Universities in National Innovation Systems

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Outline

- Universities and industrial innovation in knowledge-based economies.
  - Characteristics of the university-industry technology transfer process.
- Comparative data on the structure of OECD higher education systems.
- Comparing OECD, developing-economy systems.
- Universities in "catching-up" economies in the 19^{th} & 20^{th} centuries.
  - Challenges for developing-economy higher-education systems.
- Universities, patenting, and industrial innovation: the US Bayh-Dole Act of 1980.
- Conclusions.

Why do universities matter?

- They perform a substantial share of R&D, especially basic research, in most OECD economies.
- Innovation now draws more heavily on fundamental knowledge, an important output of universities.
- Important sources of trained S&Es and potentially, new firms.
  - Combination of research & training provides an important channel for flows of knowledge, practice, knowhow between university and industry.
- Important institutions in the absorption of technology from external sources.
  - Stronger international IPR will increase importance of domestic innovation, "inventing around" patents.
- Governments in OECD & developing economies see universities as important engines of economic development.
- But, consistent with the "NSI view," universities cannot be analyzed in isolation from other components of a national innovation system.
  - Overall higher education system (including other institutions for "tertiary" education, such as community colleges, technical schools, etc.).
    - "Bridging" institutions may be especially important for SMEs.
  - Systems of finance for industrial innovation.
  - Labor markets.
  - Broader "demand for innovation" from domestic firms, which in turn may reflect macroeconomic policy, influences on capital investment.

Universities in developing economies

- Increasing role of science in innovation => need for stronger indigenous research capability in order to "absorb" knowledge, technology from foreign sources.
- Developing-economy university research can complement, aid in absorption of, research results from international S&T networks.
  - Especially important for research on issues unique to developing-economy agriculture, public health, etc.
- University-based research trains S&Es and professionals more generally (e.g., primary & secondary teachers, physicians).
- Domestic research universities may provide an attractive "re-entry" opportunity for citizens working as S&Es in foreign economies.

The role of academic research in industrial innovation

- Surveys of US industrial R&D managers: patents & licenses are not the most important channels for access to university research for innovation (Cohen et al. 2002, Levin et al., 1987).
- All agree that "biomedical research is different": links are more direct and industrial innovation depends on academic research.
  - A "linear model" in this sector?
- In other sectors, relationship is more indirect and the supply of trained graduates, publications, faculty consulting, conferences are all more important than patents & licenses in knowledge flow (Cohen et al., 2002).
- Patents and licensing contracts rarely convey the necessary knowhow for commercialization.

Comparing OECD higher ed. systems

- Although widely cited as an important research institution, US higher ed. system ranks below those of other OECD systems on following indicators:
  - Share of national R&D performed.
  - Share of gov't R&D performed.
  - Share of higher ed. R&D supported by industry.
- Based on qualitative evidence, OECD (2002) claims that labor mobility between US higher education and industry is greater than in other systems.
- Unusual behavior of US system may reflect broader set of structural influences than those in the following indicators.

