The Manufacturing Imperative

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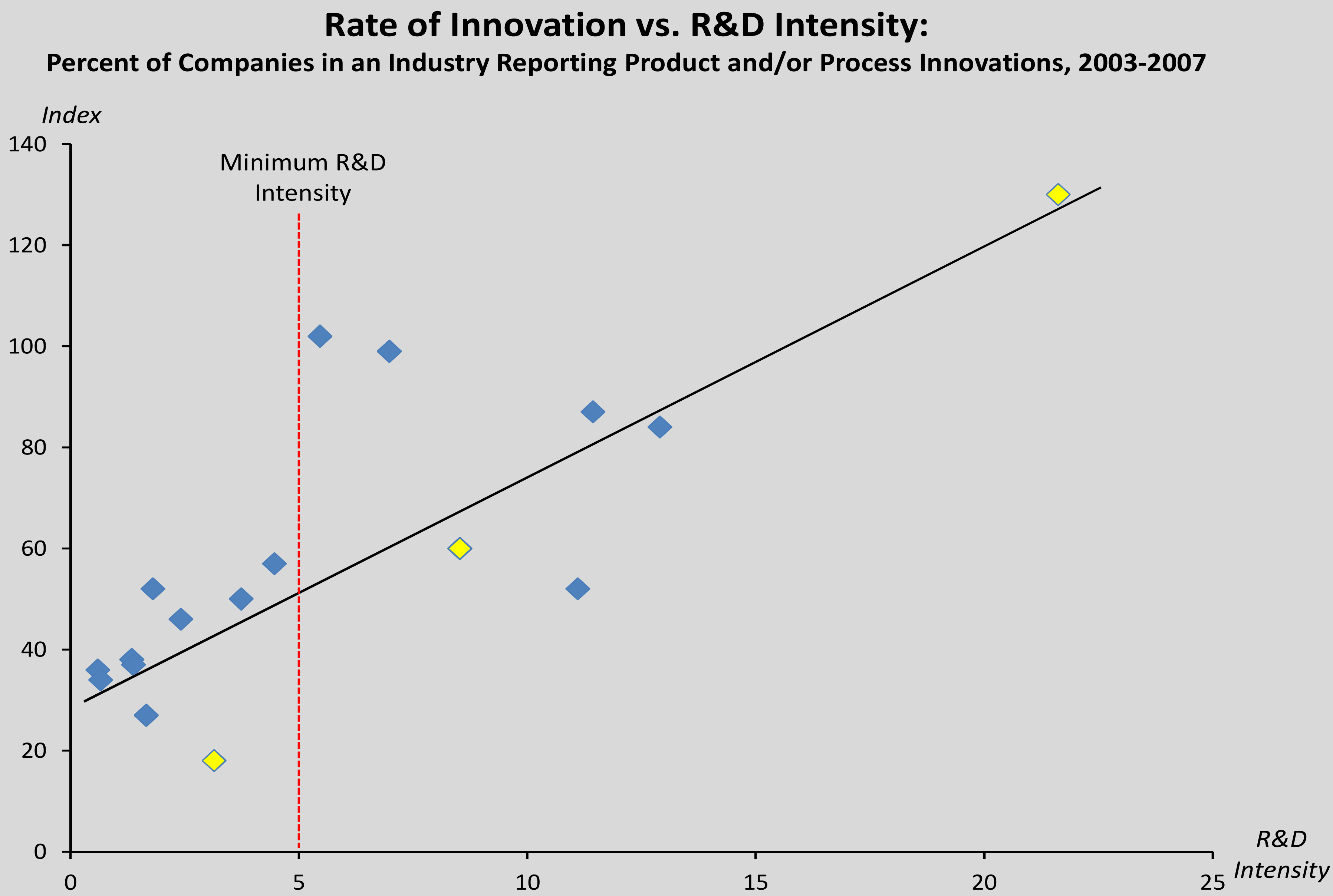
Importance of the Policy Problem – Manufacturing

Economic importance of Domestic Manufacturing (hardware and software):

1) Diversification:
   a) Manufacturing contributes $1.6 trillion to GDP and employs 11 million workers
   b) High-tech service jobs are increasingly ‘‘tradeable’’ and 30 economies have policies in place to promote service exports
2) Manufacturing accounts for 67% of US industry-performed R&D and a 57% share of U.S. industry’s scientists/engineers
3) Therefore, the fast-growing high-tech services sector must have close ties to its manufacturing base
4) Majority of trade is in manufactured products (but deficits for last 35 years)

Importance of the Policy Problem – R&D Intensity and Innovative Output



Source: Gregory Tassey, "Beyond the Business Cycle: The Need for a Technology-Based Growth Strategy," forthcoming. Index = sum of percent of companies in an industry reporting product innovations and percent reporting process innovations. R&D intensity data from *Science and Engineering Indicators 2010* , Appendix Table 4-14 (industry and other non-federal funds for R&D); innovation data from Mark Boroush, "NSF Releases New Statistics on Business Innovation," NSF *InfoBrief*, October 2010

Importance of the Policy Problem – R&D Intensity and Growth

Relationship Between R&D Intensity and Real Output Growth

Industry (NAICS Code)	Average R&D Intensity, 1999-2007	Percent Change in Real Output, 2000-2007
R&D Intensive:		
Pharmaceuticals (3254)	10.5	19.1
Semiconductors (3344)	10.1	15.4
Medical Equipment (3391)	7.5	28.4
Computers (3341)	6.1	106.2
Communications Equip (3342)	13.0	-42.3
	Group Ave: 9.5	**Group Ave: 25.4**
Non-R&D Intensive:		
Basic Chemicals (3215)	2.2	25.5
Machinery (333)	3.8	2.4
Electrical Equipment (335)	2.5	-13.6
Plastics & Rubber (326)	2.3	-4.5
Fabricated Metals (332)	1.4	4.9
	Group Ave: 2.5	**Group Ave: 2.9**

Sources: NSF for R&D intensity and BLS for real output.

Underperformance – Maintaining Domestic Supply Chains

High-tech offshoring is a multi-step process, driven by (1) increasingly attractive skilled labor and (2) capital and R&D subsidies:

1) Originally, manufacturing was offshored to take advantage of local-market opportunities, but increasingly for skilled labor (assembly in China, components in Taiwan, Korea)
   - Initially require small amount of supporting R&D
   - Host country frequently subsidizes plant and equipment
2) Host country gains some R&D experience and expands R&D infrastructure to capture synergies at "entry" tier in high-tech supply chain
3) Host country begins to integrate forward into design and/or backward into components 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) These economies are now beginning to integrate forward into services
5) Economic policy point: Co-location synergies are being lost/captured

