The Changing Atlas of World Science: Towards an Open Science Economy

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Outline

This presentation charts the decline of U.S. science against the rise of other nations, especially China. It provides an analytical description of the rise of global science and discusses the development of the 'science economy' based on new models of openness.

1. The context – the rise of global science
2. The focus – the end of science superpowers and the decline of U.S. science
3. The future – toward an open science economy

Trajectory of Research

- *BSc philosophy of science & mathematics, 1973-76*
- *1989* 'Techno-Science, Rationality and the University: Lyotard on the postmodern condition,' *Educational Theory*, 39, 2 Spring: 93-105.
- *1991, An Evaluation of Science Review Processes in New Zealand and Selected Countries*, Ministry of Research, Science and Technology, Wellington
- 1994 'The New Science Policy Regime in New Zealand: A review and critique,' *New Zealand Sociology*, 9, 2: 317-348.
- 1996 (Ed.) *Education and the Postmodern Condition*. Foreword by Jean-François Lyotard.
- *2006,* (with Tina Besley) *Building Knowledge Cultures: Education and Development in the Age of Knowledge Capitalism*.
- 2006, 'The Rise of Global Science and the Emerging Political Economy of International Research Collaborations,' *European Journal of Education*, 41 (2): 225-244.
- 2007, Research Quality, Bibliometrics and the Republic of Science, *South African Journal of Education,* 27 (2). Forthcoming in T. Besley, *Assessing Research Quality,* 2009.
- 2007, *Knowledge Economy, Development and the Future of Higher Education*.
- 2008 National Science Foundation (NSF) Workshop, 'Developing a Research Design for Short-Term and Long-Term Impacts of International Collaborative Science and Engineering Projects', July 28-29
- 2008, (with Peter Murphy & Simon Marginson) *Creativity and the Global Knowledge Economy*.

The Context

The Rise of Global Science

Changing architecture of world science

- The emerging political economy of global science is a significant factor influencing development of national systems of innovation, and economic, social and cultural development, with the rise of multinational actors and a new mix of corporate, private/public and community involvement.

- It is only since the 1960s with the development of research evaluation and increasing sophistication of bibliometrics that it has been possible to map the emerging economy of global science, at least on a comparative national and continental basis.

- The Science Citation Index provides bibliographic and citational information from 3,700 of the world's scientific and technical journals covering over one hundred disciplines. The expanded index available in an online version covers more than 5,800 journals.

World Scientific Production (1981-2000)

- In 2000 the SCI included a total of 584,982 papers, representing a 57.5% increase from 1981, when 371,346 papers were published worldwide.
- Authors from developed countries wrote 87.9% of the papers in 2000, a decrease from 93.6% in 1981.
- Developing countries saw a steady increase in their share of scientific production: from 7.5% of world papers in 1981 to 17.1% in 2000
- North America lost the lead it had in 1996, and in 2000 produced 36.8% of the world total, a decrease from 41.4% in 1981.
- European Union published 40.2% of the world total in 2000, up from 32.8% in 1981. Japan went up from 6.9% to 10.7% in 2000.
- Collectively this 'triad' has therefore maintained its dominance, accounting for 81% of the world total of scientific publications in 2000, up from 72% in 1981.
- The share of publications from the Arab States increased from 0.6% in 1981 to 0.9% in 2000, and the Central Eastern European share remained stable around 3% of the world total, both the Newly-Industrialized Countries (NIC) in Asia (a group that includes China) and Latin America and the Caribbean (LAC) increased their share significantly, respectively, from 0.6% of the world total in 1981 to 4.2% in 2000 (with China accounting for 85% of the publications an increase from 63% in 1981), and 1.3% to 3.2% in LAC countries.
- UNESCO (2005) 'What do bibliometric indicators tell us about world scientific output?' UIS Bulletin on Science and Technology Statistics Issue No. 2, September.

