Major international S&T trends and implications for the United States

- Broad expansion of S&T capabilities is underway in many countries—both policy- and market-driven.
- Growth by many measures of S&T activity is ubiquitous in much of the world …
- but is nowhere as rapid as in Asia outside of Japan.
- Consequently, the European and Japanese shares of world totals are eroding.
- The United States is generally maintaining its position …
- but it is facing both domestic and external challenges.
International R&D trends

• R&D expenditures are increasing robustly around the world…

• driven by both governments and industry, with industry funding generally expanding more rapidly.

• Firms’ cross-border R&D activities are on the rise …

• with U.S.-based multinationals expanding their investments in Asia.

• China has become the world’s third-largest R&D performing country behind the United States and Japan …

• in part reflecting R&D performed by foreign-owned, China-based firms.
International R&D trends

- International R&D spending has seen robust increases

Figure 1. Estimated worldwide R&D expenditures: 1990-2002

Billions of dollars

UNITED STATES
EU
OECD
OECD + nonmembers

Note: Billions of current dollars converted with purchasing power parities.
EU data since 1998 include 10 new member countries.
Source: OECD, Main Science and Technology Indicators database, November 2004
International R&D trends, continued

- Industrial R&D investments outpace those of governments

Figure 2. Government funds as a share of gross expenditures for research and development: 1990-2004

Percent

NOTE: EU data since 1998 include 10 new member countries.
SOURCE: OECD, Main Science and Technology Indicators database, November 2004
International R&D trends, continued

• Firms’ cross-border R&D investments are on the increase

Figure 3. R&D expenditures of foreign-owned firms in the United States and of U.S.-owned firms abroad: 1990-2002

Billions of dollars

International R&D trends, continued

• **Firms are forming more cross-border technology alliances**

**Figure 4. New international technology alliances by membership:**

1980-2003

Number

- U.S. firms only
- One or more non-U.S. firms
- U.S. and non-U.S. firms
- Non-U.S. firms only

**NOTE:** Includes business alliances with a joint R&D or technology development agreements, contracts, or equity joint ventures. 3-year moving averages.

**SOURCE:** MERIT, CATI-MERIT database
International R&D trends, continued

- U.S. multinationals are shifting overseas investments to Asia

**Figure 5. Geographical distribution of U.S. firms' overseas R&D: 1994-2002**

**Source:** R&D performed overseas by majority-owned affiliates of U.S. firms

**Source:** U.S. Department of Commerce, BEA, Survey of U.S. Direct Investment Abroad; and National Science Board, S&E Indicators 2006, appendix table 4-51.
International R&D trends, continued

- **China has become the world’s third largest R&D performer**

*Figure 6. R&D expenditures of selected regions and countries: 1990-2003*

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S.</th>
<th>EU</th>
<th>Japan</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>100</td>
<td>120</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>2003</td>
<td>200</td>
<td>250</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

**Note:** All data calculated by OECD using purchasing power parities; data differ somewhat from U.S. dollar figures. Since 1998, EU data include 10 new members.  
**Source:** OECD Main Science & Technology Indicators, various years
International R&D trends, continued

- The rapid rise of China’s R&D expenditures is unprecedented for any country in recent memory

Figure 7: China's R&D expenditures relative to those of the United States, Japan, and EU: 1991-2003

Percent

NOTE: All data calculated by OECD using purchasing power parities. EU data since 1998 include 10 new member countries. SOURCE: OECD Main Science & Technology Indicators; and NSF, S&E Indicators 2006
Increasing industrial R&D gives rise to growing numbers of researchers around the world

Figure 8. Estimated number of industrial researchers: 1981-2002

NOTE: Smaller OECD members is OECD minus U.S., Japan, UK, Germany, France, Italy, and Canada. Researchers are full-time equivalents.
Source: OECD, Main Science and Technology Indicators database, November 2004.
High technology markets

- U.S. manufacturing has shifted swiftly towards high technology, resulting in a strong world market position ...
- while Europe and Japan have lost ground to China and other Asian economies.
- High technology exports are expanding, but European, Japanese, and U.S. export shares are shrinking …
- as those of China and other Asian exporters are rising.
- The U.S. trade balance for high technology industries and goods has turned negative.
High technology markets

- Europe and Japan are losing market share in high technology manufacturing

Figure 9. Location of world's high technology manufacturing output: 1990-2003

Percent

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

SOURCE: Global Insight and S&E Indicators 2006
High technology markets, continued

- The United States has rapidly developed a very technology intensive manufacturing sector.

