Challenges and Opportunities
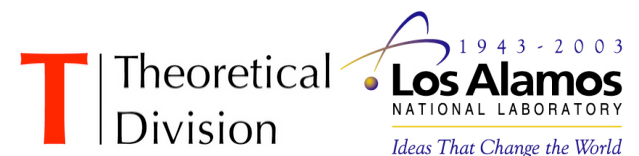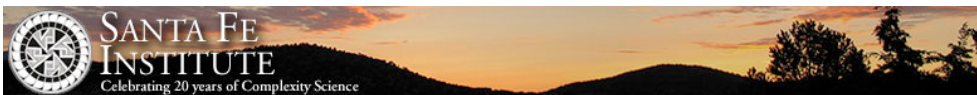
NSF Workshop (I) on Knowledge Management and Visualization Tools in Support of Discovery

Luís M. A. Bettencourt

Theoretical Division, Los Alamos National Laboratory
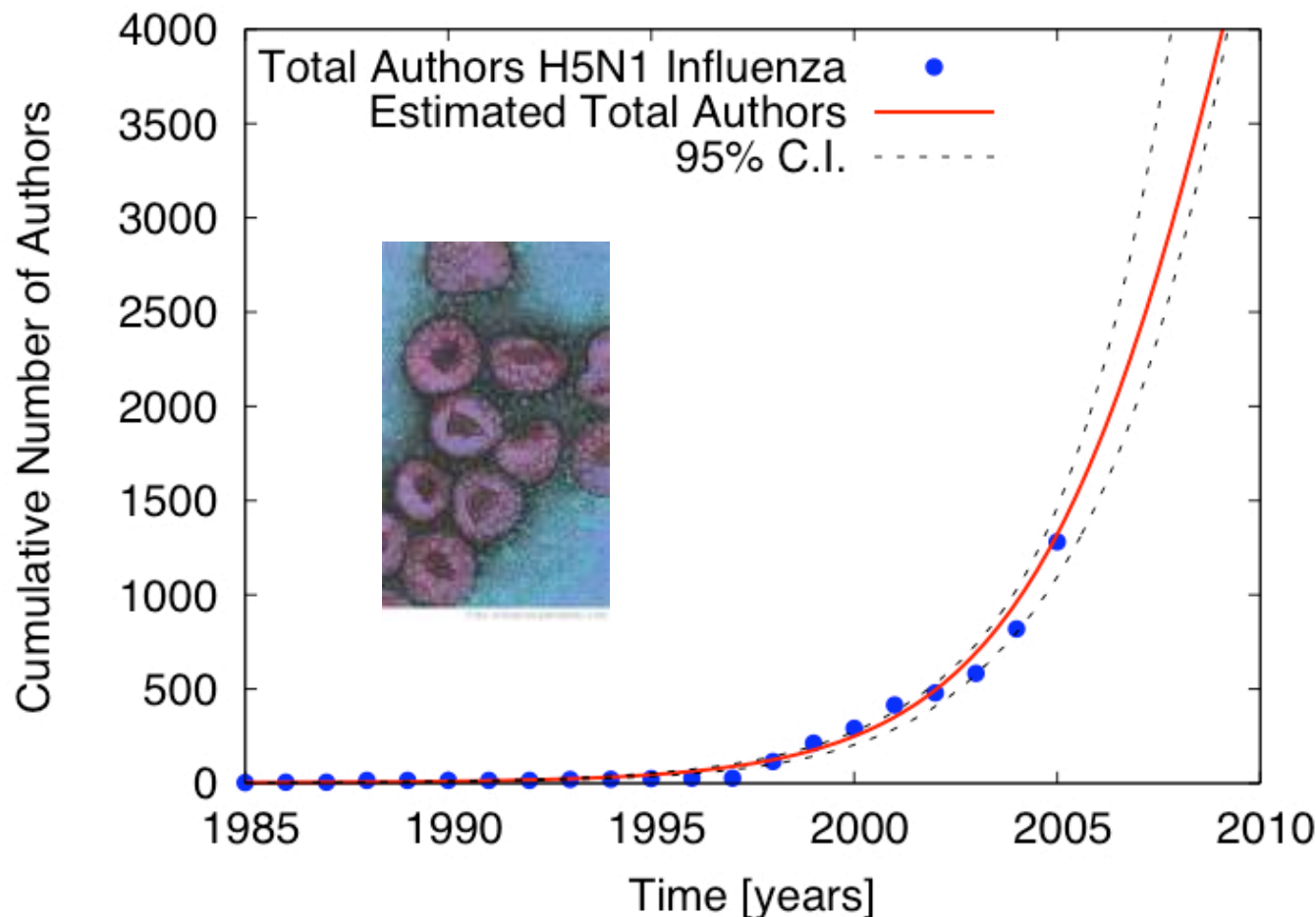
Santa Fe Institute

http://math.lanl.gov/~lmbett

NSF - March 10, 2008

H5N1 Influenza (bird flu)

