RESEARCH ARTICLE OPEN ACCESS

An Economics of Nano technology: The relative importance of Governmental funding and filing of patent applications

Dr Debasis Patnaik, Mr KVS Raxit
(Assistant Professor, Department of Economics, BITS-Pilani, K K Birla Goa Campus)
(Research Scholar, Department of Economics, BITS-Pilani, K K Birla Goa Campus)

Abstract:
The non technology applications are taking the business applications are increasing. Private activities coupled with governmental funding bestows competitive advantage on nations. Unless India gears up fast and quick it would lose yet one more business race especially in the context of liberation, globalization and privatization reforms that it has entered.The nanotechnology patent applications published in different countries'/regions' patent offices have been evaluated by using the esp@cenet ''worldwide'' database. A longitudinal analysis is done on nanotechnology patent applications data from 1991-2008. Indian data and contributions are revealed as sparse. Semiconductor devices; electric solid state devices not otherwise provided for'' (H01L) ranked first, followed by ''Preparations for medical, dental, or toilet purposes'' (A61K).

Keywords: Nano technology, world- wide patent offices, patent filing, government funding

I. Introduction

The emerging fields of nano-scale science, engineering, and technology reveal the ability to work at the sub molecular level to create large structures with fundamentally new properties and functions in biological and engineering sciences and bring competitive advantages. The worldwide nanotechnology research and development (R&D) investment reported by government organizations has increased approximately seven-fold in the last six years (Table 1 and Figure 1), from $432 million in 1997 to about $3,000 million in 2003. At least 30 countries have initiated national activities in this field. The worldwide annual industrial production in the nanotechnology sectors is estimated to exceed $1 trillion in 10 - 15 years from now, which would require about 2 million nanotechnology workers.

There is a paucity of literature on the problematic of the business aspect so nono structures. Kathyrn L A (2009) in 'Constructing Nano-Business: The Role of Technology Framing of a Commercial Domain' is a venture capital study drawn on 7year semi structured and website archival data, participant observation of nano tech investing conferences and case study of three VC firms**.** A socio semiotic space is introduced to reflect on the three activities to explain the process through which technology proponents project a business frame to support the commercialization of science-based technologies. The findings provide knowledge that can assist business people and policy makers seeking to develop science based technologies. Knol (2004) in 'Nano technologies and business opportunities' discussed opportunities in terms of tools and degrees of uncertainties.

II. Methodology and Data Base:

The nanotechnology patent applications published in different countries'/regions' patent offices have been evaluated by using the esp@cenet ''worldwide'' database. A longitudinal analysis is done on nanotechnology patent applications data from 1991-2008.

Three types of analyses were conducted using the data collected from the previous components:

– Longitudinal evolution of the number of patent publications per year and per applicant (i.e., the institution to which a patent is assigned to countries, applicant institutions, and technology fields)

– Topic analysis, where we have created content maps to identify the most important and emerging research topics in nanotechnology domain in different time intervals for each patent office (repository).

– Patent family analysis across different patent offices (repositories) including ranking those with the largest numbers of equivalent patent applications.

III. Analysis:

Table 1 (6/2003). Estimated government nanotechnology R&D expenditures in 1997-2003 (in $ millions/year). Explanatory notes: "W. Europe" includes countries in EU and Switzerland; the rate of exchange $1 = 1.1 Euro until 2002; and $1 = 0.9 Euro in 2003; Japan rate of exchange $1 = 120 yen in 2002; "Others" include Australia, Canada, China, Eastern Europe, FSU, Israel, Korea, Singapore, Taiwan and other countries with nanotechnology R&D; ( )* A financial year begins in USA on October 1 of the previous calendar year, six months before in most other countries. ( )** denotes the actual budget recorded at the end of the respective fiscal year. Estimations use the nanotechnology definition as defined in NNI (Roco et al., 2000; this definition does not include MEMS), and include the publicly reported government spending.

