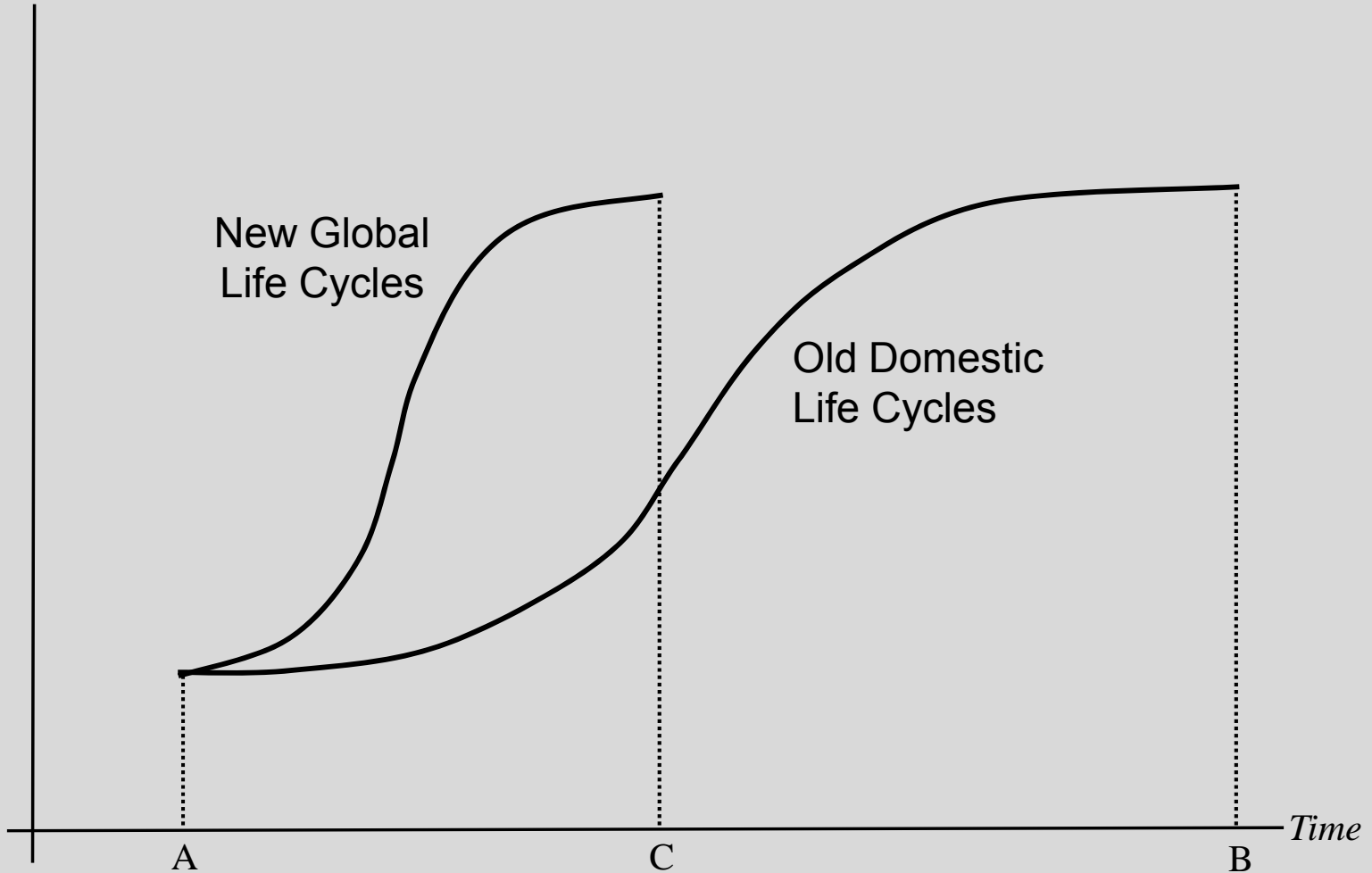
## Transition Between Two Technology Life Cycles