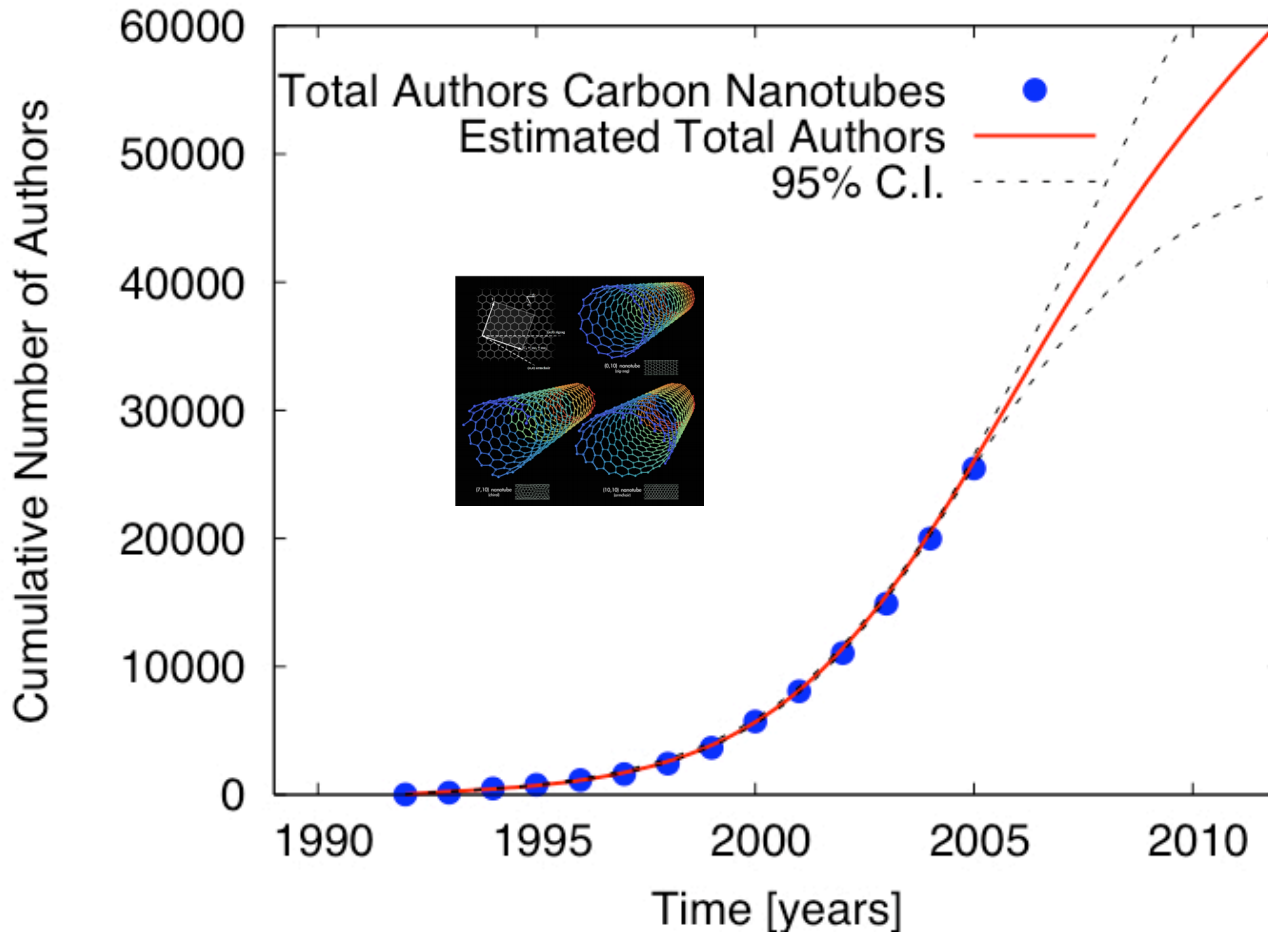[2005:1281 authors, 604 papers]