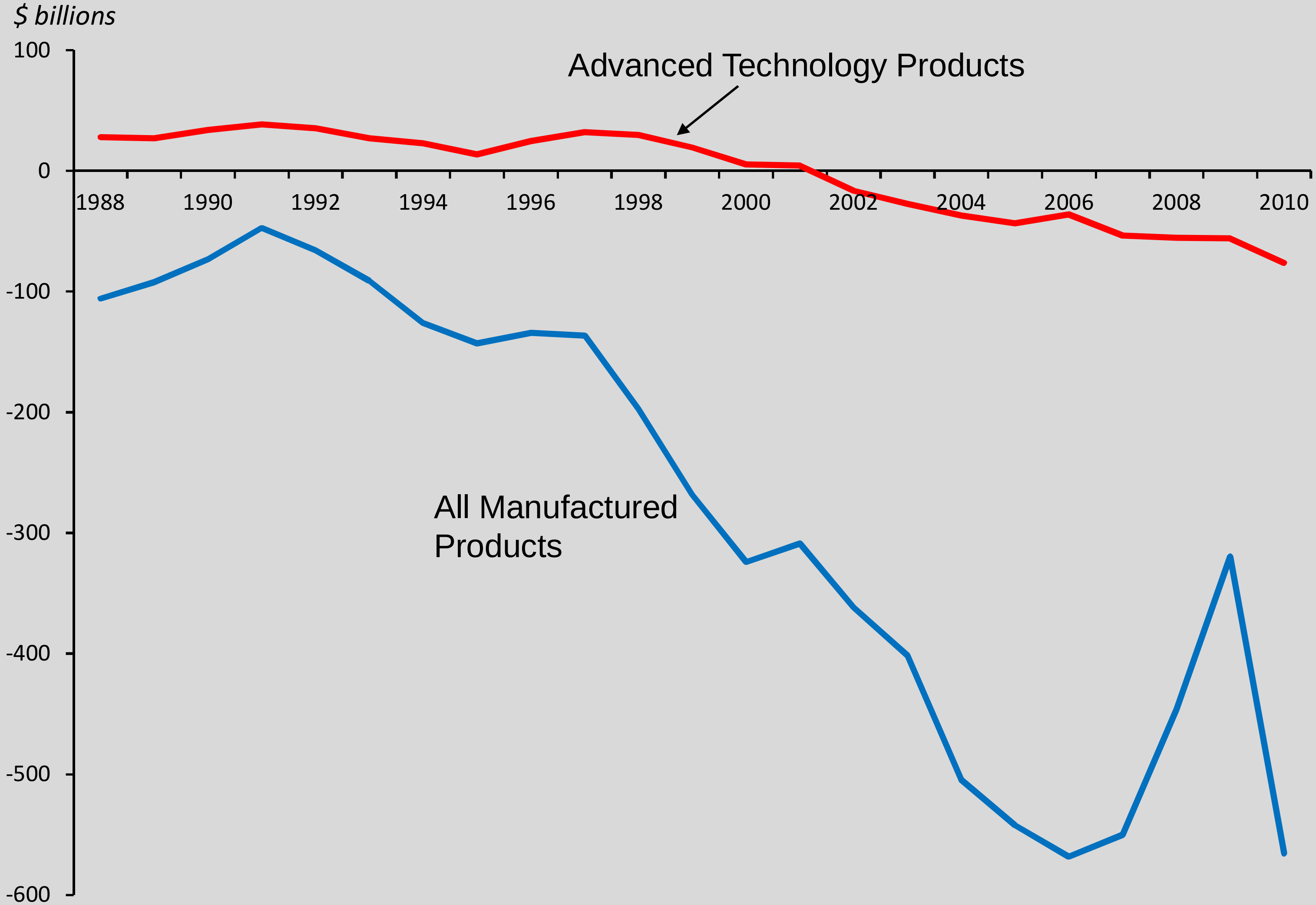
Poor Technology Life-Cycle Management:

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
- solar cells
- advanced lighting

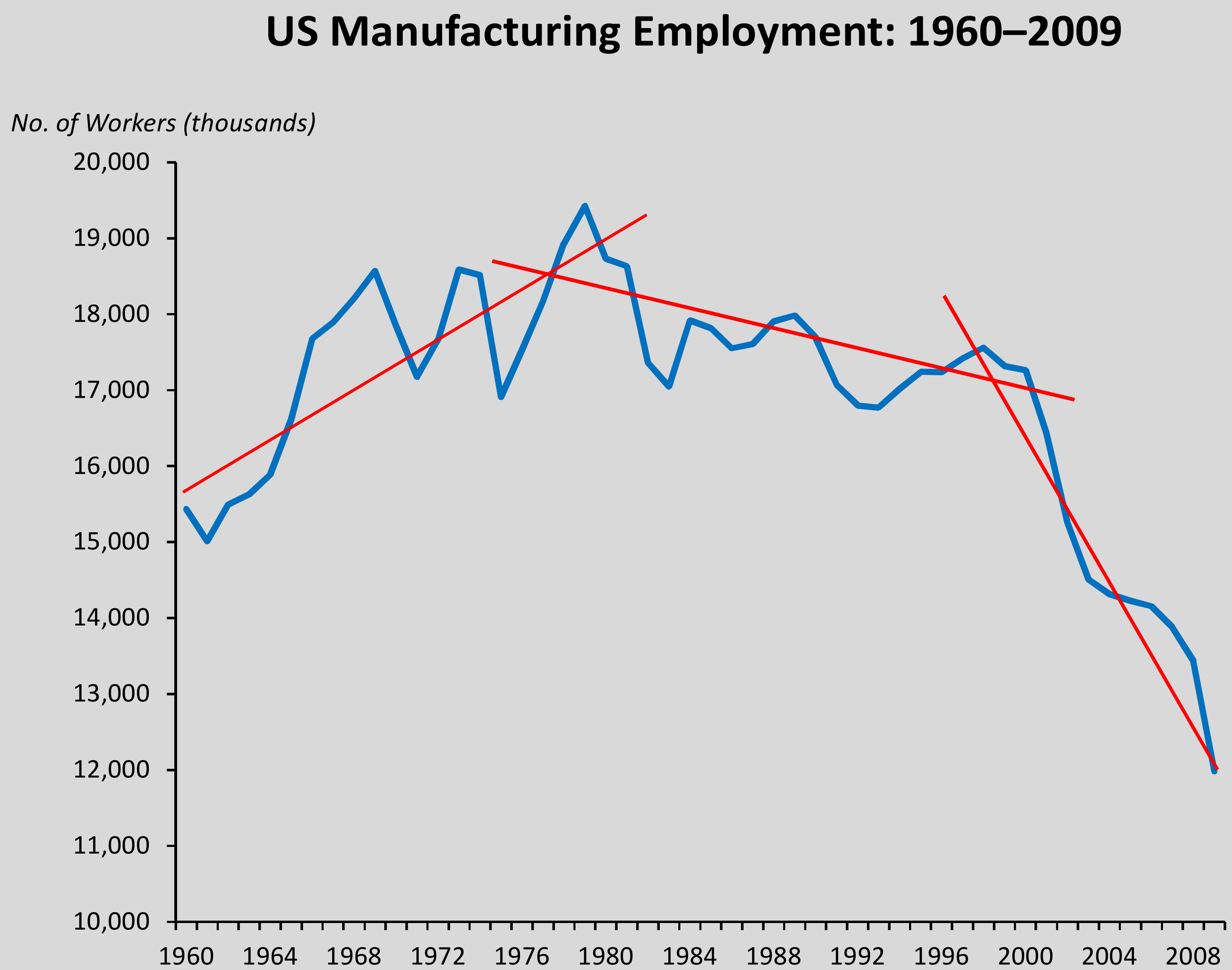
Underperformance – Manufacturing

U.S. Trade Balances for High-Tech vs. All Manufactured Products, 1988-2010



Source: Census Bureau, Foreign Trade Division for ATP data; International Trade Administration for all manufactured products