Figure 1: Universities' performance share of total national R&D, 1981-99

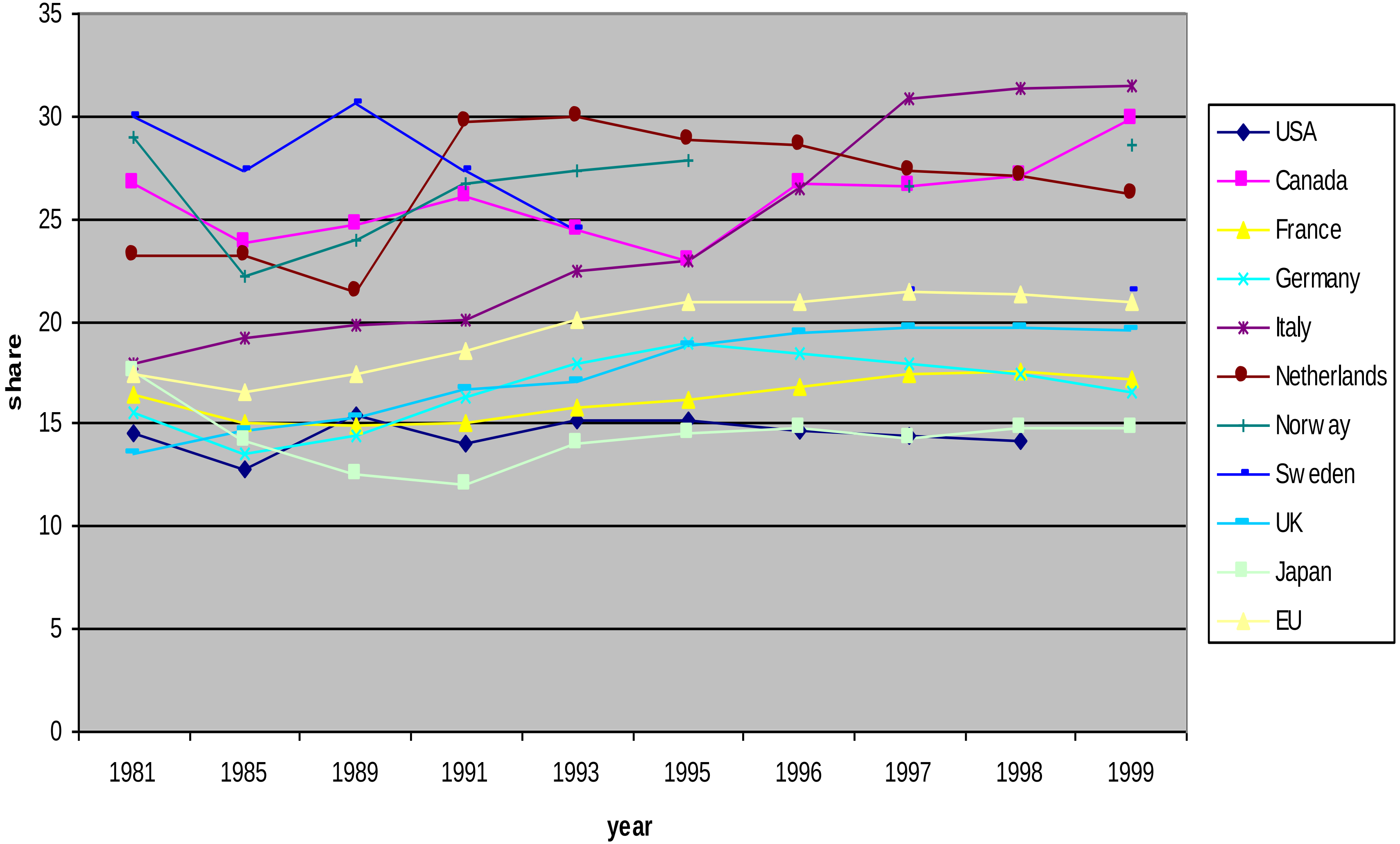