Geographic Distribution of Science

- The countries occupying the top eight places in the science citation rank order produced about 84.5% of the top 1% most cited publications between 1993 and 2001. The next nine countries produced 13%, and the final group share 2.5%.
- There is a stark disparity between the first and second divisions in the scientific impact of nations.
- 31 of the world's 193 countries produce 97.5% of the world's most cited papers (p. 314).
- South Africa, at 29th place in my rank ordering, is the only African country on the list.
- Islamic countries are only represented by Iran at 30th, despite the high GDP of many of them and the prominence of some individuals, such as Nobel prizewinners Abdus Salam (physics, 1979) and Ahmed Zewail (chemistry,1999) (p. 314).

Source: King, D. A. (2004) 'The scientific impact of nations: What different countries get for their research spending', *Nature*, Vol 430 , 15 July: 311-316, at www.nature.com/nature.

Developing the Current System

- **Small science era**
  – Boyle's "invisible college" 17th c. Europe
- **Professionalization in 18th century**

– Curie, Pasteur, Volta
- **Disciplines evolve in 19th century**

– Science, technology, physics, biology
- **Scientific Nationalism in 20th century**

– "Big science" of D. de Solla Price
- **Rise of Global Science**

Source: Caroline Wagner, (2007) 'The New Invisible College' & Peters (2007)

The U.S. Science System

Mirowski's & Sent's (2002) typology, *Science Bought & Sold*

- **The protoindustrial science regime**
- **The Cold War regime**

  - Vannevar Bush established NDRC, then OSRD in 1941 (with James Conant,Karl T. Compton, Frank B. Jewitt), and finally NSF in 1950 (to cement ties between academic, industry & military)

  - *Science, The Endless Frontier* (1945) with emphases on freedom of inquiry, the war against disease, science & public welfare, renewal of talent, science reconversion and NSF (http://www.nsf.gov/about/history/vbush1945.htm)
- **The Globalized Privatization regime**

  - shifts in science funding, end of 'big science' based on physics as model (cancelation of superconductor '93), move from funding of only elite institutions, shrinking budgets, breakdown of scientific nationalism, collapse of soviet science system, collapse of nation security imperative up until 9/11
- **New Models of Open Science – a new regime?**

How Big was Big Science?

- 80-90 % of all scientists were alive in late 20th century
- US funding for R&D grew from $15 million in 1923 to $132 billion in 2005
- Total world R&D spending was $729 billion in 2000
- All S&T >$1 trillion in 2000

Source: Caroline Wagner, (2007) ‘The New Invisible College’

U.S. Science Budget

- Total R&D $130 billion
- 50% Dept. of Defense (advanced weapons & military support systems)
- 50% ($60 billion) to 5 agencies
  - 47% to NIH (biomedical research)
  - NASA - 16%
  - NSF -10%
  - DOE - 9%
  - DOD - 9%
  - DOA – 3%
- Private sector R&D 2x Federal investment
- Total = 2.7% of GDP

U.S. Science 2008

- ‘Science has never been more crucial to deciding the political issues facing the country. Yet science and scientists have less influence with the federal government than at any time since the Eisenhower administration.’

  - Chris Mooney – author of *The Republican War on Science* (2005)

- **Republican Science Policy Under the Bush regime**

  - The Bush administration did not appoint an influential, cabinet-level science adviser

  - Many science-related agencies (such as FDA) were left leaderless for significant periods of time

  - Politicized the membership of scientific advisory committees

  - Promoted creationism in schools

  - Inhibited some lines of research on ideological grounds e.g., stem cell research

Science Policy: Obama

- ‘This is the first time we know of that a candidate for president has laid out his science policy before the election at this level of detail,’ Shawn Otto, CEO of ScienceDebate2008.
- **Obama names his science team**: Harold Varmus, a Nobel laureate and former head of the National Institutes of Health; Gilbert Ommen, a former president of the American Association for the Advancement of Science; Peter Agre, a Nobel laureate and ardent critic of the Bush administration; NASA researcher Donald Lamb; and Stanford University plant biologist Sharon Long. (McCain did not announce his team)
- ‘My administration will increase funding for basic research in physical and life sciences, mathematics and engineering at a rate that would double basic research budgets over the next decade.’
- ‘I will lift the current administration’s ban on federal funding of research on embryonic stem cell lines created after August 9, 2001 through executive order, and I will ensure that all research on stem cells is conducted ethically and with rigorous oversight.’
- ‘I will restore the basic principle that government decisions should be based on the best-available, scientifically valid evidence and not on the ideological predispositions of agency officials or political appointees.’