Underperformance – Manufacturing



Source: Bureau of Labor Statistics

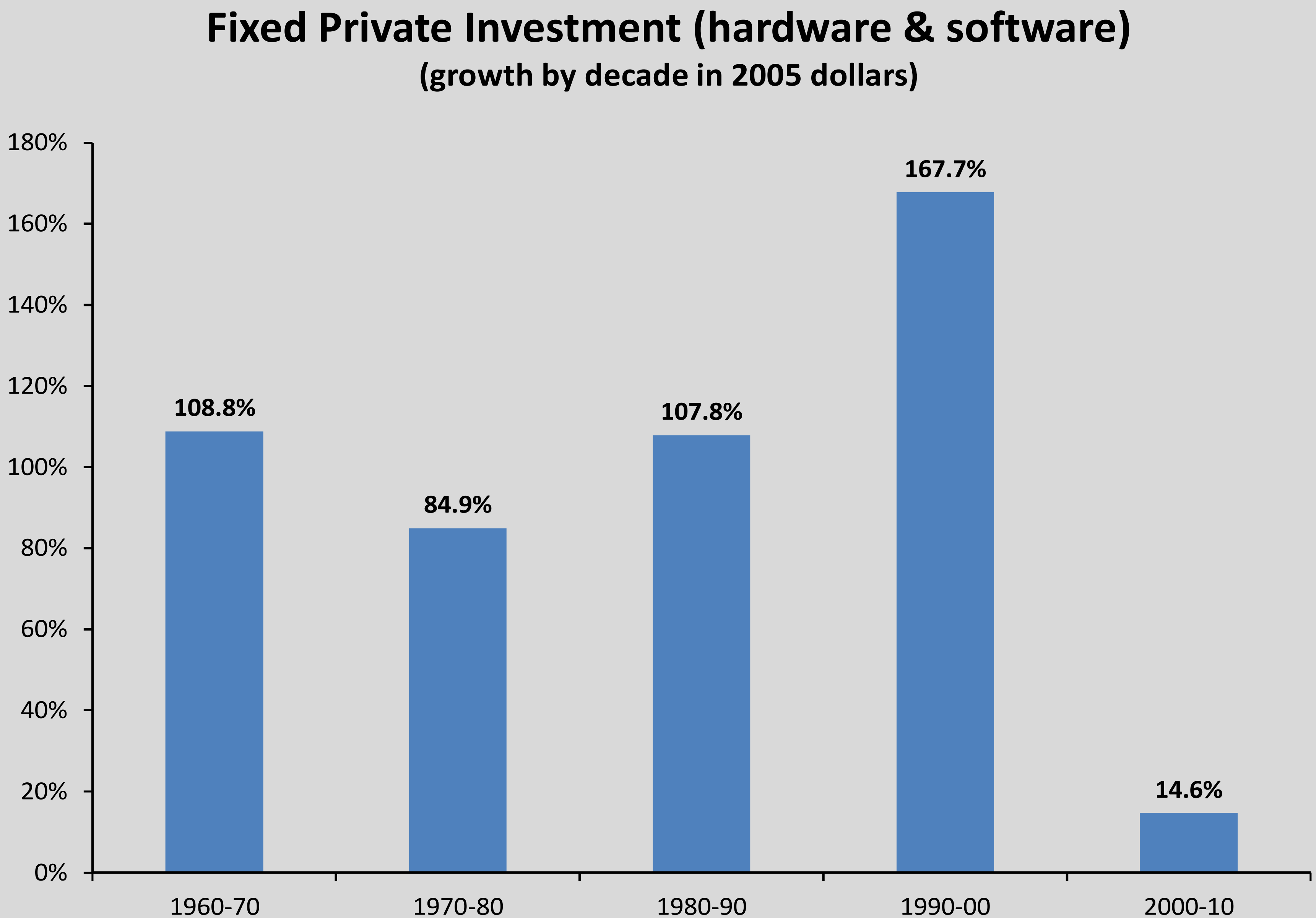
Underperformance – Manufacturing

- Germany has a trade surplus in manufacturing, even though, compared to the United States, it has a
  - 9 percent lower R&D intensity (2.53 percent vs. 2.77 percent for U.S.)
  - 39 percent higher average hourly manufacturing labor compensation
  - 12 percent higher corporate tax rate
- However, Germany has a more comprehensive and intensively managed STID policy
  - Highly skilled labor force across all technology occupations
  - Optimized industry structure (support for both large firms and SMEs)
  - Highest percentage of manufacturing value added from R&D-intensive industries

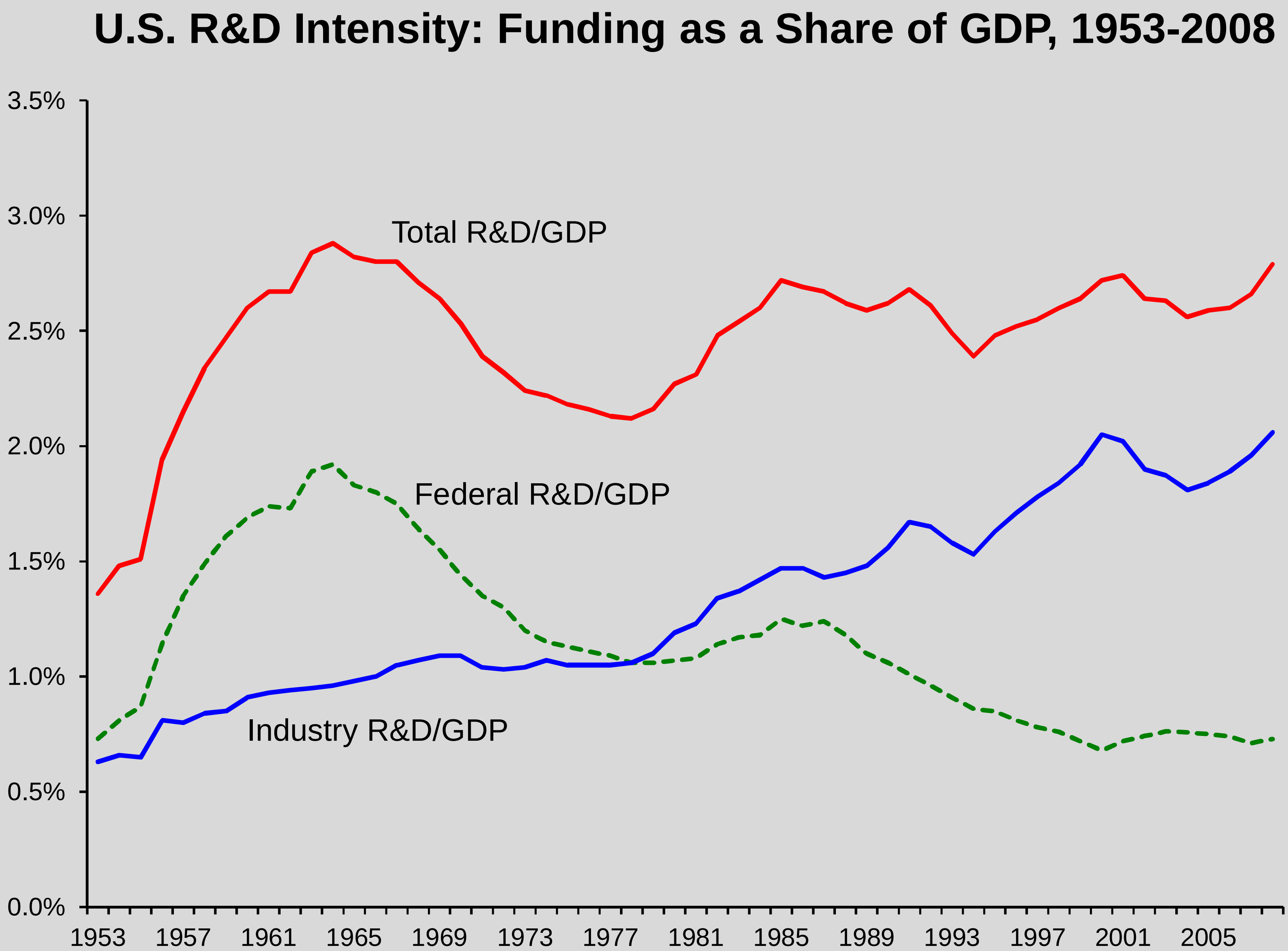
Trends in Manufacturing R&D Needing Policy Attention