**Figure 10. High technology share of total manufacturing: 1990-2003**

- United States
- EU
- Japan
- China
- Asia-8

**NOTE:** Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.

**SOURCE:** Global Insight and S&E Indicators 2006
High technology markets, continued

• High technology shares of Asian exporters are expanding

Figure 11. Export market shares in high technology goods: 1990-2003
Percent

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.
SOURCE: Global Insight and S&E Indicators 2006
High technology markets, continued

- The trade balance of U.S. high technology industries has turned negative

**Figure 12. U.S. trade balance for five high technology industries: 1990-2003**

*Billions of dollars*

*NOTE: Includes aerospace; pharmaceuticals; office and computing equipment; communication equipment; and scientific instruments.*

*SOURCE: Global Insight and S&E Indicators 2006*
High technology markets, continued

- As has the trade balance in high technology products

Figure 13. U.S. trade balance in high technology goods: 2000-2004
Billions of dollars

NOTE: Includes biotechnology, life sciences, opto-electronics, information/communication equipment, electronics, flexible manufacturing, advanced materials, aerospace, weapons, nuclear technology and software.

High technology markets, continued

• Rising Asian patent filings show growing technological sophistication

Figure 14. United States patent applications by foreign-resident inventors: 1990-2003
Thousands

[Graph showing patent applications by region from 1990 to 2003]

NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.
SOURCE: U.S. Patent and Trademark Office, special tabulation
Scientific research

• In scientific research, China and other Asian nations outside of Japan remain some distance from approaching parity with established science producing countries …

• but their scientists and engineers are collaborating with counterparts around the world and in Asia …

• and their international publishing and patenting activities, while yet modest, are on accelerating upward trajectories.

• China’s academic R&D spending in 2002 was more than double the amount in 1999 but remains at only about 10% of the national total.
Scientific research

- Academic R&D has grown robustly, with double-digit annual growth rates for China since 1999.

**Figure 15: Academic R&D expenditures: 1990-2003**

- United States
- OECD minus USA
- EU
- China

NOTE: All data calculated by OECD using purchasing power parities. EU data from 1998 onward include 10 new member states.

SOURCE: OECD Main Science & Technology Indicators, various years
Scientific research, continued

- Academic research is less prominent in Asia than in many Western countries

**Figure 16: Academic R&D as a share of total R&D: Latest available year**

*Source: OECD Main Science & Technology Indicators; and NSB, S&E Indicators 2006*
Scientific research, continued

- Scientific expertise is increasing around the world

Figure 17. Scientific and technical articles, by country/region: 1988-2003

Thousands


NOTE: Asia-8 includes South Korea, India, Indonesia, Malaysia, Philippines, Singapore, Taiwan, and Thailand.
SOURCE: ISI, Science & Social Science Citation Indexes, CHI Research, Inc., NSF
Scientific research, continued

- Growth in scientific expertise elsewhere is narrowing the U.S. quality advantage

**Figure 17a. Share of U.S. articles among most cited articles, total S&E:** 1992-2003

Percent

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 1%</td>
<td>65</td>
<td>60</td>
<td>55</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Top 5%</td>
<td>55</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Top 10%</td>
<td>45</td>
<td>40</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>All articles</td>
<td>35</td>
<td>30</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**NOTE:** Three years of article citations, lagged by 2 years.
**SOURCE:** ISI, Science and Social Science Citation Indexes, CHI Research, Inc., and NSF.
Scientific research, continued

- International scientific collaboration is commonplace

**Figure 18. Share of scientific and technical articles with international coauthorship, by country/region: 1988, 1996, 2003**

Percent

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>EU</td>
<td>Japan</td>
</tr>
</tbody>
</table>

**NOTE:** EU data include only non-EU collaborations. Asia-8 includes India, South Korea, Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand

**SOURCE:** ISI, Science/Social Science Citation Indexes; CHI Research, Inc.; NSF
Scientific research, continued

- By choice or by legacy, international science portfolios vary greatly

Figure 19. Portfolio of scientific and technical articles by field and country/region: 2003

NOTE: Ordered by percent life sciences. Asia-8 includes India, South Korea, Indonesia, Malaysia, Philippines, Singapore, Taiwan, Thailand

SOURCE: ISI, Science/Social Science Citation Indexes, CHI Research, Inc., NSF
International labor forces

- No international data exist on S&E labor forces.
- A broad proxy measure, persons with post-high school education, nearly tripled from 1980-2000, with the fastest growth occurring in Asia.
- Internationally, output of new degree holders is expanding and focusing more on the natural sciences and engineering than in the United States.
- Europe and Asia have made especially rapid strides in the graduation of new NS&E degree holders …
- and are producing the bulk of NS&E doctorates.
International labor forces

- International S&E labor force data can only be estimated

Figure 20. Population 15 years and older with tertiary education, by country/region: 1980, 2000

SOURCE: Adapted from R.J. Barrow and J. Lee, Center for International Development: International Data on Educational Attainment, 2000
International labor forces, continued

• International degree production is rising and focused on natural sciences and engineering

Figure 21. Number of first university degrees, by region: 1997 and 2002

Thousands

NOTE: Asia includes Japan, China, India, Indonesia, South Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand

SOURCE: National sources and NSF, S&E Indicators 2000 and 2006
International labor forces, continued

- Natural science & engineering degrees are a smaller share of all degrees in the United States than elsewhere

Figure 22. First university degrees in natural science and engineering as a share of total first university degrees: 1997 and 2002

SOURCE: National sources and S&E Indicators 2000 and 2006
International labor forces, continued

- Europe and Asia have made great strides in natural science and engineering degree production

**Figure 23. Number of natural science and engineering degrees per 100 24-year olds, selected locations: 1975 and 2000 or latest year**

Source: OECD, Education at a Glance, and national sources
International labor forces, continued

- The bulk of S&E doctorates have been granted outside the United States

**Figure 24. Number of S&E doctorates awarded, selected countries and regions: 2000 or latest year**

**Sources:** OECD and national statistical offices; NSF, special tabulation
International labor forces, continued

• **A few countries continue to dominate the international student market, but this may be changing**

**Figure 25. Foreign higher education students in all fields, selected countries: 2002**

*Source: Organisation for Economic Cooperation and Development, Education at a Glance, 2004*
• Large numbers of highly educated persons live outside their home countries

Figure 26. Number of persons with higher education living abroad, by country/region of origin: 1990 and 2000
Millions

SOURCE: F. Docquier and A. Marfouk: Measuring the International Mobility of Skilled Workers (1990-2000)
The U.S. S&E labor force

• For decades, U.S. science and engineering jobs have grown faster than the civilian labor force or domestic S&E degrees.

• Foreign-born scientists and engineers filled these jobs, their numbers rising especially strongly during the 1990s.

• As Asian countries develop their S&T infrastructures, fewer of their scientists and engineers—currently 2/3 of foreign S&E doctorate holders—may come to or stay in the U.S.

• The number of U.S.-issued foreign student visas remains 25% below its pre- 9/11 peak …

• and first-time full-time foreign graduate enrollment in S&E is down for the second year in a row.
The U.S. S&E labor force

- S&E jobs have grown faster than U.S. degree production, but foreign-born scientists and engineers have filled the gap.

Figure 27. Average annual growth of U.S. labor force and S&E occupations: 1960-2000

• The inflow of scientists and engineers from Asia and elsewhere accelerated in the 1990s

Figure 28: Share of foreign-born scientists and engineers in U.S. S&E occupations, by degree level: 1990 and 2000

Percent

NOTE: Data exclude postsecondary teachers because of Census occupation coding

SOURCE: U.S. Bureau of the Census 5-percent microdata samples
The U.S. S&E labor force, continued

- Foreign students earned one-third of U.S. S&E doctorates while Ph.D.s earned by white U.S. males dropped sharply.