Barrack Obama

Source: http://www.sciencedebate2008.com/www/index.php

Science Policy: McCain

- McCain has not named science advisers
- McCain wants creationism taught in schools
- ‘John McCain would criminalize a promising branch of stem cell research, according to a statement issued by the candidate's campaign. Though such legislation would probably not survive Congress, he might extend President Bush's much-criticized limitation of embryonic stem cell research.’
- Further detail and comparison
  http://www.sciencedebate2008.com/www/index.php
  In particular, see their answers to ‘A comparison of 15-year-olds in 30 wealthy nations found that average science scores among U.S. students ranked 17th, while average U.S. math scores ranked 24th. What role do you think the federal government should play in preparing K-12 students for the science and technology driven 21st Century?’

The Focus

The End of Science Superpowers & the Decline of the U.S. Science

End of Science Superpowers?

NATURE | Vol 454 | 24 July 2008

Decline of U.S. Basic Research

- In 2006 the total expenditure for R&D conducted in the U.S. was about $340B in current dollars. Of this total, basic research accounts for about 18% ($62B), applied research about 22% ($75B), and development about 60% ($204B).
- Federal funding is the primary source of basic research support in the U.S. (over 59% in 2006), of which about 56% is carried out by academic institutions.
- Federal obligations for academic research (both basic and applied) and especially in the current support for National Institutes of Health (NIH) (whose budget had previously doubled between the years 1998 to 2003) declined in real terms between 2004 and 2005 and are expected to decline further in 2006 and 2007.

Source: National Science Board, Research and Development: Essential Foundations for U.S. Competitiveness in a Global Economy. A Companion to Science and Engineering Indicators, 2008 http://www.nsf.gov/statistics/nsb0803/start.htm

Indicators of Research Outcomes- Patents

- The share of patent applications in the U.S. patent office filed by inventors residing in the U.S. dropped from 55% in 1996 to 53% in 2005. The percentage drop was largely caused by the increasing filings by Asian inventors.
- Inventions for which patent protection is sought in the world's three largest markets—the U.S., the EU, Japan—are called "triadic patent families."
- The U.S. has been the leading source of triadic filings (about 37% of the world share) since 1989, when it surpassed the EU, and its share has continued to increase.
- Source: National Science Board, Research and Development: Essential Foundations for U.S. Competitiveness in a Global Economy. A Companion to Science and Engineering Indicators, 2008 http://www.nsf.gov/statistics/nsb0803/start.htm

Indicators of Research Outcomes- Publications

- Basic research articles published in peer-reviewed journals by authors from U.S. private industry peaked in 1995 and declined by 30% between 1995 and 2005.
- The drop in physics publications was particularly dramatic: decreasing from nearly 1,000 publications in 1988 to 300 in 2005.
- The U.S. has now dropped from first to second rank in physics over the 12-year period from 1992 to 2003. The U.S. retained the first rank in all other major fields in 2003, but overall lost share of highly influential articles, dropping from 63% to 58%.
- In the field of engineering/technology, although the U.S. lost share while the EU-15 gained, the decline in U.S. share more importantly reflects the rapid rise in share by the East Asia-4 (comprising China, South Korea, Singapore, and Taiwan).
- U.S. annual growth in all S&E article publications in peer reviewed journals also slowed from 3.8% over the period from 1988 to 1992 to 0.6% from 1992 to 2003. Although the rate of growth also declined for the EU-15 and other S&E publishing centers, all exceeded the U.S. growth rate during both periods.