Figure 2: Universities' performance share of gov't-funded R&D, 1981-95

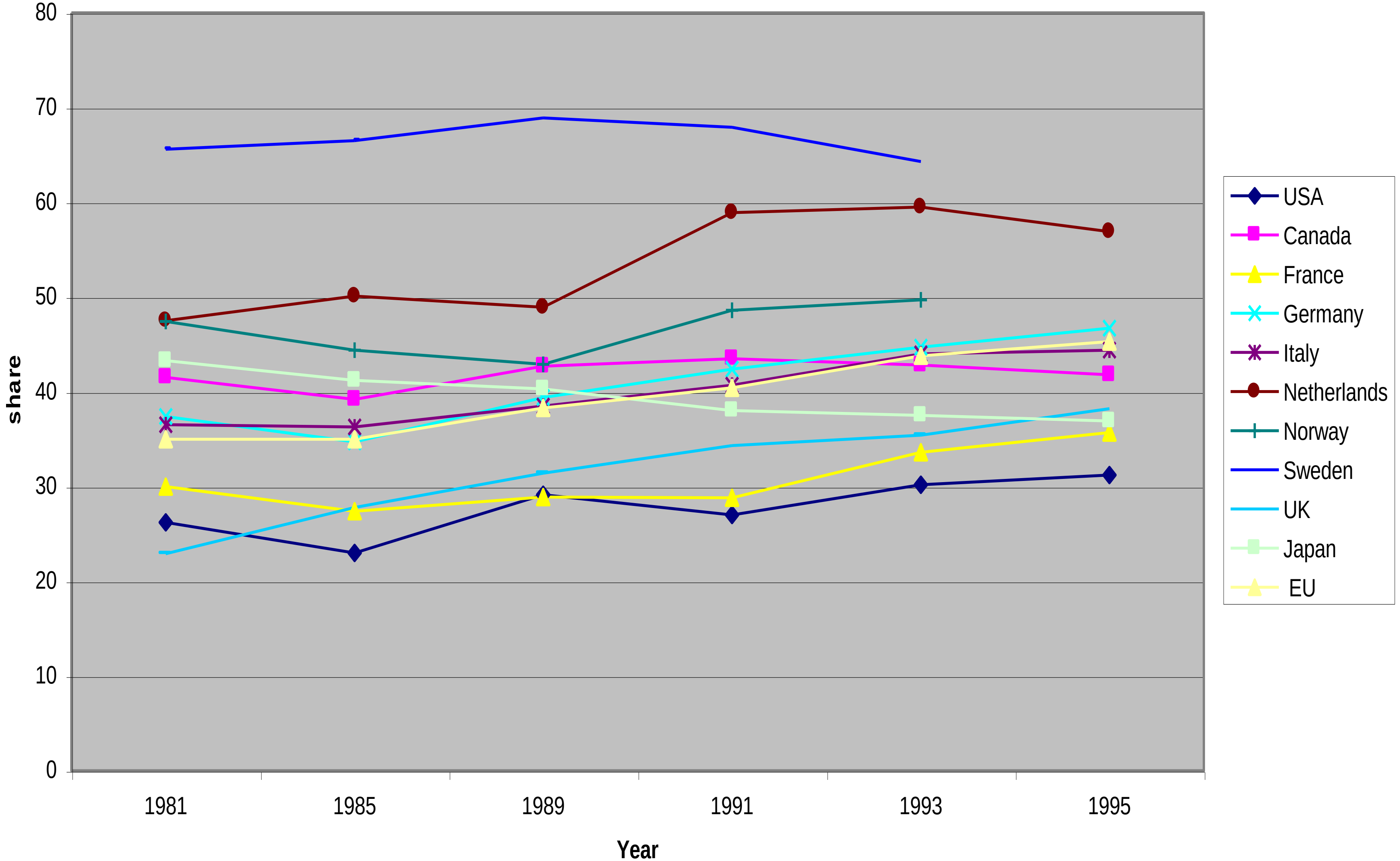
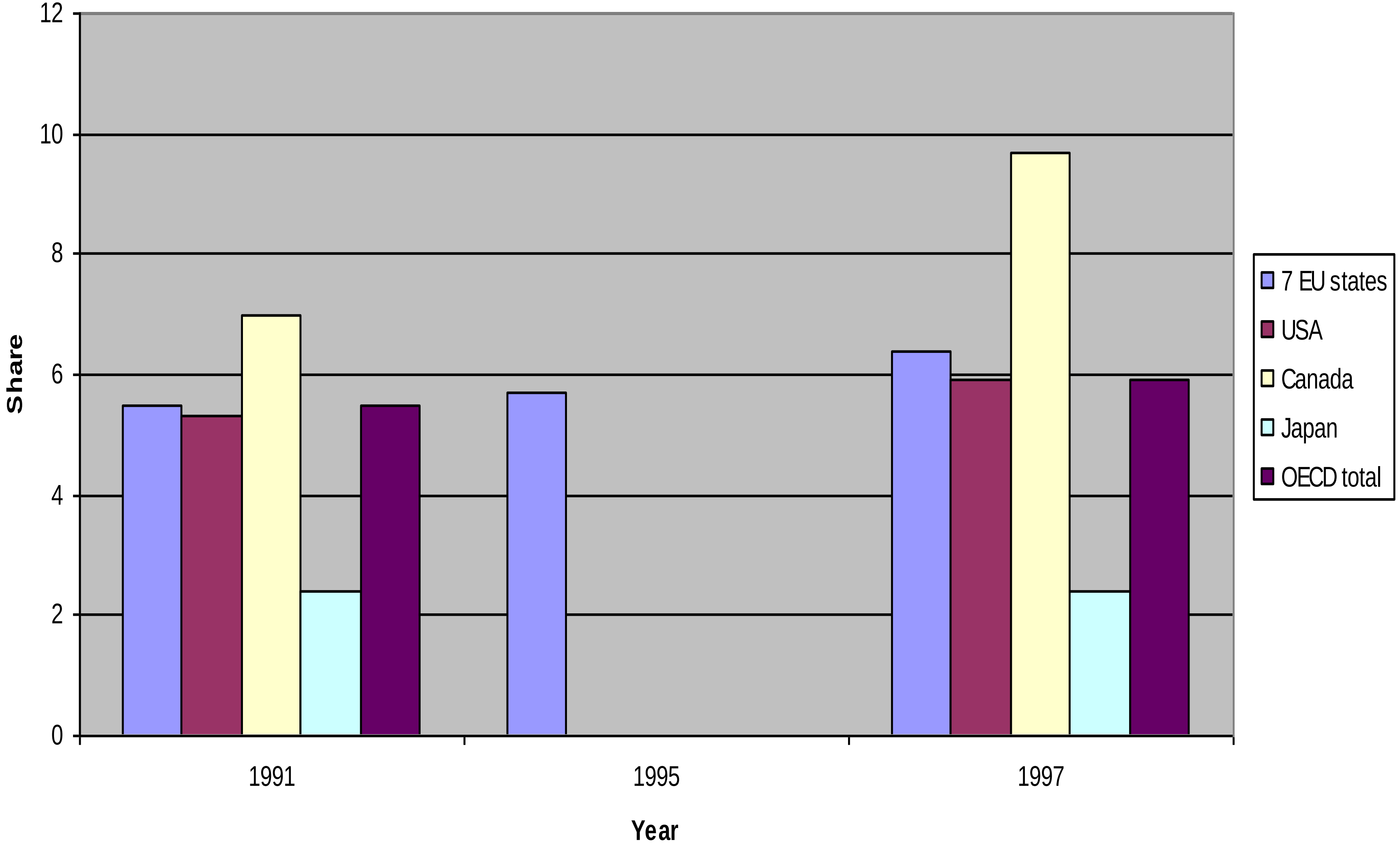


