Benchmarking the Research Competitiveness of US Chemical Engineering

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Representing the NRC Committee

Charge to the Committee

A comparative international assessment to answer:

- What is the position of US research in chemical engineering relative to that of other regions or countries?
- What key factors influence US performance in chemical engineering research?
- On the basis of current trends in the United States and abroad, what will be the relative future US position in chemical engineering research?
- Only to develop findings and conclusions—not recommendations.

Composition of the Committee

- *Chair*
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Character of Chemical Engineering World-Wide

- US
  - Clear academic identity with ‘intellectual entrepreneurs’ in academia
  - Interdisciplinary
- Europe
  - UK similar to US
  - Rest of EU: applied chemistry, process and equipment technology
- Japan
  - No distinct academic identity
- China
  - US curriculum, research aimed at commodities or materials/bio
- India
  - Like US, with stronger connections to industry

The Facts Today

- The number of diversified chemical companies is decreasing
  - Costs drive new plants to raw materials sources (Middle East) or to customers (Asia)
- Industrial R&D outlays are smaller and more focused
- Chemical companies evolving from process centered to product centered
- Globalization of the research enterprise...

Taxonomy

- For this study, the field was divided into nine divisions. Each division was then divided into several sub-areas
- Example :
  - Engineering Science of Chemical Processes
    - Catalysis
    - Kinetics and Reaction Engineering
    - Polymerization Reaction Engineering
    - Electrochemical Processes

Taxonomy

- The nine divisions:
  - Engineering Science of Physical Processes
  - Engineering Science of Chemical Processes
  - Engineering Science of Biological Processes
  - Interfacial and Molecular Science and Engineering
  - Materials
  - Biomedical Products and Biomaterials
  - Energy
  - Environmental Impact and Management
  - Process Systems Development and Engineering

Benchmarking Methods

- Methods
  - A *Virtual World Congress*. The Panel asked leading international experts to identify the "best of the best", i.e., who they would invite if asked to put together the leading conference in their subareas of expertise
  - Analysis of journal publications to uncover directions of research and relative levels of research activities in the US and the rest of the world
  - Journal-publication analysis (submissions by US vs. non-US authors
  - Citation analysis to measure the quality of research and its impact
  - Patent productivity by academic and industrial research activities
  - Analysis of trends in prizes, awards, and other recognitions received by chemical engineers.
- These indicators primarily reflect the state of *academic* chemical engineering

Findings

- Each subarea was judged to be either:
  - In the forefront
  - Among world leaders
  - Behind world leaders
- Prognosis for each subarea was either:
  - Improving (gaining ground)
  - Stable
  - Deteriorating (losing ground)

Findings

- No sub-area was found to be behind the world leaders. 12 were losing ground, 9 gaining ground, and 11 were stable.
  - Realistic given the fast pace of chemical engineering in the developing world.

- Those losing ground are generally in traditional areas, those at the front or gaining are in biological areas and energy.

