The Technology Imperative and The Future of R&D Policy

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The Technology Imperative

- **Conventional wisdom: "The world is flat"**
  - *Global diffusion of competitive assets*
  - *Technology has become a major competitive asset*
- Increasing role of technology enables nations to "tip the flat world" in their favor
- **Requires a new growth paradigm based on**
  - *Evolutionary shift in corporate strategy*
    - National → Multinational → Global
    - Result is reduced stake in the "home" economy
  - *Emergence of governments as competitors*

The Technology Imperative

The Problem:

- The United States is no longer "*the* high-tech economy"
- Resistance to adaptation in the face of the emergence of the global technology-based economy is pervasive
  - *Installed-base effect* (sunk costs: investments in intellectual, physical, organizational and marketing assets)
  - *Installed-wisdom effect* (the current approach is the best one)
- "The long run is not a problem until you get there, then it's a crisis"

The Technology Imperative

- **New growth paradigm requires revisions to long-standing economic concepts**
  - Revision to static version of the "law of comparative advantage"

    Imperative: Switch to a dynamic version of this law
  - Modification of Schumpeter's "one-sector" creative destruction model

    Imperative: Modify to a two-sector, full life-cycle model

Response: Improved R&D Policy Analysis

(1) Demonstrate importance of technology 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 market risk
- Appropriability problems
- Inadequate innovation infrastructures

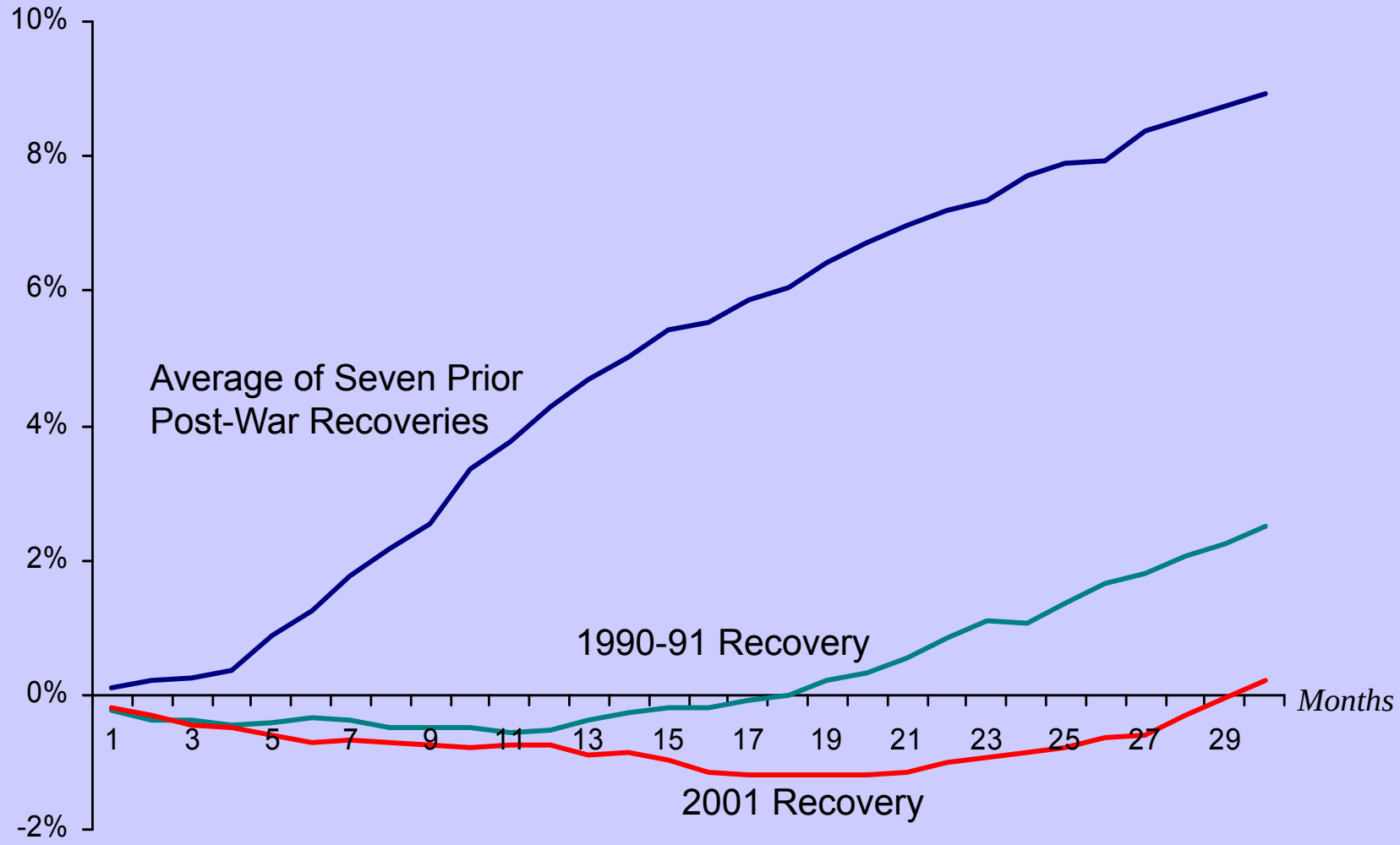
(5) Develop policy responses and management mechanisms
- Policy instruments matched with underinvestment phenomena
- Economic impact assessments

Importance of the Technology-Based Economy

1) **Technology** accounts for **one-half of output** (GDP) growth
2) **High-tech portion** of industrialized nations' **manufacturing** output has increased by a factor of between 2 and 3 over past 25 years
3) **High-tech portion** of global **trade in goods** has tripled in the past 25 years
4) **Median wages** in all 29 BLS "high-tech" industries **exceed median for all industries;** 26 of these industries exceed national median by **>50%**
5) **Technologically stagnant sectors** show **slow productivity growth** resulting **above-average price increases**
6) **Acceleration** of U.S. productivity growth in 1990s is entirely **due to technology investments**
7) **Productivity advantage** of the U.S. economy over other OECD countries **accounts for 3/4 of the per capita income gap**
8) **Rate of return** from R&D is **four times** that from physical capital

Underperformance

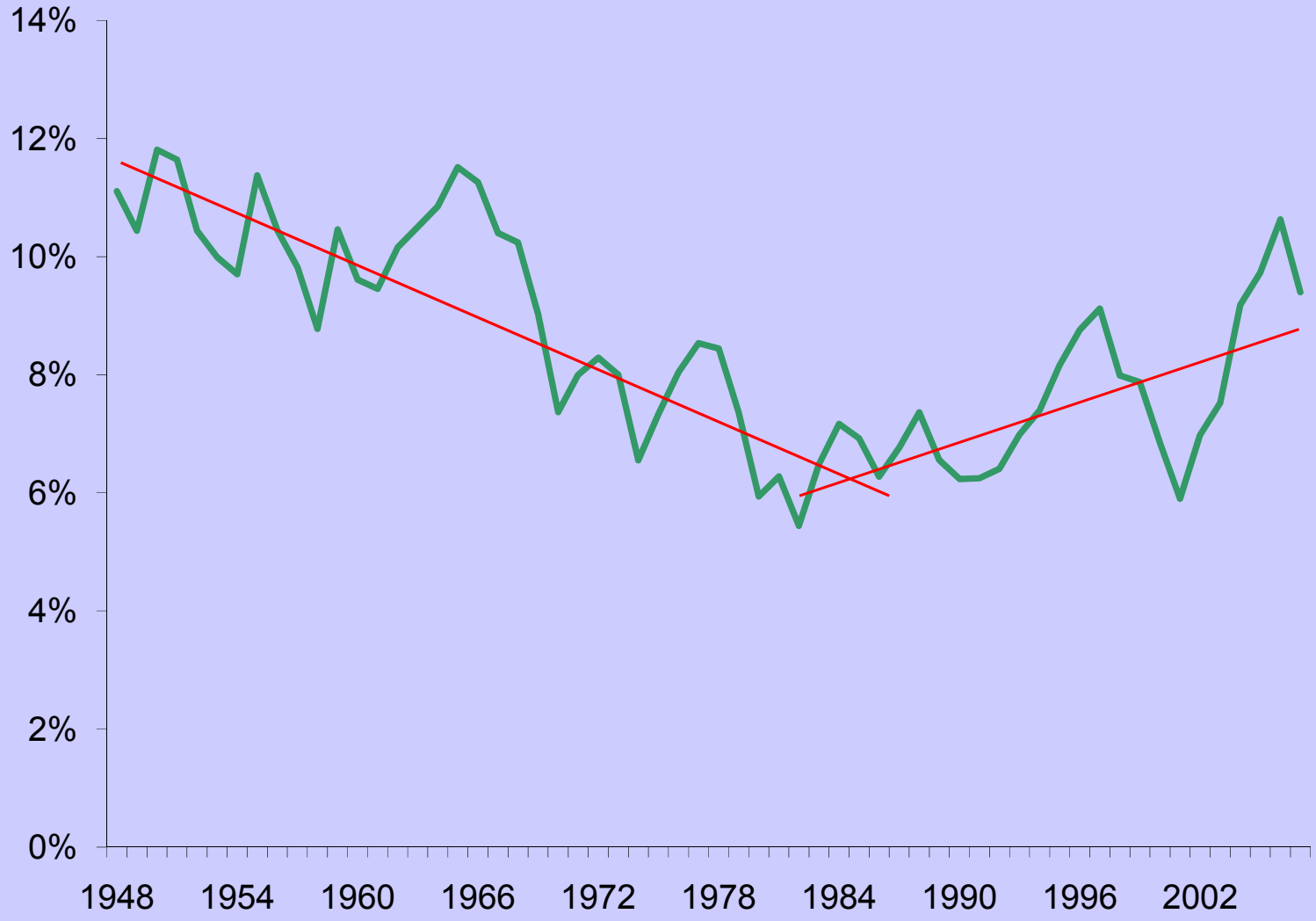
Non-Farm Private Sector Employment Growth in Post World War II Business Recoveries: Percent Change from Recession Trough