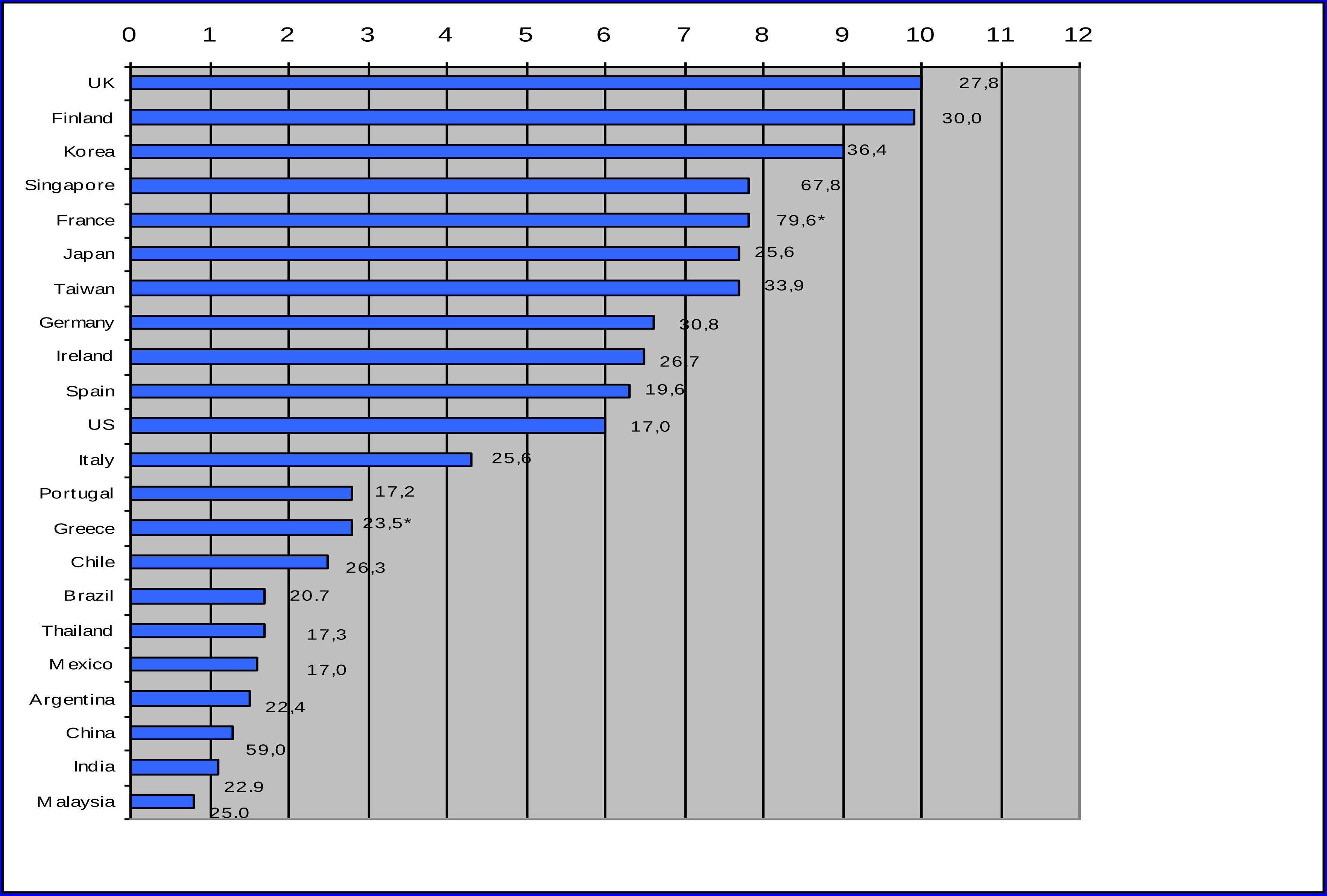
Figure 5: Fraction of HERD financed by business