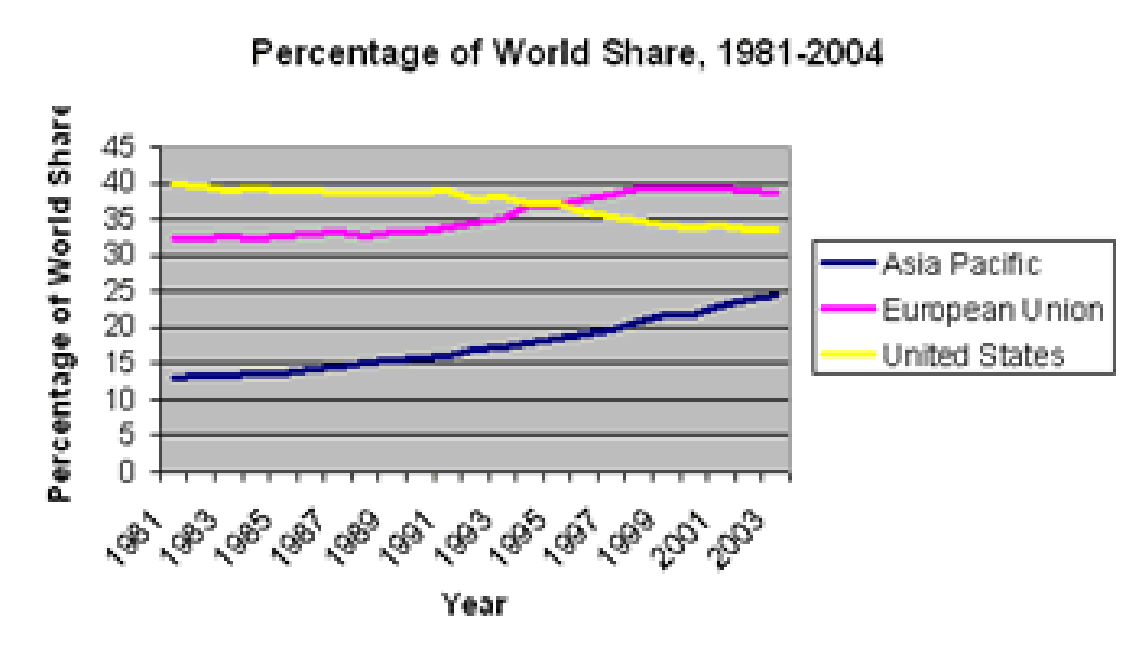
- Source: National Science Board, Research and Development: Essential Foundations for U.S. Competitiveness in a Global Economy. A Companion to Science and Engineering Indicators, 2008 http://www.nsf.gov/statistics/nsb0803/start.htm

Last of the giants?

- The decline of the U.S. economy relative to those of the rest of the world is facilitating the strengthening of science elsewhere
- An evolving multi-polar world economy is leading to multiple centres of science — the United States, the European Union, Japan, China, Russia and possibly India
- The increasing wealth of several of these societies is enabling them to lure back many younger scientists trained abroad in the world's leading institutions