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

Underperformance

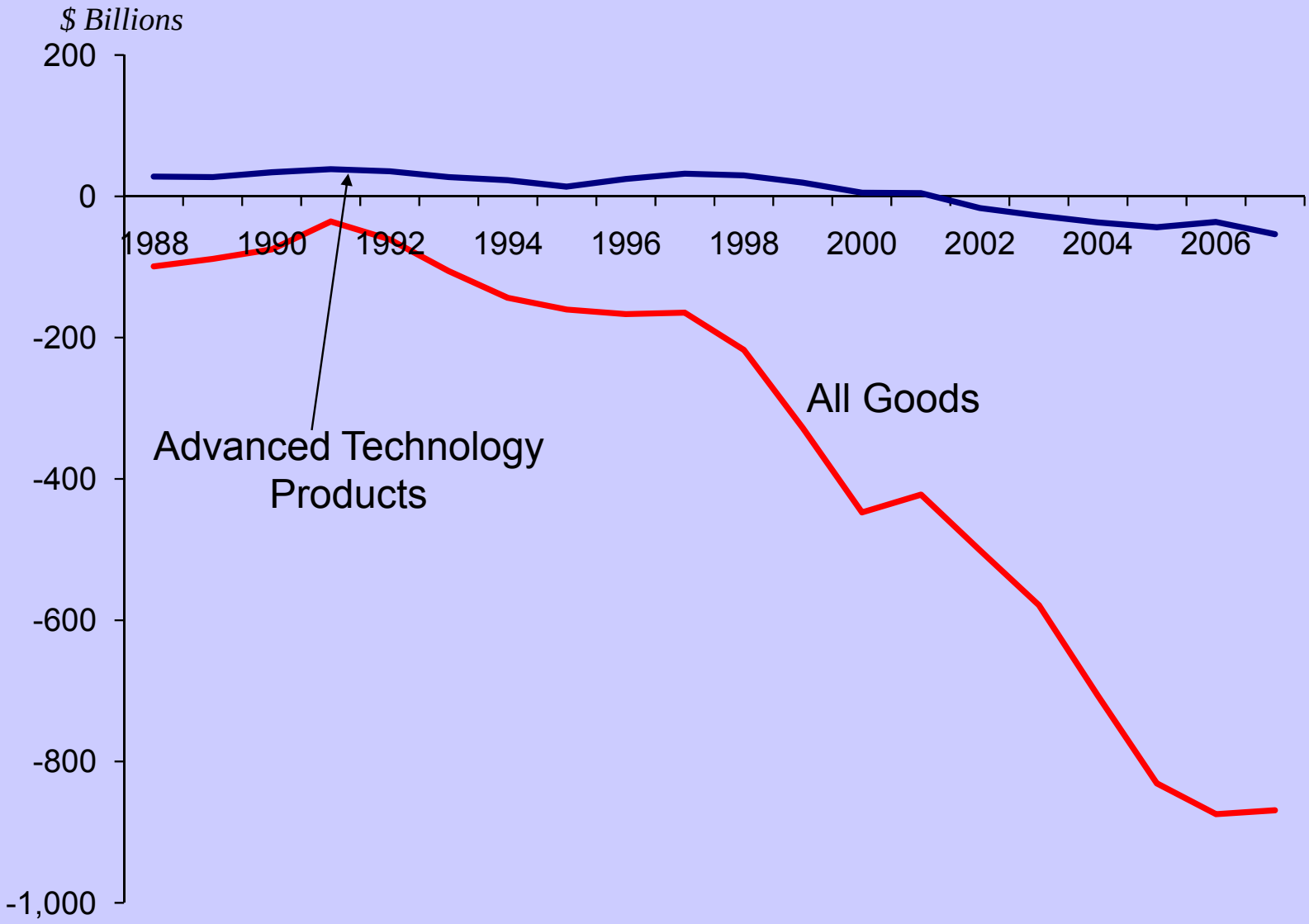
Ratio of Domestic Corporate Profits Before Taxes to GDP, 1948-2007



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

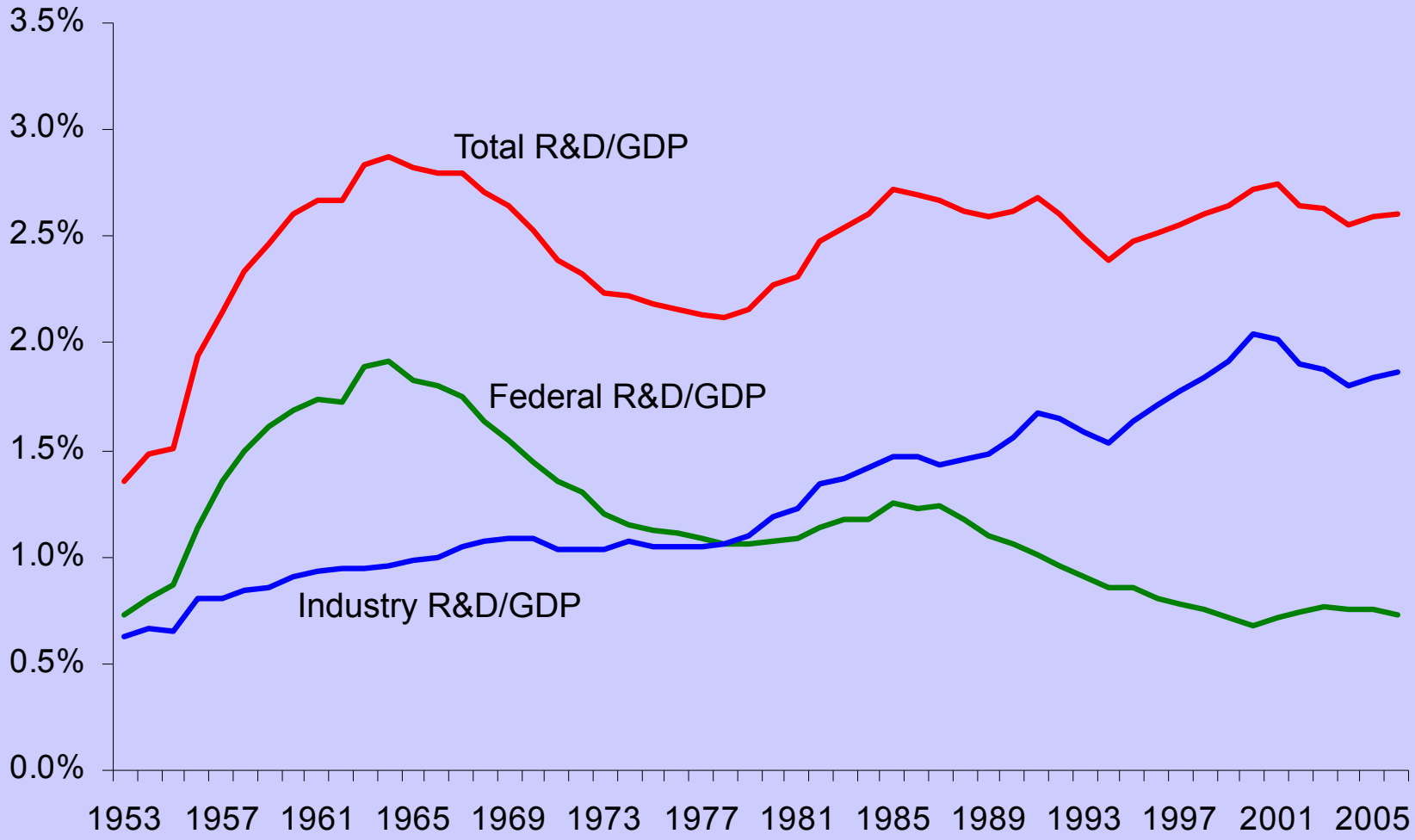
U.S. Trade Balances for High-Tech vs. All Goods, 1988-2007



