# National Systems of Innovation and the Alternative Energy Innovation Challenge

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# Technological progress: some basic definitions

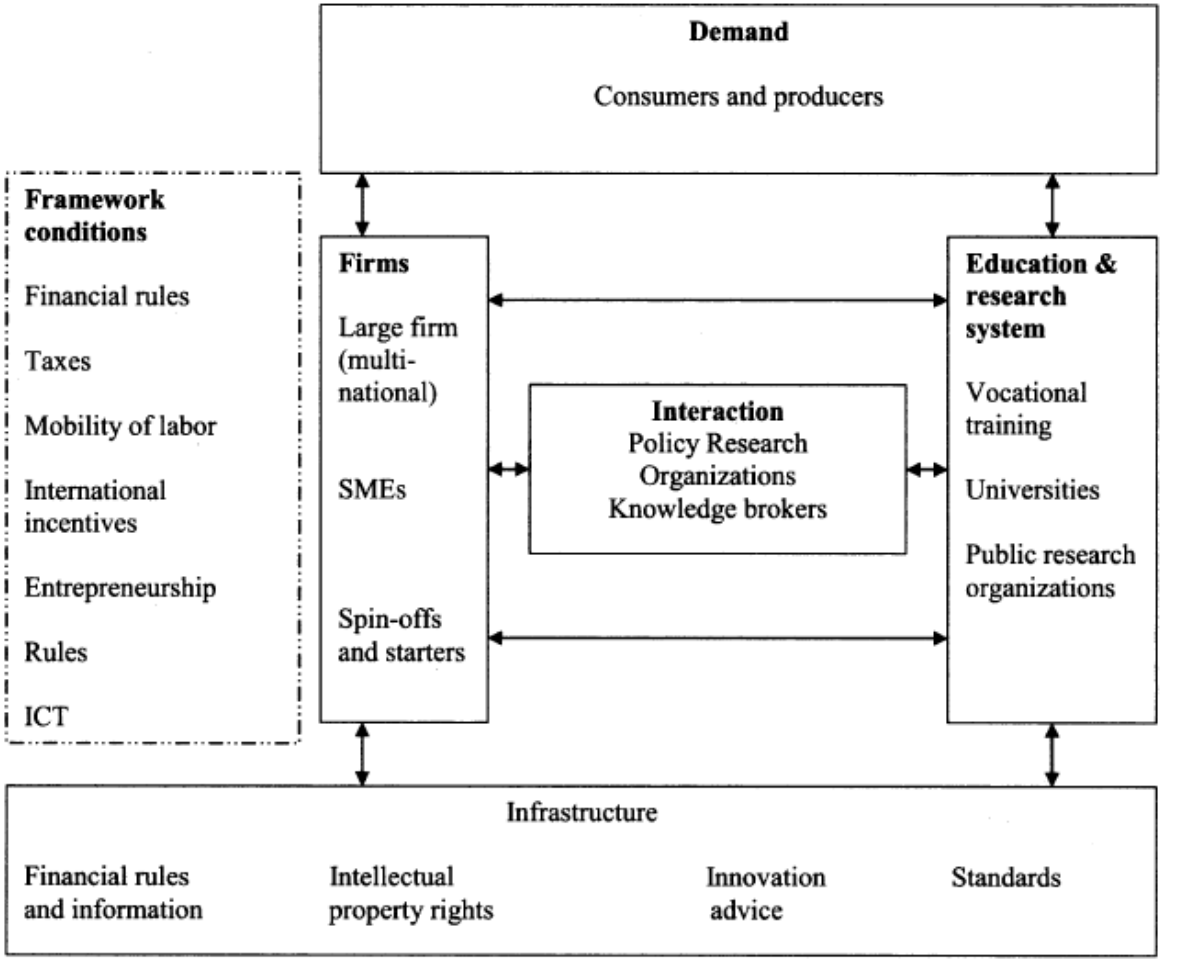
- Innovation is often defined as the creation of new-to-the-world technology.
  - This can involve the creation of fundamentally new products/processes.
  - Or the minor improvement/refinement of existing products/processes.
  - The world needs fundamental innovation to meet emissions reduction goals.

- Absorption: obtaining a sufficient understanding of a technology developed elsewhere to apply it (without significant change) in a local context.
  - This can be simply a matter of adopting a new machine or "app" that requires little expertise on the part of the user.
  - But successful absorption sometimes requires a serious investment on the part of the firm or country seeking to use the new technology effectively.

- Technological progress, at all levels of economic development, requires a combination of effective innovation and effective absorption.

# What is a "National System of Innovation?"

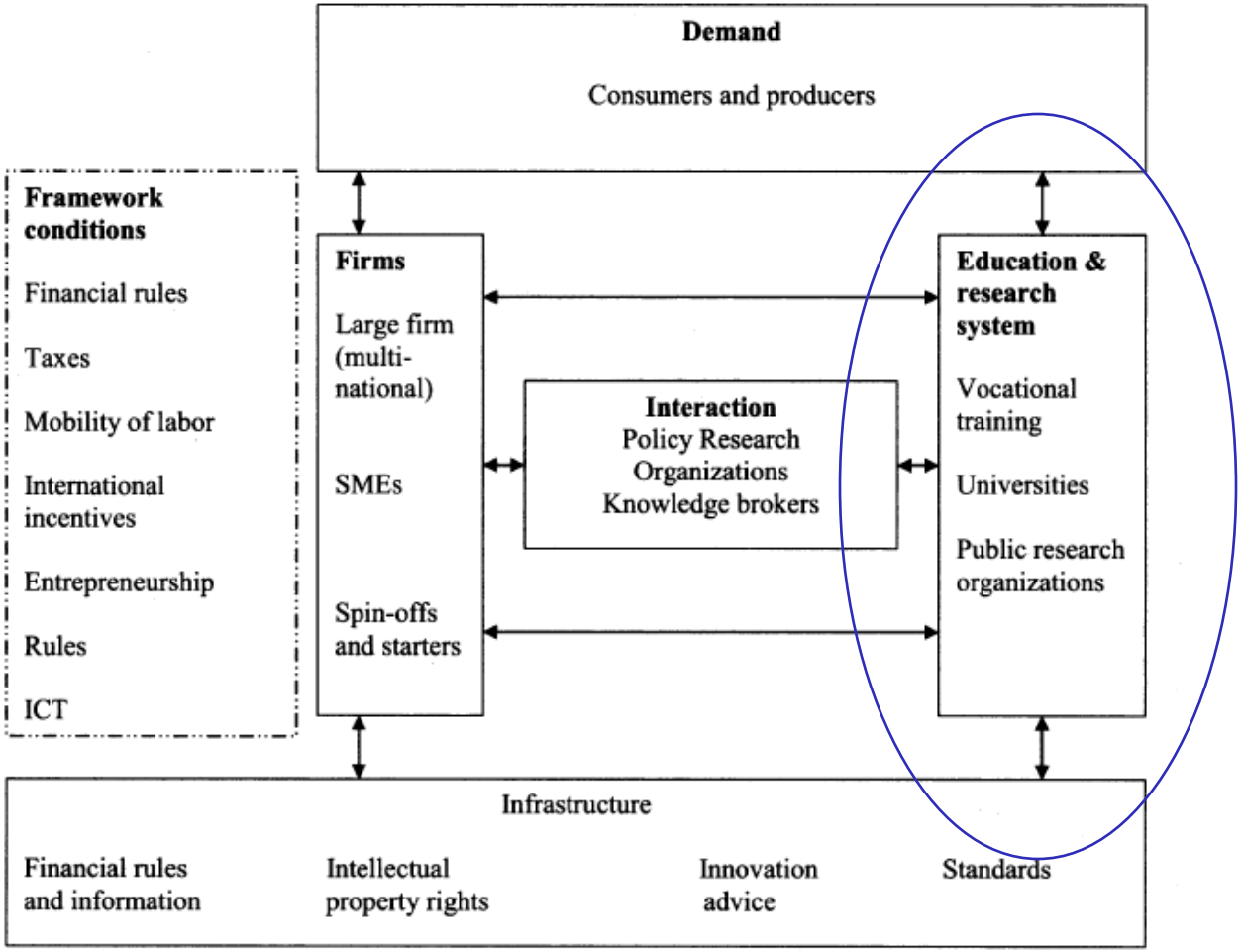
Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# Education and training systems and public research institutes provide an essential foundation...

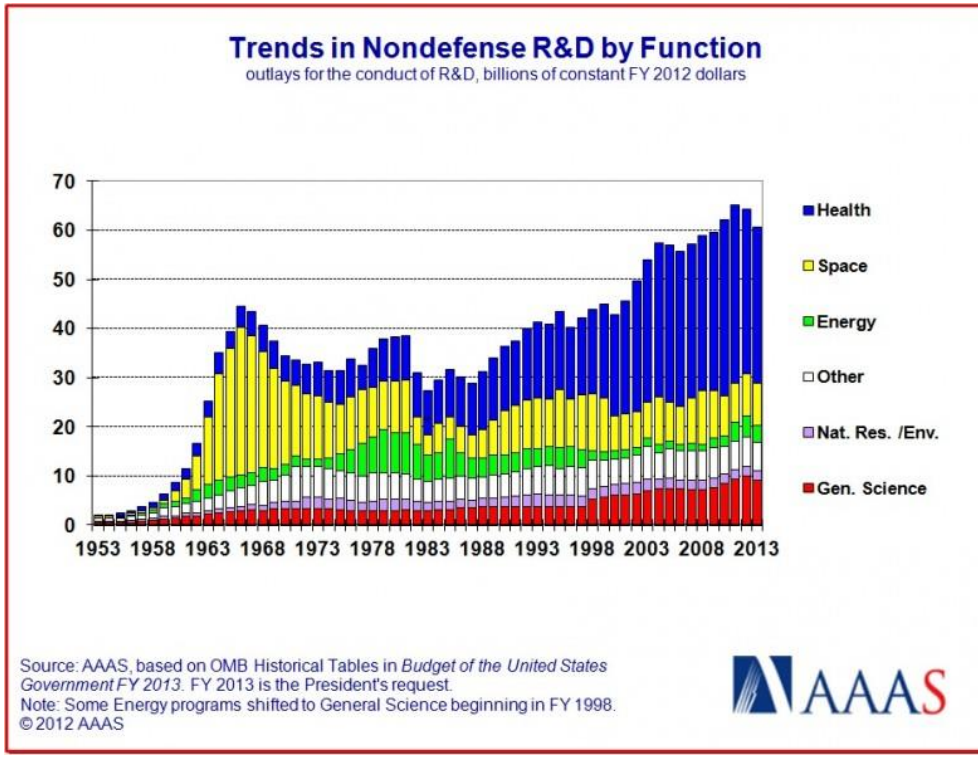
Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

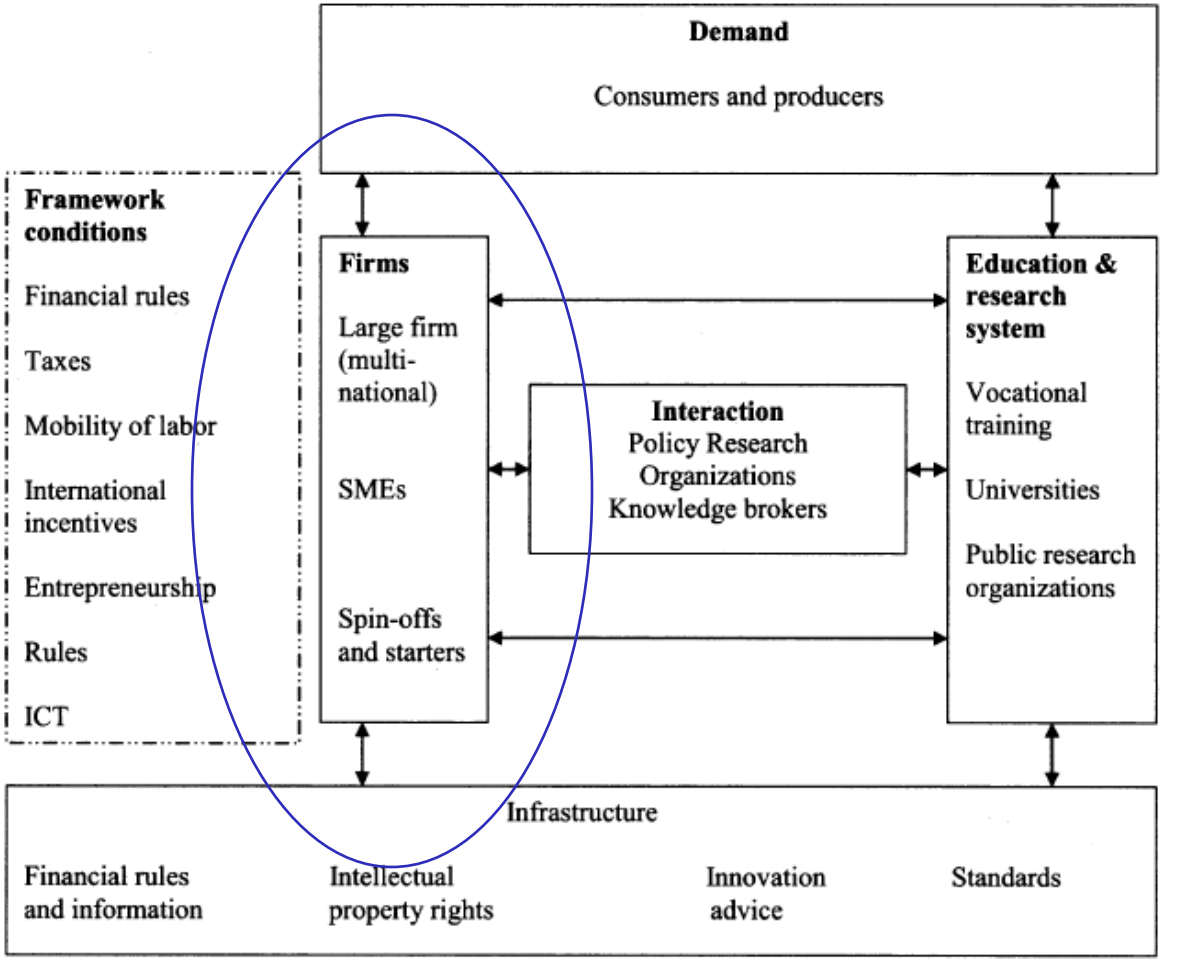
# This foundation is weak in the domain of alternative energy, and it cannot be changed overnight…