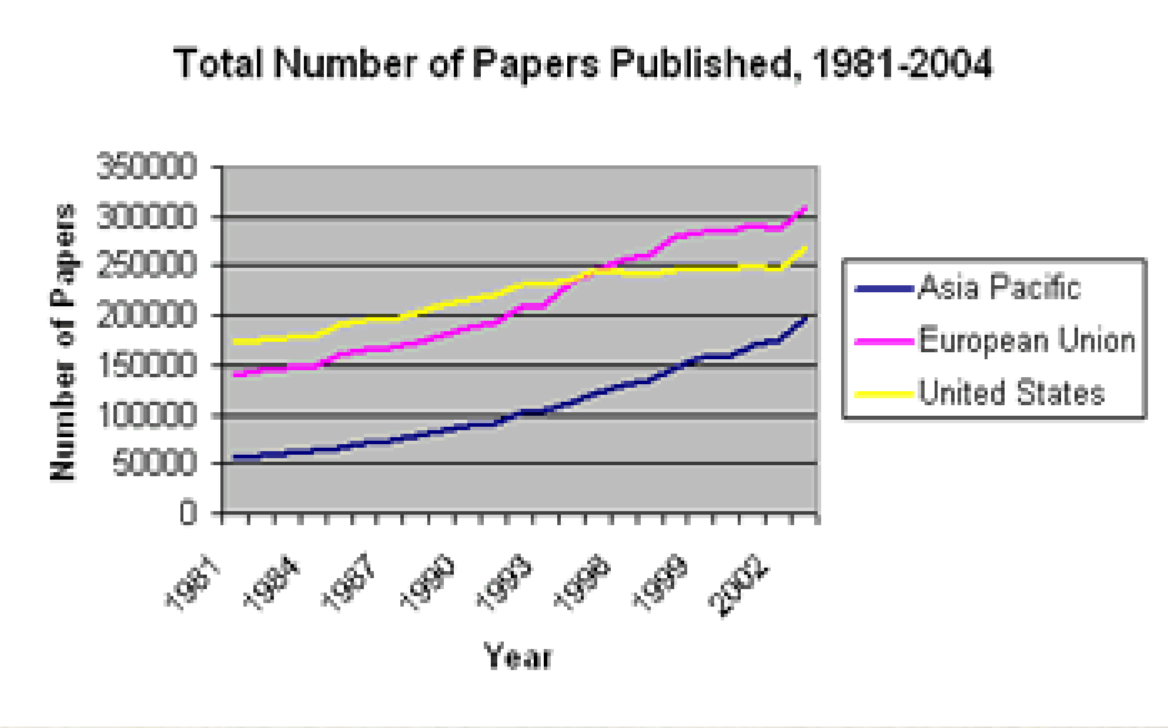
World Share of Science Output

Source: ***Science Watch, Thomson, 2005***



Total Papers Published

Source: ***Science Watch, Thomson, 2005***



Emergence of China

Production of science and engineering papers

- **14th in 1995; 5th in 2005; 2nd in 2007**

Thomson Reuters ISI

- China is moving towards an integrated system of national innovation;
- Replacing state control with more enabling frameworks;
- Focused on improving the university and research systems;
- Stepping up the internationalization of research with collaborative networks across Europe, Japan and U.S.

Asian Innovation

By the end of 2020 . . . China will achieve more science and technological breakthroughs of great world influence, qualifying it to join the ranks of the world's most innovative countries.

President Hu Jintao, 9 Jan 2006

In 20 years global science will be driven by Indian scientists. There are new interfaces in science, with new rules, where new countries can contribute on an equal footing.

Dr Vijay Raghavan, director, National Centre for Biological Sciences Bangalore,

January 2006

Globalized science system

- Rise of global science & increasing globalization of research, science, engineering and technology
- The growth of China, India and South Korea – the changing atlas of the world scientific knowledge system
- International research collaboration as a source of comparative advantage
- Importance of tracking and analyzing global knowledge flows and transfers to determine national and regional collaborations
- Use of ICT in facilitating cross border knowledge flows and also in analyzing citations, co-authorship, collaborations
- Development of new metrics systems including webometrics for the measurement of research impacts, growth & distributions
- Greater uniformity in methodology and approaches to university education and vocational training ('learning for life')
- Increasing significance of new social networking and social media for Web 2.0 science & open-access publishing

The Emergent Science System

Seven Forces are Structuring the 21st century (open) science system:

- *Openness*
- *Networks*
- *Collaboration*
- *Emergence*
- *Circulation*
- *Stickiness (place)*
- *Distribution (virtual)*

Source: Caroline Wagner, (2007) 'The New Invisible College' & Peters (2006; 2007)

The Future

Towards an Open Science Economy

Advantages of smallness

- Shift to international collaborative research.
- Virtual organization of global science teams.
- Teams produce more papers and receive more citations .
  (S. Wuchty, B. F. Jones and B. Uzzi, *Science* 316, 1036–1039; 2007)
- Big science has built in irreversible constraints – bureaucratic, fragmented, communication difficulties, organization rigidities.
- Reliance on citation analysis for judging quality with mushrooming growth in publications.
- Increasing commercialization of scientific research in large-scale environments and with less flexibility.
- Excellence in science requires nimble, autonomous organizations — qualities more likely to be found in small research settings.
- Enhanced performance through creation of several dozen small research organizations in interdisciplinary domains or in emerging fields.

Small, flexible, specialized

- Dozens of scientists who made significant advances did so in organizations with fewer than 50 full-time researchers.
- In the past decade Nobel prizes have been awarded to scientists for work done in relatively small settings: Günter Blobel (physiology or medicine), Ahmed Zewail (chemistry), Paul Greengard (physiology or medicine), Andrew Fire (physiology or medicine), Roderick MacKinnon (chemistry) and Gerhard Ertl (chemistry).