Universities in economic "catchup": US, Germany, Japan, Taiwan, S. Korea

- Rapid enrollment growth, particularly undergraduate enrollment, is common in early years of catchup.
- Other than Germany, universities often are weak in research during the early catchup period--major contribution is through training, especially in engineering, rather than research.
- Primary focus of training is industry, not gov't, employment.
- Universities' research role often complemented by other types of "tertiary education" institutions, public labs in early period.
  - But over time, greater pressure on universities to expand quality, importance of their research role, generally at the expense of public labs.
- Access by qualified students to university systems in "catchup" economies generally is open to large segments of population.
  - Relatively low fees and/or availability of financial aid, loans.
- Universities are linked into global S&T system, especially through international flows of faculty & researchers.
  - Hiring foreign scholars, bringing back expatriate S&Es.
- Great contrasts in structure of higher education systems, extent of centralized control, linkages between universities and industry, among these 5 economies.

Ratio of First University Degrees in Natural Sciences and Engineering to 24 year-olds in the Population, 1999 (all values in %)



Developing-economy university systems

- Smaller share of relevant populations is enrolled in “tertiary” education (including universities) than in most OECD economies, and this gap has widened since 1980.
  - 1980: US enrollment rate 55% vs. developing-economy enrollment rate of 5%.
  - 1995: US enrollment rate 81% vs. developing-economy enrollment rate of 9%.
  - 1995 enrollment rates within E. Asia range from 2% in Cambodia to 51% in South Korea.
- Smaller share of students in tertiary education in most developing economies are enrolled in postgraduate (MA/MS, PhD, MD) degree programs.
  - A key channel for “brain drain” is outmigration of students to enroll in foreign postgraduate programs.
- Nonuniversity institutions account for much smaller share of tertiary education in many developing economies.
  - 2-year colleges, private vocational training institutes, polytechnics serve important training function in many OECD economies.
- Incomplete data suggest that universities perform a smaller share of publicly funded R&D in most developing economies.
  - Weakens research-training links within domestic higher-education systems, NSIs.

Issues in developing-economy higher education systems

- Low enrollment rates.
  - But rapid expansion in degree output can also create problems in the labor market (Germany, Taiwan, S. Korea).
- Limited institutional differentiation, variety within developing-economy tertiary educational systems.
  - Few alternatives to universities for postsecondary training.
  - Domestic higher-education systems respond slowly if at all to changing labor markets.
- Inequality in access, unequal financial support => many developing-economy higher education systems reinforce, rather than eroding, social inequality.
- Postgraduate education is lacking.
- Underfunding of research, facilities, salaries.
  - "Social returns" to investment in tertiary education may be underestimated if one focuses solely on earnings—can't overlook knowledge spillovers.
  - Greater reliance on competitive research funding can improve performance.
  - Stronger links between R&D performance, S&E training can improve efficiency of both activities and aid domestic technology transfer.

The Bayh-Dole Act of 1980: Model for developing economies?