*Potential or Actual  
Performance–Price Ratio*



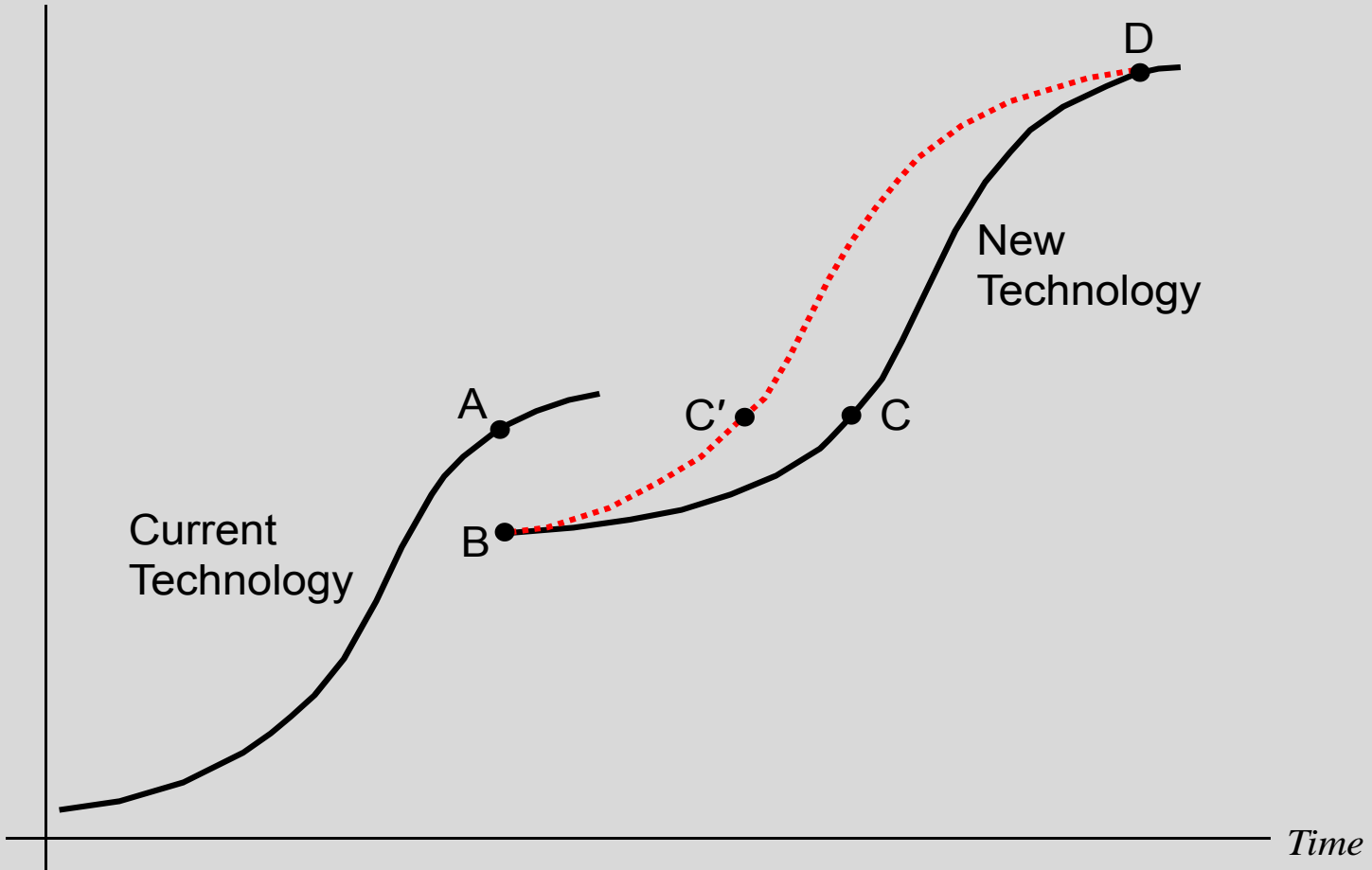
## Compression of Technology Life Cycles