Table 1. Worldwide government funding for nanotechnology R&D (June 2003)

Region	1997	1998	1999	2000	2001	2002	2003
W. Europe	126	151	179	200	~225	~400	~650
Japan	120	135	157	245	~465	~720	~800
USA	116	190	255	270	465	697	774
Other	70	83	96	110	~380	~550	~800
Total (% of 1997)	423 100%	559 129%	687 159%	825 191%	1,535 355%	2,367 543%	3,024 700%

Thus the United States has initiated a multidisciplinary strategy for development of science and engineering fundaments through the National Nanotechnology Initiative announced in January 2000. The vision-setting and collaborative model of National Nanotechnology Initiative has received international acceptance. After 2001, virtually all developed countries have national activities in this area. Japan and Western Europe have broad programs backed by government, combining academic and industry led R&D, and their current plans look ahead to four to five years. Other countries have encouraged their own areas of strength, several of them focusing on fields of the potential markets. For illustration, Korea has allocated about $10 million per year for the next ten years in nanoelectronics memory chips (this is one of the projects summing about $200 million per year in 2003 from government funding). Australia has identified nanoscale photonics as a focused area of government investment. Russia and Ukraine maintain research activities establish in 1990s, especially on advanced materials synthesis and processing. Emerging programs have been announced in Eastern Europe. In Asia Pacific, there are growing programs in Japan, China, South Korea, Taiwan and Singapore. In North America, Canadian National Research Council has created the National Institute of Nanotechnology in Edmonton, Alberta with $80 million funding for five years. In Mexico there are about 20 research groups, which are working independently. Differences among countries are observed in the research domain they are aiming for, the level of program integration into various industrial sectors, and in the time scale of their R&D targets. Several countries (beginning with Japan, Korea and China) have adopted coordinating offices at the national level similar to the National Science and Technology Council (NSTC) in the US. Nanotechnology is growing in an environment where international interactions accelerate in science, education and industrial R&D. A global strategy of mutual interest is envisioned by connecting individual programs of contributing countries, professional communities, and international organizations. International activities and agreements have increased in importance. Examples are the agreements are between NSF (US) and EC (EU), NSF (US) and Japan, APEC, Russia and China, the states of New York (US) and Quebec (Canada). For example, NSF and EC have organized periodical workshops (four workshops are held in 2002 on: Manufacturing at the Nanoscale, Revolutionary Opportunities of Nanotechnology and Societal Implications, Tools for Measurements and Manufacturing, and Materials) and sponsored a joint program solicitation for proposals.

The United States fiscal year 2004 funding request for nanoscale science, engineering and technology (noted in brief - nanotechnology) research and development (R&D) in ten federal departments and independent agencies is summarized in Table 2 (http://nano.gov). It emphasizes long-term, fundamental research aimed at discovering novel phenomena, processes, and tools; addressing NNI Grand Challenges; supporting new interdisciplinary centers and networks of excellence including shared user facilities; supporting research infrastructure; and addressing research and educational activities on the societal implications of advances in nanoscience and nanotechnology.

Table 2 (6/2003). Contribution of key agencies to NNI

Federal Department or Agency	**FY 2000 Actual ($M)**	**FY 2001 Actual ($M)**	**FY 2002 Actual ($M)**	**FY 2003 Actual ($M)**	**FY 2004 Actual ($M)**
National Science Foundation	97	150	204	221	249
Dept. of Defense	70	125	224	243	222
Dept. of Energy	58	88	89	133	197
Nat'l Institutes of Health	32	40	59	65	70
National Institute of Standards and technology (NIST)	8	33	77	69	62
National Aeronautics and Space Administration (NASA)	5	22	35	33	31
Environmental Protection Agency (EPA)	—	6	6	6	5
Homeland Security (TSA)	—	—	2	2	2
Department of Agriculture (USDA)	—	1.5	0	1	10
Department of Justice (DOJ)	—	1.4	1	1	1
TOTAL	**270 100%**	**465 172%**	**697 258%**	**774 287%**	**849 314%**

Nanoscale science and engineering R&D is mostly in a precompetitive phase (the major applications are typically expected to come after five years and are not yet well defined), and there are good win-win partnering and effort-sharing opportunities. International collaboration in fundamental research, long-term technical challenges, metrology, education and studies on societal implications will play an important role in the affirmation and growth of the field.