Source: Census Bureau, Foreign Trade Division

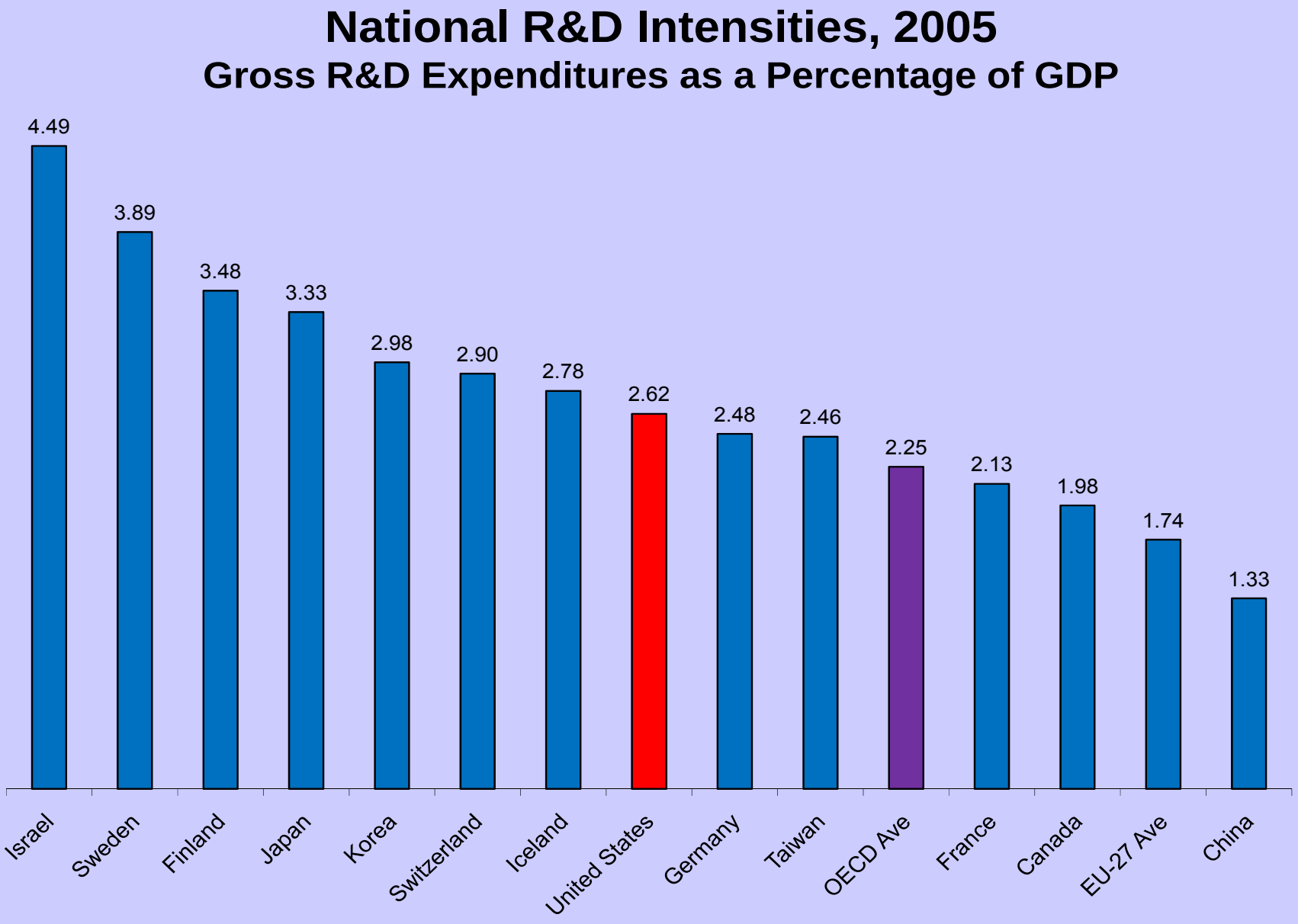
Indicators of Underinvestment – Amount

R&D Intensity: Funding as a Share of GDP, 1953-2006



Source: National Science Foundation

Indicators of Underinvestment – Amount



Source: OECD, *Main Science and Technology Indicators*, May 2007

Indicators of Underinvestment – Amount

- **High-Tech Sector:**
  - Electronics
  - Pharmaceuticals
  - Communication Services
  - Software and Computer-Related Services
- **Accounts for 7 – 10 percent of GDP**
- **Bottom Line:** The other 90+ percent of the economy is susceptible to market share erosion and decline

Indicators of Underinvestment – Amount

Trends in Value Added

Industry (NAICS Code)	% Change in Value Added 1985–2000	% Change in Value Added 2000–2006	R&D Intensity
GDP	132.6	34.4	2.6
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

Indicators of Underinvestment – Amount

Geographic Concentration:

- Six states account for almost one-half of all R&D
- Ten states account for 60 percent of all R&D
- **Bottom Line:** The remaining 40 states are not a high-tech economy

Indicators of Underinvestment – Amount

Geographic Distribution of U.S. R&D: Top Ten States by Share of R&D Performance, 2006

