ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY POLICY

Capturing nanotechnology's current state of development via analysis of patents

WORKING PARTY ON NANOTECHNOLOGY
Project A: Statistics and measurement
Workshop on statistics and measurement

14/11/2007

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Outline of this talk

- What kind of information can we get from analyses of patent applications?
  - Trends of inventive activities in nanotechnology (total or by application field)
  - Comparative strength of countries
  - Source of knowledge (Sectoral distribution of applicants)
  - Role of cumulative knowledge (Ratio of non-nanotechnology patent applications in backward citations)
  - Role of science (Ratio of non-patent literature in backward citations)
  - Technological/economical value (Forward citations)
- Implications for statistics and measurement of nanotechnology

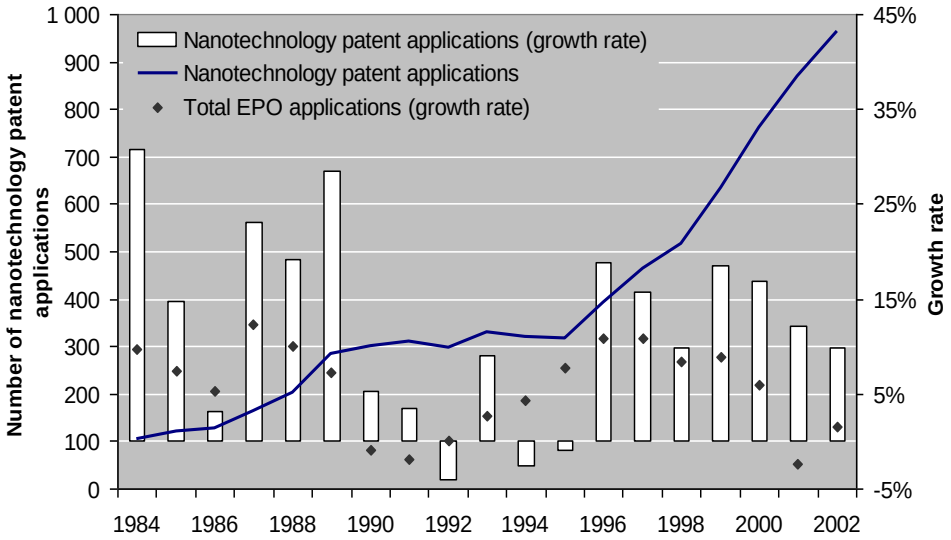
Dataset

- Nanotechnology patent applications filed to the EPO
  - Nanotechnology patent applications identified by the EPO (Y01N)
    (Definition of nanotechnology by the EPO)
    "The term nanotechnology covers entities with a controlled geometrical size of at least one functional component below 100nm in one or more dimensions susceptible to make physical, chemical or biological effects available which are intrinsic to that size. It covers equipment and methods for controlled analysis, manipulation, processing, fabrication or measurement with a precision below 100nm." (Scheu et al, 2006)
- Dataset for analysis
  - OECD Patent Database, September 2006
  - OECD/EPO Patent Citations Database, September 2006
- Note that
  - All results are based on the earliest priority date.
  - The results are not a comprehensive picture on inventive activities.
  - Not all inventions are being patented.

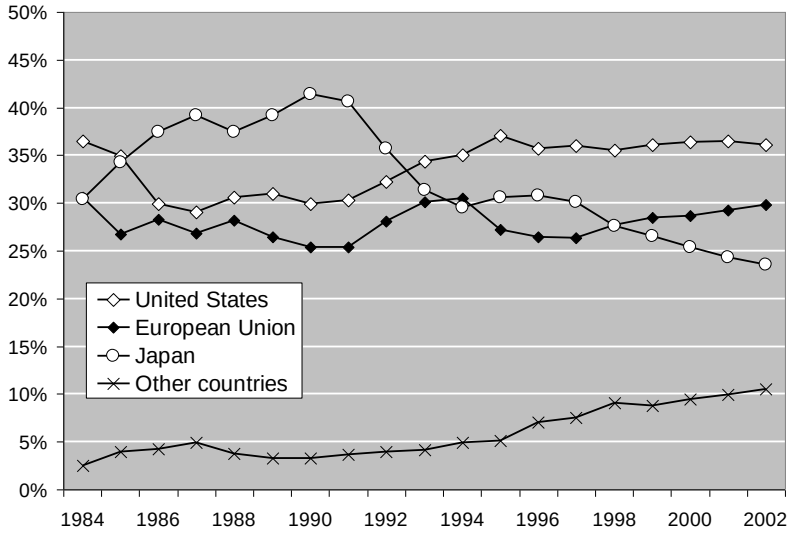
Rapid growth of nanotechnology patent applications

- Inventive activities in nanotechnology have been gathering momentum from the end of 1990s.
  - The United States, the European Union, and Japan compete with each other.
  - The influences of other countries on knowledge creation are getting important.

Trends in the nanotechnology patent applications to the EPO (direct or via PCT)



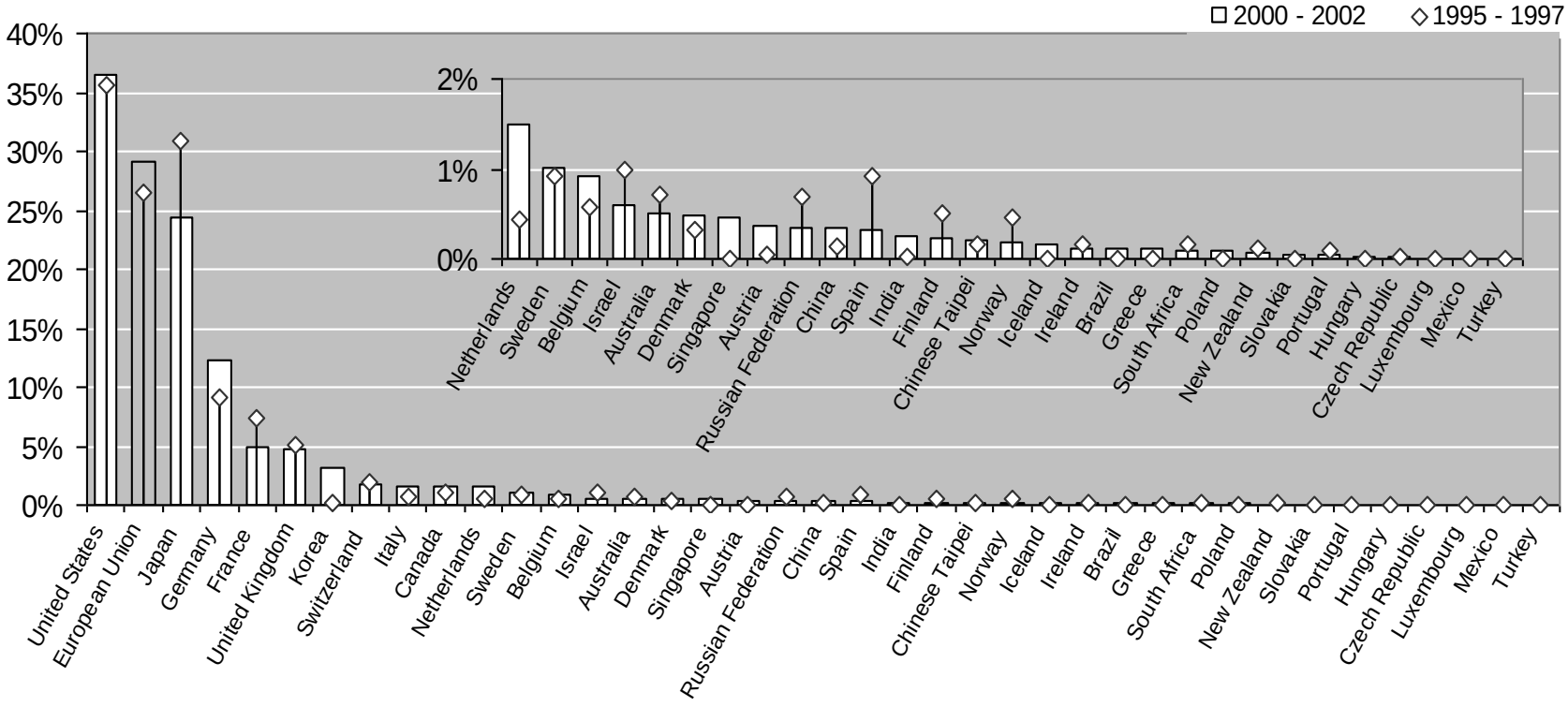
Trends in countries' share in the nanotechnology patent applications (inventors)