  J. Rogers Hollingsworth, Karl H. Müller and Ellen Jane Hollingsworth, NATURE|Vol 454|24 July 2008
- Development of small, flexible, specialized teams in regional centers (‘clustering’)
- Fostering of international collaborations and public-private partnerships

Transnational Science

- Emerging new research cultures that are no longer solely state and university-oriented
- Growth of corporate multinational research especially in new materials, biotechnology (genetics), pharmaceutics, information technology - growth of private science
- Shift in funding regimes from public to private, state to global, and big science to applied science, science to technology
- New role for humanities, performing arts and social sciences as ‘soft’ sciences and technologies concerned with new international values, legalities, global civic cultures, knowledge measurement, management and PR
- Importance of internationalization in education and research training; new forms of technology-led education on the basis of new architectures of participation and collaboration
- Emergence of global science and research organization and cultures – extra-national organizations, NGOs, UN, UNESCO, ESF and other international science-based organizations

Science Publishing in a Digital Age

- **changes in creation, production and consumption of scholarly resources** --'creation of new formats made possible by digital technologies, ultimately allowing scholars to work in deeply integrated electronic research and publishing environments that will enable real-time dissemination, collaboration, dynamically-updated content, and usage of new media' (p. 4).
- '**alternative distribution models** (institutional repositories, pre-print servers, open access journals) have also arisen with the aim to broaden access, reduce costs, and enable open sharing of content' (p. 4)

Source: *The Ithaka Report* (2007)

New Models of Open Science

- New models of open science versus expanded protection of IP
- Open source initiatives have facilitated the development of new models of production and innovation
- The public and nonprofit sectors have called for alternative approaches dedicated to public knowledge redistribution and dissemination
- Distributed peer-to-peer knowledge systems rival, the scope and quality of similar products produced by proprietary efforts
- Speed of diffusion of open source projects is an advantage
- Successful projects in software and open source biology
- Open access science has focused on making peer-reviewed, online research and scholarship freely accessible to a broader population (incl. digitized back issues)
- Open science demonstrates an “exemplar of a compound of ‘private-collective’ model of innovation” that contains elements of both proprietary and public models of knowledge production (Von Hippel & von Krogh, 2003)
- Does the expansion of a patenting culture undermine the norms of open science?
- Does the intensification of patenting accelerate or retard the development of basic and commercial research? (Rhoten & Powell, 2007).

Emergence of Science 2.0

Scientific American, 2008 & other sources

- Science 2.0 generally refers to new practices of scientists who post raw experimental results, nascent theories, claims of discovery and draft papers on the Web for others to see and comment on
- Proponents say these “open access” practices make scientific progress more collaborative and therefore more productive
- Critics say scientists who put preliminary findings online risk having others copy or exploit the work to gain credit or even patents
- Despite pros and cons, Science 2.0 sites are beginning to proliferate; one notable example is the OpenWetWare project started by biological engineers at the Massachusetts Institute of Technology
- Rich text, highly interactive, user generated and socially active Internet (Web 2.0) has seen linear models of knowledge production giving way to more diffuse open ended and serendipitous knowledge processes

Future Policy Developments

- Open science economy plays a *complementary* role with corporate & transnational science and implies strong role for governments
- Increasingly, portal-based knowledge environments and global science gateways support collaborative science (Schuchardt el at, 2007) – see Science.gov & Science.world (BL & DOE)
- Cyber-mashups of very large data sets let users explore, analyze, and comprehend the science behind the information being streamed (Leigh & Brown, 2008)
- The World Wide Web has revolutionized how researchers from various disciplines collaborate over long distances especially in the Life Sciences, where interdisciplinary approaches are becoming increasingly powerful as a driver of both integration and discovery (with regard to data access, data quality, identity, and provenance) (Sagotsky et al, 2008)
- National science review and assessment to focus on formative role in developing distributed knowledge systems based on quality journal suites in disciplinary clusters with an ever finer mesh of in-built indicators

End

Reference and full bibliography available on request

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