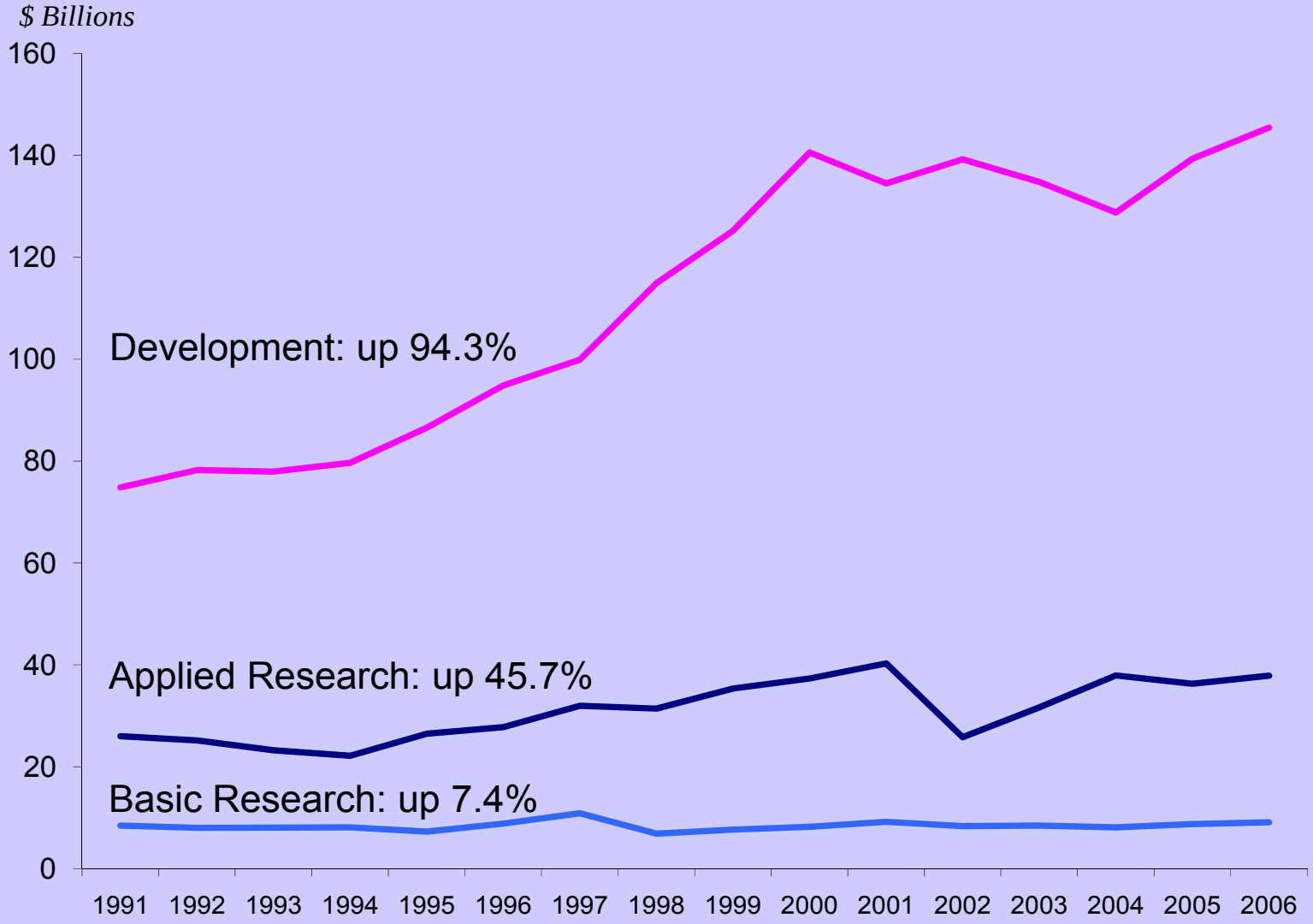
State	% of Population	% of National R&D
California	12.0	19.8%
Michigan	3.3	5.7%
New York	6.3	5.5%
Texas	7.8	4.4%
Massachusetts	2.1	4.9%
Pennsylvania	4.1	4.6%
New Jersey	2.8	4.4%
Illinois	4.2	3.9%
Washington	2.1	3.7%
Maryland	1.8	3.7%
Total	46.5	60.5%

Source: National Science Foundation

Indicators of Underinvestment – Composition

Industry Funds for R&D by Major Phase, 1991-2006

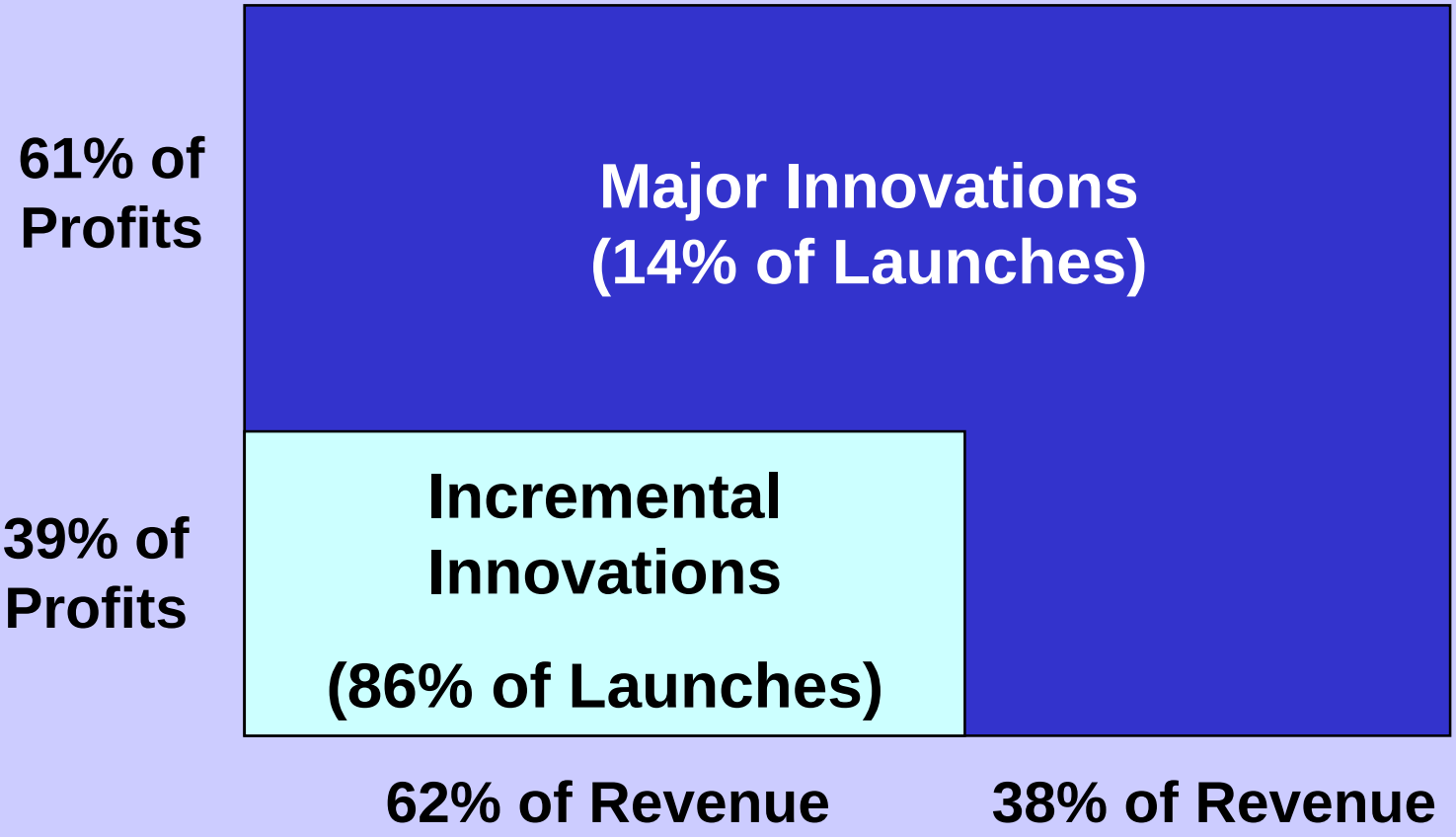
(in constant 2000 dollars)



Source: National Science Foundation

Indicators of Underinvestment – Composition

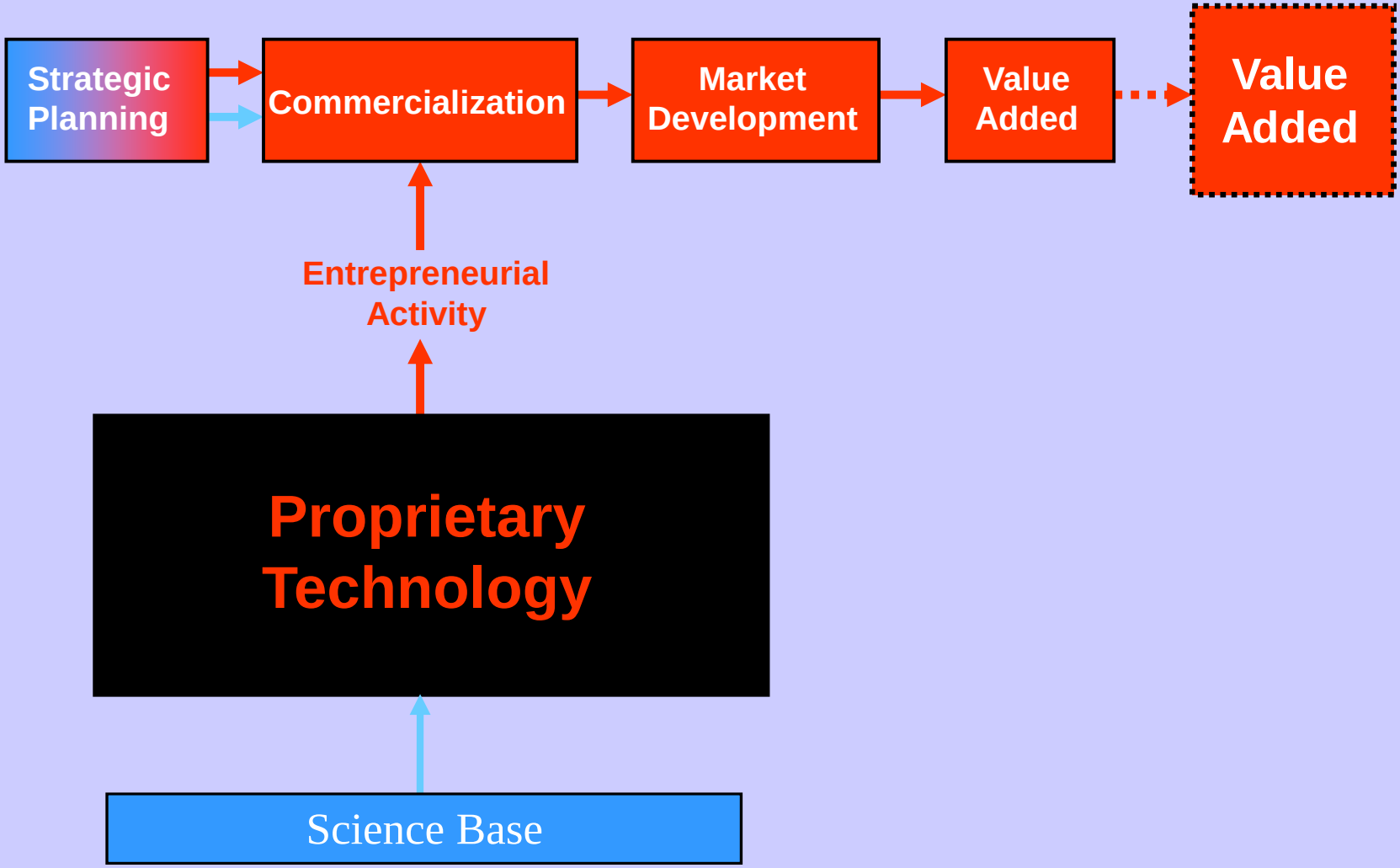
Profit Differentials for Major and Minor Innovations