Note: Patent counts are based on the earliest priority date, the inventor's country of residence, and fractional counts.
Source: OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Countries' shares in nanotechnology patent applications to the EPO

- Korea and Switzerland have 5th and 6th largest shares. The rise of BRICs is not remarkable in inventive activities.

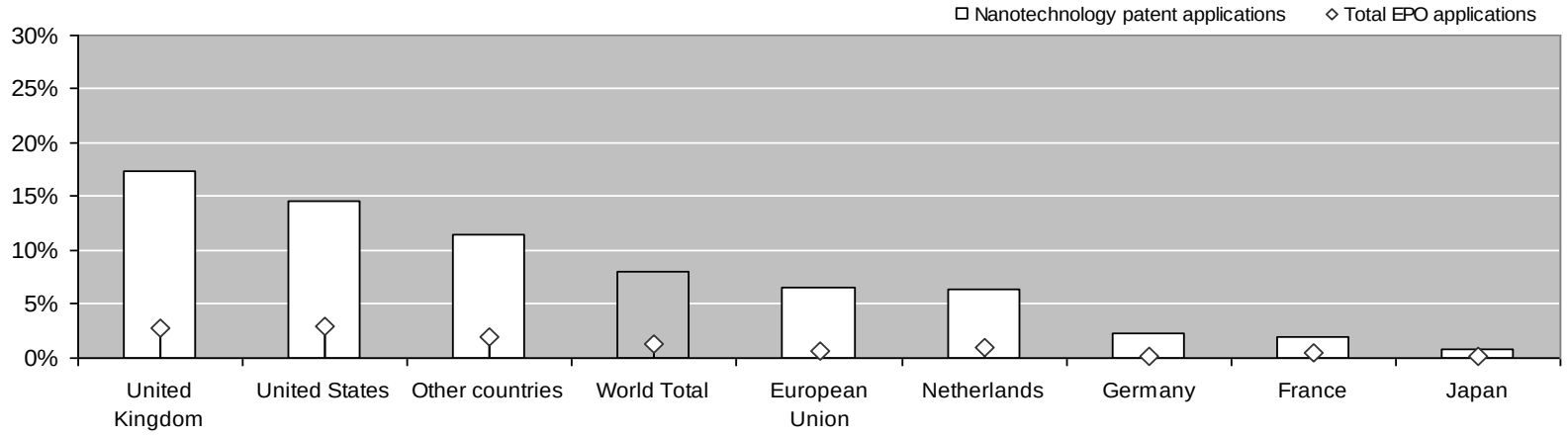


Note 1: Patent counts are based on the earliest priority date, the inventor's country of residence, and fractional counts.
Note 2: The graph covers OECD countries and Brazil, China, Chinese Taipei, India, Israel, Singapore, South Africa, Russian Federation.
Source: OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

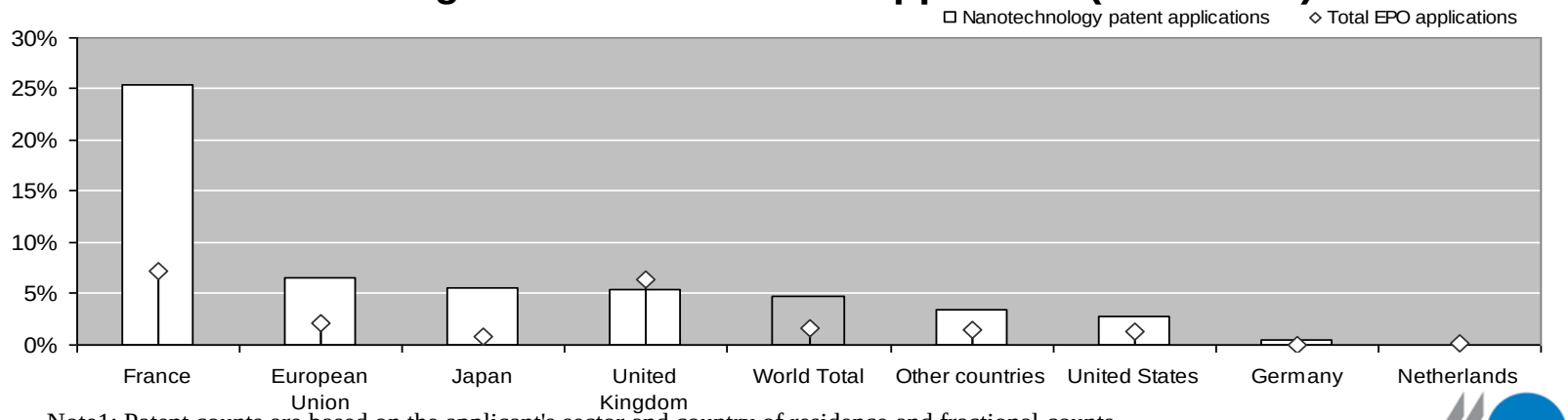
Roles of higher education and government sectors

- Higher education and government sectors are important knowledge sources.

Shares of higher education sector in applicants (1978-2005)



Shares of government sector in applicants (1978-2005)



Note1: Patent counts are based on the applicant's sector and country of residence and fractional counts.
Note2: Other countries represents all countries other than the United States, the European Union, and Japan.
Source: OECD, Patent Database, September 2006, based on a list of patents selected by the EPO. Sector classifications are based on the Eurostat sector attribution algorithm.