Disease of birds

First infected humans in 1997 in Hong Kong

371 humans infected

~63% case mortality

Carbon Nanotubes
[2005: 25464 authors, 30521 papers]

S. Ijima   1992

Important subfield
of nanotech

Allotrope of Carbon
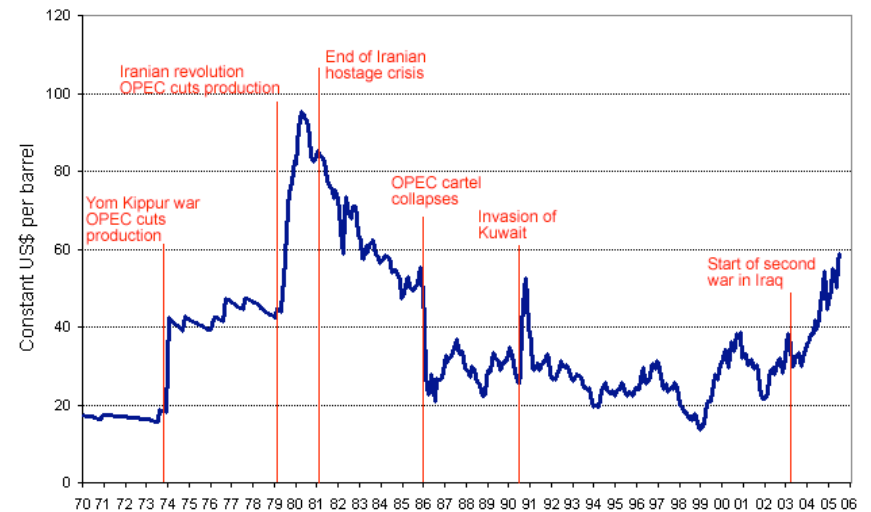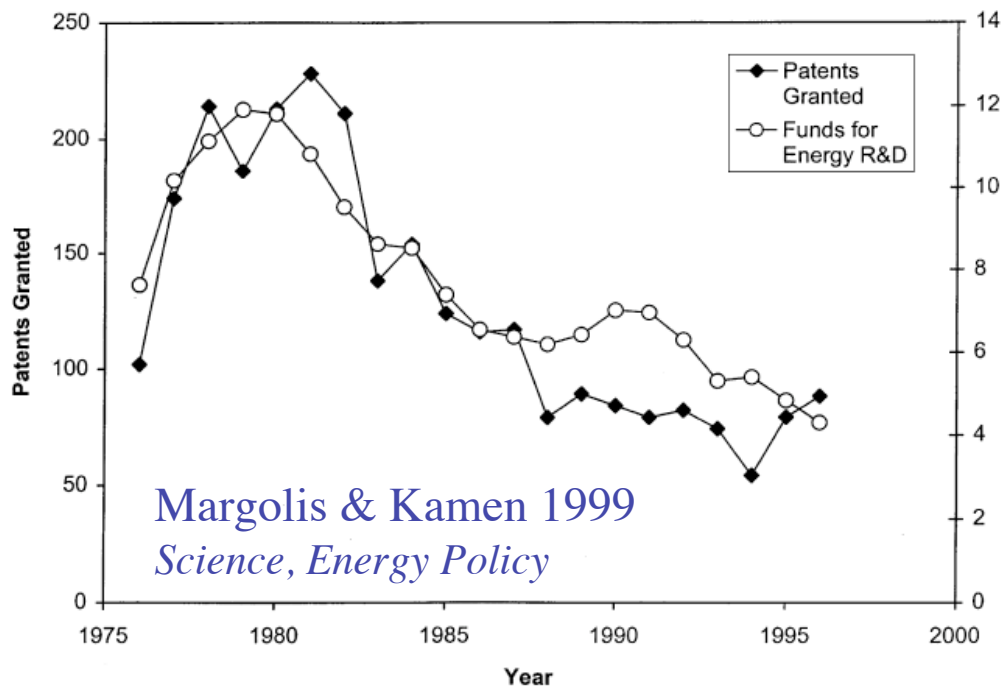
Promises to
revolutionize
Nano-engineering

Investment, productivity and innovation in energy technologies

Where's the energy sector going?
How to achieve de-carbonization?