Source: W. Chan Kim and Renee Mauborgne, "Value Innovation: The Strategic Logic of High Growth", *Harvard Business Review*, 1997

Causes of Underinvestment — Composition

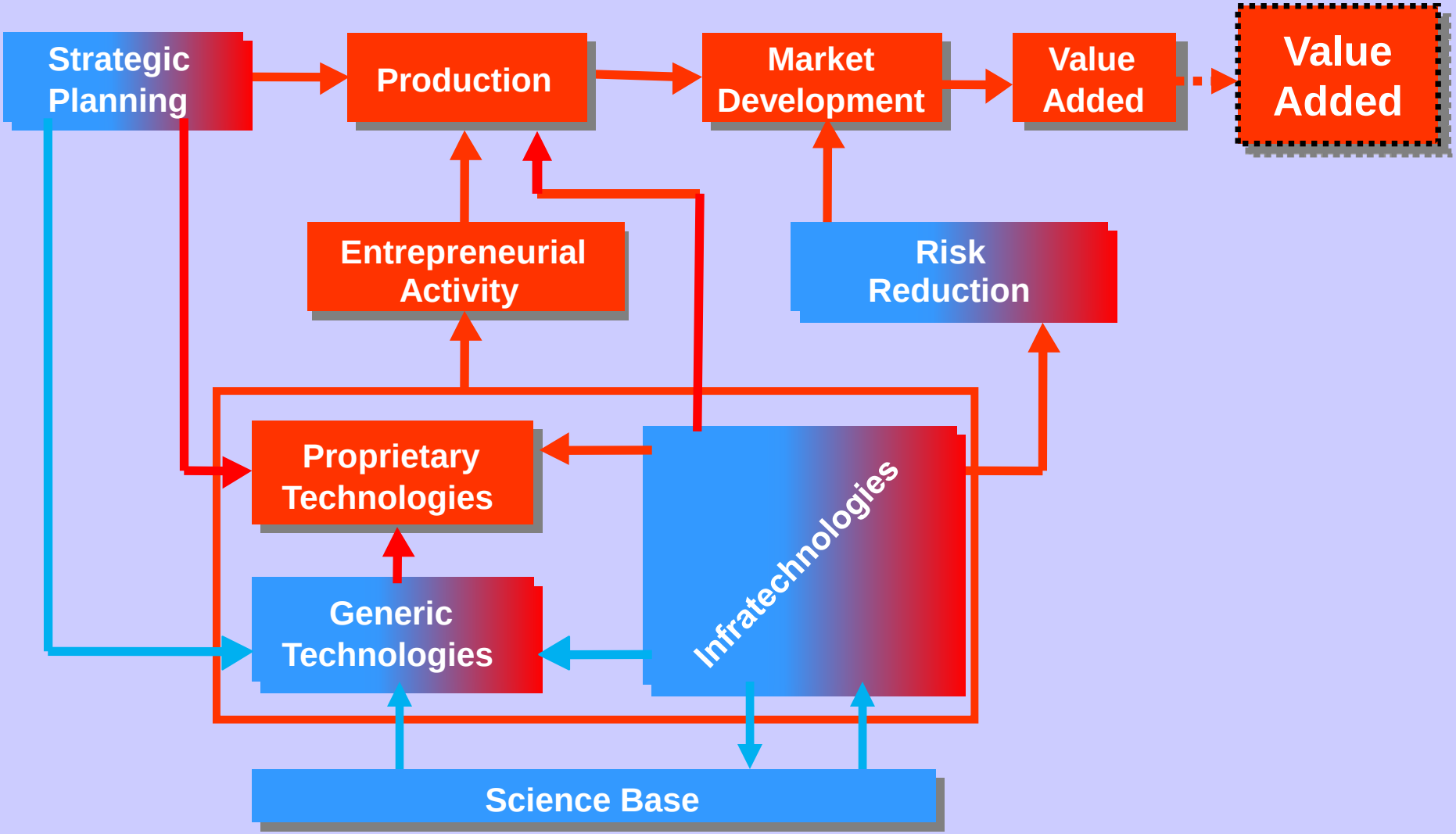
"Black Box" Model of a Technology-Based Industry