- In the U.S. and around the world, investments in alternative energy in the 1970s and early 1980s were sharply curtailed as fossil energy prices dropped…
- Leading many universities (including mine) to disband research and graduate programs in the mid-1980s
- The increase in R&D investment in the 2000s has not gone nearly far enough
- And it will take time to train a new generation of scientific experts in these fields



# Firms, of different types and sizes, build on this foundation, creating new products and services

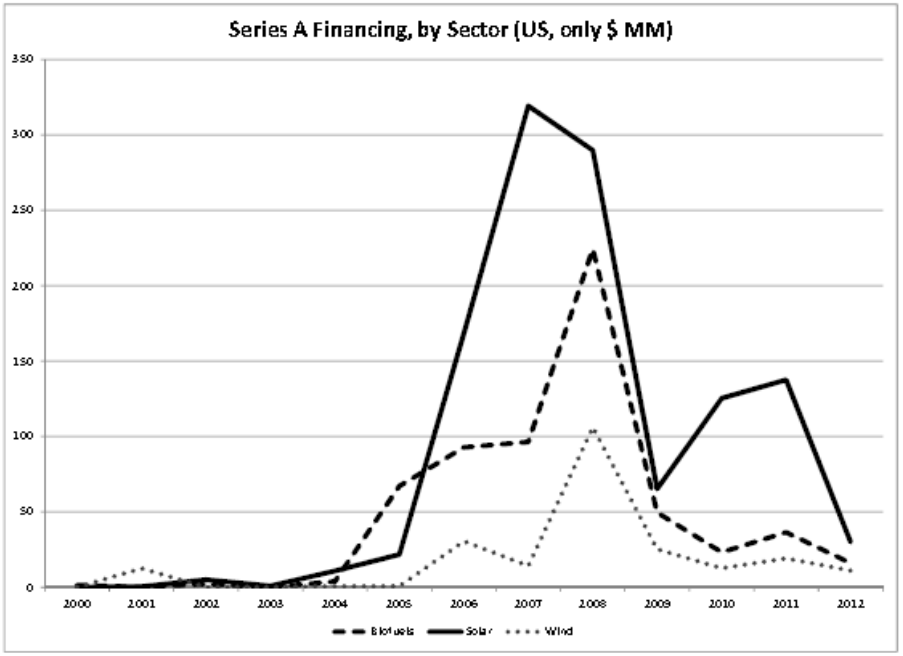
Figure 1. The Benchmark NIS Model

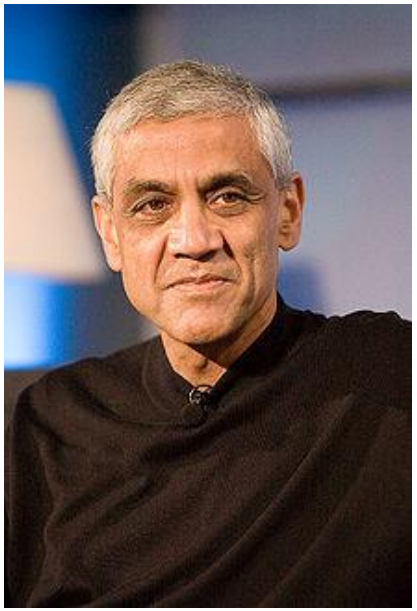



Source: Bremer et al. 2001.

# Silicon Valley has struggled to deliver alternative energy breakthroughs…

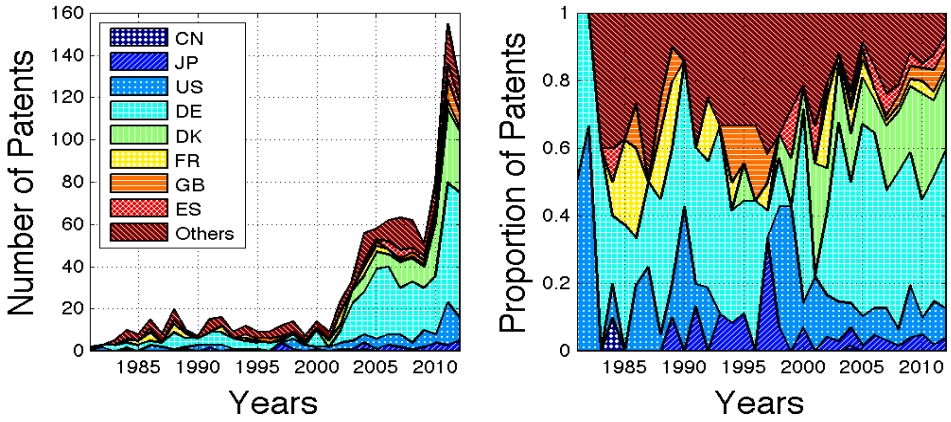
Figure 5A: Series A Financing for US-based startups in Solar, Wind and Biofuels

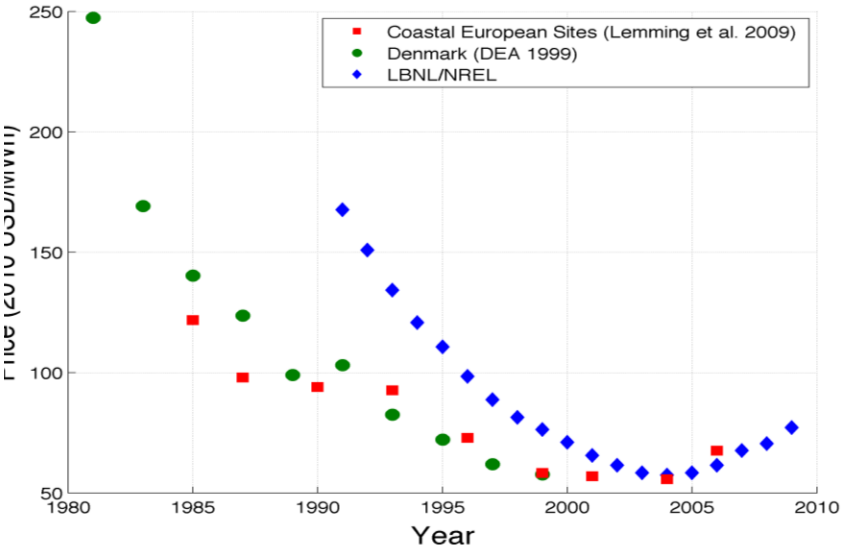


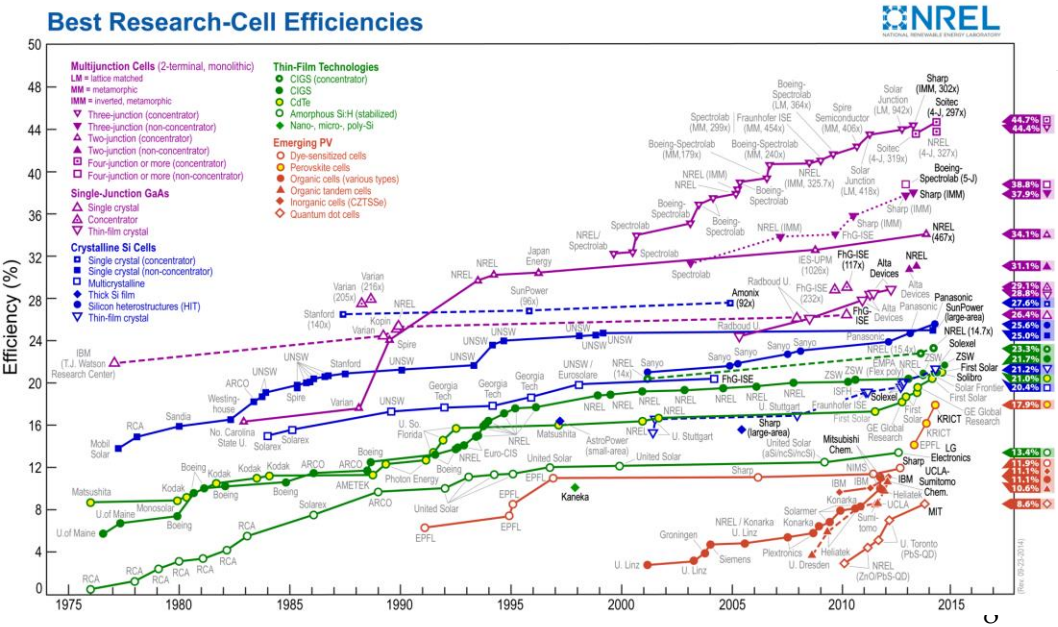
Leading Venture Capitalist Vinod Khosla

# Long established Western firms have also struggled to deliver needed breakthroughs…



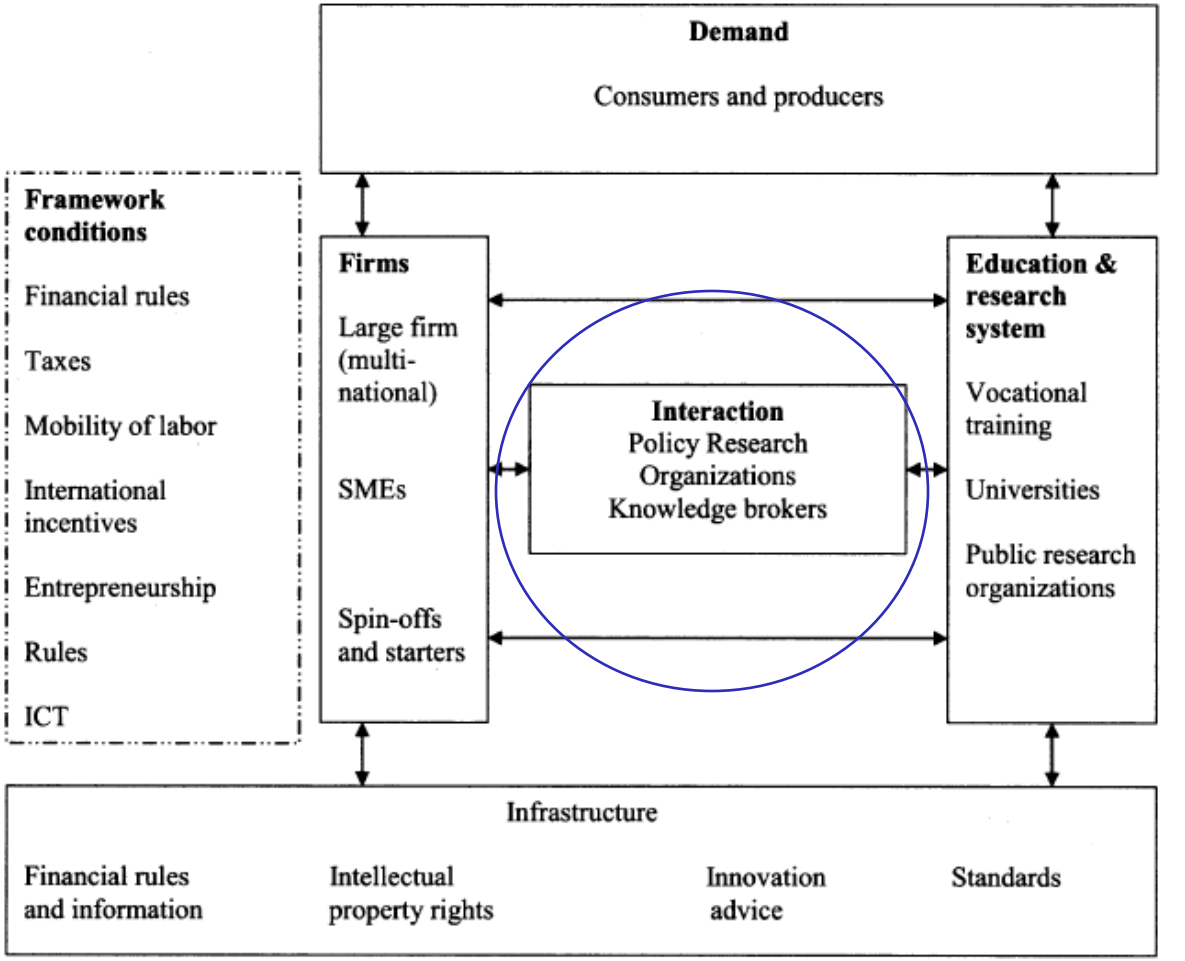




*Lantz et al. (2012)*



# Effective innovation requires individuals and institutions that bring the two main poles of the NSI together…

Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# A key role is played by individuals who move between the worlds of academia and industry