Some Figures about Nanotechnology R&D in Europe and Beyond

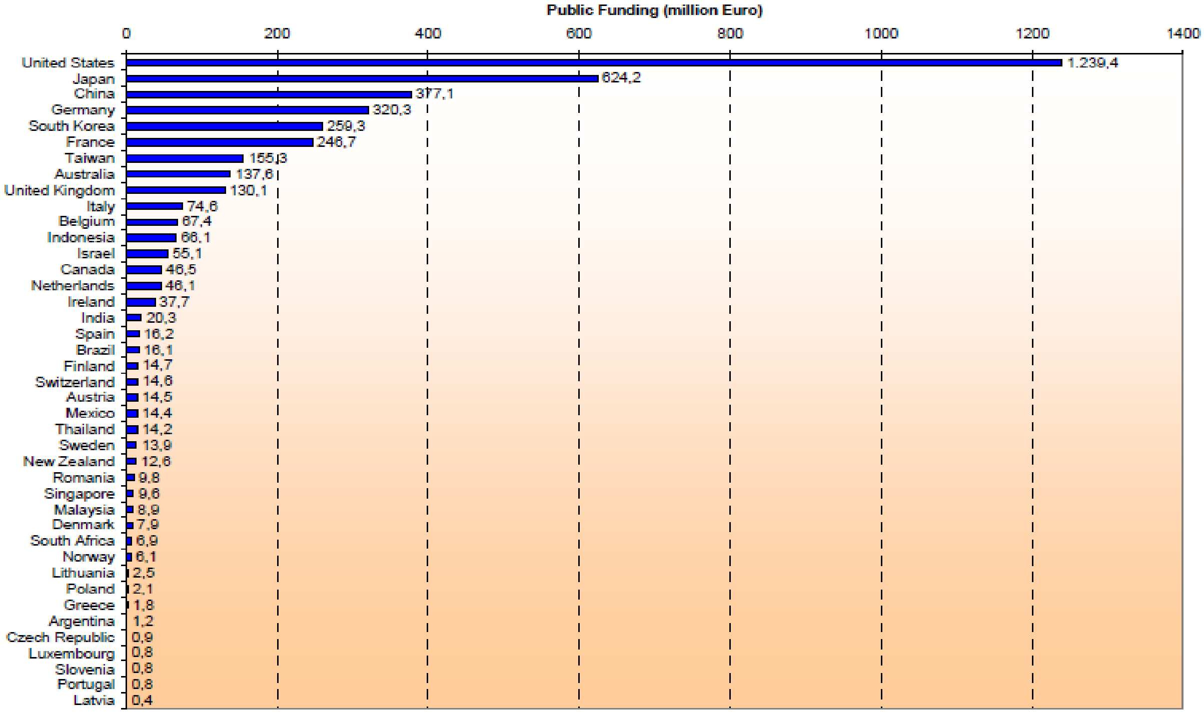
A) Funding for nanotechnology R&D in Europe and worldwide