G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

Causes of Underinvestment — Composition

Economic Model of a Technology-Based Industry



Gregory Tassey, *The Economics of R&D Policy*, 1997

Causes of Underinvestment — Composition

Application of the Technology-Element Model: Biopharmaceuticals

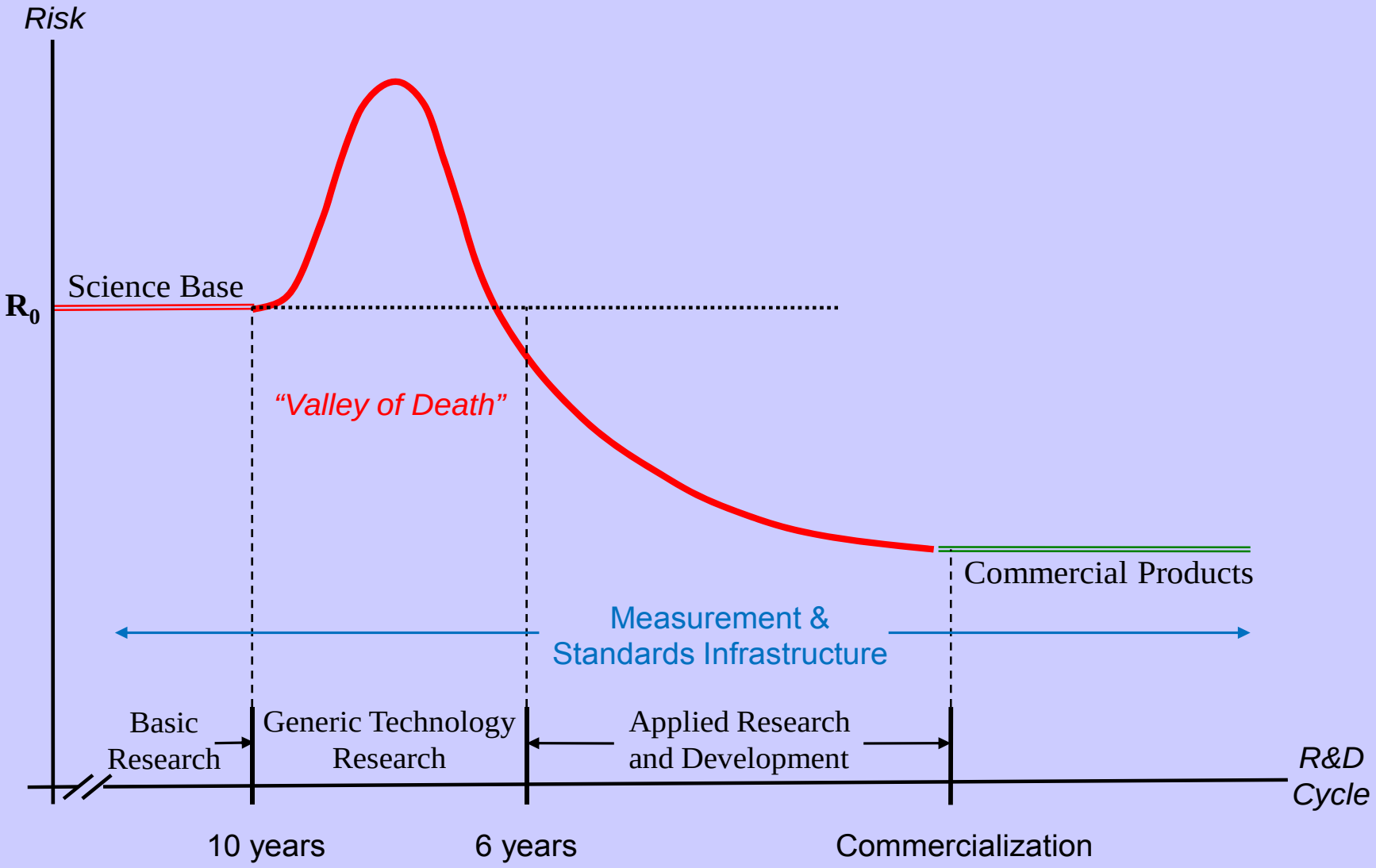
Science Base	Infratechnologies	Generic Technologies: Product	Generic Technologies: Process	Commercial Products
▪ genomics	▪ bioinformatics	▪ antiangiogenesis	▪ cell encapsulation	▪ coagulation inhibitors
▪ immunology	▪ biospectroscopy	▪ antisense	▪ cell culture	▪ DNA probes
▪ microbiology/ virology	▪ combinatorial chemistry	▪ apoptosis	▪ microarrays	▪ inflammation inhibitors
▪ molecular and cellular biology	▪ DNA sequencing and profiling	▪ bioelectronics	▪ fermentation	▪ hormone restorations
▪ nanoscience	▪ electrophoresis	▪ biomaterials	▪ gene transfer	▪ nanodevices
▪ neuroscience	▪ fluorescence	▪ biosensors	▪ immunoassays	▪ neuroactive steroids
▪ pharmacology	▪ gene expression analysis	▪ functional genomics	▪ implantable delivery systems	▪ neuro-transmitter inhibitors
▪ physiology	▪ magnetic resonance spectrometry	▪ gene delivery systems	▪ nucleic acid amplification	▪ protease inhibitors
▪ proteomics	▪ mass spectrometry data	▪ gene testing	▪ recombinant DNA/genetic engineering	▪ vaccines
	▪ nucleic acid diagnostics	▪ gene therapy	▪ separation technologies	
	▪ protein structure modeling/analysis techniques	▪ gene expression systems	▪ transgenic animals	
		▪ monoclonal antibodies		
		▪ pharmacogenomics		
		▪ stem-cell		
		▪ tissue engineering		

Public Technology Goods — **Mixed Technology Goods** — **Private Technology Goods**

G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

Causes of Underinvestment — Composition

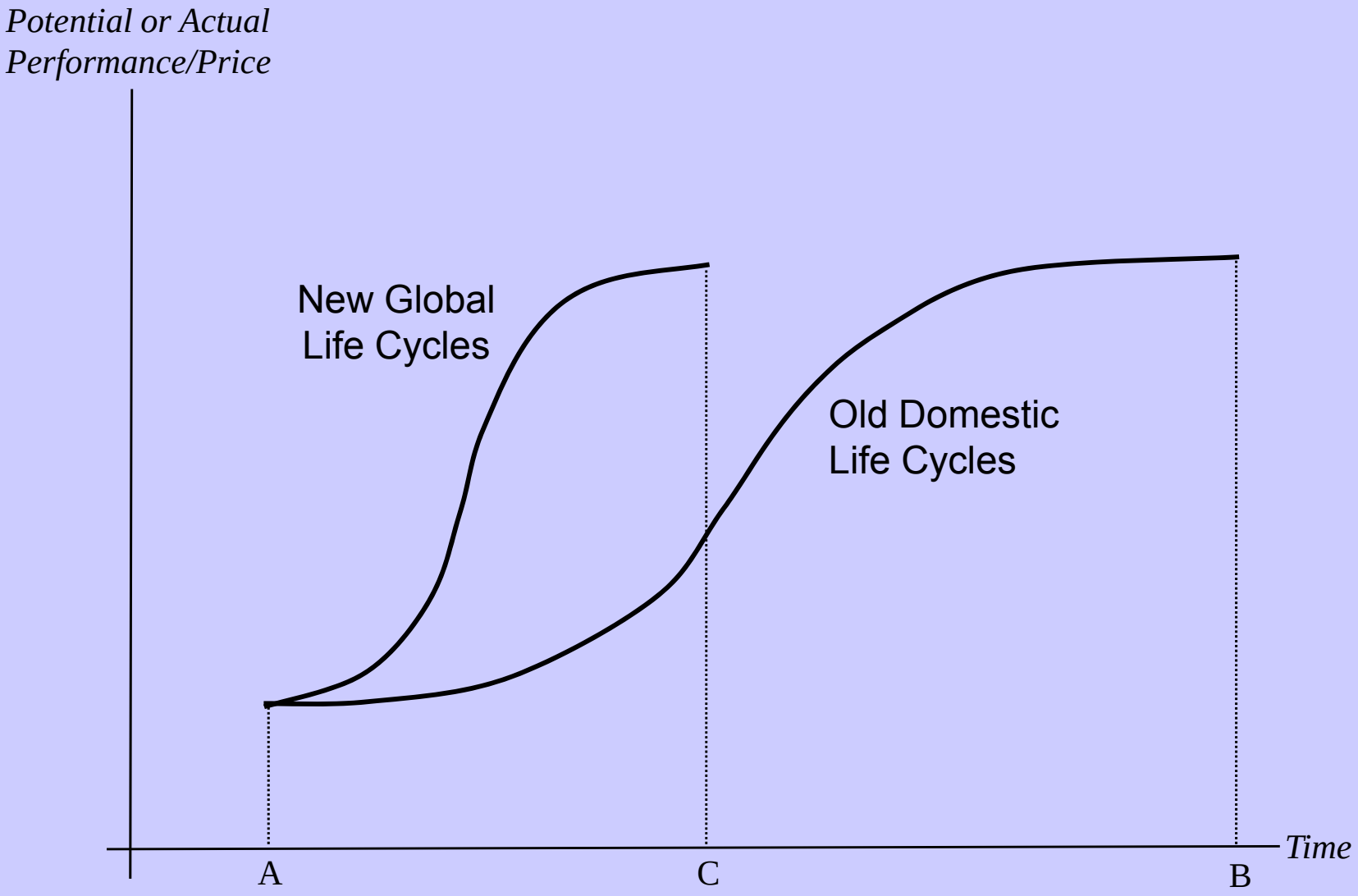
Overcoming the Innovation Risk Spike (Valley of Death)



Source: G. Tassey, "Underinvestment in Public Good Technologies", *Journal of Technology Transfer* 30: 1/2 (January, 2005)