Definition of application fields based on main IPC

Field name	IPC	Definition in IPC (8th edition)
Electronics	H01L	SEMICONDUCTOR DEVICES; ELECTRIC SOLID STATE DEVICES NOT OTHERWISE PROVIDED FOR
	H01J	ELECTRIC DISCHARGE TUBES OR DISCHARGE LAMPS
	G06N	COMPUTER SYSTEMS BASED ON SPECIFIC COMPUTATIONAL MODELS
	G11	INFORMATION STORAGE
Optoelectronics	G02	OPTICS
	H01S	DEVICES USING STIMULATED EMISSION
Medicine and biotechnology	A61	MEDICAL OR VETERINARY SCIENCE; HYGIENE
	C12	BIOCHEMISTRY; BEER; SPIRITS; WINE; VINEGAR; MICROBIOLOGY; ENZYMOLOGY; MUTATION OR GENETIC ENGINEERING
Measuements and manufacturing	G01	MEASURING; TESTING
	B01	PHYSICAL OR CHEMICAL PROCESSES OR APPARATUS IN GENERAL
	B21	MECHANICAL METAL-WORKING WITHOUT ESSENTIALLY REMOVING MATERIAL; PUNCHING METAL
	B23	MACHINE TOOLS; METAL-WORKING NOT OTHERWISE PROVIDED FOR
	B32B	LAYERED PRODUCTS, i.e. PRODUCTS BUILT-UP OF STRATA OF FLAT OR NON-FLAT, e.g. CELLULAR OR HONEYCOMB, FORM
Environment and energy	C02F	TREATMENT OF WATER, WASTE WATER, SEWAGE, OR SLUDGE
	H01M	PROCESSES OR MEANS, e.g. BATTERIES, FOR THE DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICAL ENERGY
Nano materials	B01J	CHEMICAL OR PHYSICAL PROCESSES, e.g. CATALYSIS, COLLOID CHEMISTRY; THEIR RELEVANT APPARATUS
	B81B	MICRO-STRUCTURAL DEVICES OR SYSTEMS, e.g. MICRO-MECHANICAL DEVICES
	B82B	NANO-STRUCTURES; MANUFACTURE OR TREATMENT THEREOF
	C01B	NON-METALLIC ELEMENTS; COMPOUNDS THEREOF
	C01G	COMPOUNDS CONTAINING METALS NOT COVERED BY SUBCLASSES C01D OR C01F
	C03B	MANUFACTURE, SHAPING, OR SUPPLEMENTARY PROCESSES
	C03C	CHEMICAL COMPOSITION OF GLASSES, GLAZES, OR VITREOUS ENAMELS; SURFACE TREATMENT OF GLASS; SURFACE TREATMENT OF FIBRES OR FILAMENTS FROM GLASS, MINERALS OR SLAGS; JOINING GLASS TO GLASS OR OTHER MATERIALS
	C04	CEMENTS; CONCRETE; ARTIFICIAL STONE; CERAMICS; REFRACTORIES
	C07	ORGANIC CHEMISTRY
	C08	ORGANIC MACROMOLECULAR COMPOUNDS; THEIR PREPARATION OR CHEMICAL WORKING-UP; COMPOSITIONS BASED THEREON
	C09	DYES; PAINTS; POLISHES; NATURAL RESINS; ADHESIVES; COMPOSITIONS NOT OTHERWISE PROVIDED FOR; APPLICATIONS OF MATERIALS NOT OTHERWISE PROVIDED FOR
	C22	METALLURGY; FERROUS OR NON-FERROUS ALLOYS; TREATMENT OF ALLOYS OR NON-FERROUS METALS
	C23C	COATING METALLIC MATERIAL; COATING MATERIAL WITH METALLIC MATERIAL; CHEMICAL SURFACE TREATMENT; DIFFUSION TREATMENT OF METALLIC MATERIAL; COATING BY VACUUM EVAPORATION, BY SPUTTERING, BY ION IMPLANTATION OR BY CHEMICAL VAPOUR DEPOSITION, IN GENERAL; INHIBITING CORROSION OF METALLIC MATERIAL OR INCRUSTATION IN GENERAL
	C30	CRYSTAL GROWTH

Source: Based on the classification in Nanotechnology Researchers Network Centre, Japan.

Example of technologies in application fields

- Nanotechnology consists of a set of technologies on the nanometre scale.

Field	Key phrases
Electronics	Semiconductor memories, Magnetic random access memories, Flat panel display devices, Quantum information processing, and Molecular devices.
Optoelectronics	Lasers, Photonic crystals, Optical devices, Optical waveguides.
Environment and energy	Fuel cell electrode, Non-aqueous electrolyte secondary cell; and Lithium secondary cell.
Medicine and biotechnology	Applications of TiO_2 to sun screening, Drug deliveries, Molecular detection method, and High resolution DNA detection method.
Nano materials	Carbon nanotubes, Organic nanotubes, Nano-whisker, and Oxide particles.
Measurements and manufacturing	Matrix screening methods, Scanning probe microscope, and polymer processing method.

Top-down nanotechnologies

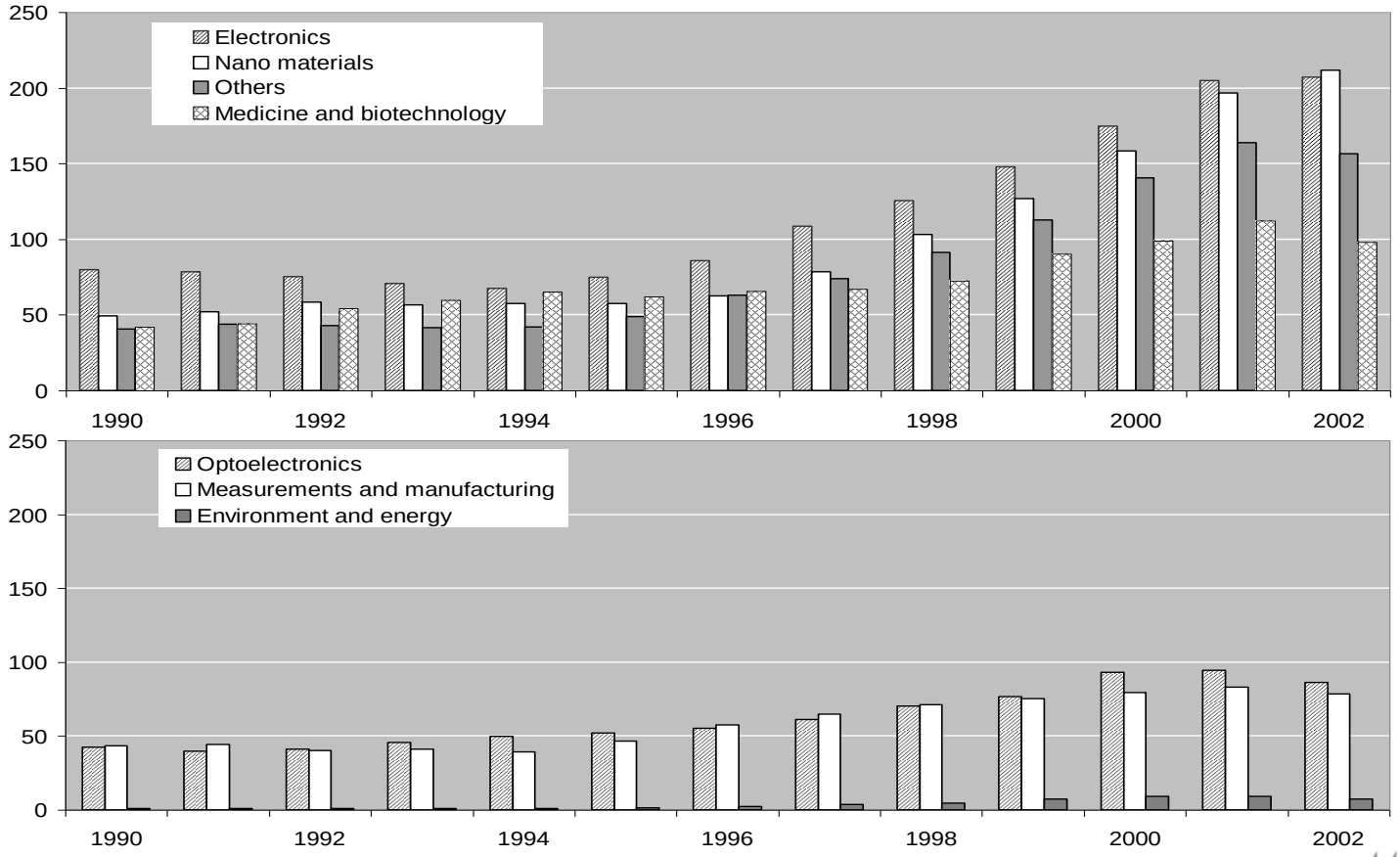
Bottom-up nanotechnologies

Note: Key phrases are identified by frequency analysis on title of nanotechnology patents
Source: OECD, Patent Database, September 2006 based on a list of patents selected by the EPO.

Rising of bottom-up nanotechnologies

- Intense efforts to develop the bottom-up nanotechnologies, *i.e.* “Nano materials”, are being conducted in the past decade.