- Manufacturing sector's average R&D intensity (3.7 percent) has remained flat since the mid-1980s
  - has not been helped by offshoring of low R&D-intensive industries
  - pales compared to truly "R&D-intensive" industries, whose ratios range from 5 to 22 percent
- Need for effective policy response is great
  - most of the global economy's $1.3 trillion annual R&D spending targets manufacturing technologies
  - U.S. manufacturing firms are increasing offshore R&D at *three* times the rate of domestic R&D spending
- Government funding of manufacturing R&D increases the sector's R&D performance intensity from 3.7 to 4.1 percent

Underinvestment – Aggregate

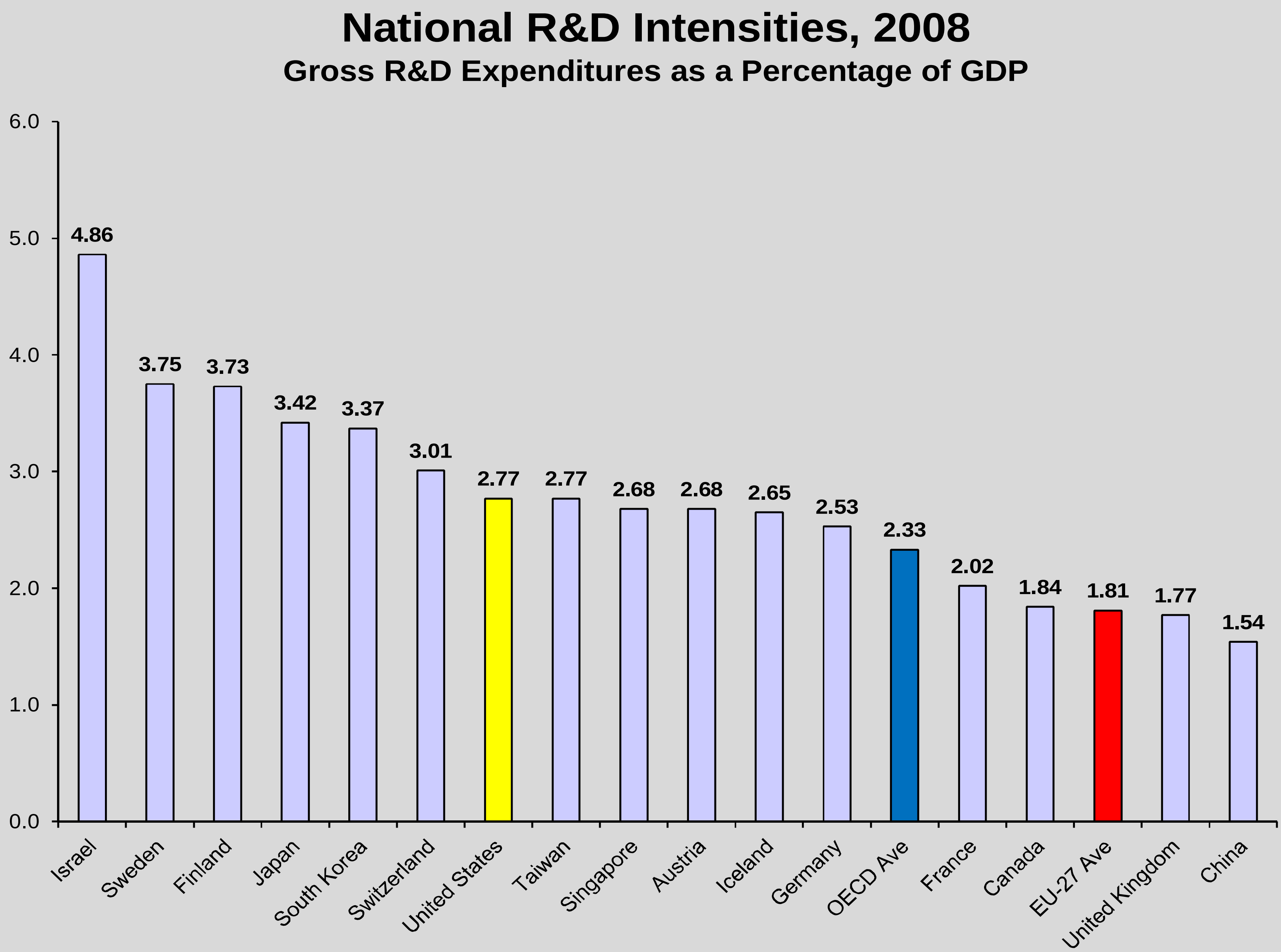


Source: Gregory Tassey, "Beyond the Business Cycle: The Need for a Technology-Based Growth Strategy," forthcoming. Data from Bureau of Economic Analysis, NIPA Table 5.3.5 (includes both equipment and software) and Table 5.3.4 (price indexes for fixed private investment)