Causes of Underinvestment — Composition

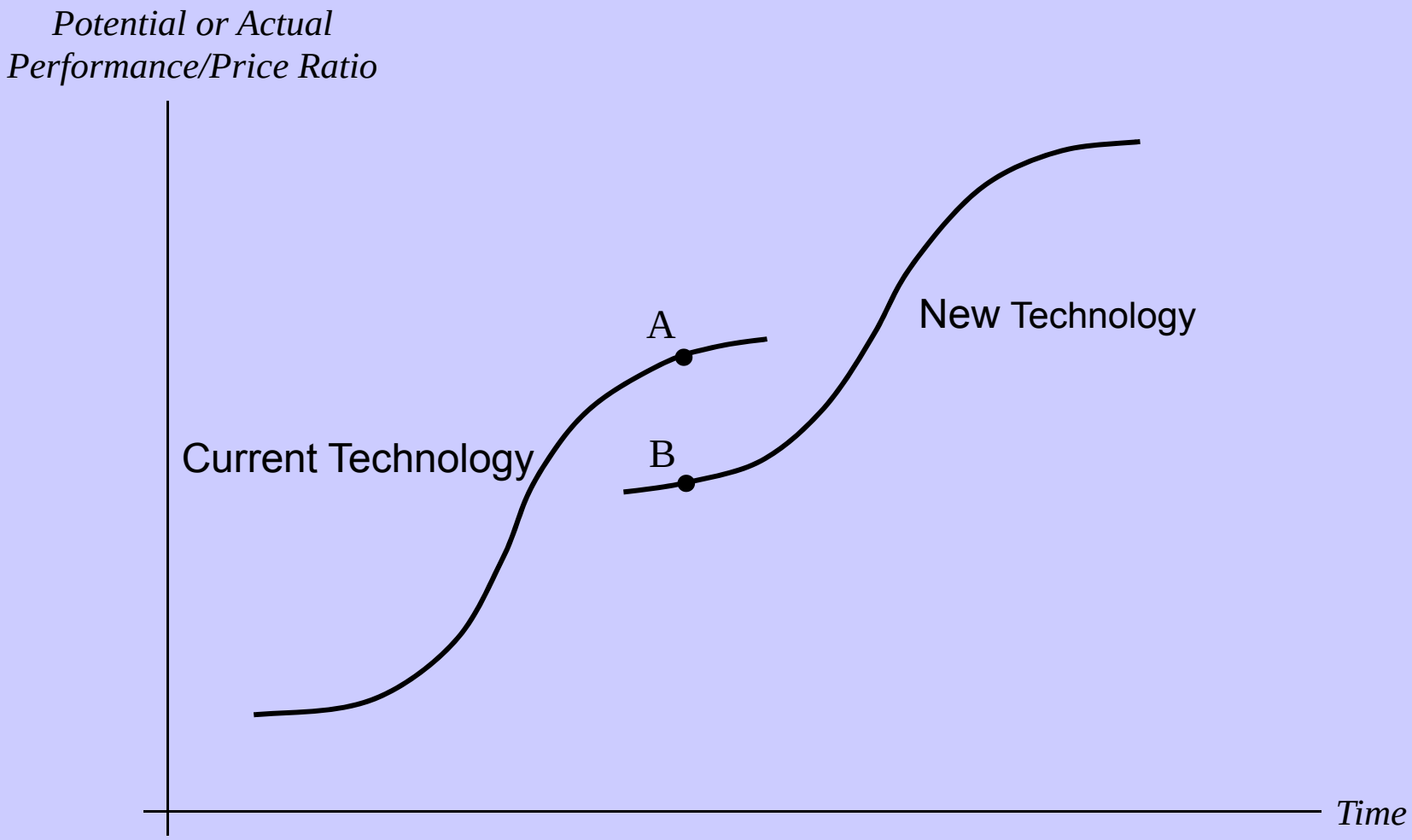
Compression of Technology Life Cycles



G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

Causes of Underinvestment — Composition

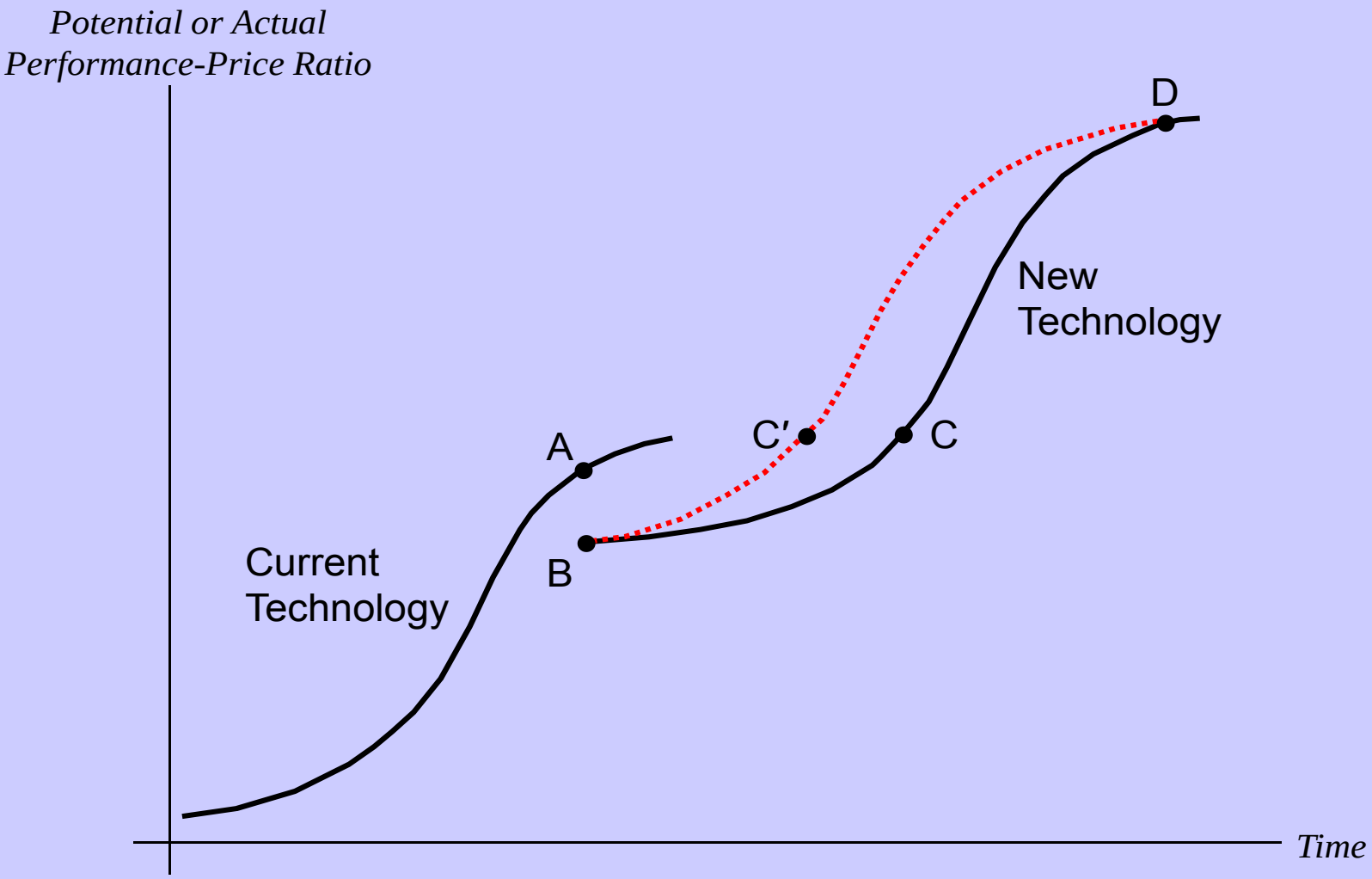
Transition Between Two Technology Life Cycles