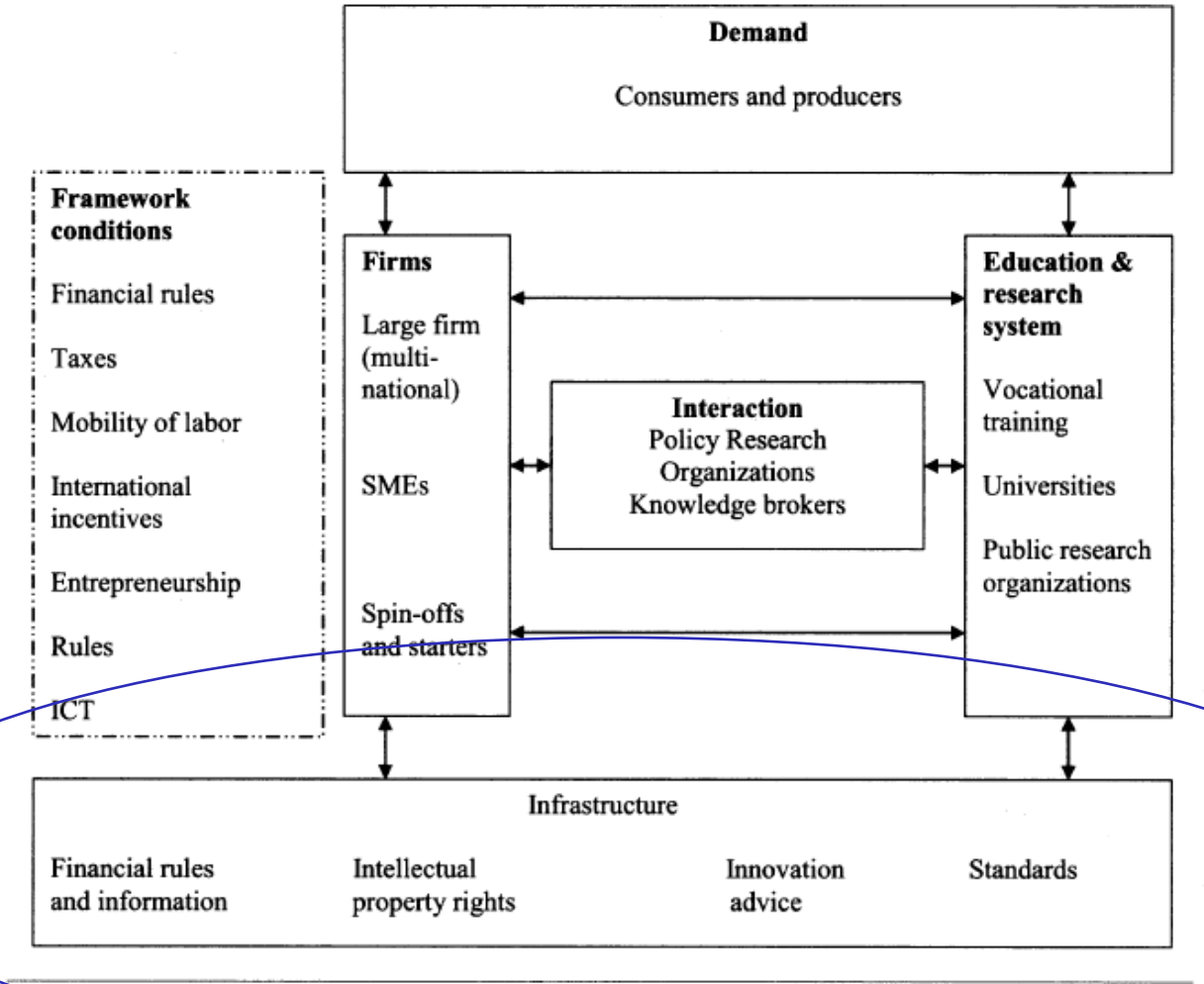
- Jay Whitacre is a celebrated engineering professor at Carnegie Mellon University.
- He is also the founder of Acquion Energy, a start-up seeking to create important innovations in energy storage technology.
- Knowledge is embodied in people, and technology transfer requires people who can move across national and organizational boundaries.
- Even in innovation systems that rely less on start-up firms, researchers like Jay play a critical role in bringing new science into commercial practice.
- Globally, there are too few Jay Whitacres!

Jay Whitacre, Associate Professor
Materials Science and Engineering
Carnegie Mellon University

AQUION ENERGY

# Successful innovation requires a broader set of institutional and legal arrangements

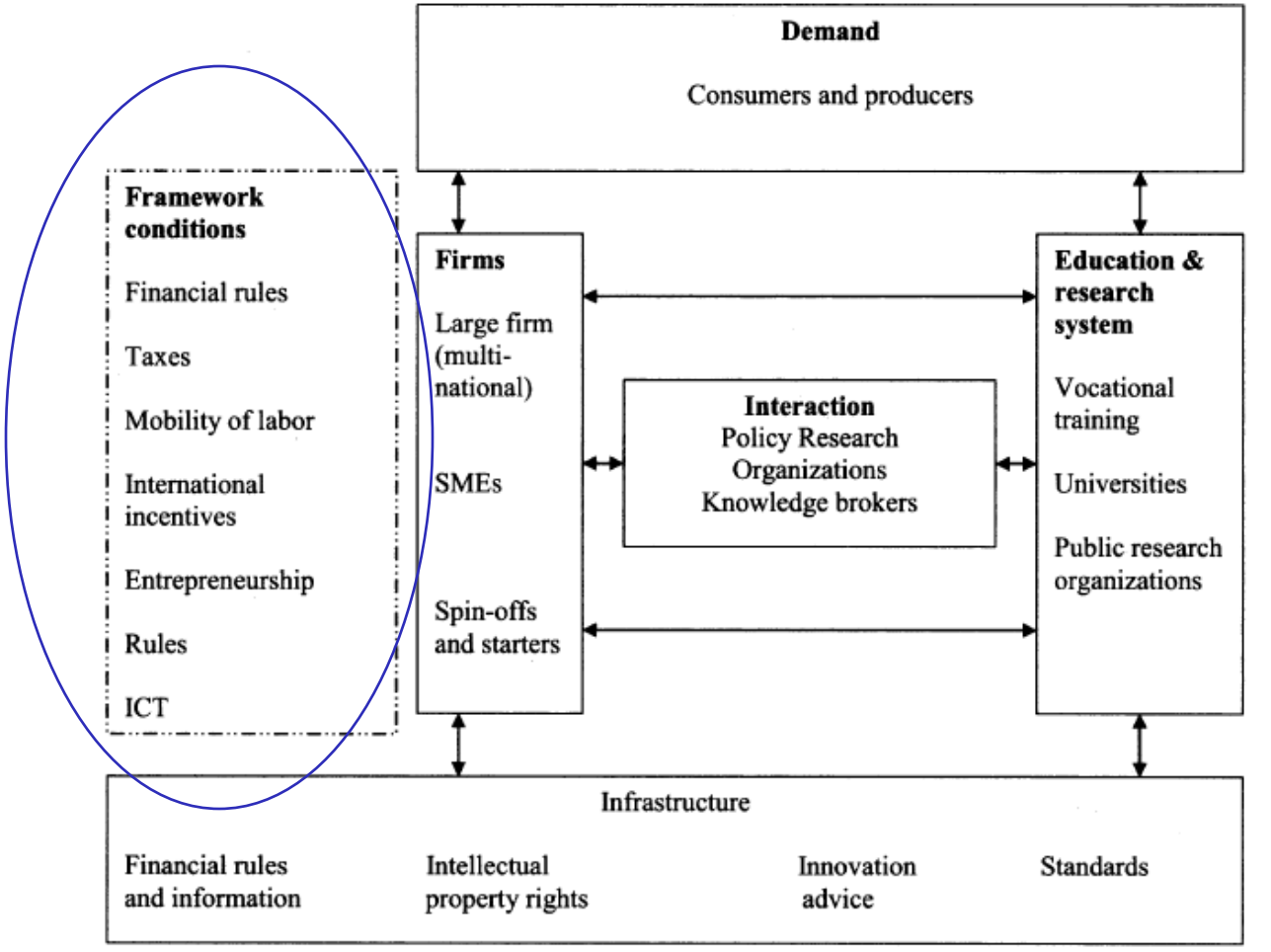
Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# …And an even broader set of institutional arrangements that support business in general

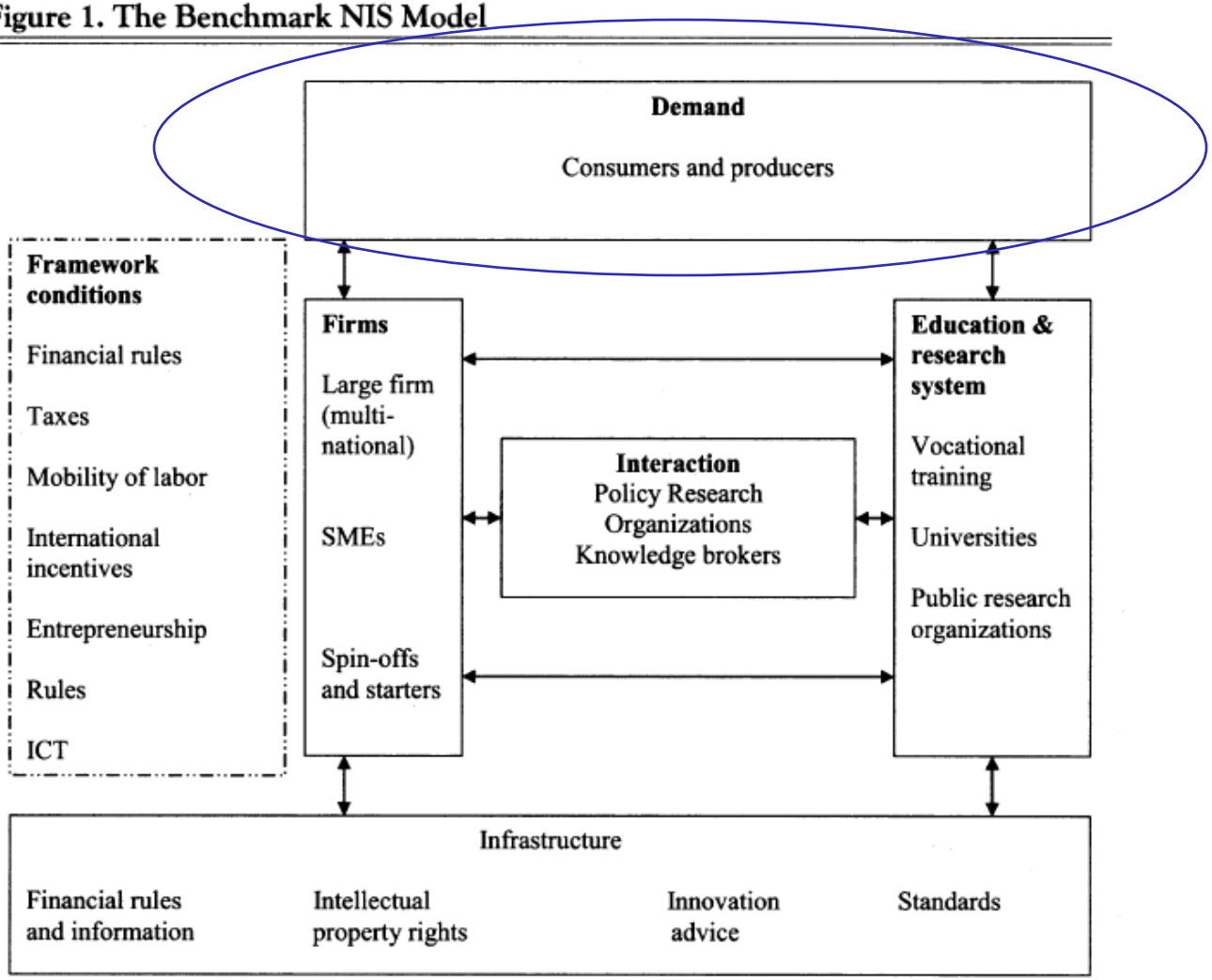
Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# In market economies, innovating firms respond to market demand…

Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# Energy innovation responds to market demand…