Measures of competition in all subareas: International Papers

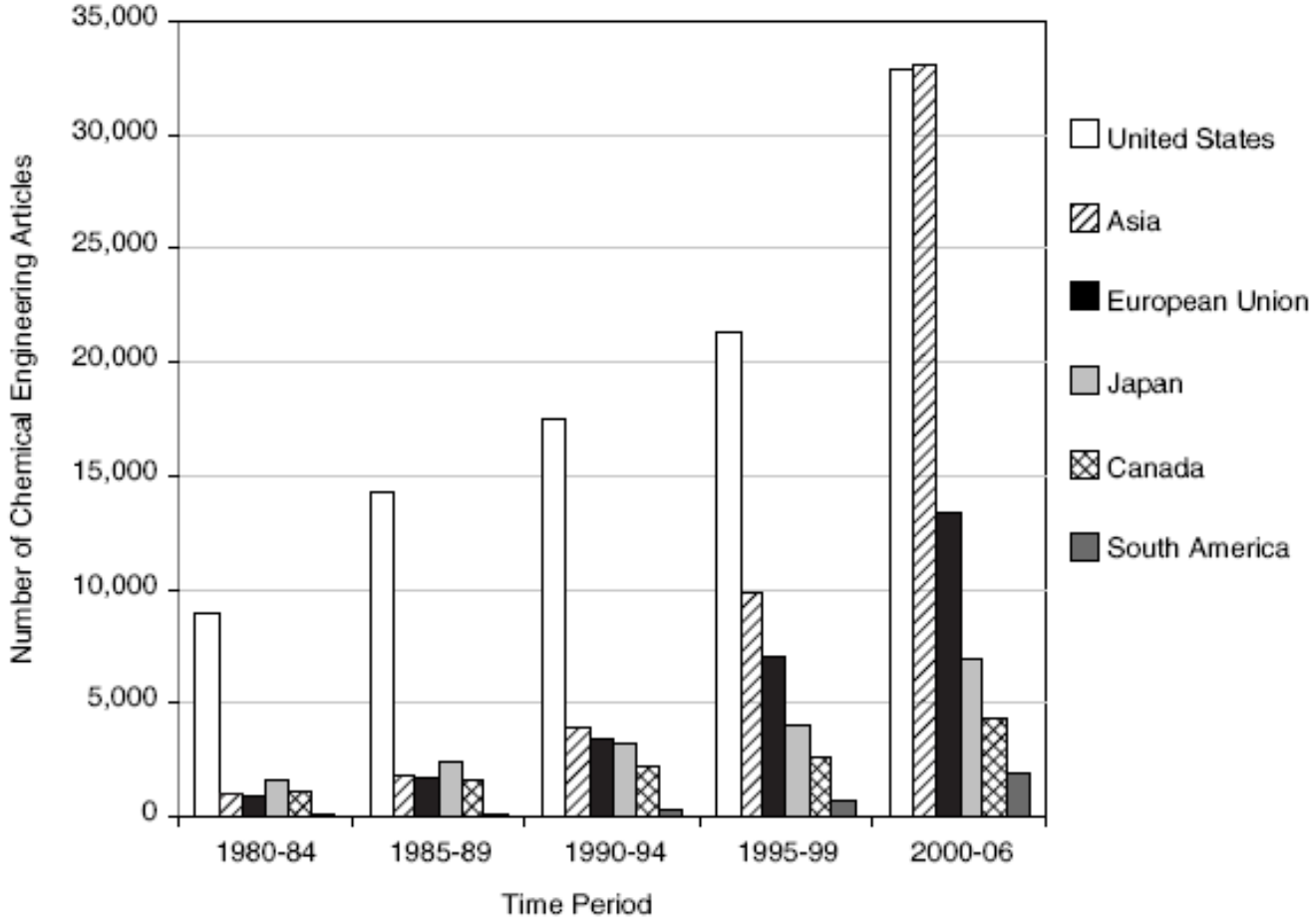
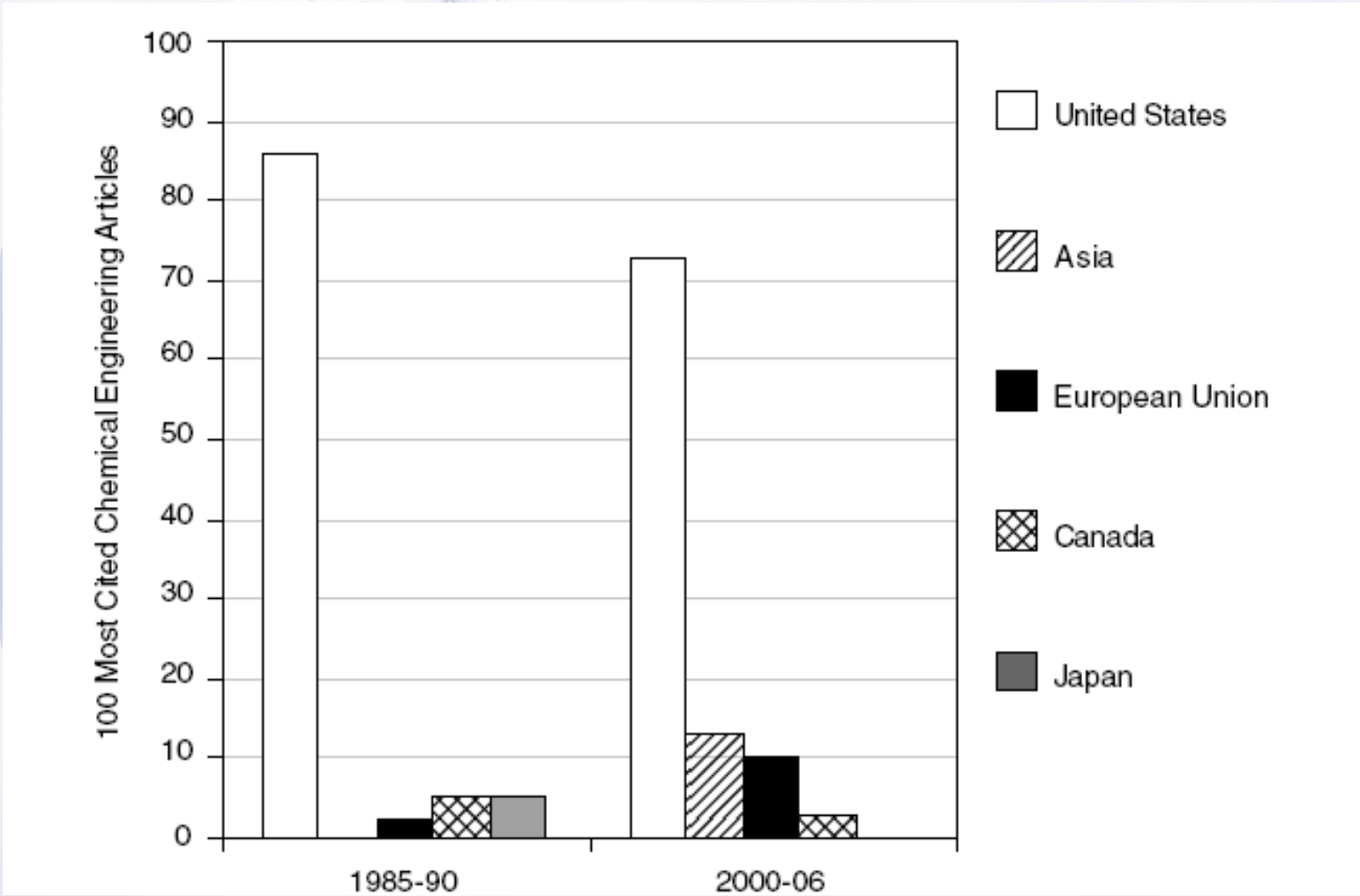