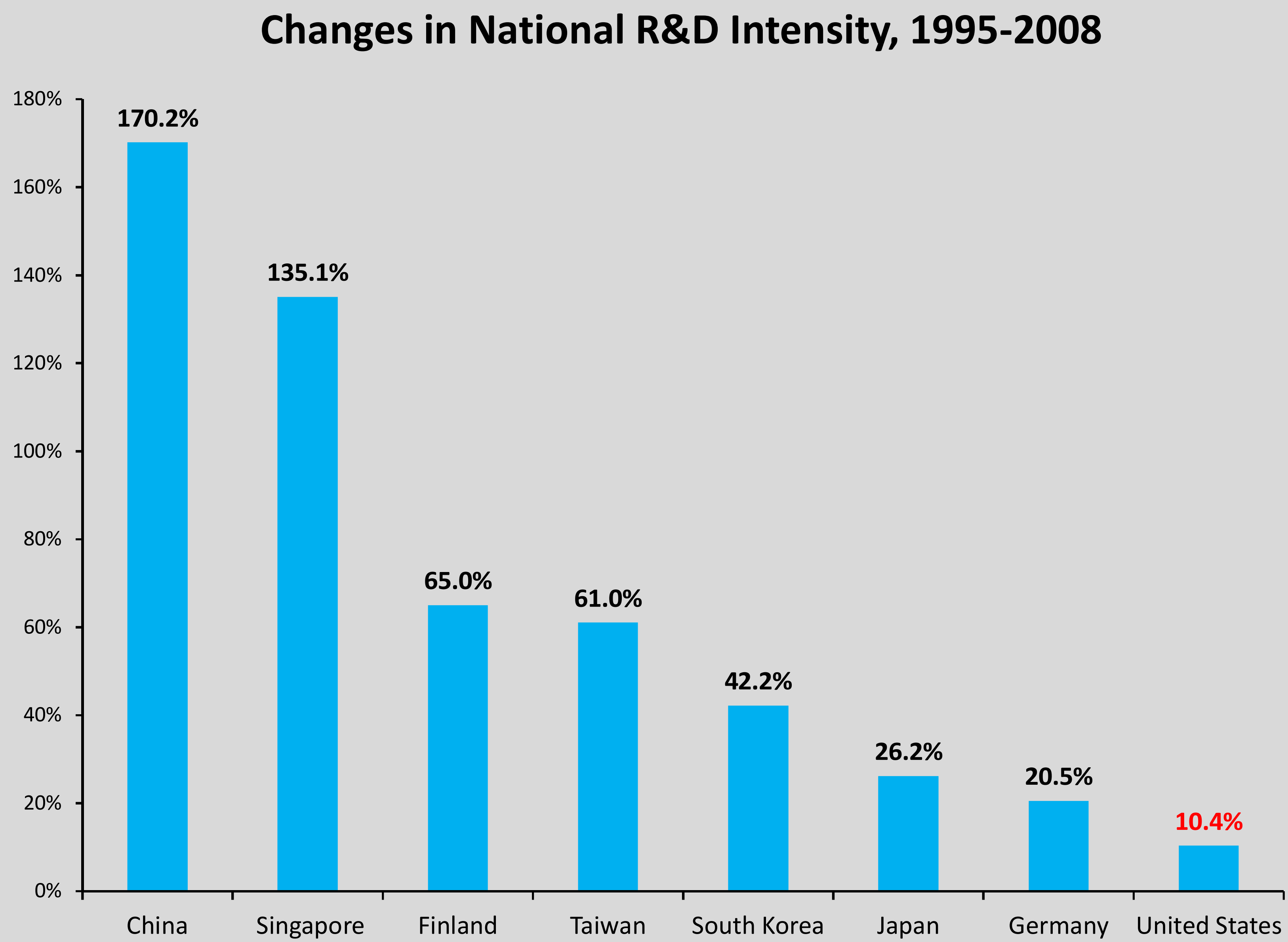
Gregory Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies," *Journal of Technology Transfer 35* (2010): 283-333. Data from the National Science Foundation.

Underinvestment – Amount of R&D



Source: OECD, *Main Science and Technology Indicators*, 2010.

Underinvestment – Amount of R&D



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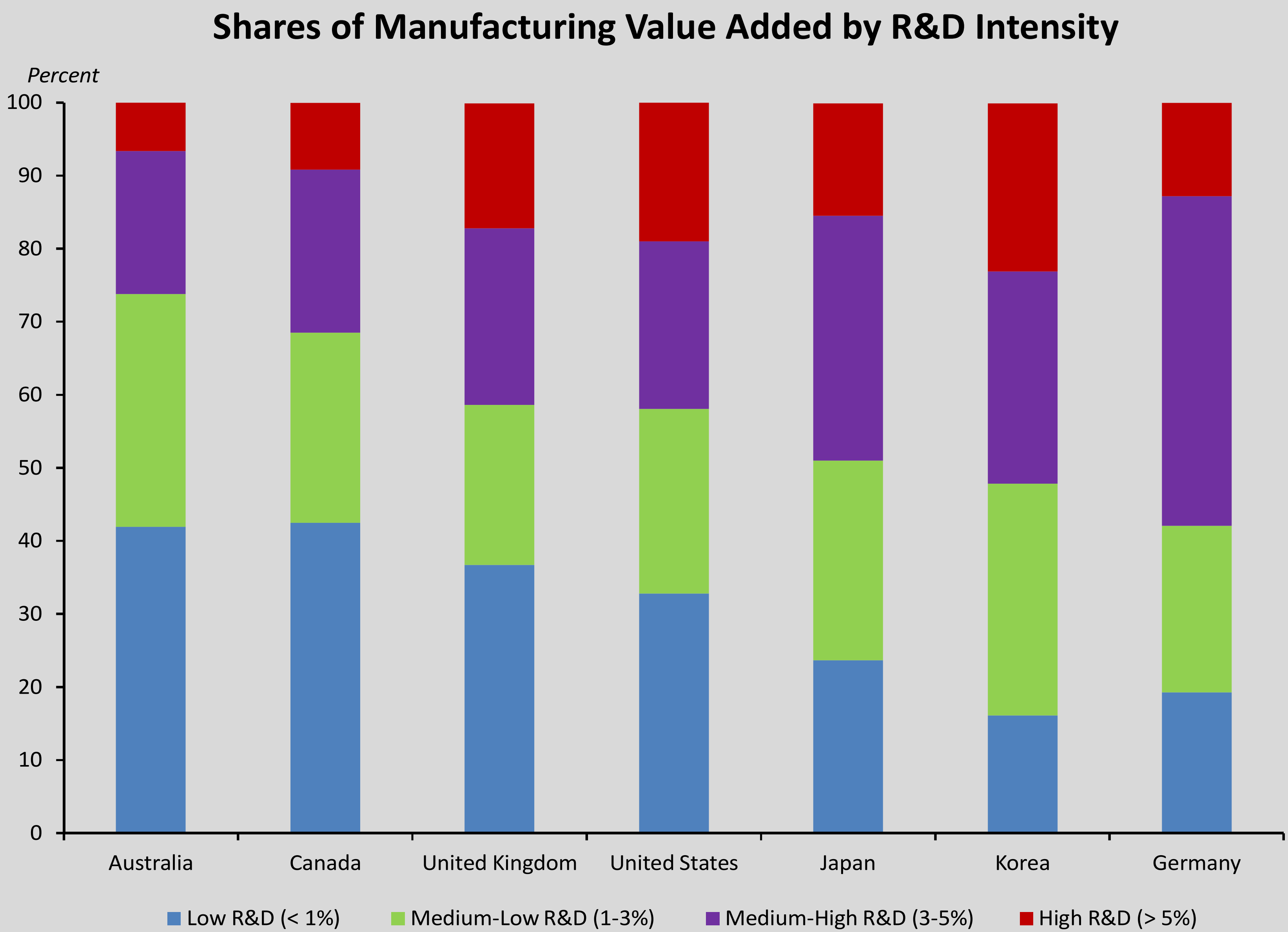
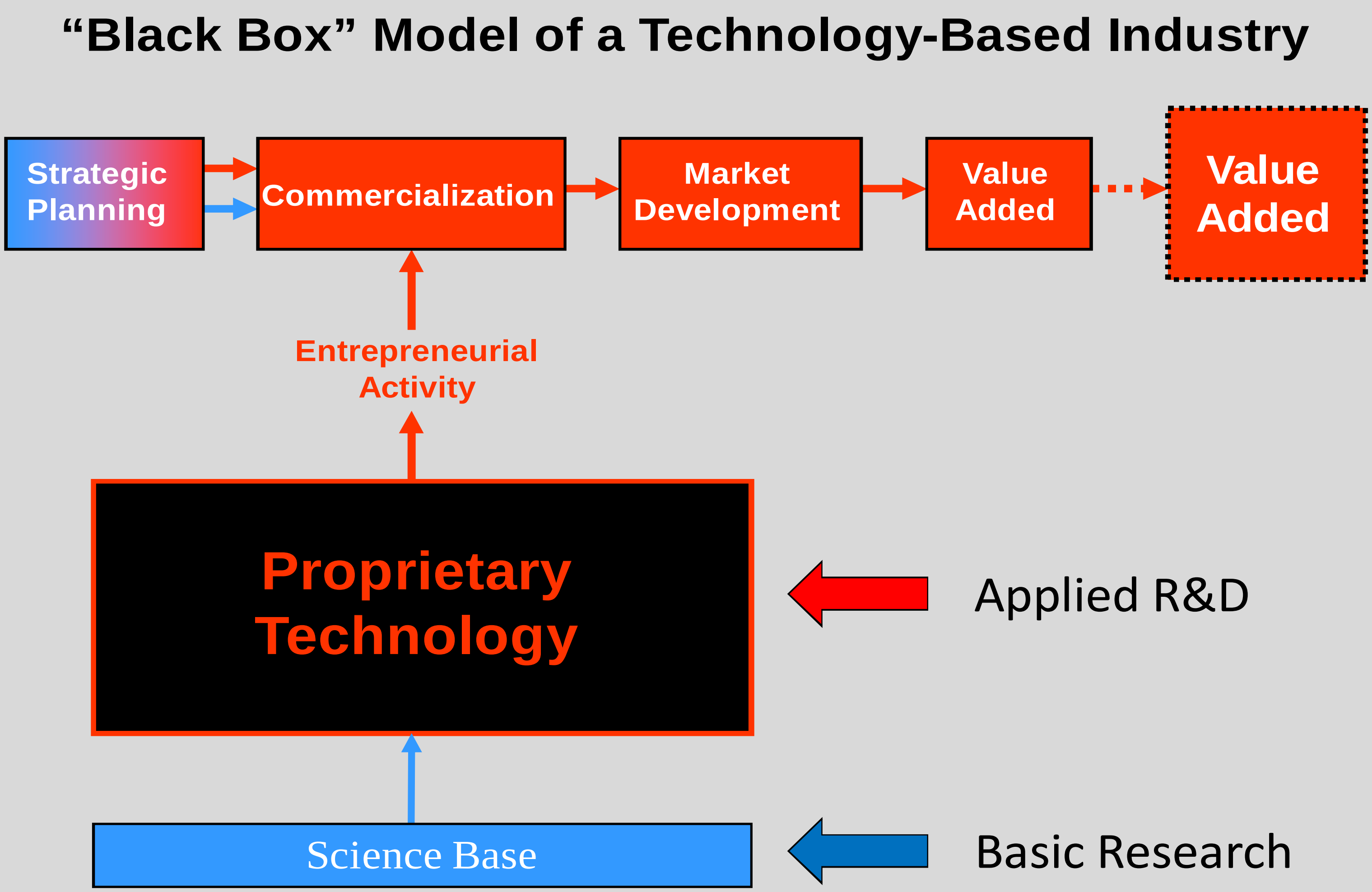
Underinvestment – Amount of R&D