Trends in the nanotechnology patent applications by application fields



Note: Patent counts are based on the earliest priority date and fractional counts.

Source: OECD, Patent Database, September 2006 based on a list of patents selected by the EPO.

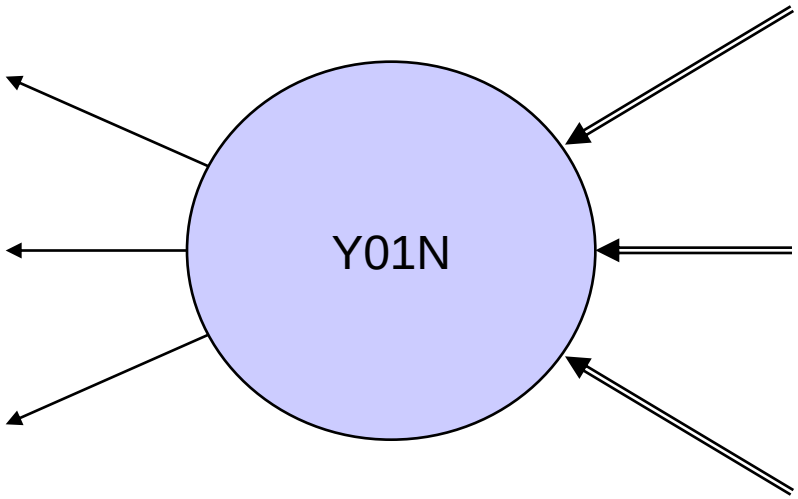
Citation analysis

Backward citations (citations from nanotech patent applications)

- Linkage between scientific and inventive activities
- Influence of prior art on nanotechnology

Forward citations (citations to nanotech patent applications)

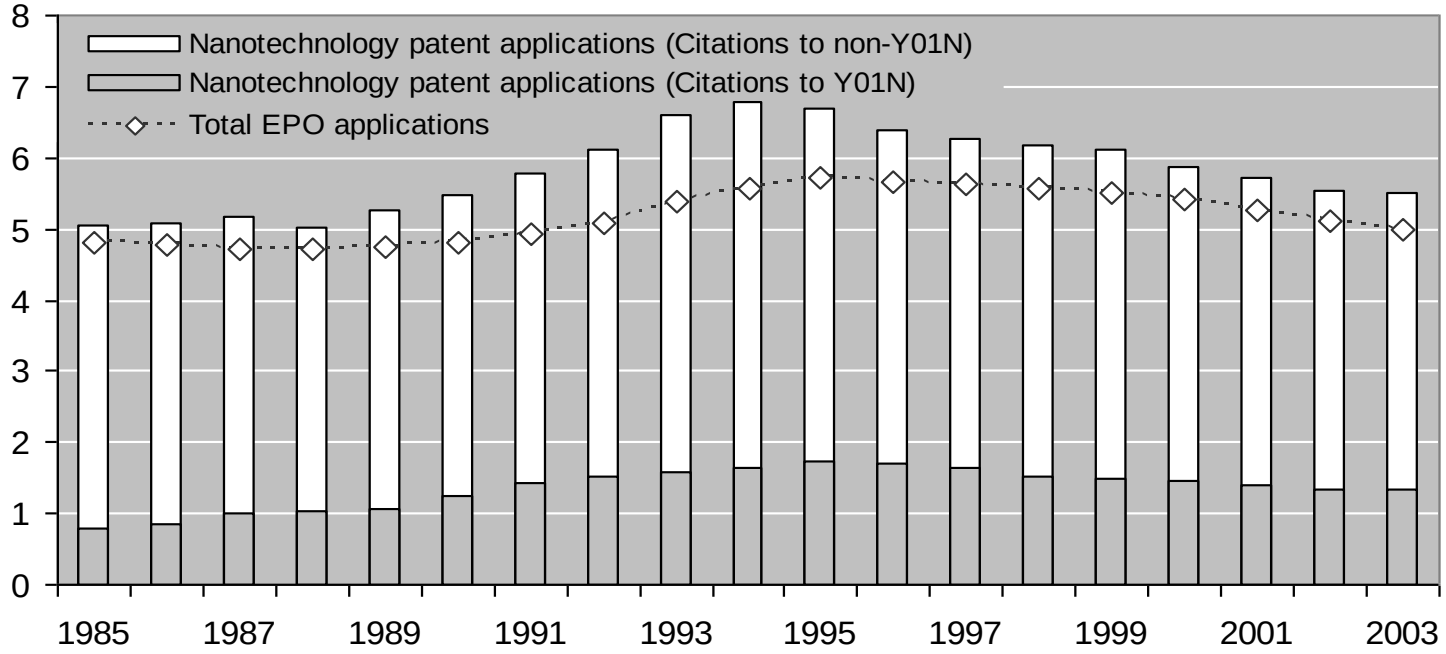
- Technological value
- Economical value
- Influence of nanotechnology on successive inventions

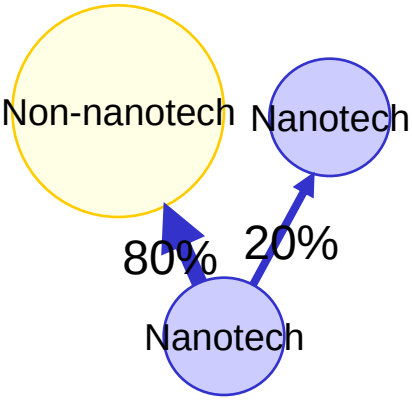


Role of cumulative knowledge in traditional technologies

- Knowledge base of nanotechnology comes from non-nanotechnology patent applications.

Average backward citations per nanotechnology patent application and total EPO application





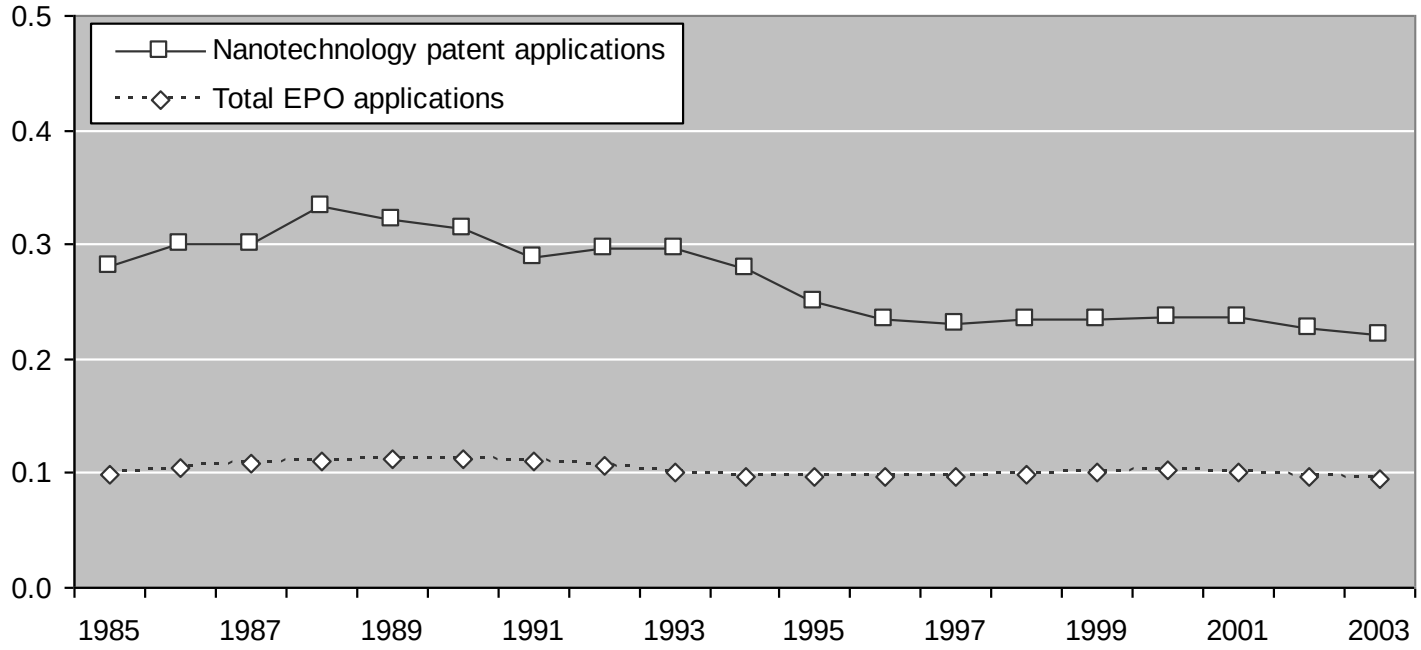
Note: Patent counts are based on the earliest priority date. Figure shows three years' moving average.

Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Science fuels the development of nanotechnology

- Science linkages in nanotechnology patent applications is larger than total EPO applications.

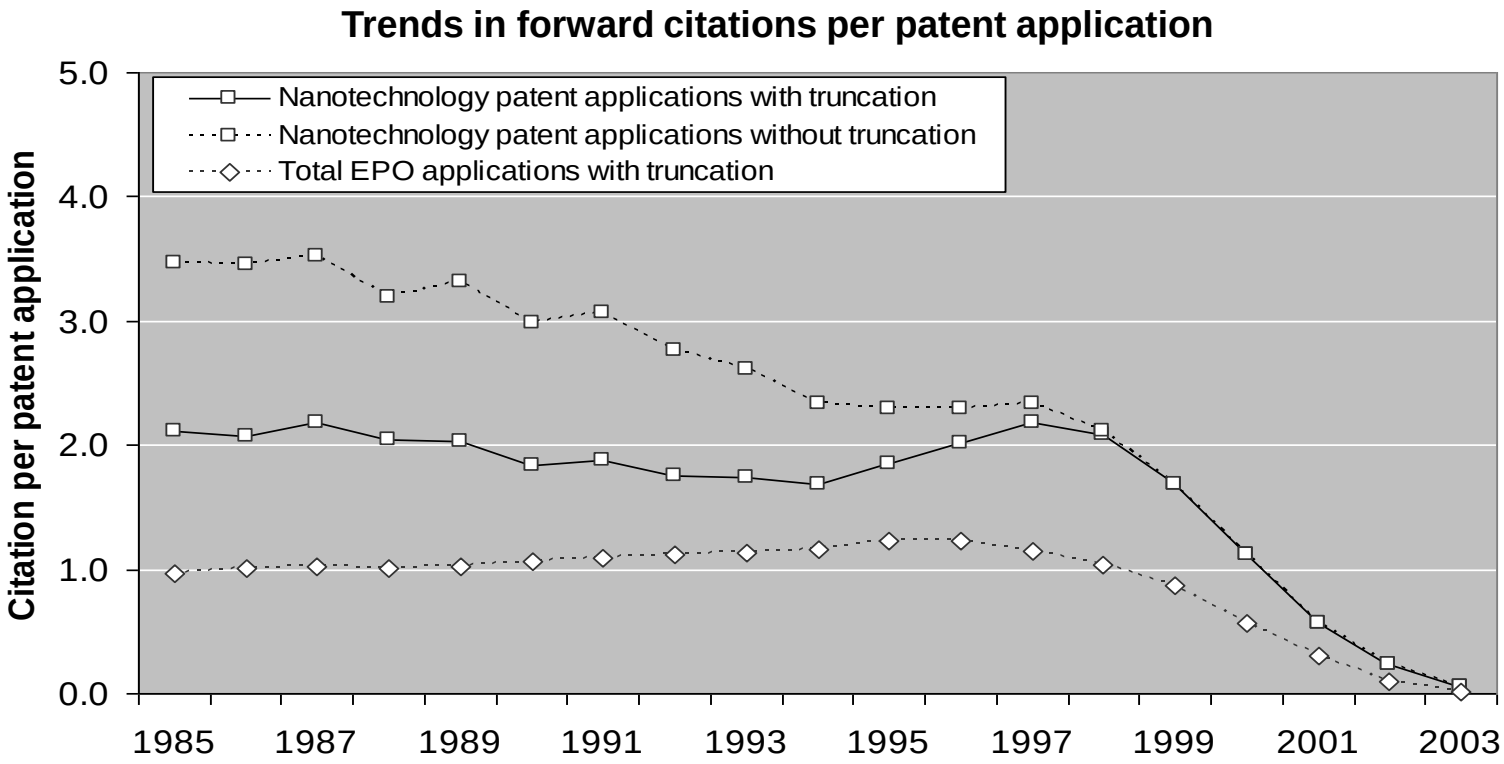
The ratio of NPL citations in the nanotechnology patent applications



Note: Patent counts are based on the earliest priority date. Figure shows three years' moving average.
Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Technological/economical value of nanotechnology patent applications

- Higher forward citations to nanotechnology patent applications suggest their high technological/economical values.



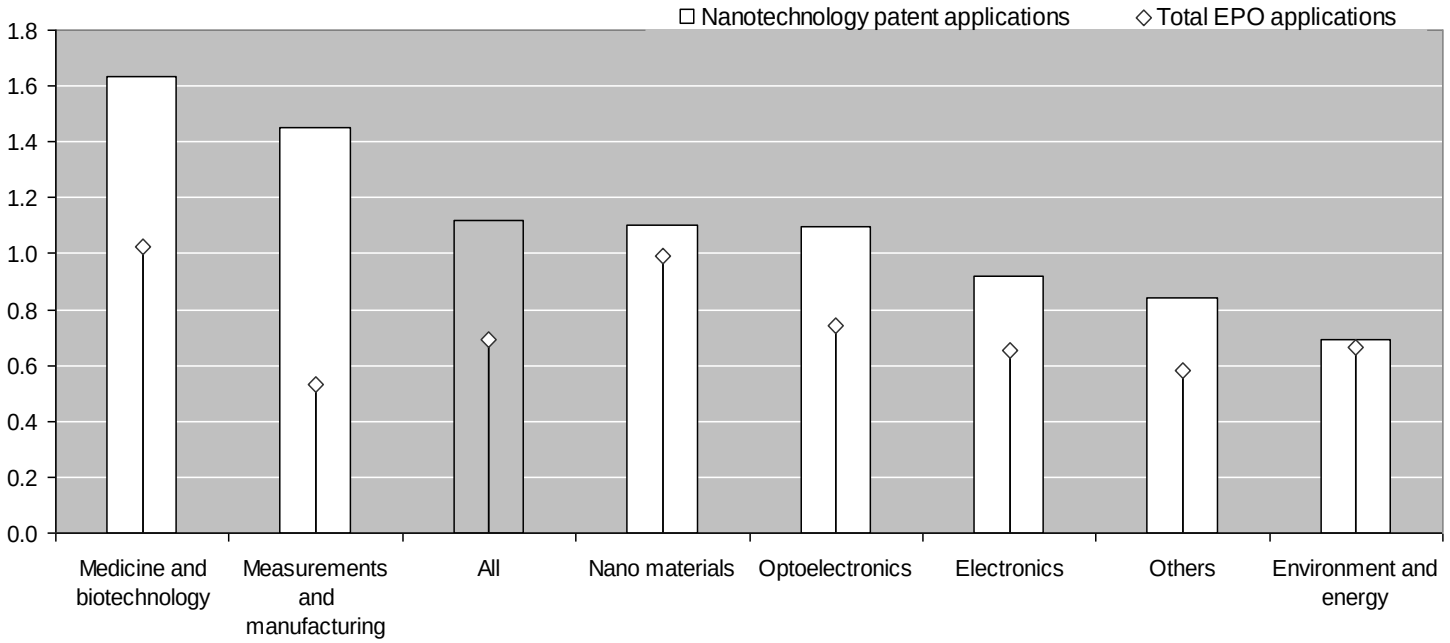
Note: Patent counts are based on the earliest priority date. Forward citations received within five years from priority year are counted. Figure shows three years' moving average.

Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Technological/economical value of nanotechnology patent applications

- Notably high citations to nanotechnology related to “Measurements and manufacturing” rationalise its important roles in the development of nanotechnology.

Average forward citations per patent application in nanotechnology (1995-2003)



Note: Patent counts are based on the earliest priority date. The application field of a patent is identified based on the main IPC. No truncation in the period of forward citations

Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Conclusions

- Inventive activities in nanotechnology have been gathering momentum from the end of 1990s.
- Nanotechnology is a set of technologies on the nanometre scale rather than a single technological field.
- Higher education and government sectors are important knowledge sources.
- Science fuels nanotechnology.
- High forward citations to nanotechnology patent applications suggest their high technological/economical values.

- Two kinds of nanotechnologies co-exist.
  - Top-down/Bottom-up

Top-down/Bottom-up nanotechnologies

- Top-down nanotechnologies
  - The majority of nanotechnologies, especially nanotechnologies related to “Electronics” and “Optoelectronics”, are seemingly realised by a top-down process.
  - Mutual interactions among these top-down nanotechnologies appear to be weak, because they are usually pushing the technological frontier of their own.
  - Thanks to cumulative knowledge so far. The top-down nanotechnologies would have social and economical impacts in the short and medium term.
- Bottom-up nanotechnologies
  - Intense efforts to develop the bottom-up nanotechnologies, e.g. “Nano materials”, are being conducted in the past decade.
  - It will take a while until bottom-up nanotechnologies have social and economic impacts.

Implications for statistics and measurement of nanotechnology

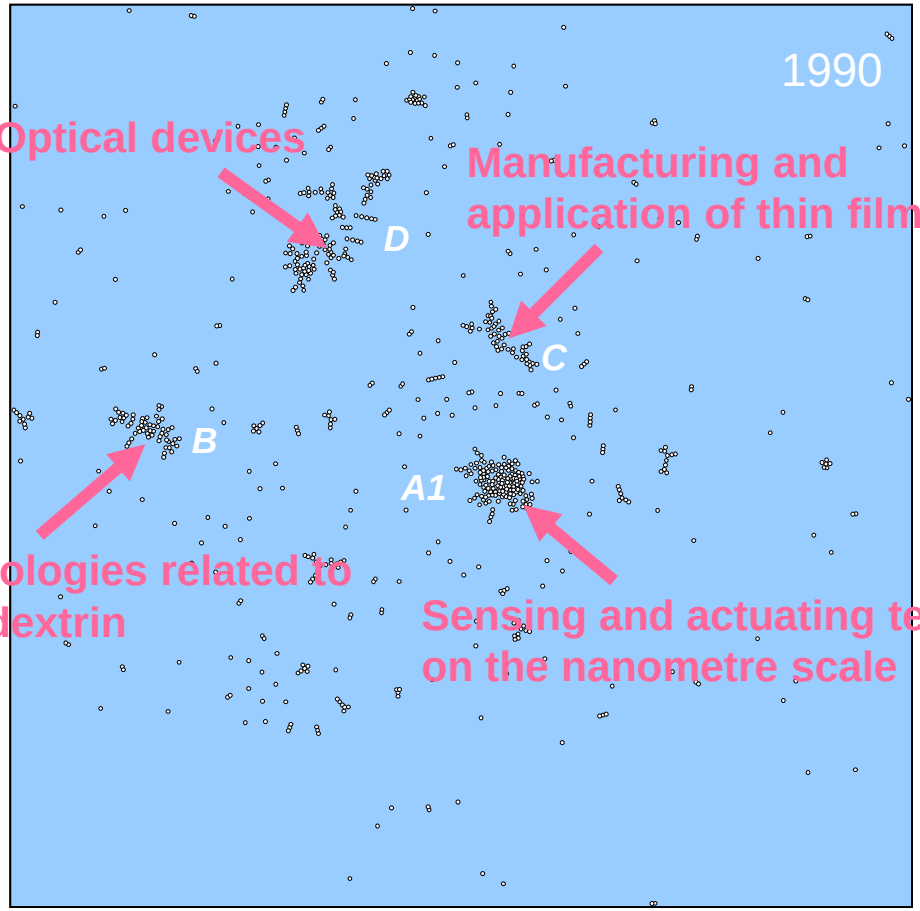
- Recent progress of patent database opens a way to analyse the nature of nanotechnology.
  - Trends of inventive activities in nanotechnology (total or by application field)
  - Comparative strength of countries
  - Source of knowledge (Sectoral distribution of applicants)
  - Role of cumulative knowledge (Ratio of non-nanotechnology patent applications in backward citations)
  - Role of science (Ratio of non-patent literature in backward citations)
  - Technological/economical value (Forward citations)

- But…

Implications for statistics and measurement of nanotechnology

- No unified guideline to select nanotechnology patent applications.
  - This study applied Y01N. But the USPTO created class 977 and the JPO created ZNM. And there are many analyses based on different strategies to select nanotechnology patent applications.
- Wide range of applications.
  - Nanotechnology statistics and measurement strongly depend on the selection of technologies.
  - Application field's level analyses would be desirable to measure characteristics of nanotechnology precisely.
    E.g. "Nano-electronics" vs. "Nano-biotechnology"
- And furthermore, nanotechnology has been…

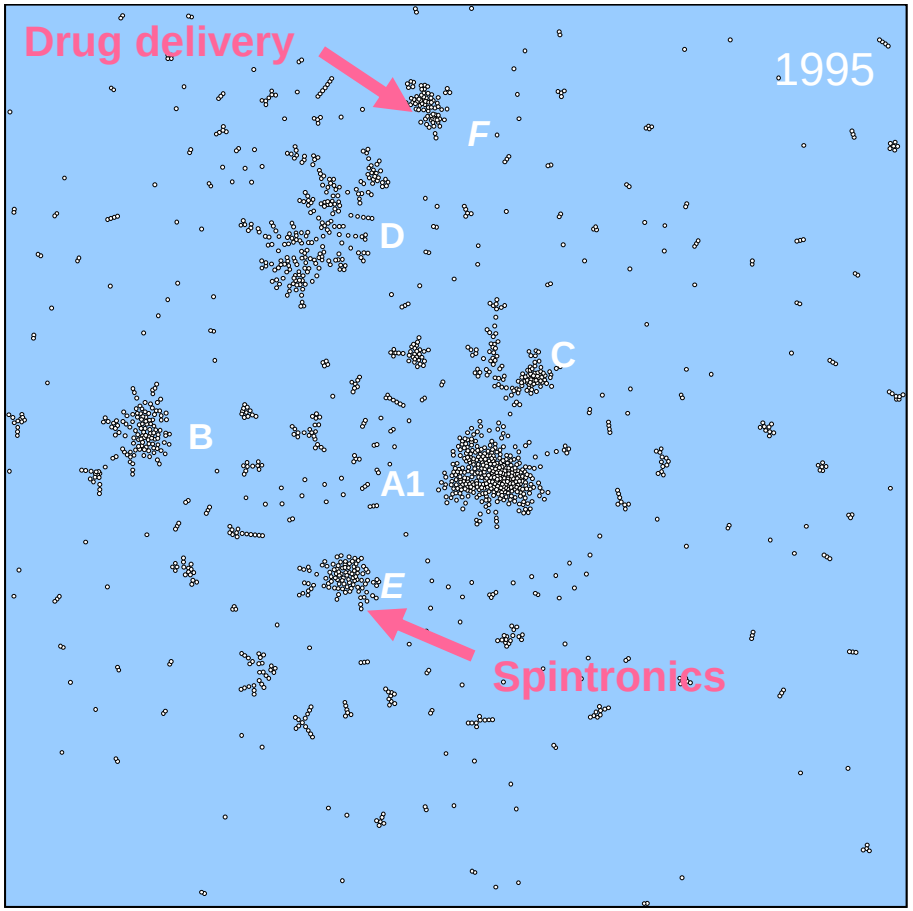
Nanotechnology in 1990



- A Circle shows a patent application.
- Patent applications linked by citations localise.
- Direction of a citation is not considered.