**Figure 29: S&E doctorates conferred by citizenship status and race/ethnicity: 1990-2003**

*NOTE: Physical sciences includes earth, ocean, and atmospheric sciences. Social sciences includes psychology. Excludes unknown citizenship or race/ethnicity.*

*SOURCE: NSF, Survey of Earned Doctorates, special tabulation.*
The U.S. S&E labor force, continued

- Large numbers of foreign doctorate holders continue to stay after degree receipt …

Figure 30: Foreign student plans after receipt of U.S. S&E doctorate: 1983-2003

Thousands

Source: NSF, Survey of Earned Doctorates, Special Tabulation
The U.S. S&E labor force, continued

- Asian locations are the source of two-thirds of foreign U.S. S&E Ph.D. recipients but are developing indigenous infrastructures

Figure 31: Origin of foreigners earning U.S. S&E Ph.D.s: 1983-2003

SOURCE: NSF, Survey of Earned Doctorates, special tabulation
The U.S. S&E labor force, continued

- Foreign student visas are down by one-quarter since 2001; other high-skill visa categories are flat

Figure 32. Student, exchange, and other high-skill-related temporary visas issued: 1998 - 2004

Thousands

SOURCE: U.S. Department of State, Immigrant Visa Control and Reporting Division
The U.S. S&E labor force, continued

• A leading indicator hints at declining foreign enrollments in advanced U.S. S&E study

Figure 33. Change in first-time full-time graduate enrollment in S&E, by citizenship status: 2001-2003

Percent

SOURCE: NSF, Survey of Graduate Students and Postdoctorates in S&E
The U.S. S&E labor force, continued

• A large number of retirements is impending.
• Women and underrepresented minorities have been earning rising shares of S&E degrees …
• yet continuing demographic shifts in the college-age cohort pose challenges to raising domestic S&E degree output …
• and the performance of U.S. students in elementary and secondary school gives cause for concern.
• Prospects for the U.S. S&E workforce are for:
  • slower growth
  • rising retirements and
  • increasing average age.
The U.S. S&E labor force, continued

- A large number of retirements from the U.S. S&E labor force is impending

**Figure 34. Persons in the U.S. S&E labor force nearing retirement age, by degree level: 2003**

**Thousands**

<table>
<thead>
<tr>
<th>Degree Level</th>
<th>Bachelor's</th>
<th>Master's</th>
<th>Doctorate</th>
</tr>
</thead>
<tbody>
<tr>
<td>55 and older</td>
<td>800</td>
<td>600</td>
<td>200</td>
</tr>
<tr>
<td>60 and older</td>
<td>400</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

**Source:** NSF, National Survey of College Graduates, 2003
The U.S. S&E labor force, continued

- **Women and minorities have earned rising shares of S&E degrees**

**Figure 35. U.S. S&E bachelor's degrees earned by women and minorities: 1990-2001**

- U.S. women
- U.S. underrepresented minorities
- U.S. Asian

**NOTE:** U.S. citizens and permanent visa holders only.

**SOURCE:** U.S. Department of Education, IPEDS Completions surveys
The U.S. S&E labor force, continued

• Yet continuing demographic changes pose challenges to raising domestic S&E degree output

Figure 36. Composition of U.S. 18-24-year olds: 1990-2020

SOURCE: U.S. Bureau of the Census
The U.S. S&E labor force, continued

• ... while the performance of U.S. students in K-12 gives cause for concern

Figure 37. Average science literacy score of 15-year-old students, by country: 2003

U.S. academic S&E trends

- Since 1990, inflation-adjusted academic R&D expenditures have almost doubled, driven by federal and institution funds.
- Academic laboratory construction is booming but equipment spending is at a long-time low.
- Relatively fewer S&E doctorate holders are employed in academia, and fewer have traditional faculty positions, especially among young Ph.D.s.
- The academic S&E labor force has become more diverse with more women, underrepresented minorities, and foreign-born.
- The number of academic researchers is growing but government support—despite strong funding growth—reaches fewer of them, especially among the young.
U.S. academic S&E trends

• Since 1990, inflation-adjusted academic R&D expenditures have almost doubled, driven by federal and institution funds