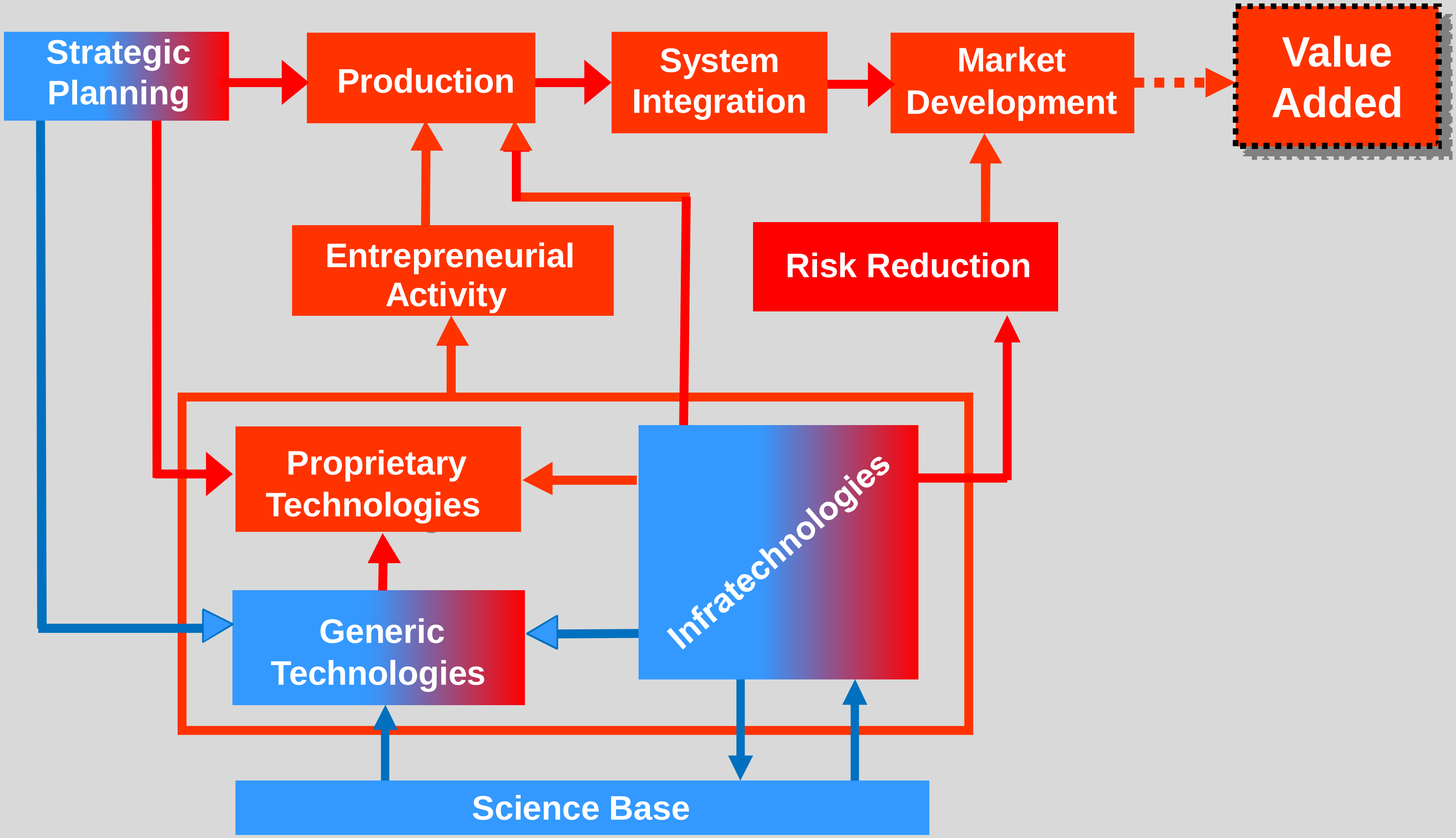
Stephen Ezell and Robert Atkinson (2011), *International Benchmarking of Countries' Policies and Programs Supporting SME Manufacturers*. Washington: DC: Information Technology and Innovation Foundation, September. Data from OECD, “Industry and Services STAN Database: “Value-added shares relative to manufacturing,” http://stats.oecd.org/index.aspx?r=228903

Identifying Underinvestment – Technology-Element Growth Model



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

Economic Model of a Technology-Based Industry



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Application of the Technology-Element Model: Biotechnology

Science Base

- genomics
- immunology
- microbiology/ virology
- molecular and cellular biology
- nanoscience
- neuroscience
- pharmacology
- physiology
- proteomics

Infratechnologies

- bioinformatics
- bioimaging
- biomarkers
- combinatorial chemistry
- DNA sequencing and profiling
- electrophoresis
- fluorescence
- gene expression analysis
- magnetic resonance spectrometry
- mass spectrometry
- nucleic acid diagnostics
- protein structure modeling & analysis techniques