*Potential or Actual  
Performance/Price*



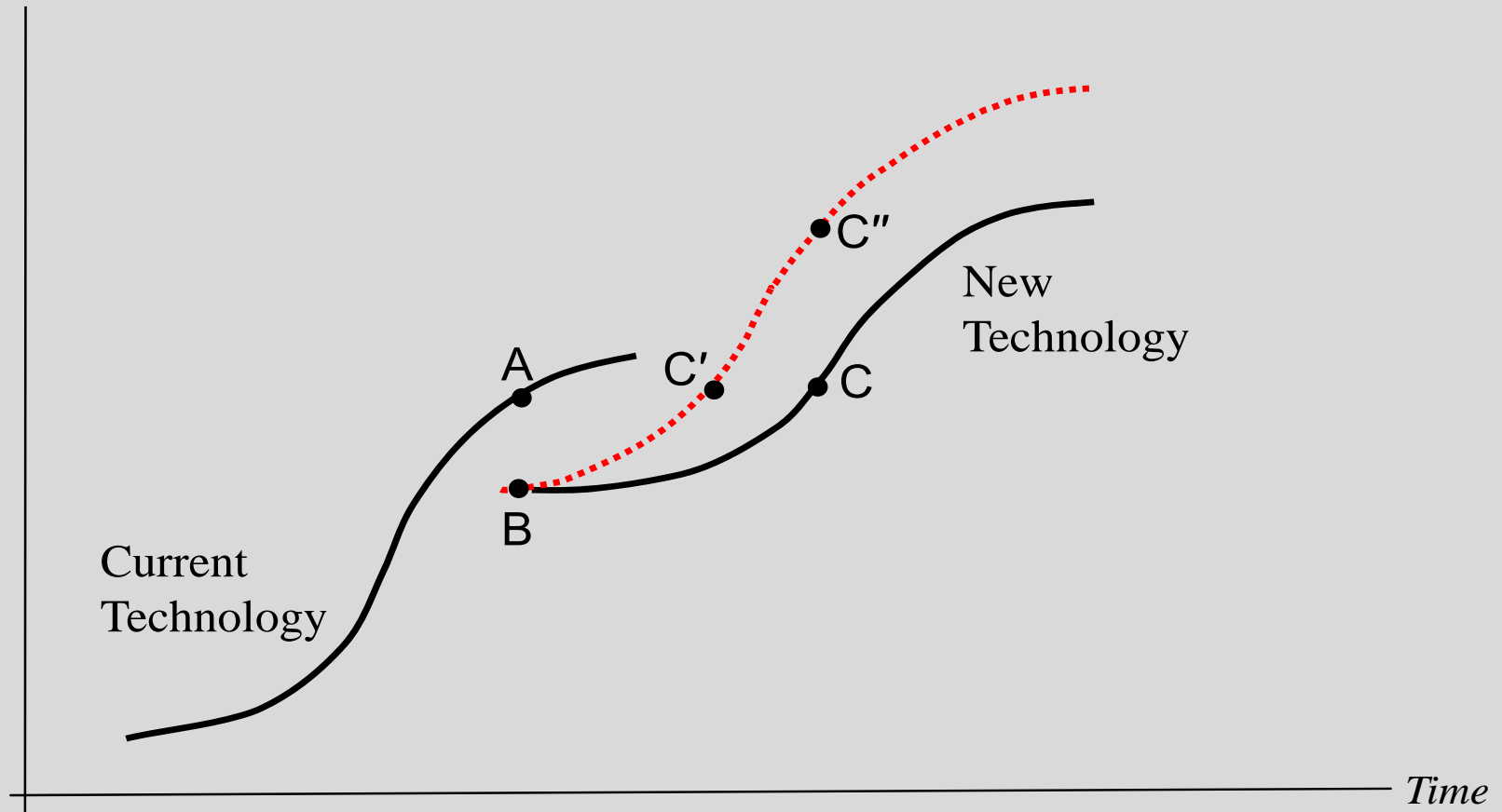
## Life-Cycle Market Failure: Generic Technology