Figure 38. Expenditures for academic R&D by source of funds:
1990-2003

Billions of dollars

NOTE: Current dollars; excludes capital expenditures.
SOURCE: NSF, Survey of Academic Research and Development Expenditures
U.S. academic S&E trends, continued

• Academic laboratory construction is booming but equipment spending is at a long-time low

Figure 39. Expenditures for academic research equipment as a share of total academic R&D expenditures: 1990-2003

Percent

NOTE: Excludes capital expenditures.
SOURCE: NSF, Survey of Academic Research and Development Expenditures
U.S. academic S&E trends, continued

- The number of academic S&E Ph.D.s are increasing, but relatively fewer have traditional faculty positions

Figure 40. Faculty and tenure track status of academic S&E Ph.D.s 4-7 years after receipt of doctorate: 1989-2003

Percent

SOURCE: NSF, Survey of Doctorate Recipients, special tabulation
U.S. academic S&E trends, continued

- The academic labor force includes a rising proportion of women, minorities, and foreign-born

Figure 41. Composition of academic doctoral S&E workforce by race/ethnicity, sex, and citizenship at degree conferral: 1989-2003

Source: NSF, Survey of Doctorate Recipients, special tabulation
U.S. academic S&E trends, continued

- Strongly rising government funding reaches proportionately fewer of a growing number of researchers

Figure 42: Academic S&E Ph.D.s receiving federal government support for their research: 1989 and 2003

SOURCE: NSF, Survey of Doctorate Recipients, special tabulation
Broader U.S. R&D trends

• Total U.S. R&D expenditures have rebounded robustly after declining in 2002.
• R&D performance with external partners is increasing in the form of R&D partnerships and alliances and contracted out R&D.
• Federal support of innovation by small businesses is increasing.
• But U.S. venture capital, seedbed of startup companies, has become risk-averse.
**Broader U.S. R&D trends**

- Total U.S. R&D investment has rebounded robustly after declining in 2002

![Figure 43. U.S. R&D expenditures by source of funds: 1990-2004](image)

*Billions of dollars*

*NOTE:*Current dollars; 2004 data are preliminary. Other includes $8 billion from universities.

*SOURCE:* NSF, National Patterns of R&D Resources
Broader U.S. R&D trends, continued

- Industrial R&D performance in concert with other firms is increasing ...

**Figure 44. Contracted out U.S. industrial R&D: 1993-2003**

*Note: Percent is ratio of contracted out R&D to R&D performed internally.*

*Source: NSF, Survey of Industrial Research and Development*
Broader U.S. R&D trends, continued

• and U.S. firms are forming alliances with firms worldwide to develop and market new technologies

Figure 45. New strategic technology alliances involving U.S. firms: 1990-2003
Number

SOURCE: MERIT, CATI database, special tabulation
Broader U.S. R&D trends, continued

- Federal support of innovation by small businesses is increasing ...

**Figure 46. Federal Small Business Innovation Research funds, by phase: 1990-2003**

Millions of dollars

<table>
<thead>
<tr>
<th>Year</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1991</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1992</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1993</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1998</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1999</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2000</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2003</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**NOTE:** Phase I awards are for feasibility assessment; Phase II awards are for further development.

**SOURCE:** U.S. Small Business Administration, annual series
Broader U.S. R&D trends, continued

• but U.S. venture capital, seedbed of startup companies, has grown risk-averse

Figure 47. U.S. venture capital disbursements by stage of financing: 1994-2004

Percent

SOURCE: Thompson Venture Economics
Conclusion

• The globalization of R&D, science and technology, and S&E labor markets continues as countries seek competitive advantage and as R&D spending, business investment, people and employers cross borders.

• Human capital is a key ingredient in these developments. Three factors affecting the size of the U.S. S&E labor force are:
  • Retirements,
  • S&E degree production, and
  • immigration.
Conclusion, continued

- A prolonged slowdown in the growth of the U.S. S&E labor force would produce wage growth adjustments whose net effects in this fluid environment are hard to assess.
- Better data, metrics and models are needed to capture the evolving dynamics of international S&E labor markets and other aspects of S&T systems.