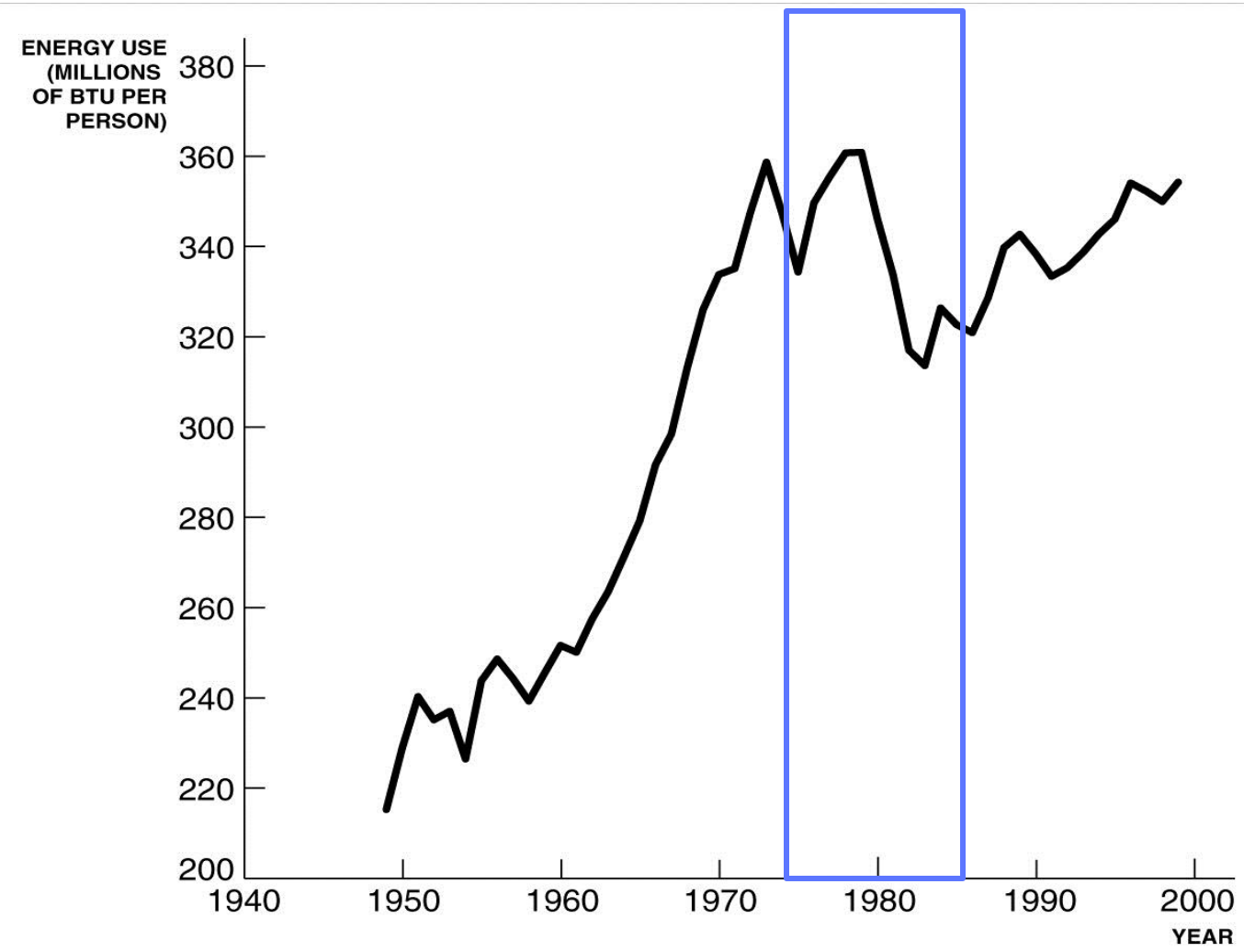
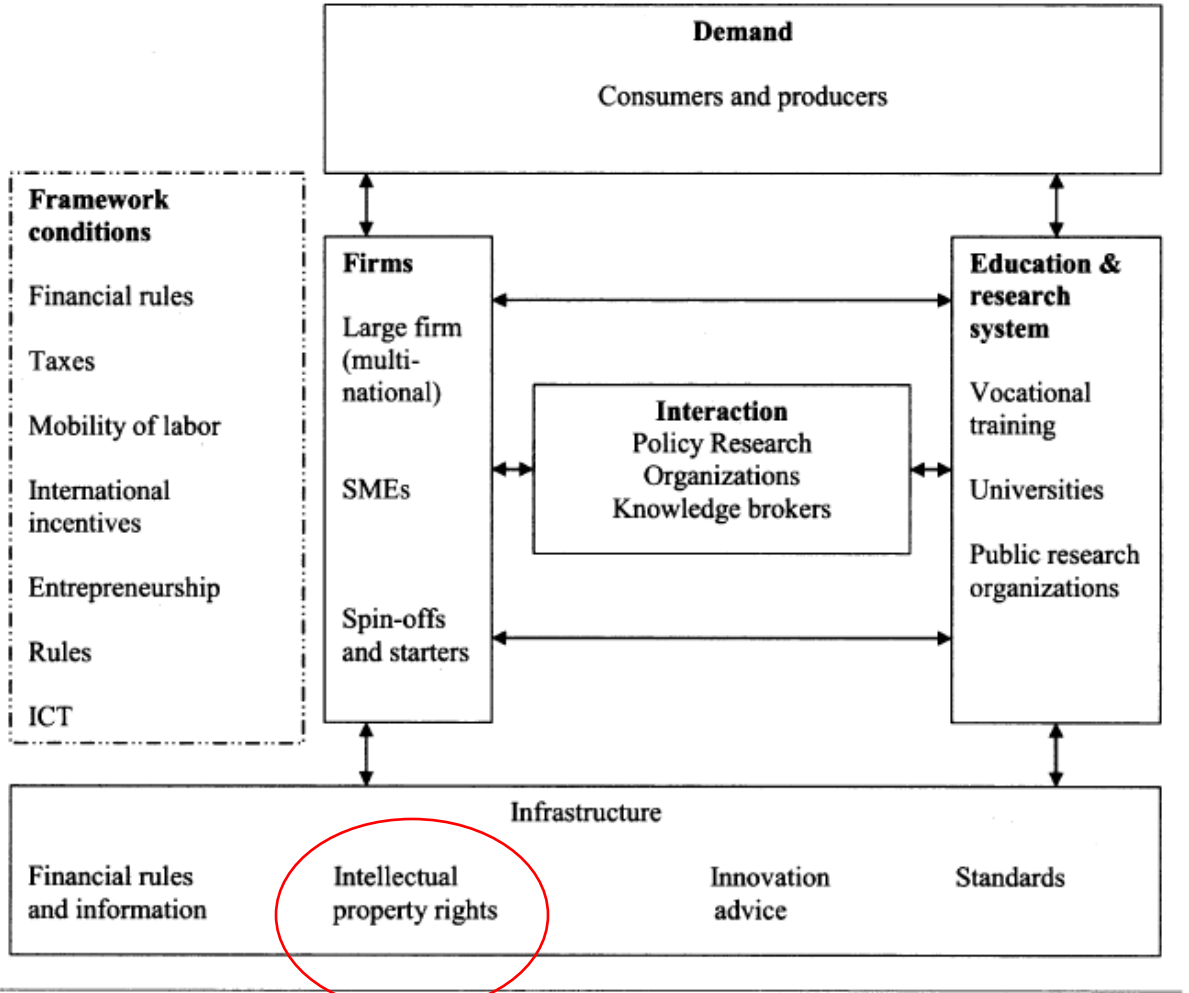



FIGURE 9.4 PER CAPITA ENERGY USE IN THE U.S. ECONOMY, 1949–99

*Economic Growth*, 2nd Edition

# IPR is only one small piece of the institutional framework that enables innovation…

Figure 1. The Benchmark NIS Model




Source: Bremer et al. 2001.

# A Western fixation with strong IPR is the least of our worries right now…

- The story one sometimes hears at international conferences:
  - Great alternative energy technology has been developed in the West.
  - If only Western nations would not insist on patenting and licensing this technology…
  - Then developing countries could easily deploy this technology to escape environmental disaster.
- The inconvenient truth regarding the state of green technology:
  - Western alternative energy innovations fall far short of what is needed.
  - And even if we gave away what we have invented for free…
  - The new technologies would still cost more to operate than standard technologies.
  - So developing nations would not use them anyway.
- Complaints about IP as a barrier to the diffusion of alternative energy technology are largely misplaced – these are ***not*** the main barriers.

# The inventor of "fracking" did not bother to take out patents to protect his inventions…

- George Mitchell developed new techniques for fossil energy extraction known as "fracking."
- These techniques significantly increased American natural gas production.
- Combined with modest policy interventions, this could significantly reduce U.S. energy-related carbon emissions.

George F. Mitchell

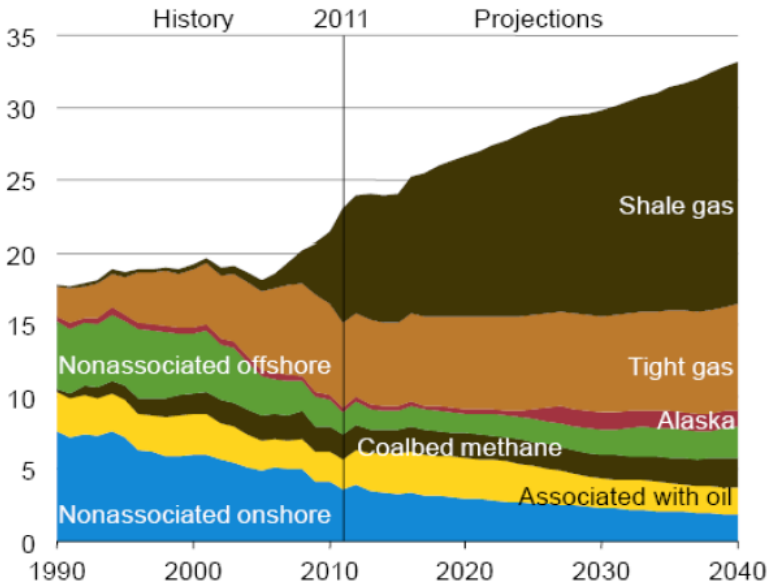
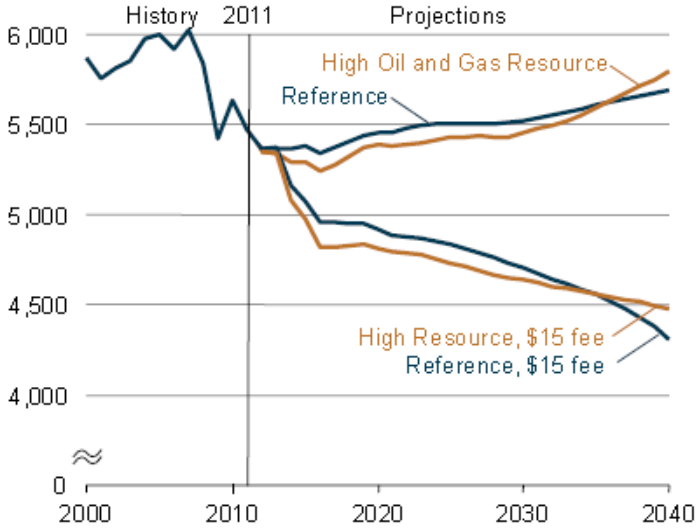



Figure 5. Energy-related carbon dioxide emissions in four cases, 2000-2040 (million metric tons)



# But there is very little use of this technology outside the United States…

- Many nations, including China, have extensive deposits of natural gas that could be extracted by "fracking"– some nations have deposits much larger than the United States.

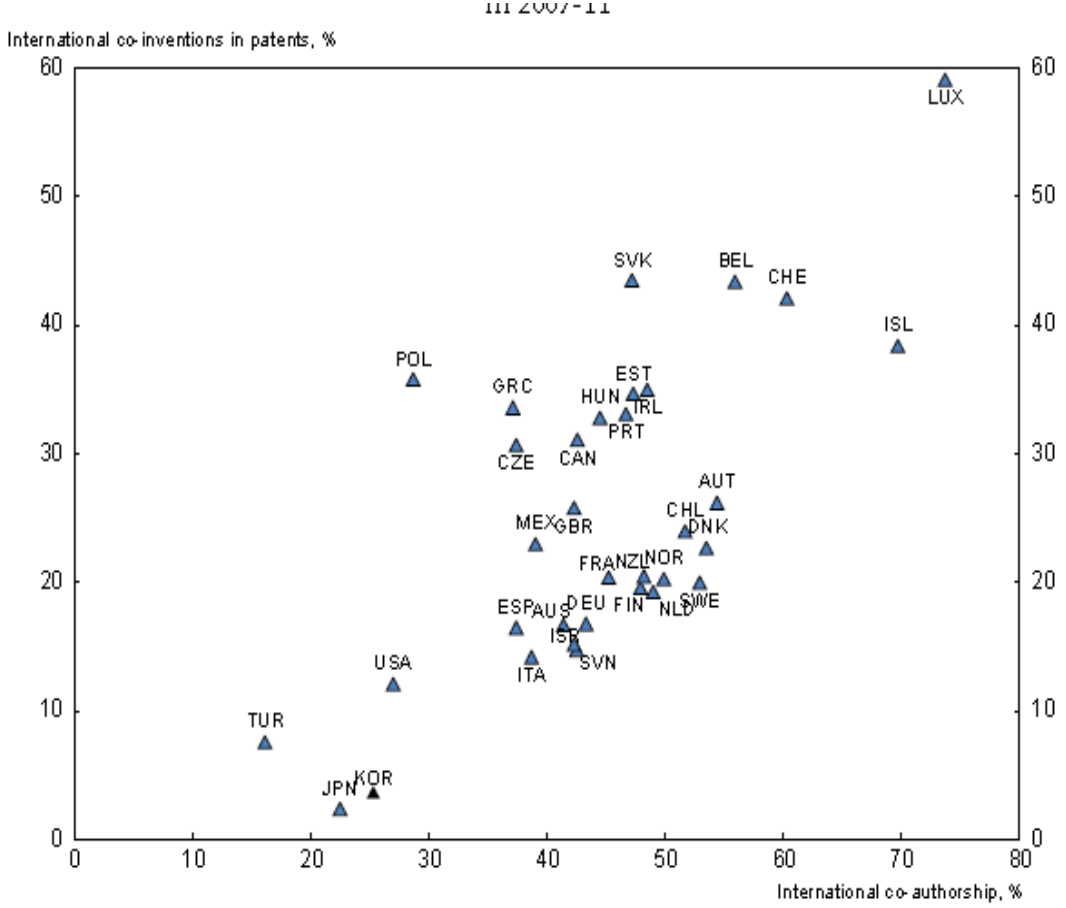
- But even in 2014, there is relatively little commercial activity taking place outside the United States.