Patenting & licensing policies: The Bayh-Dole Act of 1980

- Passed in 1980 to encourage commercial development of federally funded inventions in university and government labs. The Act enabled these institutions to obtain patents on inventions and to license them to private parties, including exclusive licenses.
- The Act constituted a Congressional endorsement of university licensing.
- Bayh-Dole has been widely cited (*Economist*, OECD) as an important contributor to US economic growth during the 1990s.

"Emulation" of the Bayh-Dole Act.

- Discussions or policy changes affecting "technology transfer" activities of national universities have taken place in Japan; Italy; Germany; Denmark; France; Canada, among other nations.
  - Bayh-Dole widely cited by proponents of such initiatives as a policy model.
- Many policy initiatives focus on patenting of university inventions.
- Some initiatives (Sweden, Japan) include authority or in some cases, public financial support for creation of "technology transfer offices."
- At least some developing economies (Brazil, S. Africa) are considering similar policies.

But several issues have not been addressed

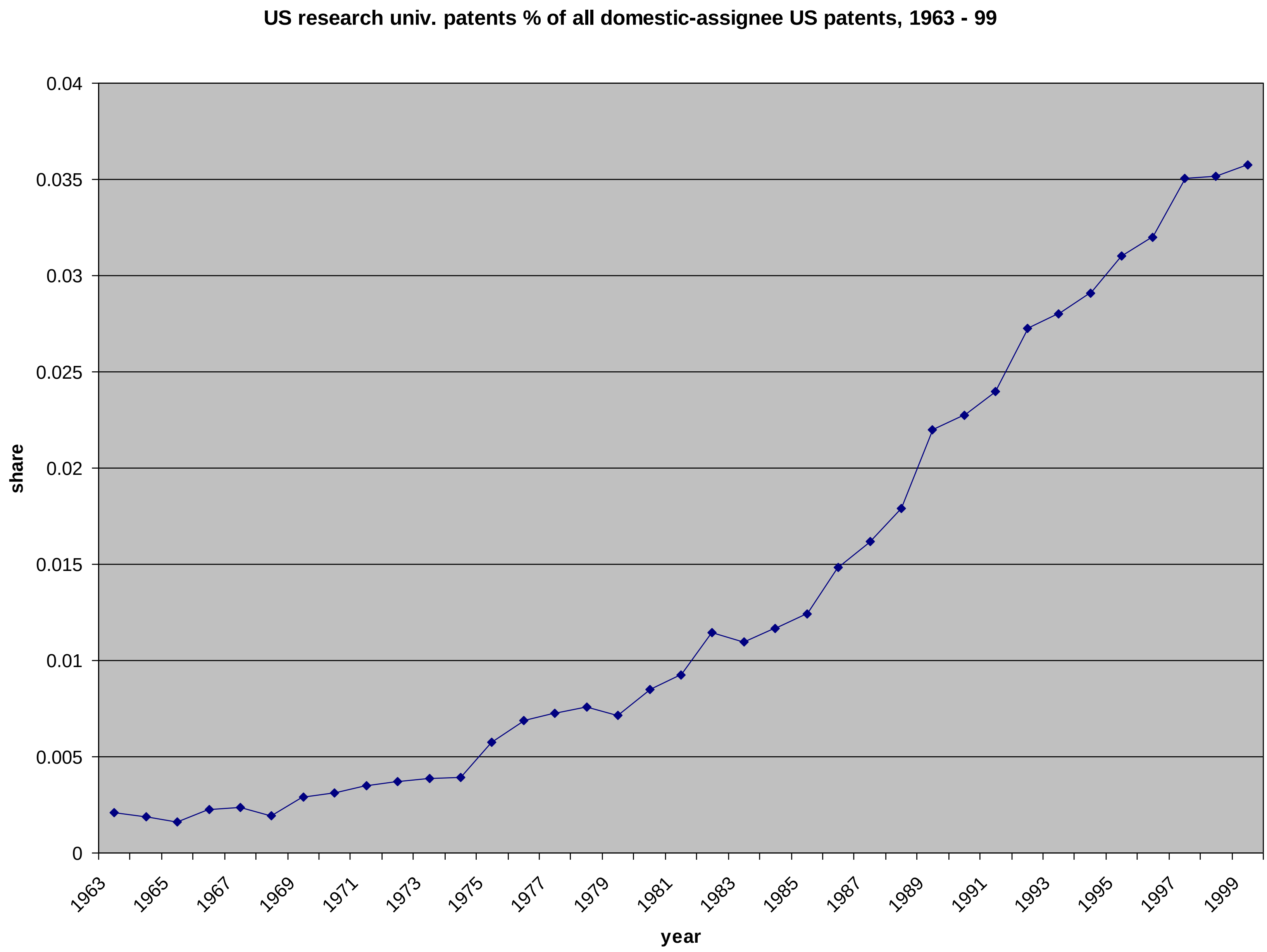
- How important has the Bayh-Dole Act been in supporting university-industry collaboration and technology transfer in the United States?
  - *Would growth in these activities have occurred without the Bayh-Dole Act?*
- Will emulation of the Bayh-Dole Act accelerate collaboration and technology transfer in other nations' university systems?