Generic Technologies

Product

- antiangiogenesis
- antisense
- apoptosis
- bioelectronics
- biomaterials
- biosensors
- functional genomics
- gene delivery systems
- gene testing
- gene therapy
- gene expression systems
- monoclonal antibodies
- pharmacogenomics
- stem-cell
- tissue engineering

Process

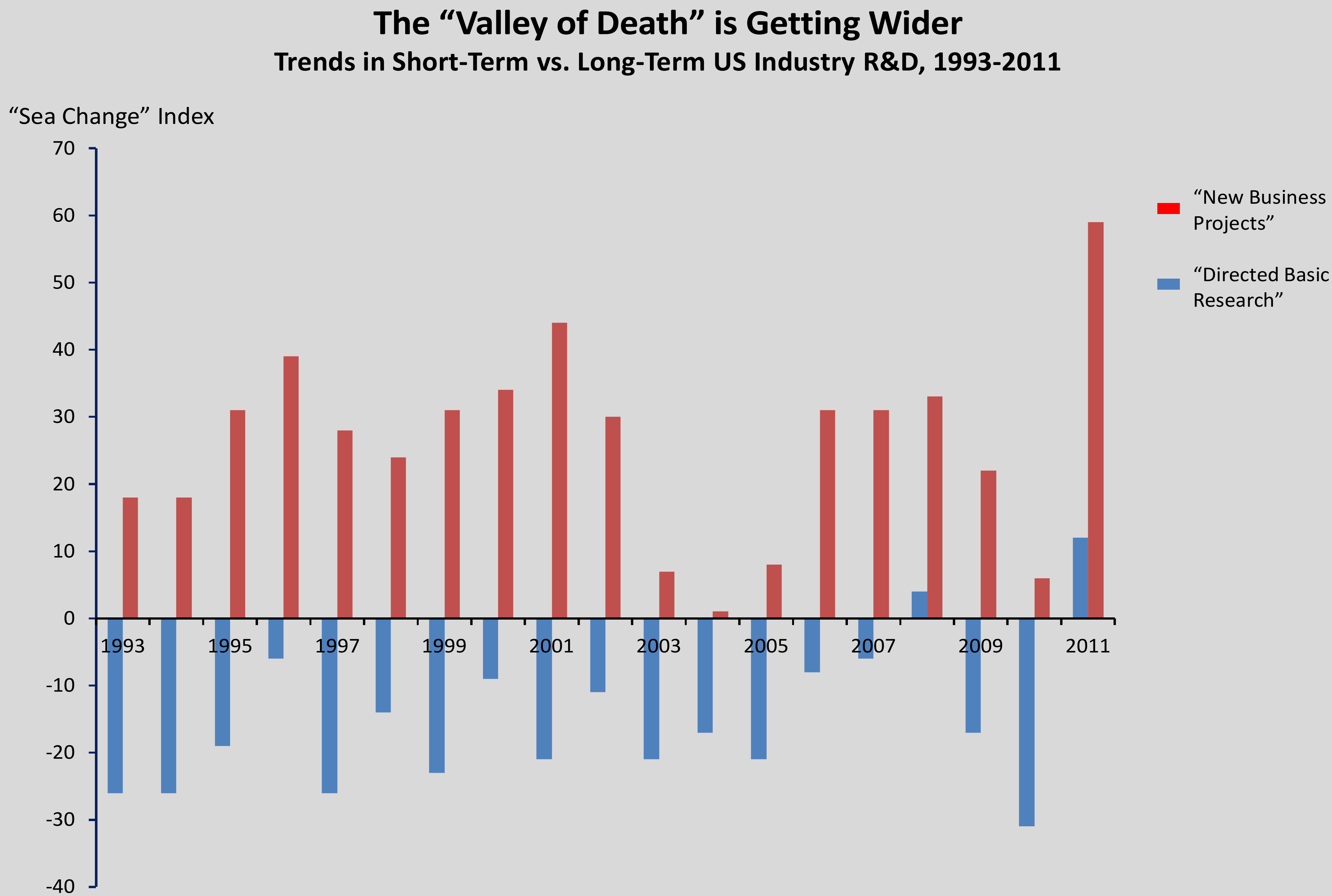
- cell encapsulation
- cell culture
- microarrays
- fermentation
- gene transfer
- immunoassays
- implantable delivery systems
- nucleic acid amplification
- recombinant DNA/genetic engineering
- separation technologies
- transgenic animals

Commercial Products

- coagulation inhibitors
- DNA probes
- inflammation inhibitors
- hormone restorations
- nanodevices
- neuroactive steroids
- neuro-transmitter inhibitors
- protease inhibitors
- vaccines

Public Technology Goods ← Mixed Technology Goods → Private Technology Goods

Causes of Underinvestment – Composition of R&D



Source: Gregory Tassey, "Beyond the Business Cycle: The Need for a Technology-Based Growth Strategy" (forthcoming); Compiled from the Industrial Research Institute's annual surveys of member companies.

Causes of Underinvestment – Composition of R&D

Federal R&D Portfolio is not Optimized for Economic Growth

- Historical focus has and continues to be on "mission" R&D programs (national objectives such as defense, health, energy, space, environmental)—90 percent of federal R&D
  - National defense and health account for 81 percent of the federal R&D budget
  - Using NAICS codes to track federally funded R&D performed by industry,
    - 75 percent of federal R&D allocated to the manufacturing sector goes to two NAICS 4-digit industries: aerospace and instruments
    - These two industries account for 15 percent of company-funded R&D and about 10 percent of high-tech value added

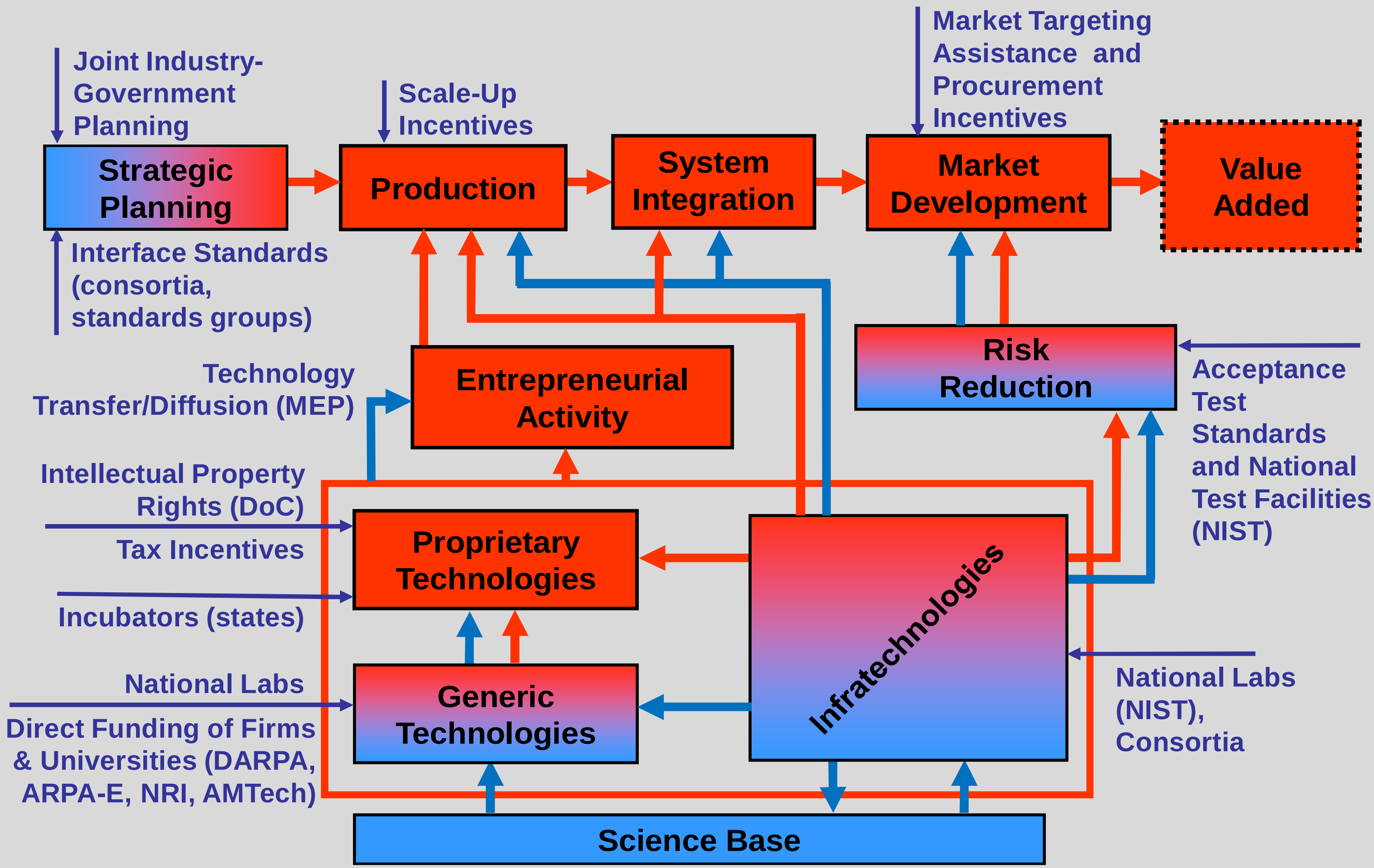
Policy Implication: While economic activity is stimulated by this skewed funding strategy, the federal portfolio is not close to being optimized for economic growth

