Economic Rationales and Metrics for an Advanced Manufacturing Sector

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March 2012
Policy initiatives and metrics evolve from economic rationales:

1) Does a modern economy need an advanced manufacturing sector, including nanotechnology?

2) If yes, what are the economic (underinvestment) metrics and hence rationales for government support roles?

3) What are the policy response mechanisms for each type of underinvestment?
   a) The nature of the underinvestment phenomenon determines the most efficient policy mechanism
   b) The policy response determines impact assessment metrics
Policy Focus: Multifactor Productivity

Source: Bureau of Labor Statistics
Compression of Technology Life Cycles

New Global Life Cycles

Old Domestic Life Cycles

Performance/Price Ratio

Time

Common rationales for government support of advanced manufacturing R&D:

- Excessive risk (increase costs)
  - The “Valley of Death”

- Spillovers (reduce benefits)

- Long development time (reduce benefits)
## Application of the Technology-Element Model: Nanotechnology

<table>
<thead>
<tr>
<th>Science Base</th>
<th>Infratechnologies</th>
<th>Technology Platforms</th>
<th>Commercial Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ carbon-based nanomaterials</td>
<td>▪ biological detection and analysis tools</td>
<td>▪ carbon nanotubes</td>
<td>▪ hardened nanomaterials for machining/drilling</td>
</tr>
<tr>
<td>▪ cellulosic nanomaterials</td>
<td>▪ in silico modeling &amp; simulation tools</td>
<td>▪ dendrimers</td>
<td>▪ flame-retardant nanocoatings</td>
</tr>
<tr>
<td>▪ magnetic nanostructures</td>
<td>▪ in-line measurement techniques to enable closed-loop process control</td>
<td>▪ hybrid nanoelectronic devices</td>
<td>▪ sporting goods</td>
</tr>
<tr>
<td>▪ molecular nanoelectronic materials</td>
<td>▪ sub-nanometer microscopy</td>
<td>▪ ultra-low-power devices</td>
<td>▪ solar cells</td>
</tr>
<tr>
<td>▪ quantum dots</td>
<td>▪ high-resolution nanoparticle detection</td>
<td>▪ self-powered nanowire devices</td>
<td>▪ sunscreen/cosmetics</td>
</tr>
<tr>
<td>▪ optical metamaterials</td>
<td>▪ thermally stable nanocatalysts for high-temperature reactions</td>
<td>▪ nanoparticle sensors</td>
<td>▪ targeted delivery of anticancer therapies</td>
</tr>
<tr>
<td>▪ solid-state quantum-effect nanostructures</td>
<td>▪ epitaxy</td>
<td>▪ scalable deposition method for polymer-fullerene photovoltaics</td>
<td></td>
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<tr>
<td>▪ functionalized fluorescent nanocrystals</td>
<td>▪ nanoparticle fluorescent labels for cell cultures and diagnostics</td>
<td>▪ inkjet processes for printable electronics</td>
<td></td>
</tr>
<tr>
<td>▪ quantum-confined structures</td>
<td>▪ metal nanoparticles &amp; conductive polymers for soldering/bonding</td>
<td>▪ purification of fluids with nanomaterials</td>
<td></td>
</tr>
</tbody>
</table>

### Mixed Technology Goods

- Self-repairing & long-life wood composites
- Anti-microbial coatings for medical devices

### Public Technology Goods

- Inkjet processes for printable electronics
- Purification of fluids with nanomaterials
- Roll-to-roll processing

### Private Technology Goods

- Hardened nanomaterials for machining/drilling
- Flame-retardant nanocoatings
- Sporting goods
- Solar cells
- Sunscreen/cosmetics
- Targeted delivery of anticancer therapies
- Biodegradable and lipid-based drug delivery systems
R&D Efficiency: Overcoming the Innovation Risk Spike (Valley of Death)

The “Valley of Death” is Getting Wider
Trends in Short-Term vs. Long-Term US Industry R&D, 1993-2011

## Potential R&D Cost Reductions in Biopharmaceutical Development with Improved Infratechnologies

<table>
<thead>
<tr>
<th>Technology Focus Area</th>
<th>Expected Actual Cost per Approved Drug (millions)</th>
<th>Percentage Change from Baseline</th>
<th>Expected Present-Value Cost per Approved Drug (millions)</th>
<th>Percentage Change from Baseline</th>
<th>Development Time (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>$559.6</td>
<td>—</td>
<td>$1,240.9</td>
<td>—</td>
<td>133.7</td>
</tr>
<tr>
<td><strong>Individual Scenarios</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bioimaging</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Biomarkers</td>
<td>$347.9</td>
<td>—38%</td>
<td>$676.9</td>
<td>—45%</td>
<td>108.2</td>
</tr>
<tr>
<td>Bioinformatics</td>
<td>$375.0</td>
<td>—33%</td>
<td>$746.3</td>
<td>—40%</td>
<td>116.6</td>
</tr>
<tr>
<td>Gene expression</td>
<td>$345.8</td>
<td>—38%</td>
<td>$676.0</td>
<td>—45%</td>
<td>111.9</td>
</tr>
<tr>
<td><strong>Combined Scenarios</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservative</td>
<td>$421.2</td>
<td>—25</td>
<td>$869.6</td>
<td>—30</td>
<td>122.4</td>
</tr>
<tr>
<td>Optimistic</td>
<td>$289.2</td>
<td>—48</td>
<td>$533.1</td>
<td>—57</td>
<td>98.1</td>
</tr>
</tbody>
</table>
Complex Infrastructure for Efficient Transactions in High-Tech Markets

Causes of Underinvestment – Composition of R&D

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

Policy Response

Need a **Total-Technology-Life-Cycle** Growth Strategy

- Germany has a trade surplus in manufacturing, even though, compared to the United States, it has a
  - Approximately the same R&D intensity (2.82 percent vs. 2.90 percent for U.S.)
  - 26 percent higher average hourly manufacturing labor compensation

- **Reason:** Germany has a more comprehensive and intensively managed STID policy
  - Coordinated government R&D programs
  - Strongly integrated R&D and manufacturing
  - Highly skilled labor force across all technology occupations
  - Optimized industry structure (support for both large firms and SMEs)
  - Highest % of manufacturing value added from R&D-intensive industries
Target #1: Enable vigorous *development and commercialization* of transformative manufacturing technologies

- Increase efficiency of *technology platform development* through
  - coordinated *public and private research* in precompetitive advanced manufacturing technology
  - Implement *government-wide funding and portfolio management*
- Expand R&E tax credit to lower industry’s cost of R&D

**IMPACT:** Higher Rates of Innovation

Target #2: Promote *domestic deployment* of advanced manufacturing technologies to increase productivity and economic growth across all manufacturing industries

- Maintain *competitive industry structures* including opportunities for small and medium firms (SMEs)
- Provide the *skilled workforce* needed for deployment of new technologies
- Facilitate *scale-up (capital formation)* to enable rapid market penetration
- Use *government procurement* to leverage new market development

**IMPACT:** Market Share Growth
**Impact Metrics for a Nanotechnology Innovation Cluster Model**

### Short-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

### Medium-Term
- Supply-chain structure established
- New-skilled graduates produced
- Compression of R&D cycle
- New technology platforms & infratechnologies produced
- Commercialization
  - New products
  - New processes
  - Licensing

### Long-Term
- Broad industry and national economic benefits
  - Return on investment
  - GDP impacts

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**National Economic Impact**

**Multiplier Effect**

**Benefits to Participants**