Evidence for underinvestment in energy science & technology
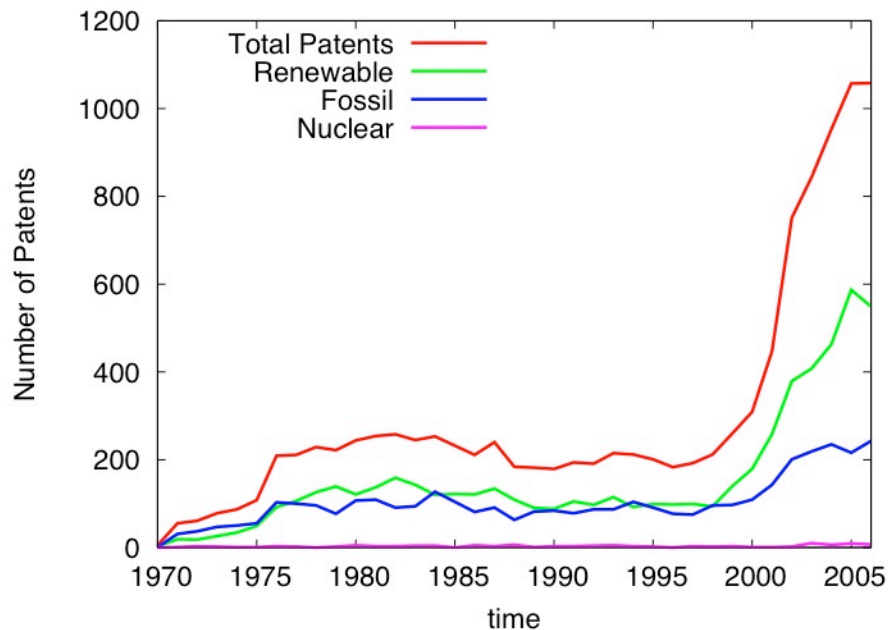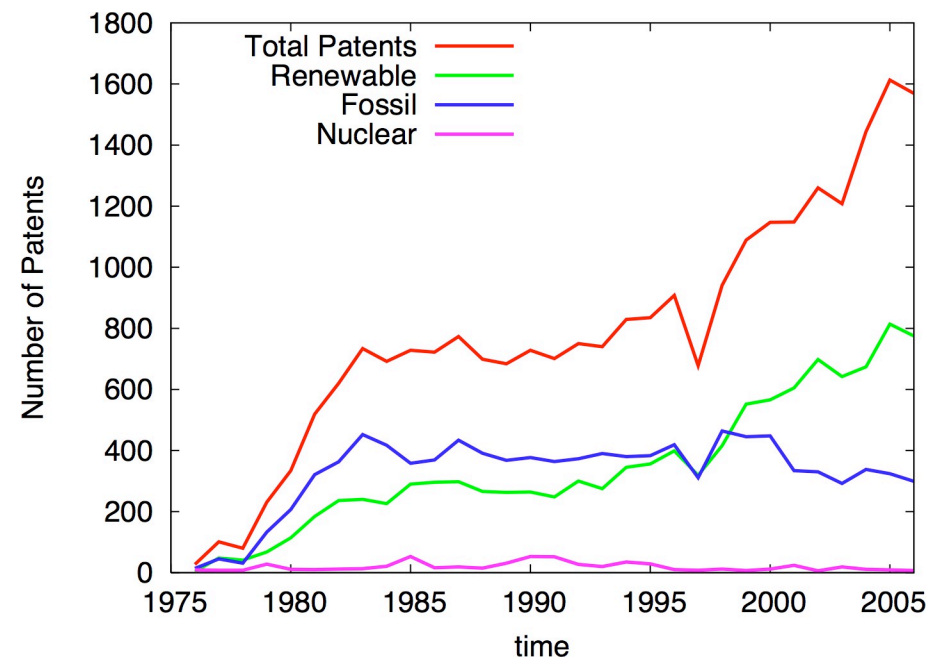
USA 1976-1999