Country	Funding (€)	Country	Funding (€)
European Union		**Third Countries**	
Austria	13,1[i]	Argentina	0.4[ii]
Belgium	60,0*[iii]	Australia	62[iv]
Czech Republic	0,4[v]	Brazil	5.8[vi]
Denmark	8,6[vii]	Canada	37.9[viii]
Finland	14,5[ix]	China	83.3[x]
France	223,9[xi]	India	3.8[xii]
Germany	293,1[xiii]	Indonesia	16.7[xiv]
Greece	1,2*[xv]	Japan	750[xvi]
Ireland	33,0[xvii]	Malaysia	3.8[xviii]
Italy	60,0*[xix]	Mexico	10[xx]
Latvia	0,2*[xxi]	New Zealand	9.2[xxii]
Lithuania	1,0[xxiii]	Singapore	8.4[xxiv]
Luxembourg	0,8[xxv]	South Africa	1.9[xxvi]
Netherlands	42,3[xxvii]	South Korea	173.3[xxviii]
Poland	1,0*[xxix]	Taiwan	75.9[xxx]
Portugal	0,5*[xxxi]	Thailand	4.2[xxxii]
Slovenia	0,5*[xxxiii]	USA (Federal)	910[xxxiv]
Spain	12,5[xxxv]	USA (States)	333.3[xxxvi]
Sweden	15,0[xxxvii]	**Third Countries Total**	**2,490**
United Kingdom	133,0[xxxviii]		
EU-25 Total	**915**		
EC	**370**		
Candidate Countries and Associated States			
Israel	46[xxxix]		
Norway	7[xl]	**Total EU**	**1,285**
Romania	3.1[xli]	**Total EU + CC + AS**	**1,360**
Switzerland	18.5[xlii]	**World Total**	**3,850**
CC & AS Total	**75**		

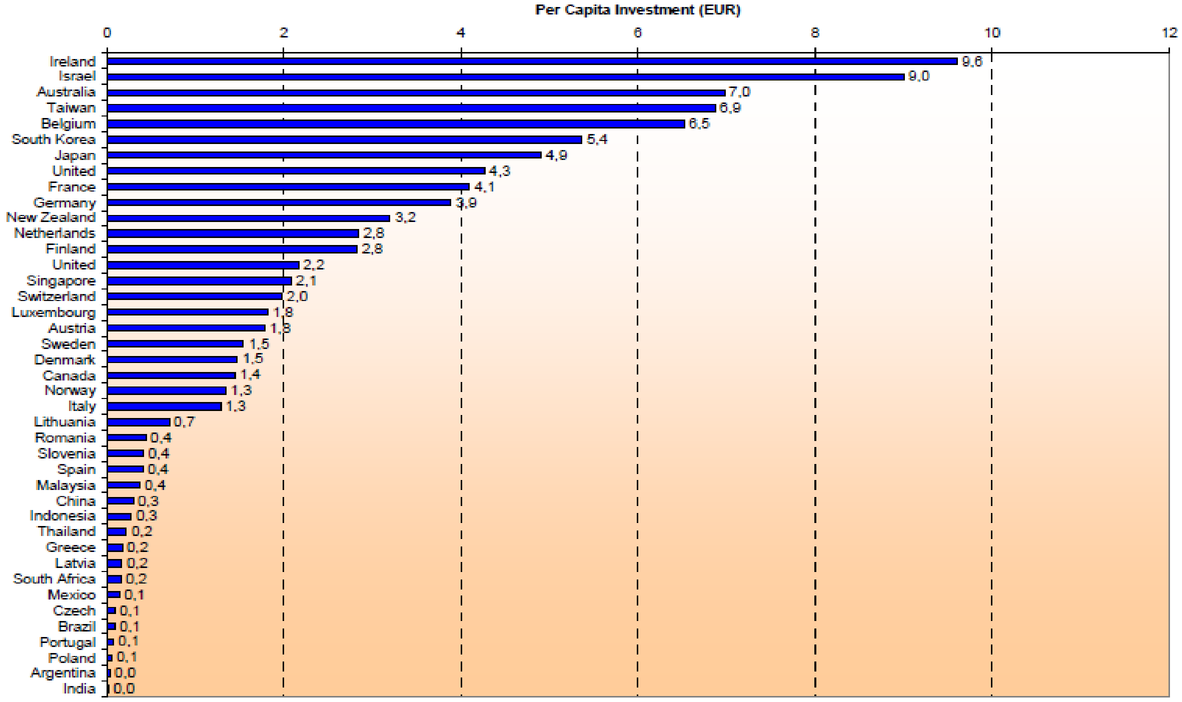
Table 1: Estimated worldwide public funding for nanotechnology R&D in 2004
Source: European Commission, 2005 and various sources indicated by superscripted

references. Data are unavailable for Cyprus, Estonia, Hungary, Iceland, Liechtenstein, Malta, Slovakia and Turkey. Data indicated with * are taken from 2003.