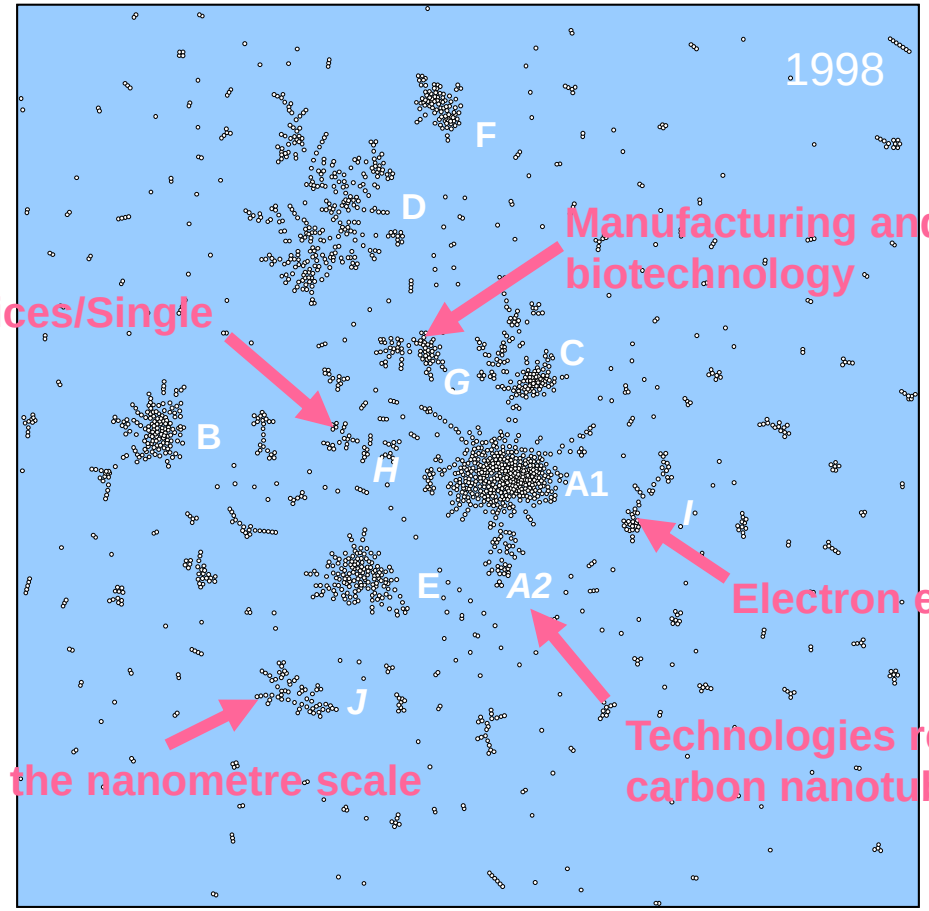
Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Nanotechnology in 1995



Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

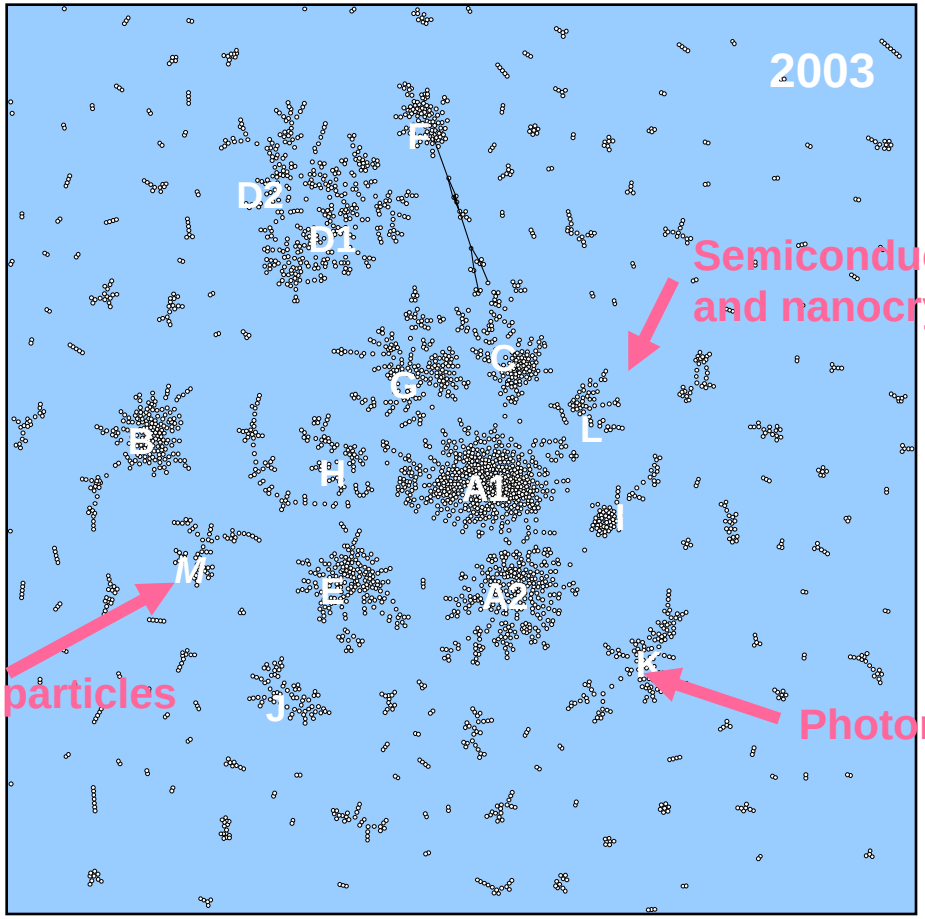
Nanotechnology in 1998



Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Nanotechnology in 2003

- Continuous nucleation and development of technologies



Semiconductor nanoparticles and nanocrystals

Application of nanoparticles as pigments

Photonic crystals

Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Implications for statistics and measurement of nanotechnology