Source: Gregory Tassey, *The Economics of R&D Policy*, 1997

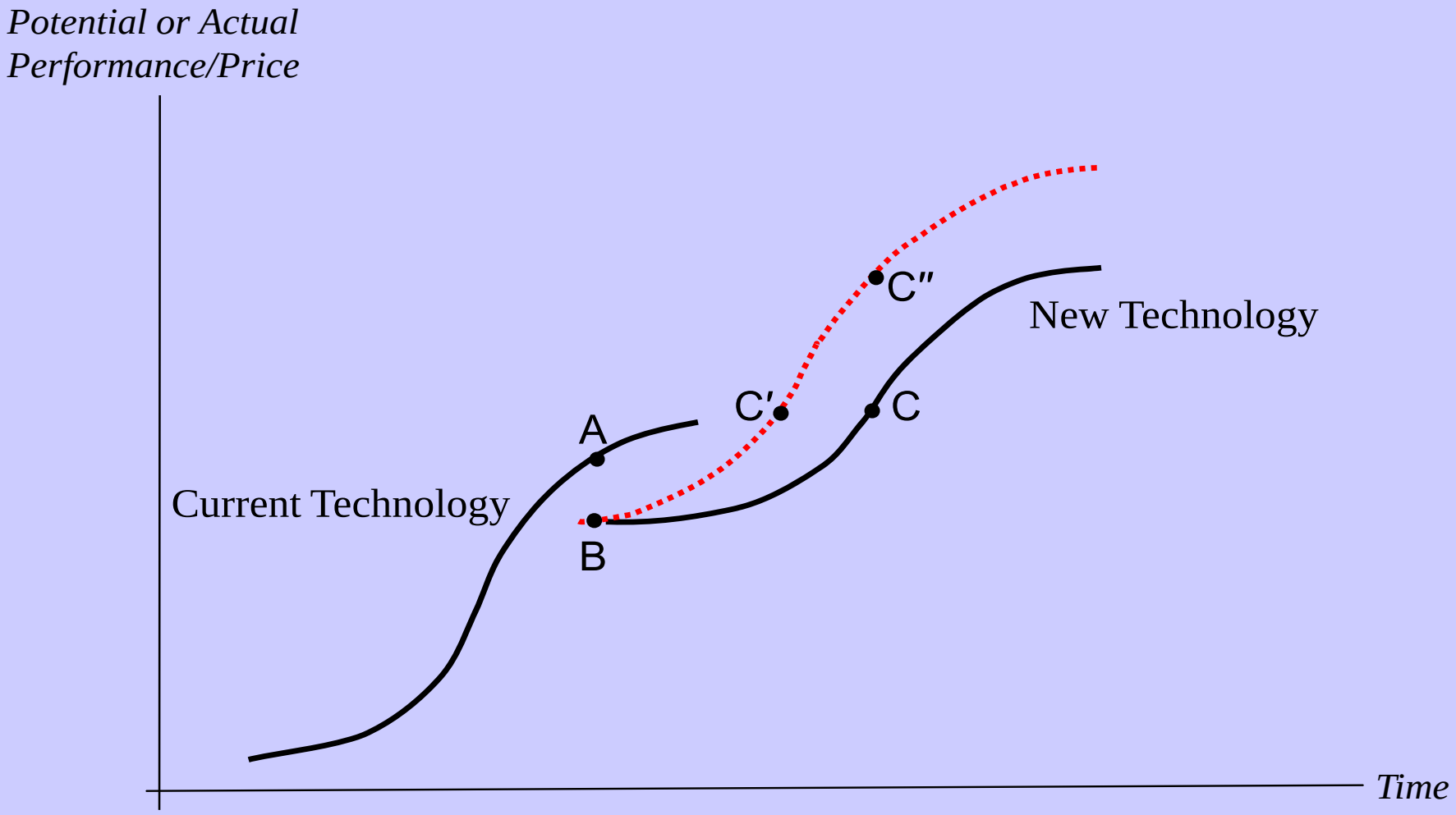
Policy Response

Life-Cycle Market Failure: Generic Technology



G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

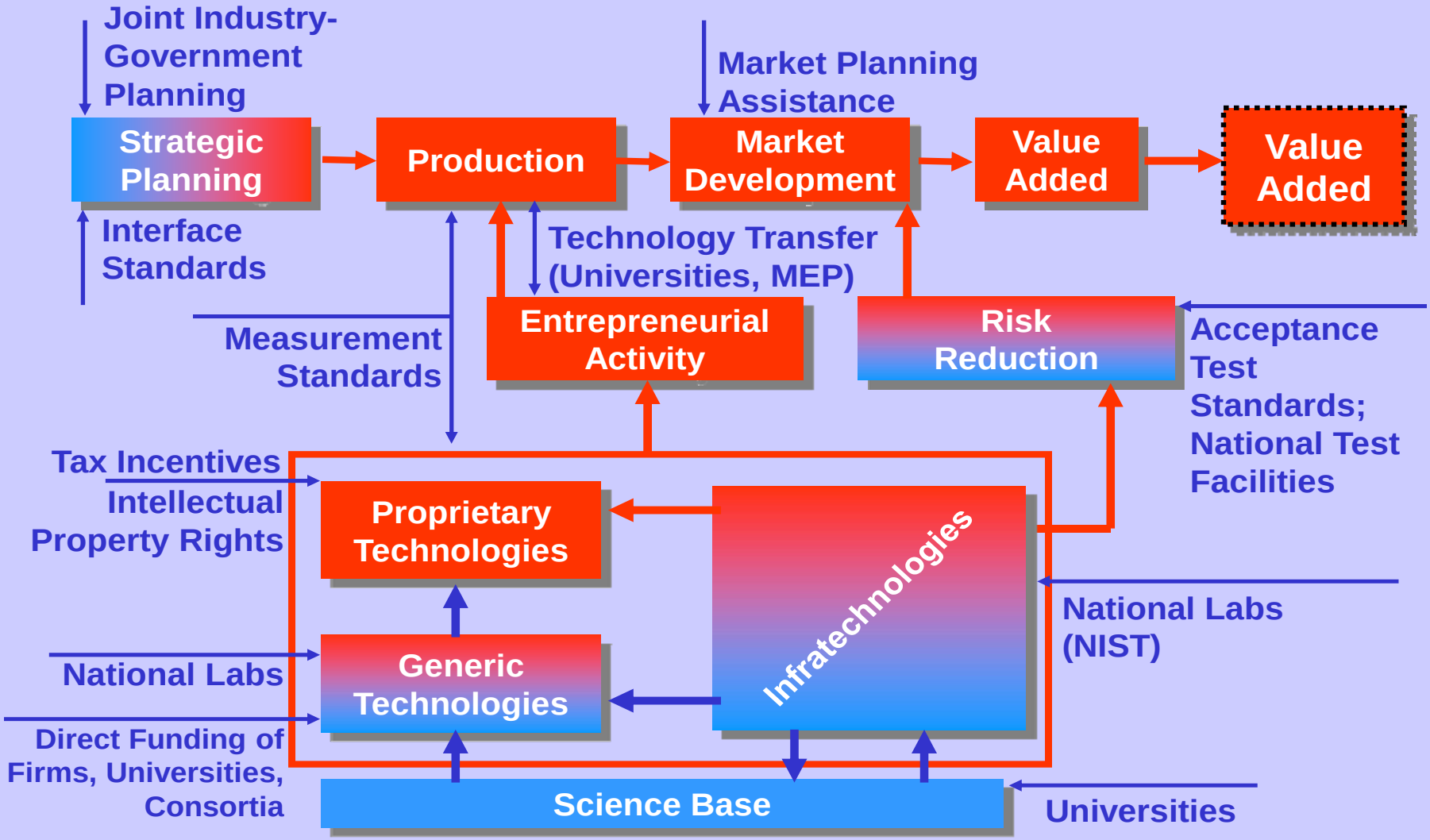
Life Cycle Evolution: Infratechnology



Source: Gregory Tassey, *The Technology Imperative*, Edward Elgar, 2007

Policy Response

Targets for Science, Technology, Innovation and Diffusion (STID) Policy



G. Tassey, *The Technology Imperative*, Edward Elgar, 2007

Response: Improved R&D Policy Analysis

- **Tax Incentives: R&E Tax Credit**
  - Still temporary after 27 years (renewed 13 times)
  - No consensus on what market failure is being targeted
  - Limited analysis of the credit's impacts
  - No analysis of alternative forms of tax incentives
- **Government Funding of R&D**
  - Okay to fund breakthrough *technology* research and even applied R&D to support social objectives (defense, health care)
  - Not okay to fund *any* technology research to support economic growth (ATP → TIP)
  - No explicit agreement on underinvestment (market failure)

Policy Principles

1) The high-income economy must be the high-tech economy – *higher R&D intensity*
2) Technology life cycle must drive policy – *R&D and diffusion policy efficiency* over entire cycle
3) Technology-based competition is a public-private problem – *public-private asset (multi-element) growth model*
4) Policy emphasis must be on relatively immobile assets – *skilled labor and innovation infrastructure*
5) U.S. technology-based growth policy process must be improved – *more resources and better scope and integration*

R&D Policy Imperatives

1) R&D intensity should be doubled to ~ 5 percent
2) R&E Tax Credit must be restructured and enlarged to a 10 percent flat credit
3) Federal R&D must be better balanced across IT, nanotechnologies, biotechnology, etc.
4) Government R&D funding must be element based
   a) science
   b) generic technology (proofs of concept)
   c) infratechnologies
5) R&D efficiency must increased
   a) more technology clusters
   b) better timing of policies over technology life cycle

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

– Robert Louis Stevenson