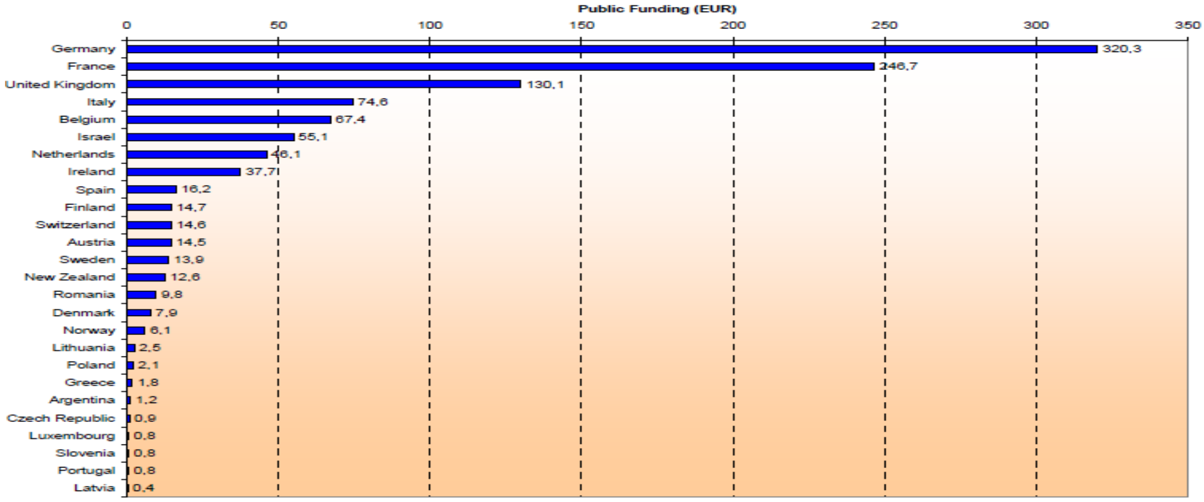
Figure 1:Absolute world public expenditure in 2004(PPP corrected)



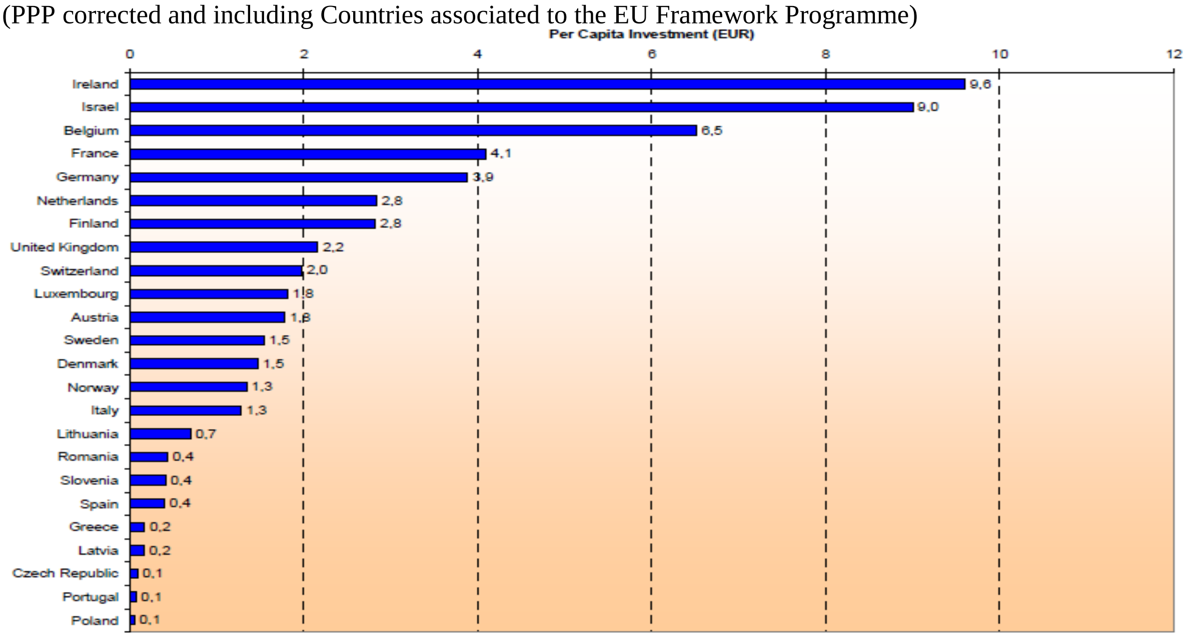
World Per capita Public Expenditure in 2007 (PPP corrected)