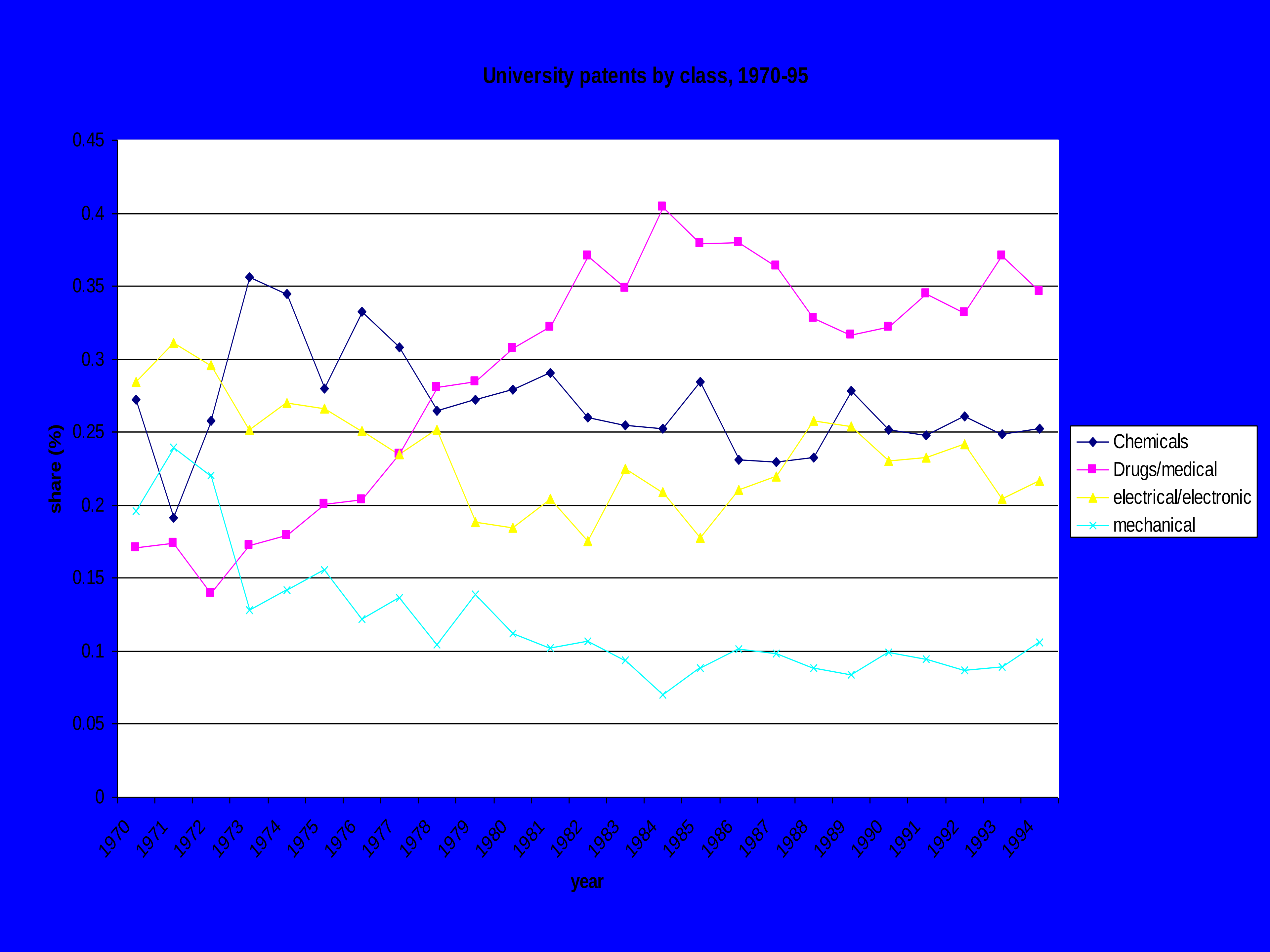
US university patenting before & after 1980