Margolis & Kamen 1999
Science, Energy Policy

Innovation periods in energy technologies correlate with high prices

Theoretical Division | Los Alamos NATIONAL LABORATORY
1943 - 2003
Ideas That Change the World

energy patterns
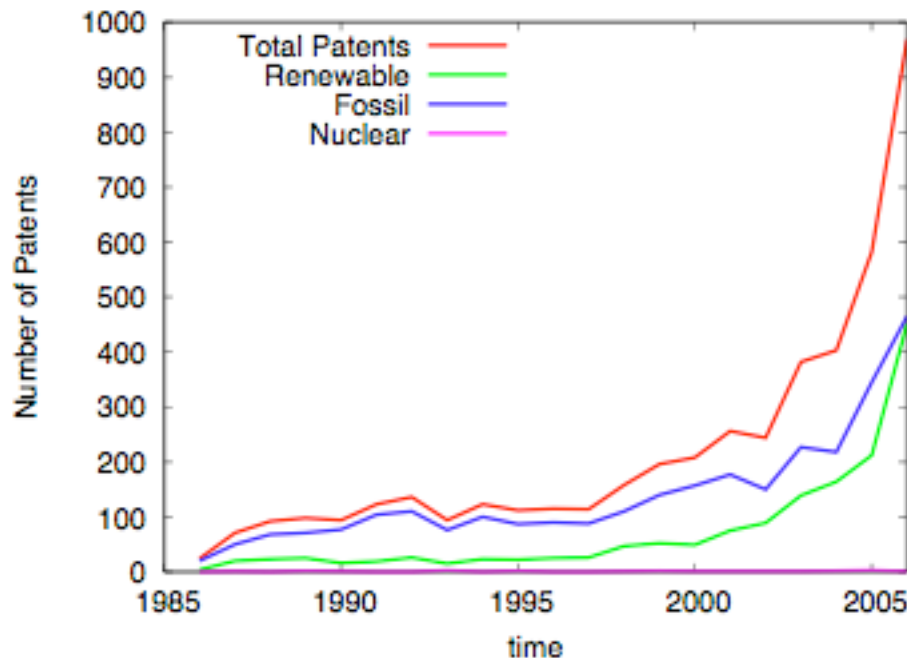
US Patent and Trademark office
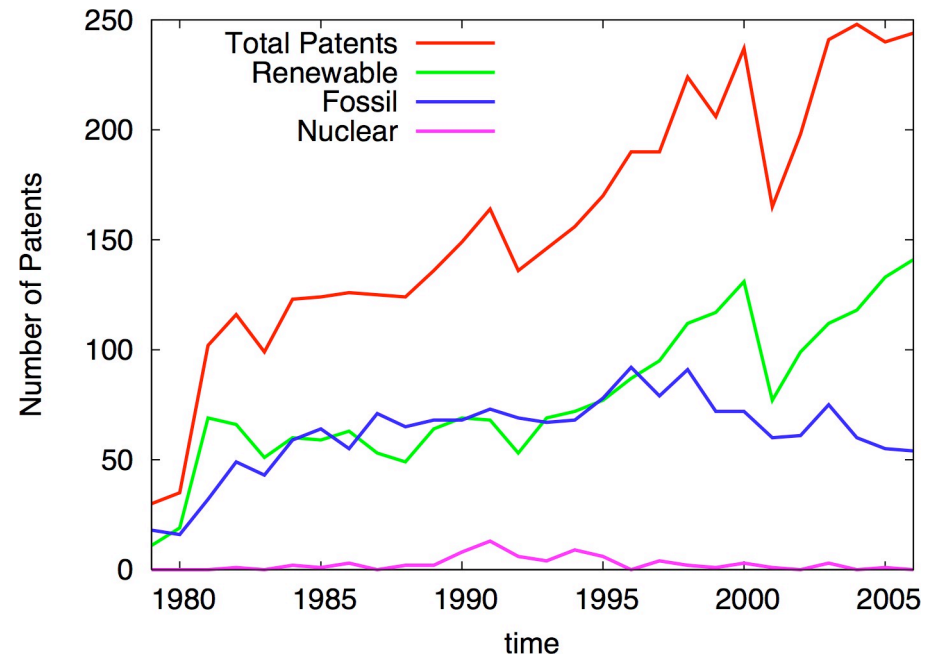
Japanese Patent office