EU absolute public expenditure in 2004
(PPP corrected and including Countries associated to the EU Framework Programme)



EU per capita public expenditure in 2004
(PPP corrected and including Countries associated to the EU Framework Programme)

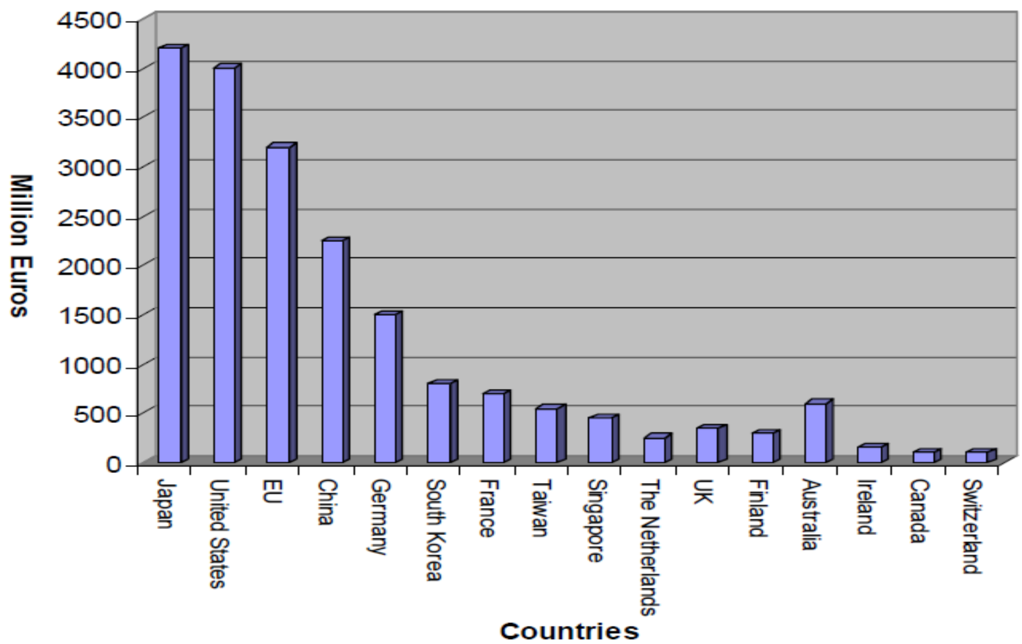


GOVERNMENT FUNDING IN NANOTECHNOLOGY 2006-2010

Japan is likely to overtake the United States in terms of government funding for nanotechnology over the next few years. However, if State funding was added to the USA total then it would lead all countries by a comfortable margin. In Europe, the German yearly spend on nanotechnology far exceeds any other country and is roughly the same as all other European countries combined at around €330milllion per year.