FIGURE 1 Number of published papers in chemical engineering from various geographic regions.
NOTE: Asia comprises China, Korea, Taiwan, and India, and the European Union includes 25 countries.

International Quality



Does CHEG have the people?

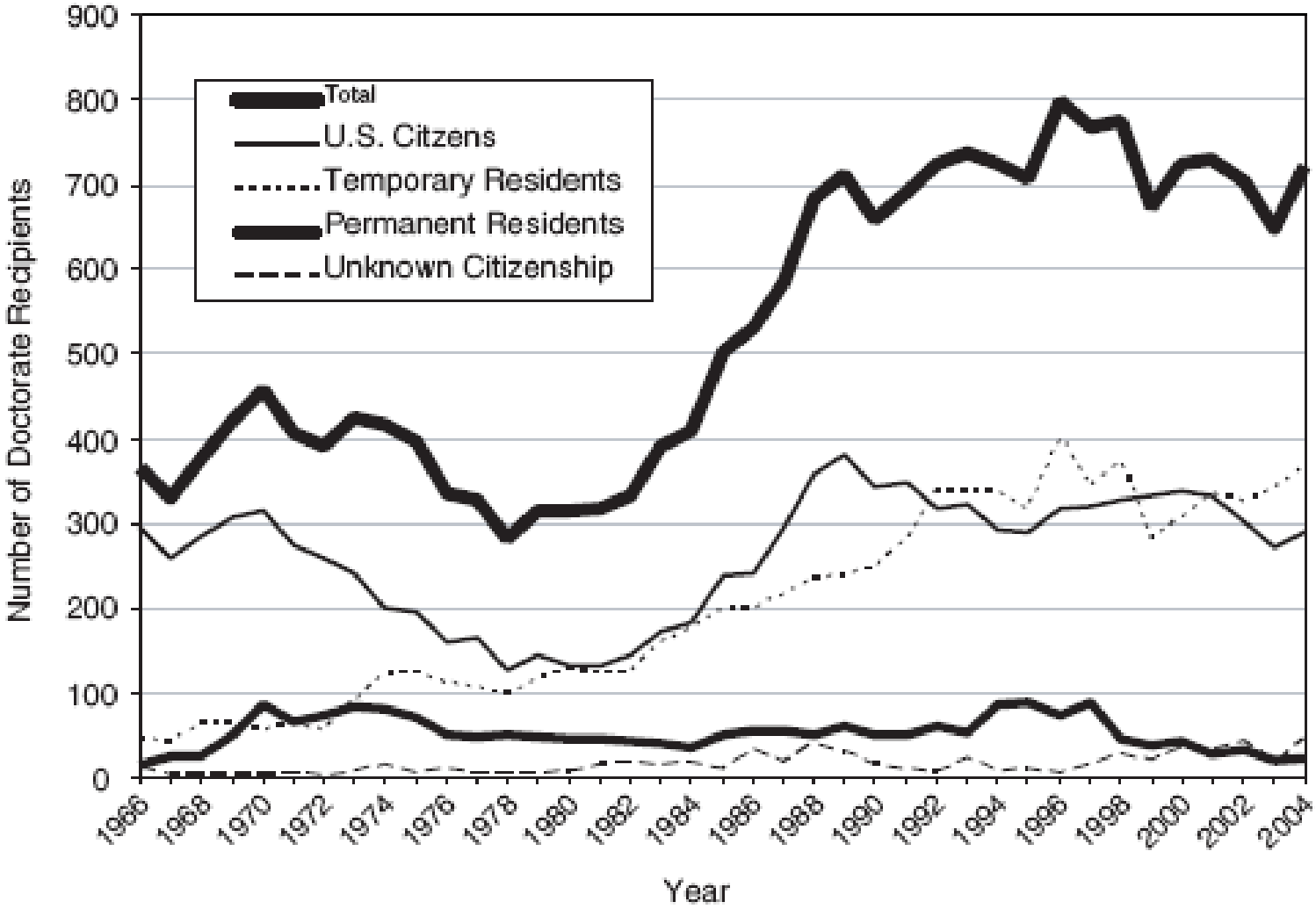


FIGURE 5.5 Earned doctoral degrees in chemical engineering from U.S. institutions as a function of residency status, 1966-2004.

Conclusions

- US chemical engineering research is strong and at the “Forefront” or “Among World Leaders” in all sub-areas of chemical engineering, and is expected to remain so

- US research is particularly strong in fundamental engineering science across the spectrum of scales from macroscopic to molecular
  - Primary competition comes from other disciplines rather than from non-US chemical engineers
  - Recent trends of increasing applications research with a parallel decrease in basic research may undermine the historical strength and pre-eminence of US chemical engineering

Conclusions (cont.)

- Trends in research funding policies will continue to
  - reduce chemical engineering's dynamic range
  - strengthening its molecular orientation in bio- and materials-related activities
  - reduce research in macroscopic processes
  - Japanese and European efforts maintain a more balanced approach.

Conclusions (cont.)

- Chemical engineers will be essential to interdisciplinary teams taking molecular and nano information to create macroscopic processes and products – the job of engineers!