Two periods of explosive growth in the late 70s and since late 90s

country temporal patterns

Chinese Patent office

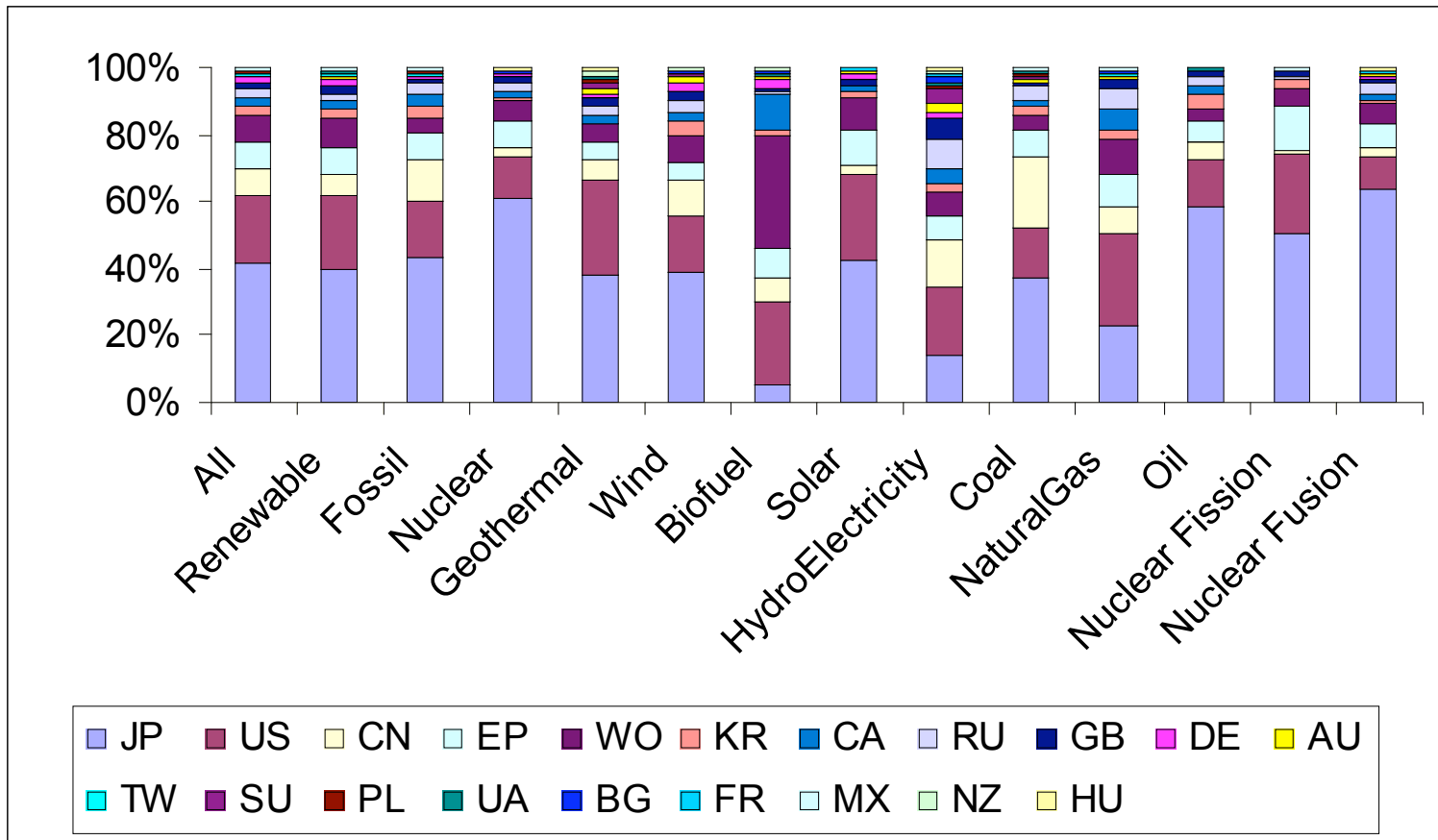## European Patent office
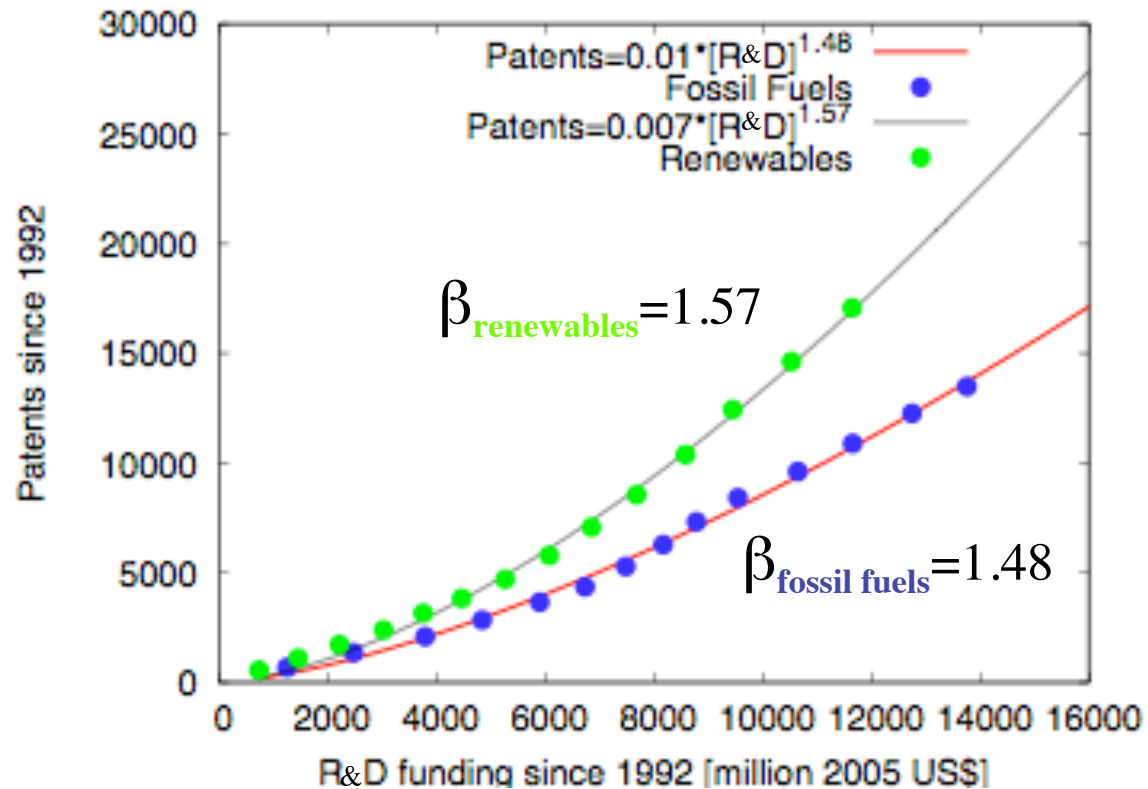