The EU Seventh Framework Programme will be contributing approximately €600million per year until 2013; therefore as a whole, Europe has a larger yearly spend in nanotechnology than USA or Japan. Overall it would therefore seem that Europe compares favorably to other regions; however, Germany aside, no country has really embraced nanotechnology and its potential in the same manner as the USA and various Asia-Pacific countries.

Asia-Pacific governments are providing significant funds for nano-science and nanotechnology; and have generally embraced the area with greater enthusiasm than their European counterparts. Nanotechnology has been designated a national S&T key technology area by most Asia-Pacific governments, alongside materials, medicine, the environment and ICT; all areas which nano-science and nanotechnology underpin.



Projected Nanotechnology Funding Worldwide 2006-2010, in million euros

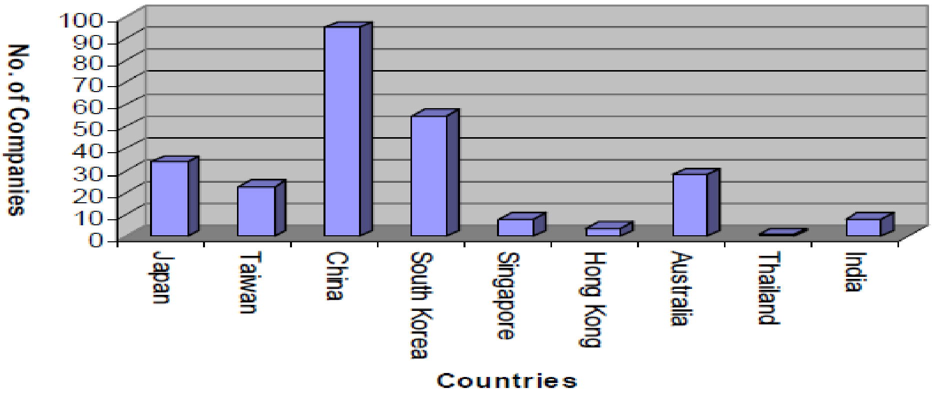
NANOTECHNOLOGY COMPANIES IN EUROPE

There are now over 300 nanotechnology companies in Europe (see figure) exploring the plethora of opportunities across various sectors, over a third of which are based in Germany. Germany and the United Kingdom lead the way in Europe in nanotechnology in terms of SME activity and big business investment. Germany especially is noticeable for the willingness of its indigenous companies to embrace the potential of nanotechnology. There are nanotechnology R&D activities at scores of German based multinationals including Infineon, Daimler Chrysler, Schott, Carl Zeiss, Siemens, Osram, BASF, Bayer and Henkel.

NANOTECHNOLOGY COMPANIES IN ASIA-PACIFIC

There are now over 250 nanotechnology companies in Asia-Pacific (see figure) exploring the plethora of opportunities across various sectors, over a third of which are based in China; although most of the Chinese companies are re-branded chemicals companies.

Japan, Taiwan and South Korea lead the way in terms of incorporating nanotechnology into products and processes. These countries are notable for the willingness of their indigenous companies to embrace the potential of nanotechnology (much like Germany in Europe). There are nanotechnology R&D activities at scores of Japanese and Korean based multinationals including Samsung, LG, Hitachi, Nikon and Fujitsu.



Nanotechnology companies in Asia-Pacific 2007

Analysis method of patent applications for nano:

Data collection and pre-processing

Nanotechnology publications from different countries'/ regions' patent offices (repositories) were extracted from the esp@cenet ''worldwide'' database into our database by using keyword ''title–abstract'' searching.

A patent office is a governmental or intergovernmental organization which controls the issue of patents. Different countries have their own patent offices, such as the USPTO, the JPO, the Canadian Intellectual Property Office (CIPO), and the South Korean Intellectual Property Office (KIPO). In addition to national (country level) patent offices, there are several regional (country group level) patent offices as well, such as the EPO and the World Intellectual Property Organization (WIPO). The EPO grants European patents for the 27 member states of the European Patent Convention. The WIPO is a specialized agency of the United Nations with 184 member states in 2008. It grants patents for all of its member states. Many countries publish patent applications and/ or grant patent rights for public information (Chemical Abstracts Service 2008).