- The key technologies were not patented, but their application requires skilled labor currently found only in Western energy companies.

- Western companies do not find the regulatory and business environment nearly as welcoming outside the United States, and few large-scale investments have yet been made.

# We are moving toward increasingly *international* systems of innovation!

- The innovation systems driving technological advance are no longer just "national" in scope.
- Great universities draw students and faculty from around the world.
- Leading MNCs increasingly do R&D outside their home country.
- Rising international co-invention of patents and international co-authorship of scientific papers.



# International research collaboration can help shore up our basic research foundation…

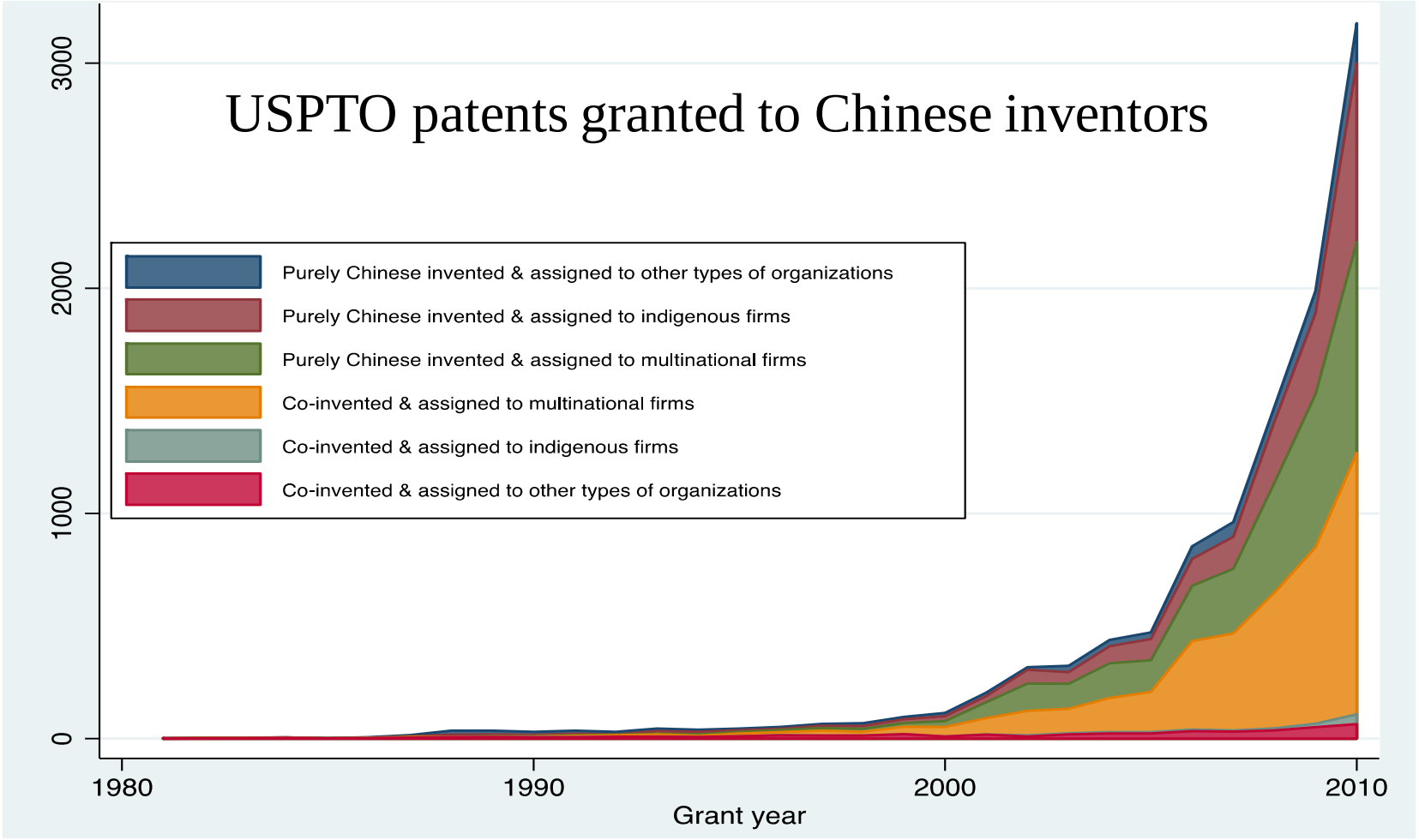
Exhibit 6 : Shares of International Co-authorship US and Major Collaborators with US

| | Share of S&E articles internationally co-authored | | US share of Country's Intl Collaborations | | Country's Share of US Int'l Collaborations | |
|---|---|---|---|---|---|---|
| | 1997 | 2012 | 1997 | 2012 | 1997 | 2012 |
| World | 15.7% | 24.9% | 43.8 | 43 | --- | -- |
| US | 19.3 | 34.7 | -- | -- | --- | -- |
| China | 25.7 | 26.7 | 35.1 | 47.5 | 3.2 | 16.2 |
| UK | 31.0 | 55.1 | 30.0 | 35.2 | 12.4 | 14.3 |
| Germany | 35.5 | 55.5 | 29.9 | 31.0 | 13.3 | 13.3 |
| Canada | 33.5 | 50.2 | 53.0 | 48.9 | 12.1 | 11.4 |
| France | 37.3 | 58.2 | 28.4 | 28.5 | 8.9 | 8.8 |
| Italy | 36.1 | 51.1 | 32.2 | 34.0 | 6.8 | 7.4 |
| Japan | 16.4 | 30.0 | 44.4 | 37.1 | 9.9 | 6.8 |
| Australia | 29.4 | 52.4 | 36.1 | 32.9 | 4.3 | 6.0 |
| South Korea | 27.6 | 30.8 | 51.5 | 53.9 | 2.8 | 6.0 |

Source: Tabulated from Indicators 2014, Appendix table 5-41 and 5-56

http://www.cmu.edu/global/presence/

# Multinational R&D allows poor nations to collaborate in frontier research and development



# Further expansion of MNC R&D could bring significant benefits in alternative energy innovation

- By connecting the impressive talent of emerging economies to the well developed global R&D programs of major MNCs, international co-invention could raise R&D productivity…
- And allow researchers in less developed countries to participate in the advancement of the global technology frontier…
- And help ensure that multinationals create technology appropriate for emerging markets.
- To realize this potential, emerging markets need to have investment regimes that attract and retain multinationals.

# Think globally, act locally – but don't insist on buying locally…

- Trade frictions have emerged, limiting trade in alternative energy hardware.
- The best way to develop these industries at a global level may involve a concentration of ***innovation*** in the West and a concentration of ***production*** in developing countries, where manufacturing costs are lower.
- Developing countries may also become a critical test bed for the deployment of new technologies.
- Realizing the benefits of this potential partnership requires open markets and open investment regimes around the world.
- The transition to cleaner energy technologies will be hard enough without policies that raise the price of these alternatives.

# A central role for local innovation in adaptation!

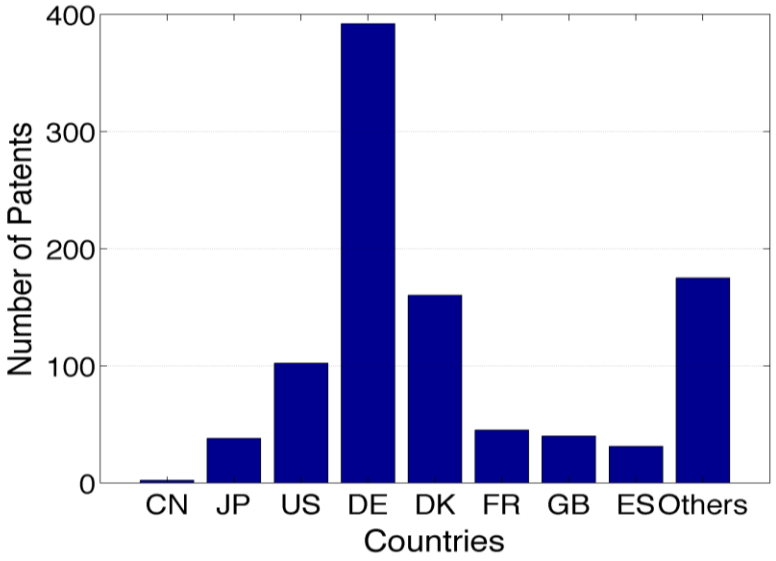
- Agriculture is among the most climate-sensitive activities.
- And agriculture is a much bigger component of GDP in poor, tropical developing countries.
- Genetic engineering could develop crop varieties that resistant to temperature changes, drought, etc.
- But that will require important potential export markets to get over their irrational aversion to GMOs.
- Plenty of scope for international cooperation here, too – and a significant amount of the innovation will have to be undertaken in developing countries.

# The key learnings

- National systems of innovation are complex and multifaceted.
- No one country's national system of innovation is currently meeting the alternative energy innovation challenge with much success.
- A deeper international integration of systems of innovation may be the key to greater success moving forward.
- This will require building an environment attractive to Western multinationals, productive for host countries, and open to trade in alternative energy hardware.

# China's rise as a manufacturer of cleantech hardware has brought lower prices, but not (yet) fundamental innovation

Wind Turbine Patent Grants in EPO Member States




**Shi Zhengrong**
**施正荣**
**Founder of Suntech**

SUNTECH
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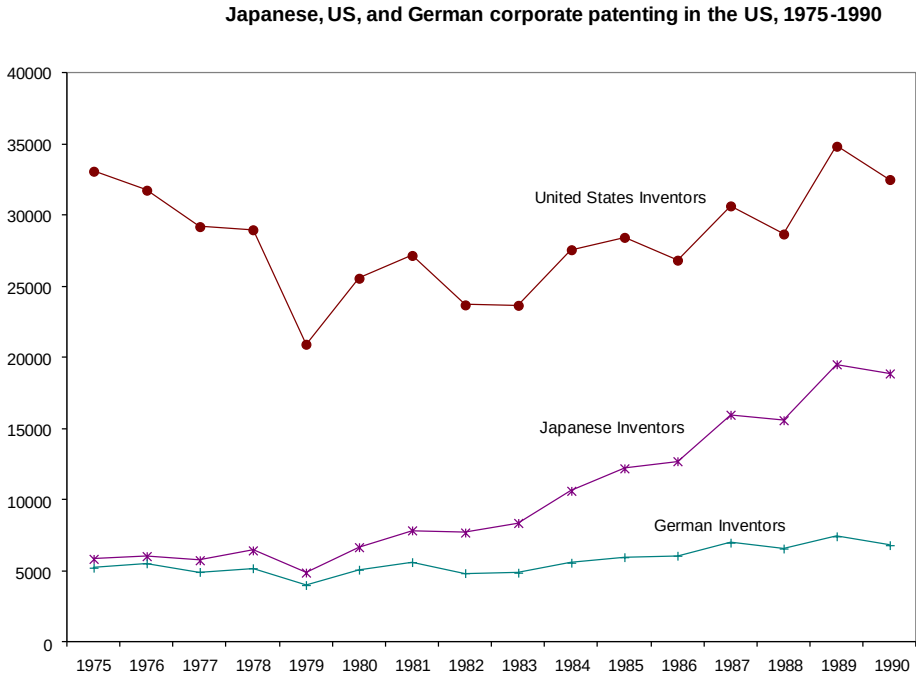
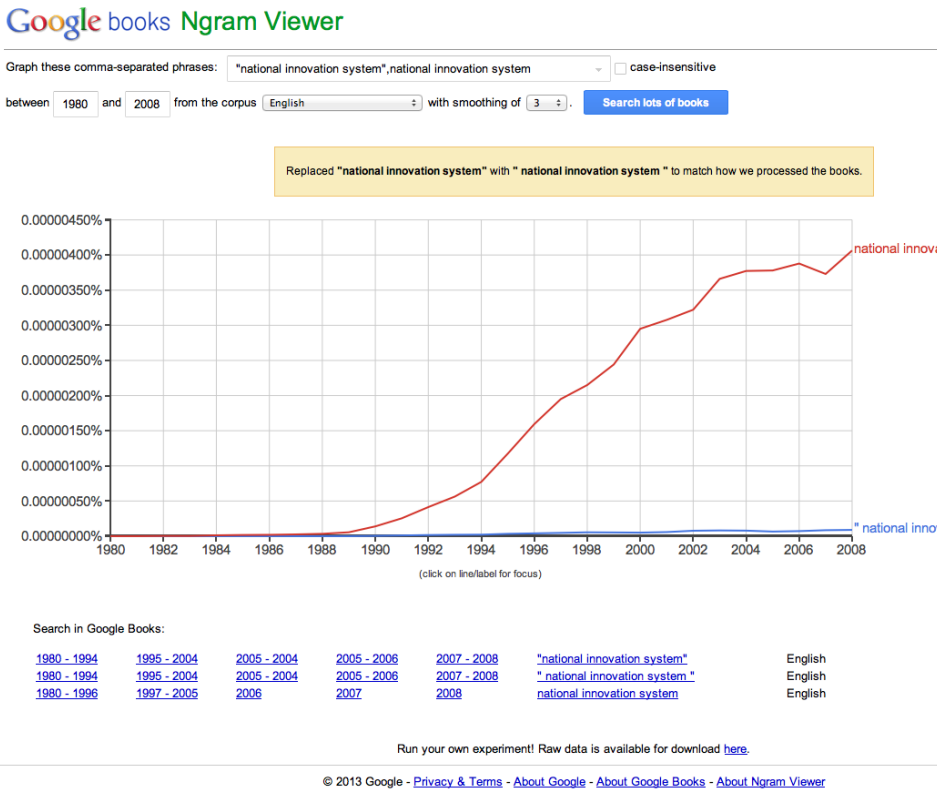
# Interest in this framework grew in the 1980s, as Japan appeared to be on an unstoppable rise…