China is a recent newcomer with explosive growth
Europe has had sustained but low levels of patenting over decades

Regional distribution of patents
technology & nation

Returns in innovation to R&D investments

Renewable technologies' patents show greater returns to R&D investment relative to **fossil fuels**

Network of co-patenting
hydrogen fuel cells
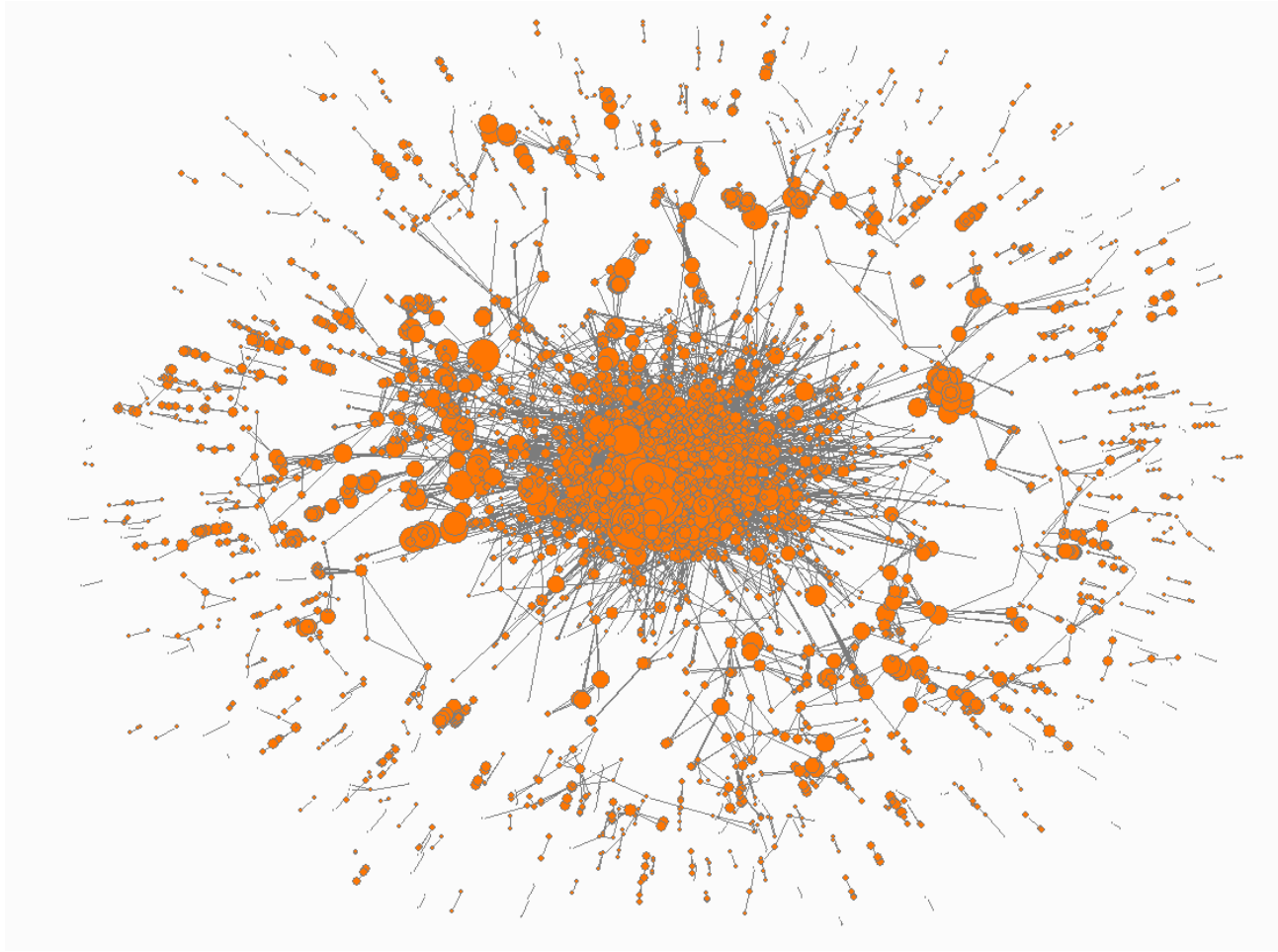
Challenges and Opportunities