- Example: federally funded "generic" (proof-of-concept) technology research
  - Defense (DARPA): $3.1 billion
  - Energy (ARPA-e): $400 million
  - General economic growth (NIST's ATP/TIP): $60 million

Sources: National Science Foundation: *Federal R&D Funding by Budget Function, FY 2008-10*, Table 2; *Science and Engineering Indicators 2010*, Appendix Table 4-13; Bureau of Economic Analysis R&D Satellite Account

Policy Response

Managing the Entire Technology Life Cycle:
Science, Technology, Innovation, Diffusion (STID) Policy Roles



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Three Targets of Manufacturing R&D Policy

Amount of R&D

- Create financial incentives for private companies to increase investments in R&D and increase the R&D intensity of the manufacturing sector
- Increase Federal investment in research aimed at broad sector growth objectives in addition to those related to agency missions

Composition of R&D

- Create incentives for private-sector investment in early phases of R&D cycle
- Create public-private partnerships to meet industry's long-term research needs and IP management requirements through support for technology clusters
- Fund research aimed at manufacturability to overcome scaling issues
- Target the "other" 90% of manufacturing value added (outside NAICS 3345 and 3364)
- Eliminate barriers to private investment in new firms (high technical risk, appropriability, skilled labor acquisition, and process-capability barriers)

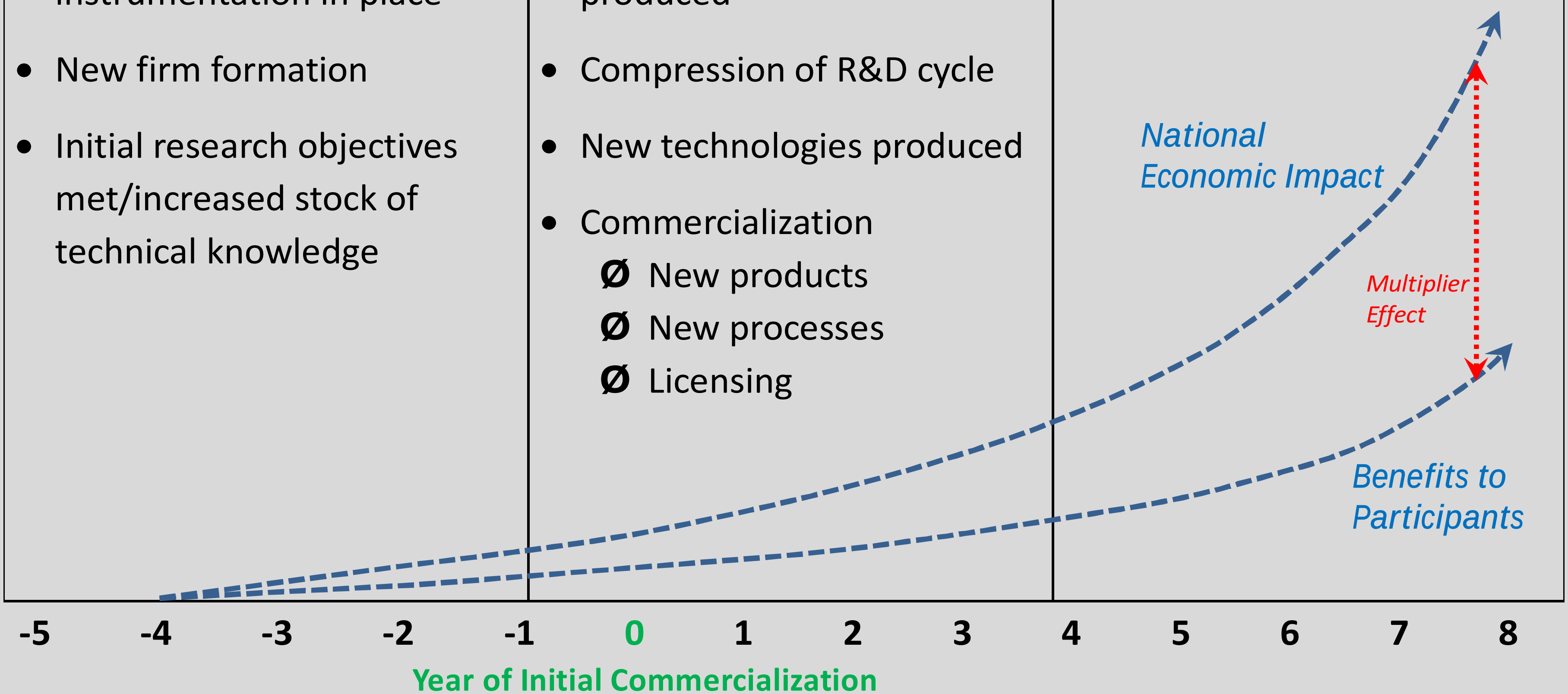
Efficiency of R&D

- Improve timing and content of R&D through road mapping and portfolio management techniques
- Increase rates of return and shorten the R&D cycle through technology clusters
- Build in technology transfer through cluster design and co-located supply chain

Policy Response

Impact Metrics for Regional Technology Cluster Model

Short-Term	Medium-Term	Long-Term
• Partnership structures & strategic alliances organized • New research facilities and instrumentation in place • New firm formation • Initial research objectives met/increased stock of technical knowledge	• Supply-chain structure established • New-skilled graduates produced • Compression of R&D cycle • New technologies produced • Commercialization Ø New products Ø New processes Ø Licensing	• Broad industry and national economic benefits Ø Return on investment Ø GDP impacts



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

– Robert Louis Stevenson