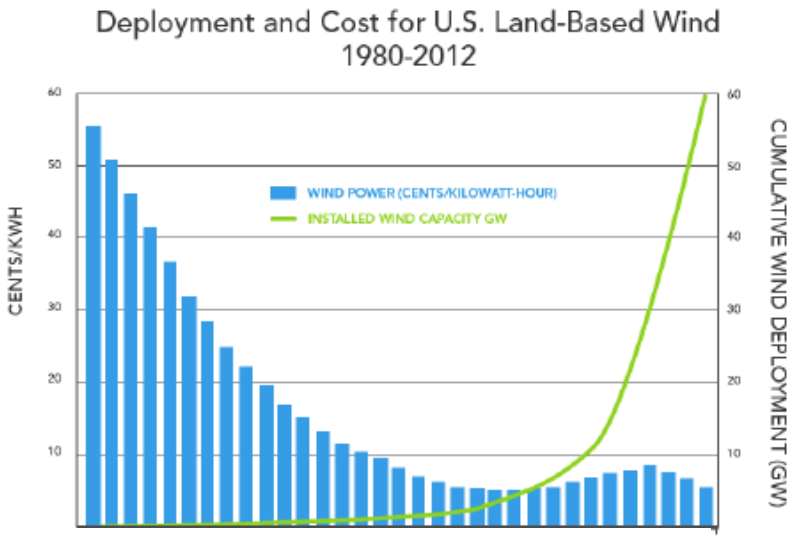


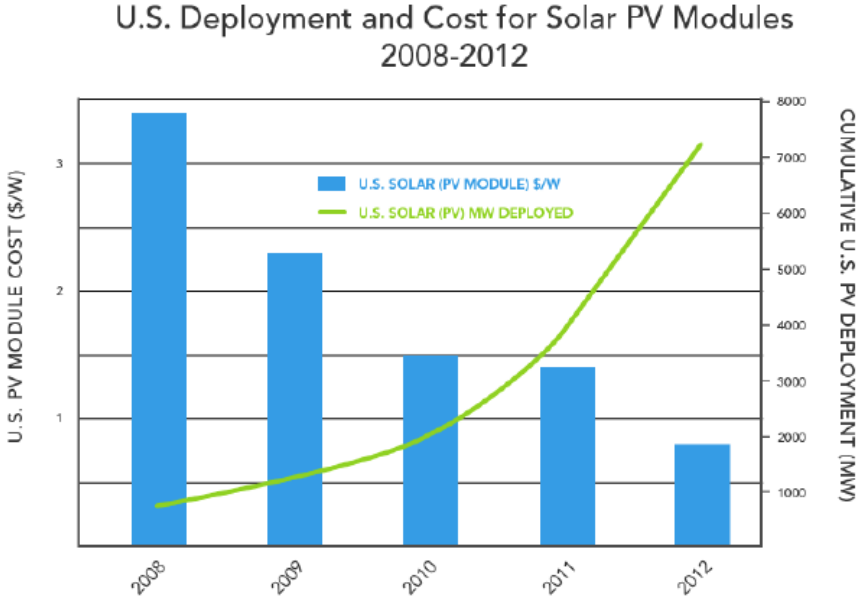



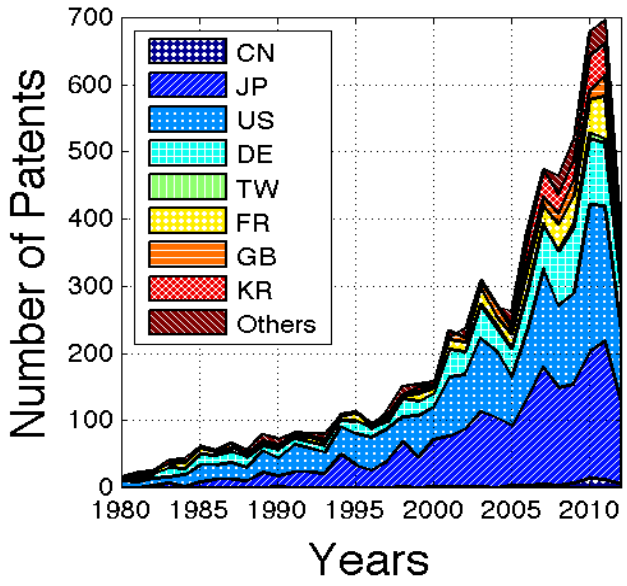
# The alternative energy innovation challenge will require a global effort

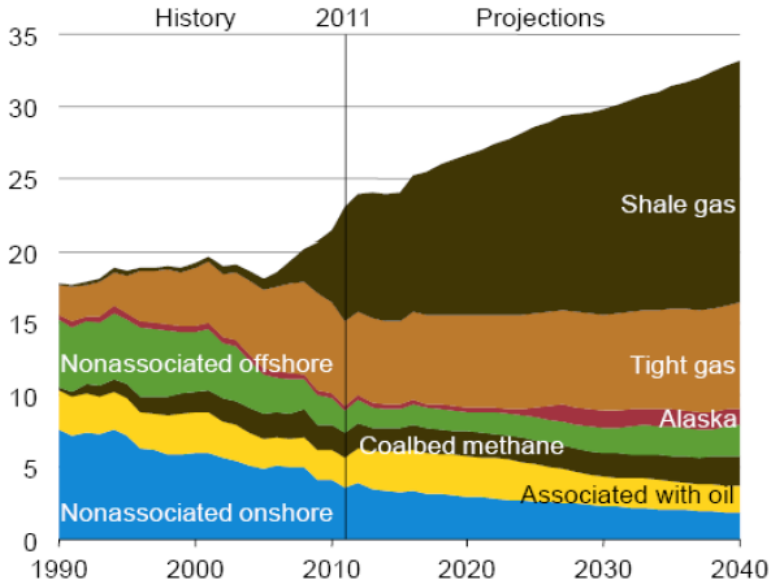
- To meet global environmental emissions reduction goals, we need radical innovation ***and*** rapid adoption/absorption.
- The capabilities for significant innovation are mostly concentrated in developed countries – but the challenges are great, progress has been slow.
- We need a stronger global basic research foundation.
- The major innovations that come will not be easy or cheap to use – effective adoption/absorption will require significant investments by developing countries and a price on carbon.
- A greater degree of international cooperation will be required to achieve our technological goals.
  - Open global markets for clean technology goods
  - Open investment regimes in developing countries
  - A greater degree of international technological collaboration