*Potential or Actual  
Performance–Price Ratio*

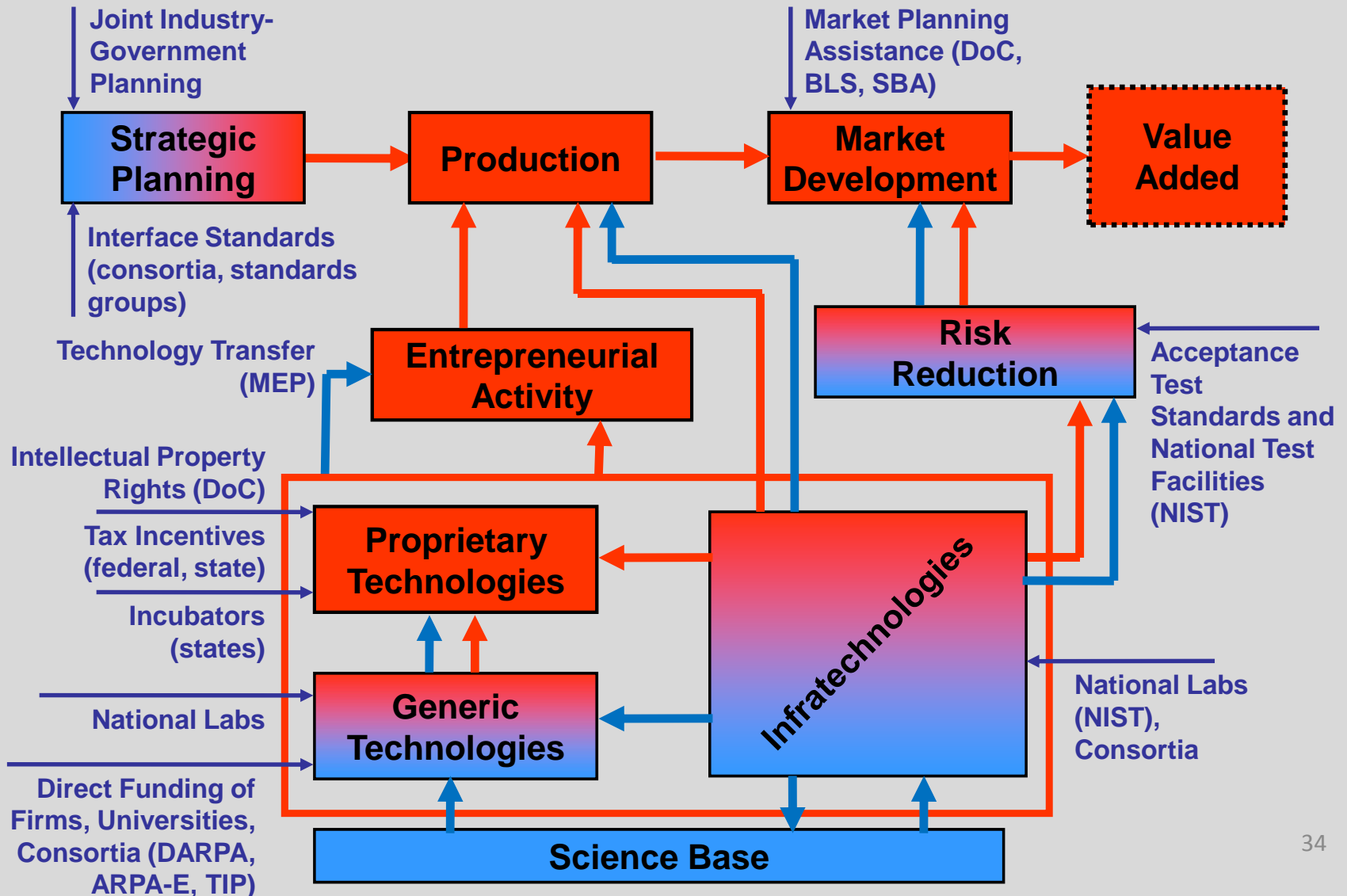


## Life Cycle Evolution: Infratechnology

*Potential or Actual  
Performance–Price*



## Science, Technology, Innovation, Diffusion (STID) Policy Roles



## Four Targets of R&D Policy:

- **Amount** of R&D
  - Lower the user cost of R&D capital
- **Composition** of R&D
  - Manage the technology life cycle through R&D portfolio adjustments
- **Distribution** of R&D among tiers in high-tech supply chains
  - Promote supply-chain integration in the domestic economy through R&D funding and technology clusters
- **Efficiency** of R&D
  - Increase the output and shorten the R&D cycle through technology clusters and other forms of collaboration and portfolio management methods

## The Bottom Line:

- 1) Amount of R&D: Manufacturing's **R&D intensity** should be doubled to **6-7 percent**
- 2) Amount of R&D: Restructure the **R&E Tax Credit** and enlarge it to approximately a **20 percent flat** credit (ASC is a move in the right direction)
- 3) Composition of R&D: **Federal R&D** must be **increased** and **better balanced** using a portfolio approach **optimized for economic growth**
- 4) Composition of R&D: **Federal R&D** must be **element-based**, distinguishing among science, generic technology (proofs of concept), and infratechnologies
- 5) R&D efficiency and Distribution of R&D: Increase technology clusters, improve timing of policies over technology life cycle
- 6) Overall: A **STID policy analysis function** must be established

**“Sooner or later, we sit down to  
a banquet of consequences”**

**– Robert Louis Stevenson**