- Many US universities were active patenters long before 1980.
  - Collaborative ties between university, industrial researchers reflected unusual insitutional structure of US higher education.
- Slower growth in federal academic R&D support, financial pressure on US universities, and a few universities' licensing successes contributed to growth in university patenting and licensing during the 1970s:
  - Biomedical technologies dominate university patenting and licensing before & after 1980.
  - In contrast to earlier periods, most US universities began direct management of patenting and licensing.
  - Universities with little or no experience in patenting and licensing during the 1970s entered these activities in the 1980s.
- Many accounts attribute 1980s' growth in university patenting to the Bayh-Dole Act, but the Act may be an effect of increased patenting, rather than a cause.

Other US policy developments during the 1970s and 1980s influenced growth of university patenting, licensing

- ***Diamond v. Chakrabarty***: Life forms are deemed patentable by the US Supreme Court in 1980.
- Creation of the Court of Appeals for the Federal Circuit in 1982. The Court becomes a strong "pro-patentholder" judicial body.
- Other federal actions strengthen intellectual property protection in domestic, international economy during the 1980s.
- "War on Cancer" spurred research in molecular biology.


US research univ. patents % of all domestic-assignee US patents, 1963 - 99
share
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
year


University patents by class, 1970-95
share (%)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
year
Chemicals
Drugs/medical
electrical/electronic
mechanical

“Emulating” Bayh-Dole?

- Much of the growth in patenting & licensing would have occurred without Bayh-Dole:
  - Growth in biomedical research funding and discoveries.
  - Broader strengthening of federal intellectual property rights.
- Growth in patenting and licensing, licensing revenues are heavily concentrated in biomedical technologies.
- For many US universities, financial returns are modest or negative.
  - Staff and legal expenses for patenting and licensing offices are high.
  - University of California systemwide net institutional revenues in 1999-2003 = **US$16M/yr**., small share of overall research budget of nearly **US$3B/yr**.
    - UC one of the highest-grossing university licensing offices in US.
- Partly because of lack of experience, much of the “post-Bayh-Dole” growth in patenting has affected “marginal” inventions.

“Emulating” Bayh-Dole? (2)

- Are patents and licenses necessary to support transfer and commercialization of university inventions? Evidence is mixed.
  - Emphasis on patenting creates frictions in some university-industry collaborations.
  - Industry R&D managers rank “nonpatent channels” as more important outside of biomedical technologies.
- Technology transfer and commercialization rely on other institutions outside of the U.S. university, such as venture capital and equity markets.

Conclusions

- Universities have played an important historic role in innovation and growth within the NSIs of developed, newly-industrialized economies.
  - But the structure of university systems and their historic roles differ considerably.
- The importance of universities' role in economic catchup seems likely to increase.
- An important basis for university contributions to economic & technological growth since the 19th century is their links to the international S&T system.
- Their combined performance of advanced research and training in many NSIs is another important source of university contributions to economic growth.
- Channels for knowledge flow, technology transfer between universities and domestic firms are numerous and involve much more than codified knowledge.
  - Relative importance of different channels differs among technologies.

Conclusions (2)

- Institutions outside the university system play a key role in the effectiveness of university systems in research, training within NSIs.
  - Other tertiary education institutions, as well as “bridging” institutions (extension services; Frauenhofer Institutes, etc.).
  - Public research laboratories.
  - Domestic labor-market flexibility, mobility; industrial finance systems.
- Essential design decisions:
  - Balance between domestic universities, public laboratories in performance of publicly funded R&D.
  - Postgraduate vs. undergraduate training.
  - Differentiation within national “tertiary education” systems.
  - Strengthening links with the international science system, including other developing-economy universities.
- There is no single formula for success; principles for successful policy design include
  - Competition among domestic research performers.
  - Greater labor mobility between university and industry, as well as between universities and the international R&D system.
  - A variety of types of tertiary educational and “bridging” institutions.
  - Improved access (for both entry and completion) for all groups within a nation to tertiary education.