# First, the good news…



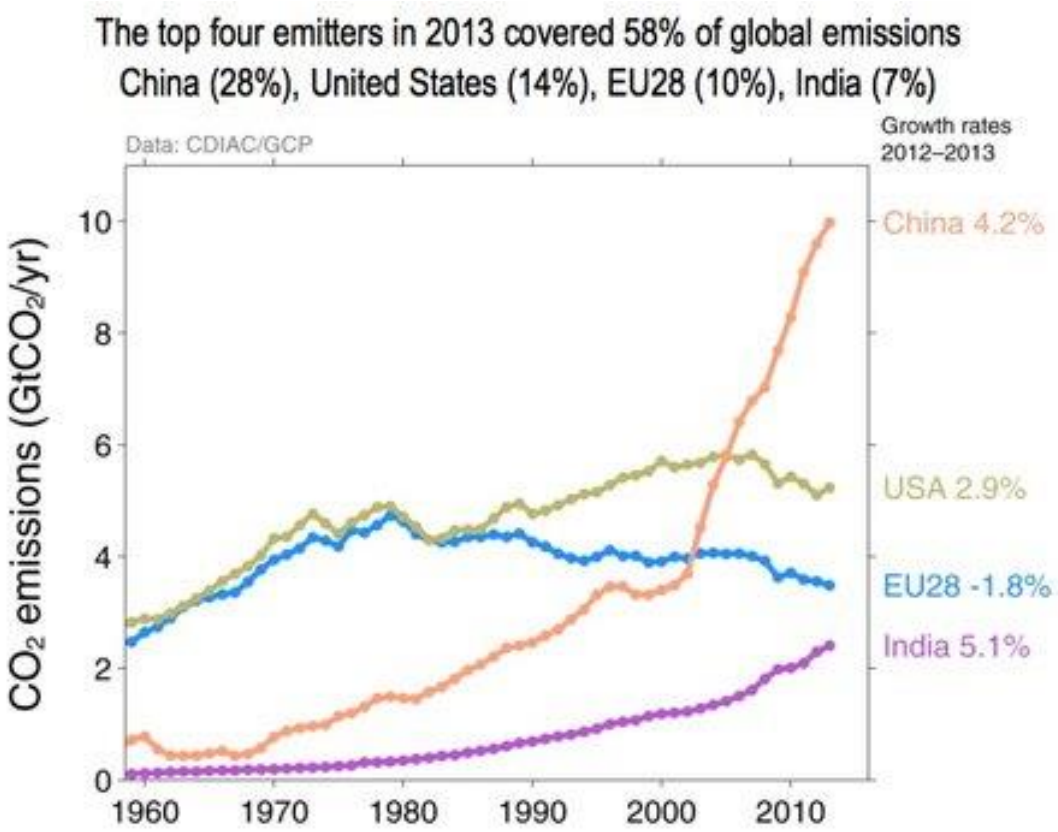



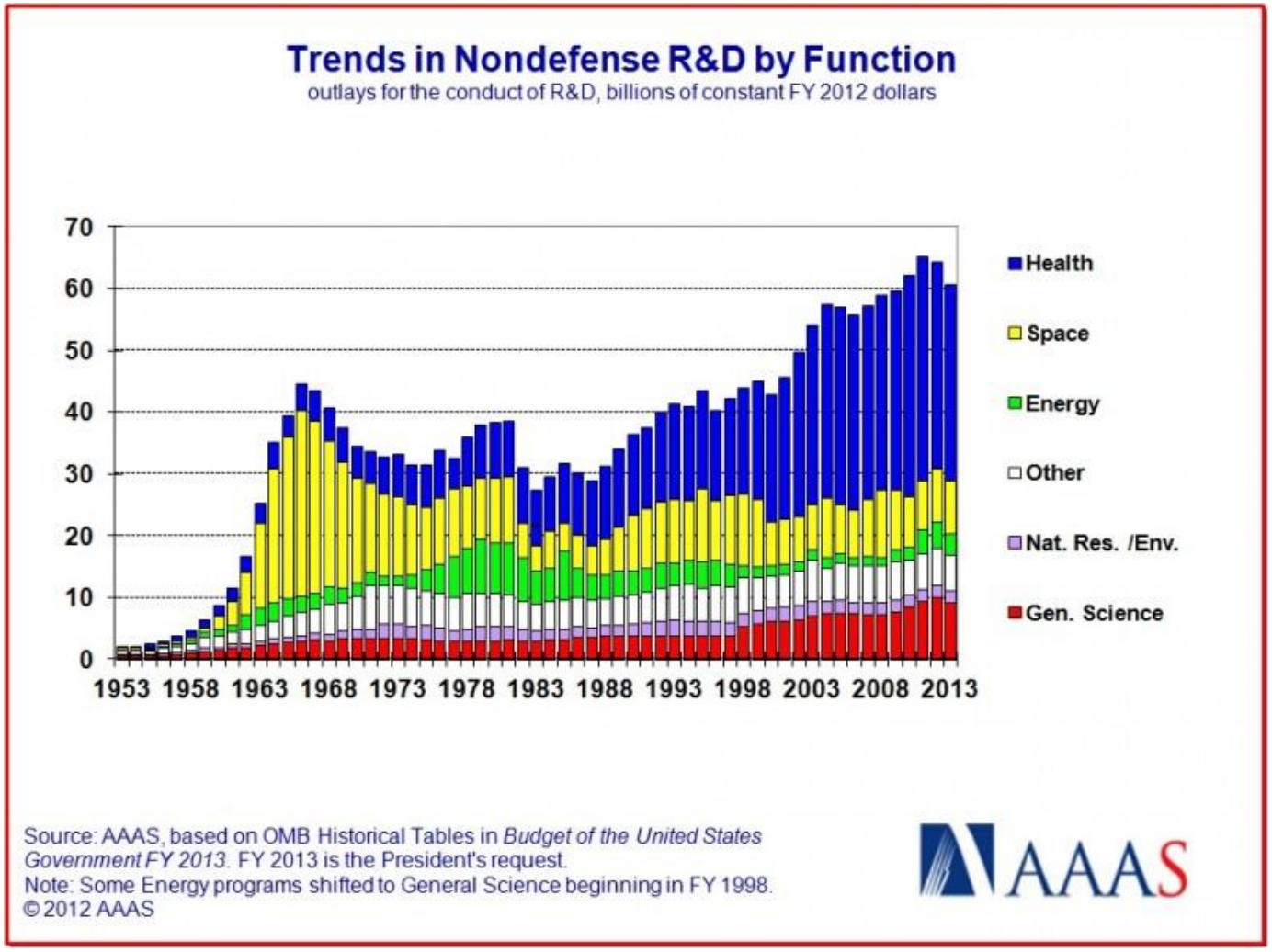
# The critical role of China…

- We can only mitigate climate change at a global level if China slows its emissions growth…
- China does not (yet) have the capability to innovate in a fundamental way in this space.
- But it has established itself as the cheapest place in the world to manufacture and deploy certain kinds of new energy technologies.

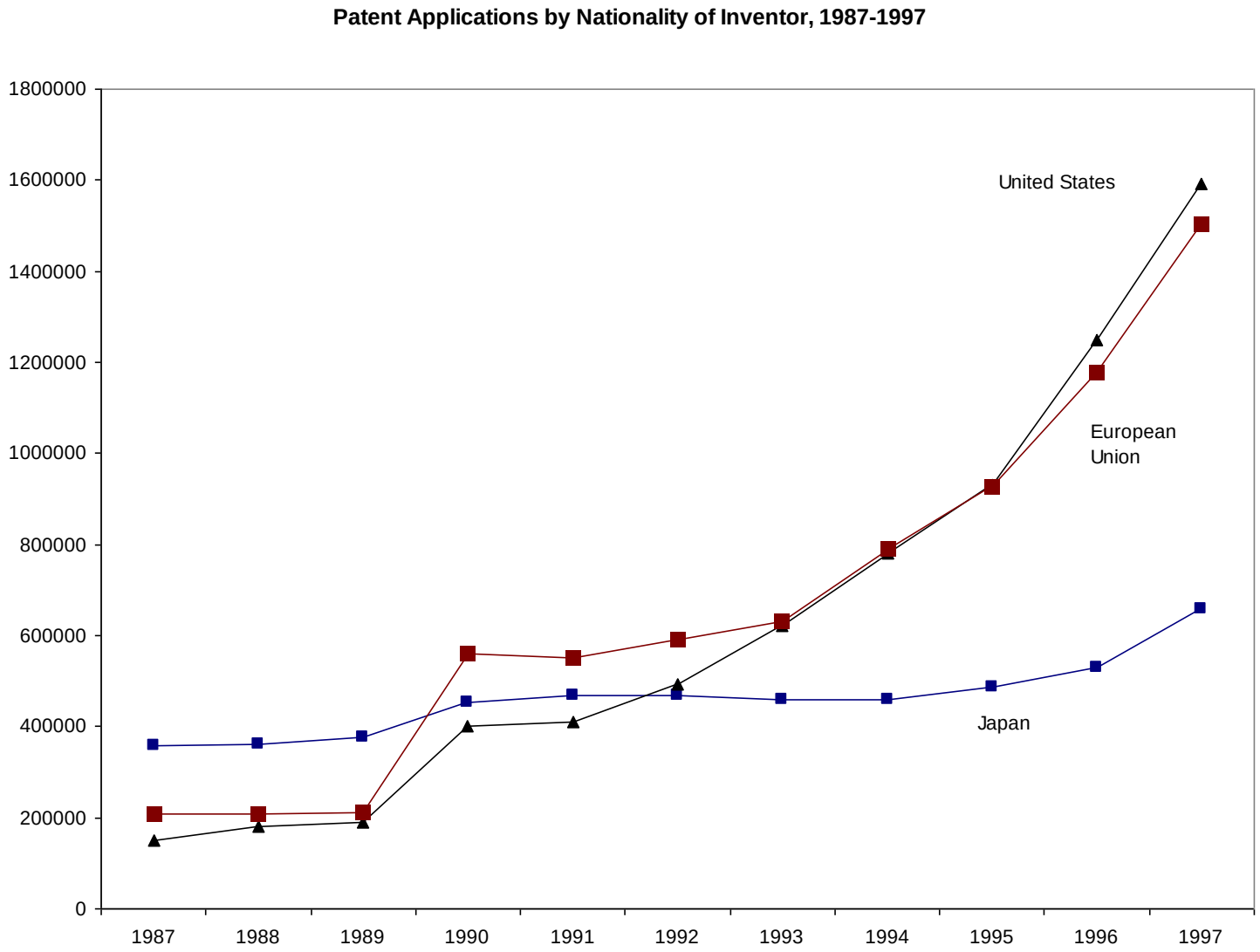



Source: Global Carbon Project

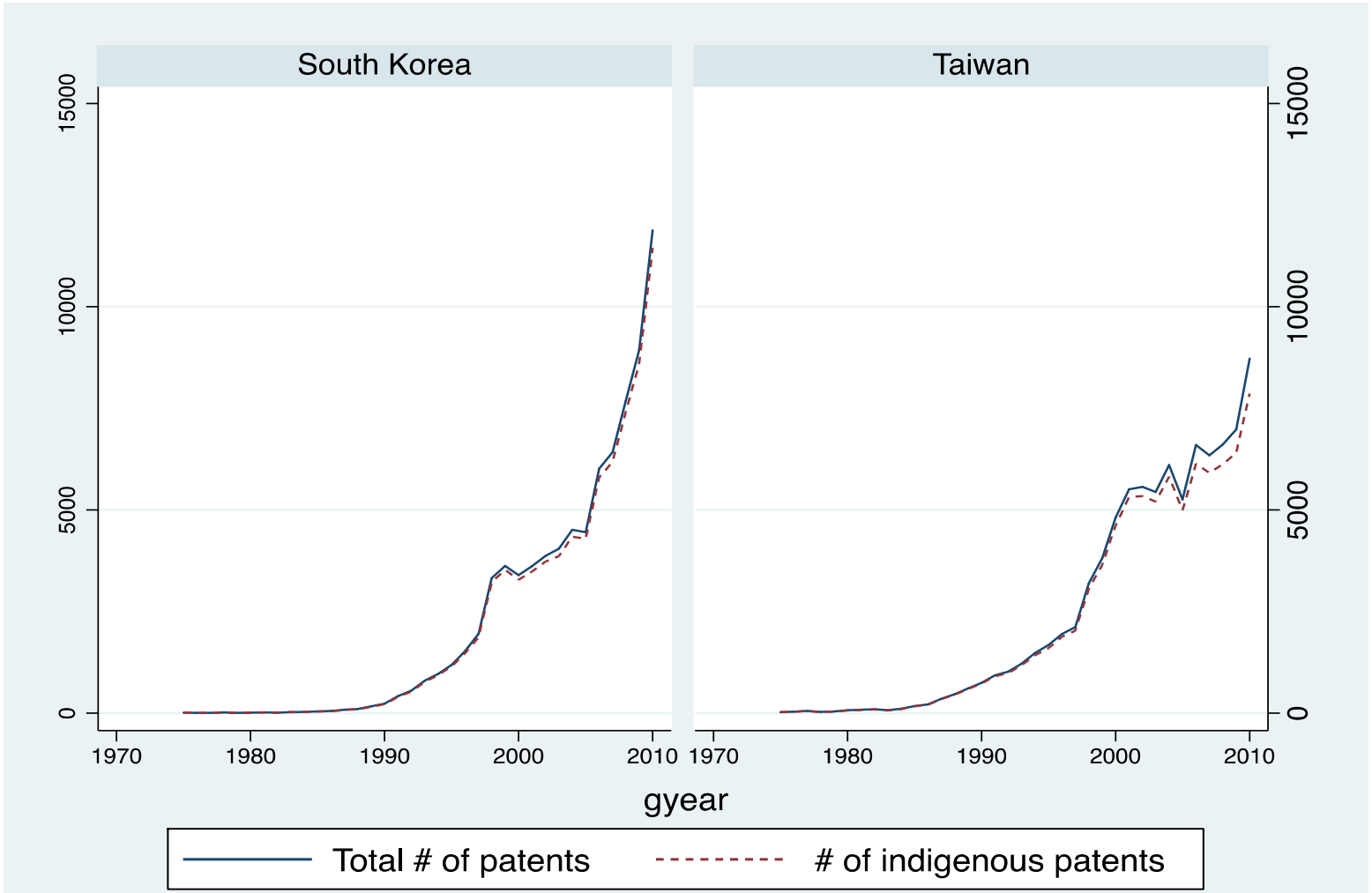
# The innovation we need will require a broader, deeper science base…



# As Japan's innovative strength receded, this idea has also undergone some rethinking



# This is quite different from the technological "great leaps forward" in East Asia in the 1980s and 1990s.



# Think globally, act locally – but don't insist on buying locally…

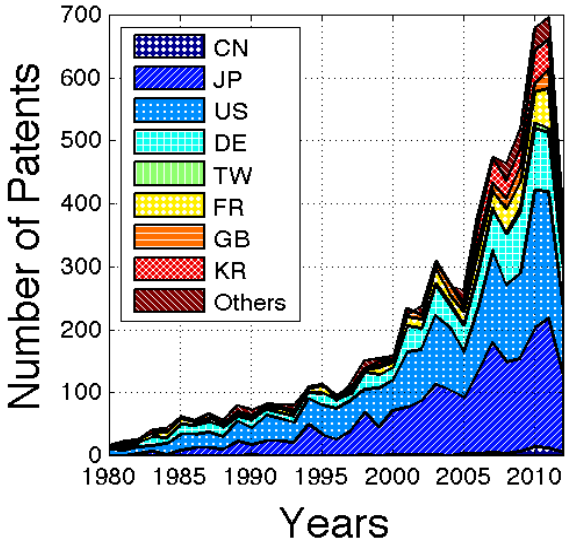
- Trade frictions have emerged, limiting international trade in alternative energy hardware and raising prices in importing countries

- It is neither politically feasible nor strategically sensible for the United States to always turn the other cheek when other nations violate trade rules…

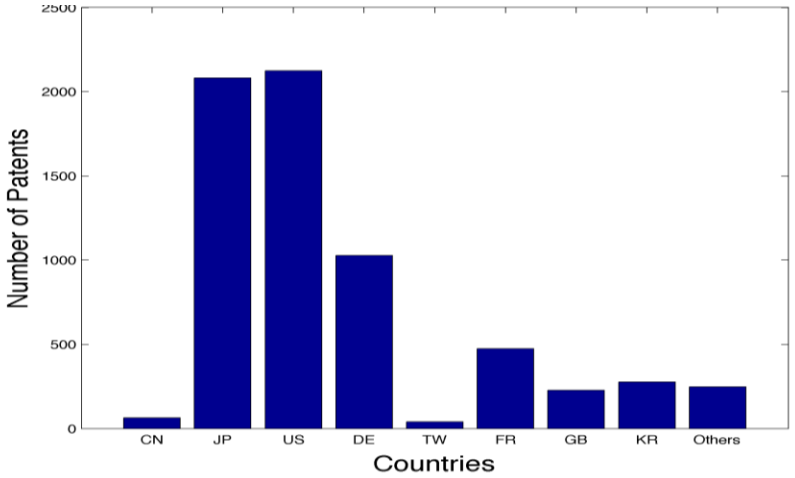
- But the best way to develop these industries at a global level may involve a concentration of ***innovation*** in the West and a concentration of ***production*** in developing countries.

- The transition to cleaner energy technologies will be hard enough without policies that raise the price of these alternatives.