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Opportunities

New (information) Technologies:

Social information is quantifiable, plentiful, real time
       scientific publications
       patents
       usage
       social networks, virtual societies, open source economy
Biological data is quantified, plentiful and real time
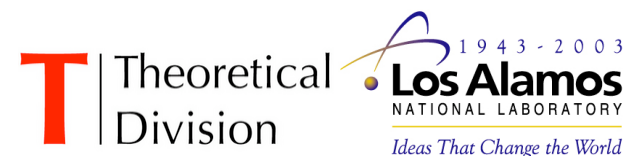   genomics
       proteomics
       brain electrophysiology, imaging
       detailed, large scale environmental/ecological data

Large scale simulation, visualization, (spatial) mapping, real time streaming, modeling and prediction, graphs

Opportunities

New access to empirical quantitative information transformative to

Economics: "mystery" of endogenous growth, increasing returns
Sociology: division of labor, subcultures, social breakdown
**Cognitive Sciences:** rational choice / bounded rationality, heuristics
Innovation Studies: social networks, knowledge spillovers

Genomics: systems biology, artificial genomes, genetic therapies
Ecology: Biodiversity, Productivity, Robustness, Networks, foodwebs
Neuroscience and artificial intelligence: how does the brain work?
Algorithms and architectures for open ended unsupervised learning
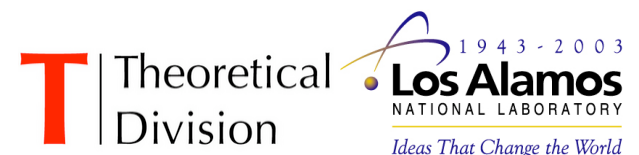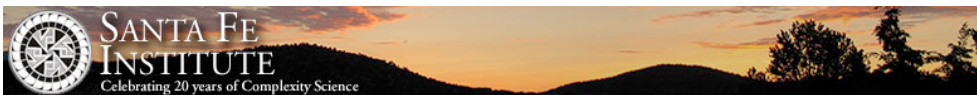
Challenges

What are New Science breakthroughs at hand?

1. **Quantitative Empiricism**:
   tools to expand quantitative investigation:where? how?
   maps, databases, graphs, descriptive statistics

2. **Modeling and falsification**:
   confront data promptly against predictive models

3. **Conceptual Breakthroughs [Theory]**
   Identify **important** scientific problems
   How to conceptualize theory in terms of data observables

Strategy: What are the Problems with **these 3 ingredients**?