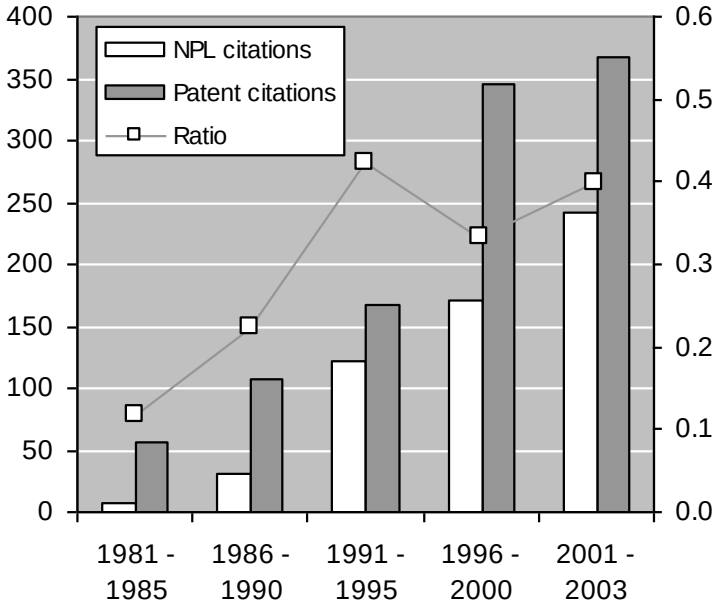
- No unified guideline to select nanotechnology patent applications.
  - This study applied Y01N. But the USPTO created class 977 and the JPO created ZNM. And there are many analyses based on different strategies to select nanotechnology patent applications.
- Wide range of application.
  - Nanotechnology statistics and measurement strongly depend on the selection of technologies.
  - Application fields level analyses would be desirable to measure characteristics of nanotechnology precisely.
    E.g. “Nano-electronics” vs. “Nano-biotechnology”
- And furthermore, nanotechnology has been evolving over time!
  - The development of statistics should be forward-looking and have a certain degree of flexibility along with the development of nanotechnology.

Impacts of science on inventive activities

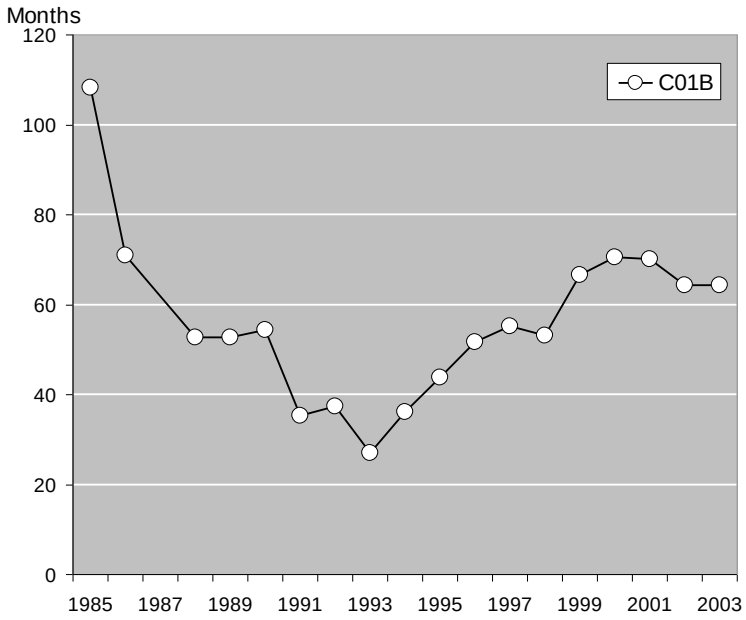
- Scientific activities have crucial roles in knowledge creation and flow in nanotechnology.

  e. g. Nanotechnology patent applications in C01B (Carbon nanotubes)

Trends of patent citations and NPL citations in the nanotechnology patent applications



Trends in time-lags between successive inventions

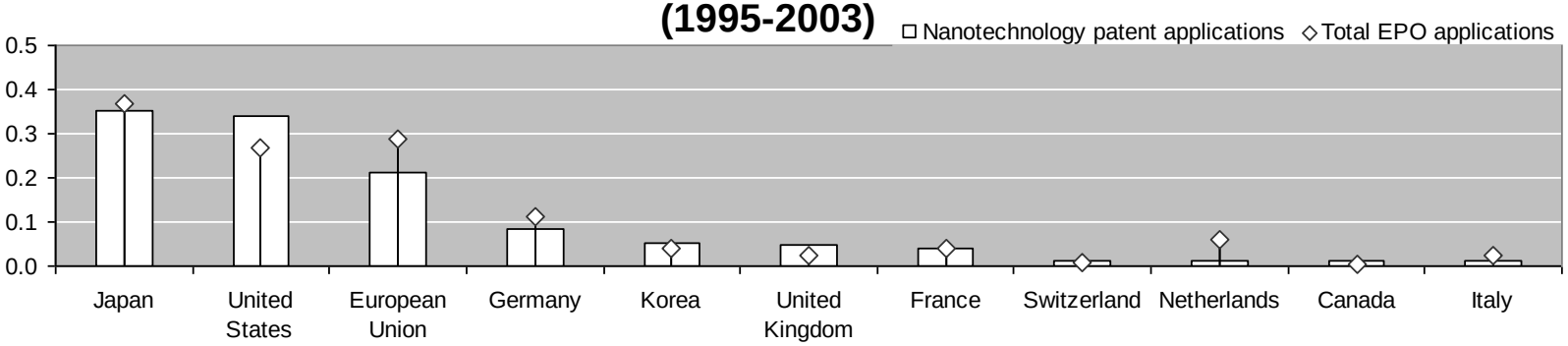


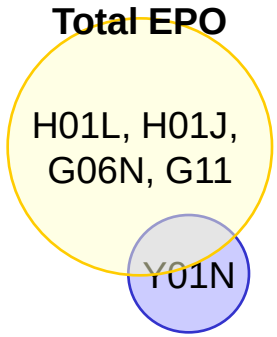
Note: Patent counts are based on the earliest priority date and the main IPC. Time-lags show three years' moving average.
Source: OECD, EPO citations database September 2006 and OECD, Patent Database, September 2006, based on a list of patents selected by the EPO.

Role of cumulative knowledge

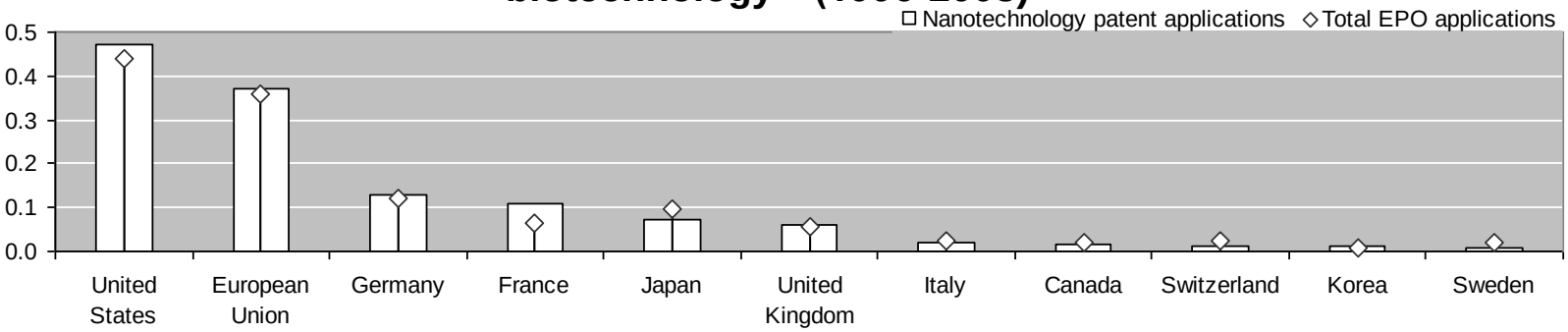
- Current development of nanotechnology likely relies on existing technologies and cumulative knowledge is crucial in its development.

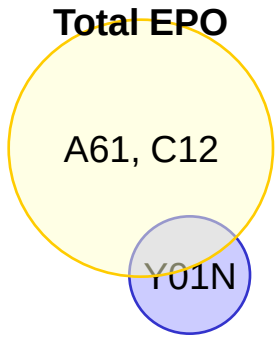
Countries' share in nanotechnology patent applications related to "Electronics" (1995-2003)





Countries' share in nanotechnology patent applications related to "Medicine and biotechnology" (1995-2003)





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