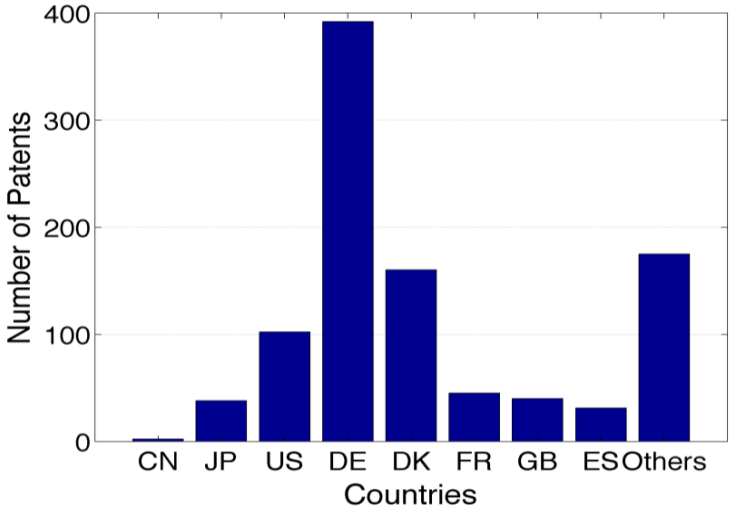
# But this effort has failed to yield significant innovation…




Solar Patents




Wind Patents




Shi Zhengrong
施正荣

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# It is hard to shift the global scientific center of gravity…but it did happen (once) in the 20th century!

Figure A1: Nobel Prizes

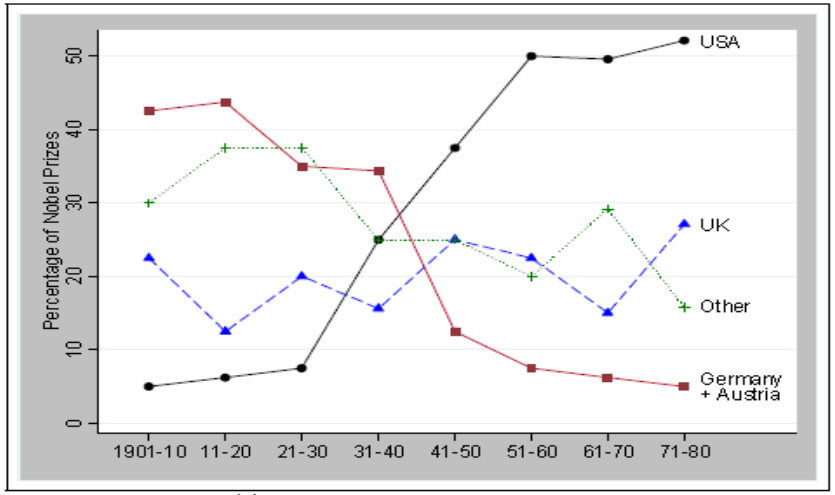



Figure A1: Nobel Prizes in physics and chemistry

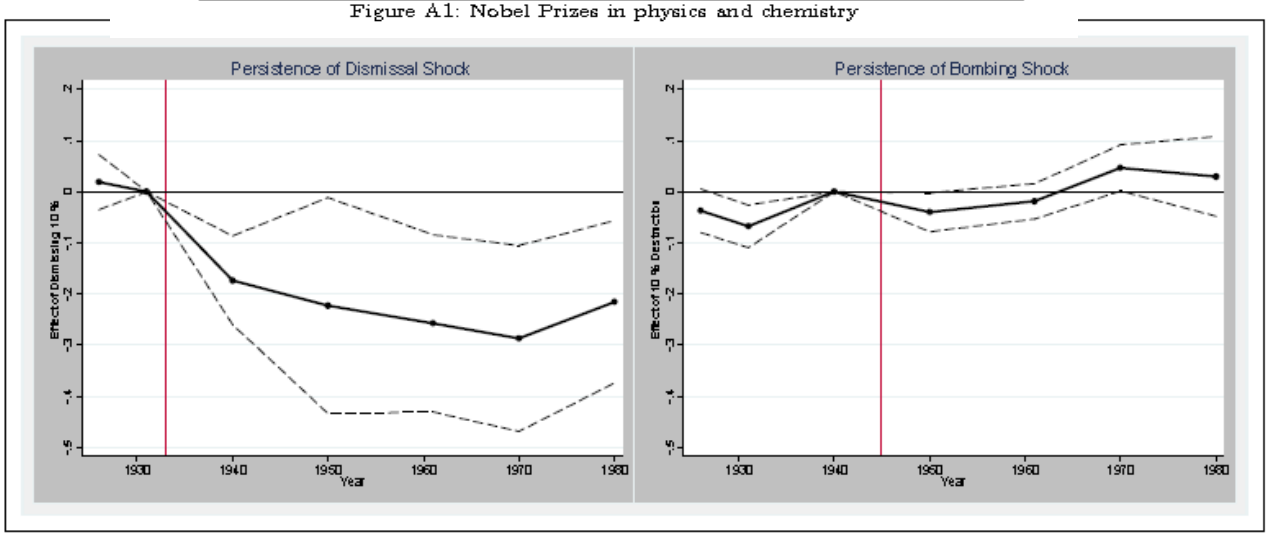


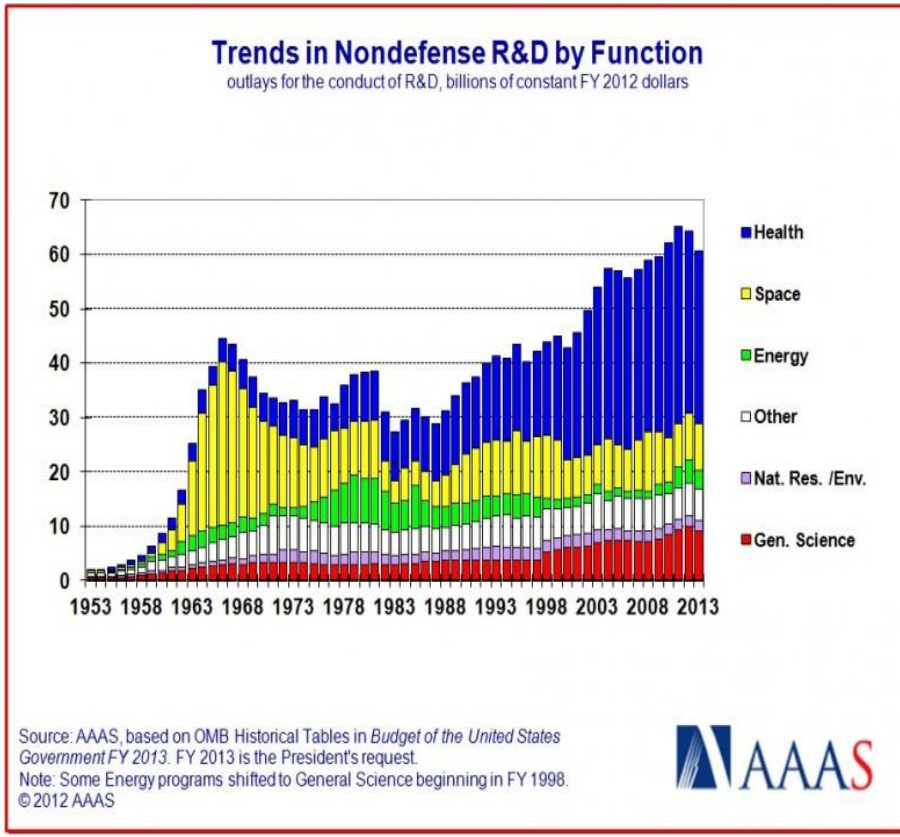

Figure 3: Persistence of 10% shocks - publications

Wilhelm von Humboldt

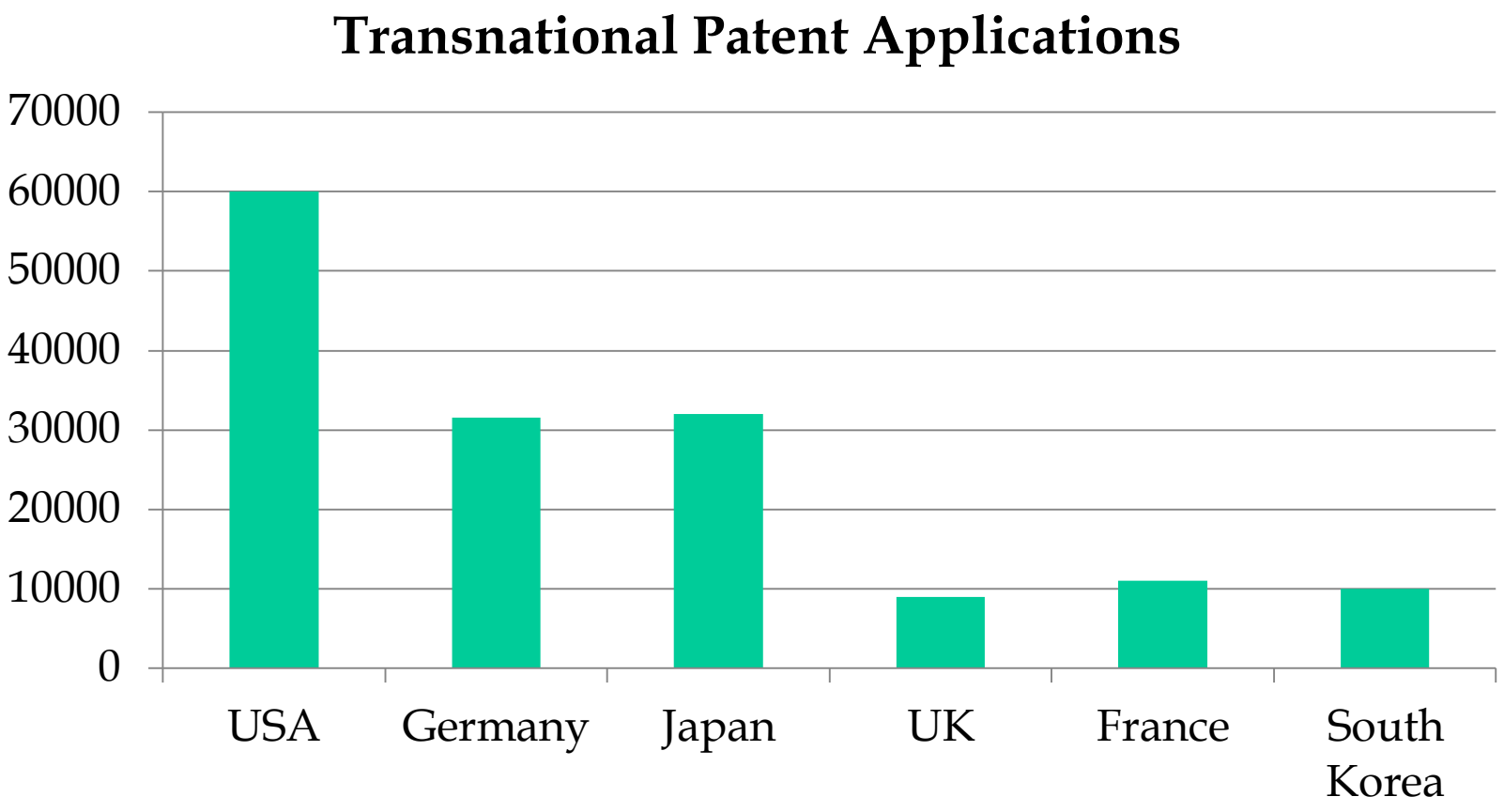
Fabian Waldinger

# An inadequate foundation of basic research…

- Universities and public research institutes will create the basic scientific foundation upon which alternative energy innovation will build
- The developed world (still) possesses the world's top universities and research institutes…
- But the governments of many advanced nations face financial strains that will limit their ability to invest for the foreseeable future…
- Rising nations are investing in their own universities, but these are unlikely to displace the current Western centers of global science.
- This leaves us with an inadequate foundation of basic research.



# Invention seems to be highly concentrated in a small number of (mostly) developed economies



# The traditional concept of a "national" system of innovation is almost certainly too broad…

- There is limited knowledge spillover between the aircraft industry and the pharmaceutical industry in any country

- More generally, "national" systems of innovation tend to work quite differently in different industries, with limited connections across industries


# Innovation systems differ substantially, even among countries at similar levels of development

- Research Universities: MIT, Stanford, Carnegie-Mellon University
- A strong IPR regime
- Silicon Valley/Venture Capital
- Immigrant entrepreneurs, engineers, and programmers

- Research Universities: Technische Universitat Berlin, Universitat Heidelberg
- A strong IPR regime
- Apprenticeship systems for vocational education
- Fraunhofer and Max-Planck Institutes
- Mittelstand

# The German and American systems possess some common elements…

- Research Universities: MIT, Stanford, Carnegie-Mellon University
- A strong IPR regime
- Silicon Valley/Venture Capital
- Immigrant entrepreneurs, engineers, and programmers

- Research Universities: Technische Universitat Berlin, Universitat Heidelberg
- A strong IPR regime
- Apprenticeship systems for vocational education
- Fraunhofer and Max-Planck Institutes
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# But America's "Silicon Valley" has proven difficult for Germany to imitate…

- Research Universities: MIT, Stanford, Carnegie-Mellon University
- A strong IPR regime
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- Research Universities: Technische Universitat Berlin, Universitat Heidelberg
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- Apprenticeship systems for vocational education
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# And America has been unable to transplant key German institutions into its system…

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- A strong IPR regime
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# This shows that national systems of innovation are hard to develop and hard to change!

- Research Universities: MIT, Stanford, Carnegie-Mellon University
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# Slow progress on solar energy…