A reliable international database covering patent information from multiple patent offices is the esp@ cenet ''worldwide'' database, which is maintained by the EPO together with the member states of the European Patent Organization. Esp@cenet includes three databases:
– ''EPO'' database
– ''WIPO'' database
– ''worldwide'' database

The esp@cenet ''worldwide'' database contains the patent applications examined and published by 85 individual countries'/regions' patent offices, including the USPTO, EPO, and JPO. The esp@cenet ''worldwide'' database holds more than 60 million patents (Espacenet Website, ''Coverage of the worldwide database'') (Espacenet Website, ''Coverage of the worldwide database'') (EPO 2008). English translations for all other languages are provided for the bibliographic information, and selected content information (such as abstract, claim, and description) are also provided. Owing to the limitation of the search functions of esp@cenet, we collected the patent applications by searching the nanotechnology keywords only in each patent application's title and abstract (''title–abstract'' search).

The esp@cenet ''worldwide'' database previously has been used to examine patents in biology (Oldham and Cutter 2006), hydrogen and fuel cells (Seymour et al. 2007), and globalization of knowledge (Andersen et al. 2006).

Patent parsing

Two sets of patent information were parsed into our database from the collected patent applications:
– Nanotechnology patent applications published in different countries'/regions' patent offices (repositories)
– Patent family information of these patent applications.

Table 1 shows the data field limitation of our patent application collection. Most of the data fields are available in the esp@cenet ''worldwide'' database.

Table 1 Data field limitation of the *esp@cenet* "worldwide" database

Data field	Available
Publication number	Yes
Publication date	Yes
Inventor name	Yes
Applicant institution name	Yes
Applicant country	*
International patent classification code (IPC)	Yes
European patent classification code (EPC)	*
Citation information	No
Priority number(s)	Yes
Title	Yes
Abstract	Yes
Claim	*
Description	*

* The patent application data from some countries/regions' patent offices is incomplete

However, it does not contain the citation information for patent applications published in patent offices other than EPO and WIPO (Espacenet Website, ''What is a cited document?''). For some regional or country patent offices, the bibliographic data (such as the application country, European patent classification code (EPC), claim, or description) are incomplete. All the selected repositories in our study are part of EPO and WIPO.
A patent application for an invention is originally filed in one country; however, it can be filed later in other countries as well. The original, first application filing generally is considered to be the priority application (Hingley and Park 2003). In esp@cenet, such related applications or ''members of corresponding documents'' or ''equivalents'' and have exactly the same priority (Espacenet Website, ''Also published as documents'').
A patent family is a group of patents that are all related to each other. We use the esp@cenet patent ''simple family'' definition as comprising all the documents having exactly the same priority or combination of priorities (Espacenet Website, ''Patent families''). The International Patent Documentation Centre (INPADOC) defines as ''expanded family'' all the documents sharing directly or indirectly (e.g., via a third document) at least one priority (Espacenet Website, ''Patent families'').

IV. Results

We collected the nanotechnology patent applications published from 1991 to 2008 from the esp@cenet ''worldwide'' database. We focused attention on the leading 15 country/regional patent offices that cover more than 98% of the whole collection; each has more than 100 patent applications.

Global increase of nanotechnology patents

The evolution of the total number of nanotechnology patent applications in the 15 repositories per year from 1991 to 2008 is shown in Fig 1. This figure also shows the number of non-overlapping nanotechnology patent applications by considering one patent application per family. The annual rate of increase for all the patent publications is more pronounced between 2000 and 2008 (34.5%). This rate is higher than that of Science Citation Index's article publication rate of 20–25% for the same period when we use the same keyword ''title–abstract'' search approach as for patent applications.
The percentage of nanotechnology patent application as compared to the total number of patent applications in all the technical areas is illustrated in Fig. 2.

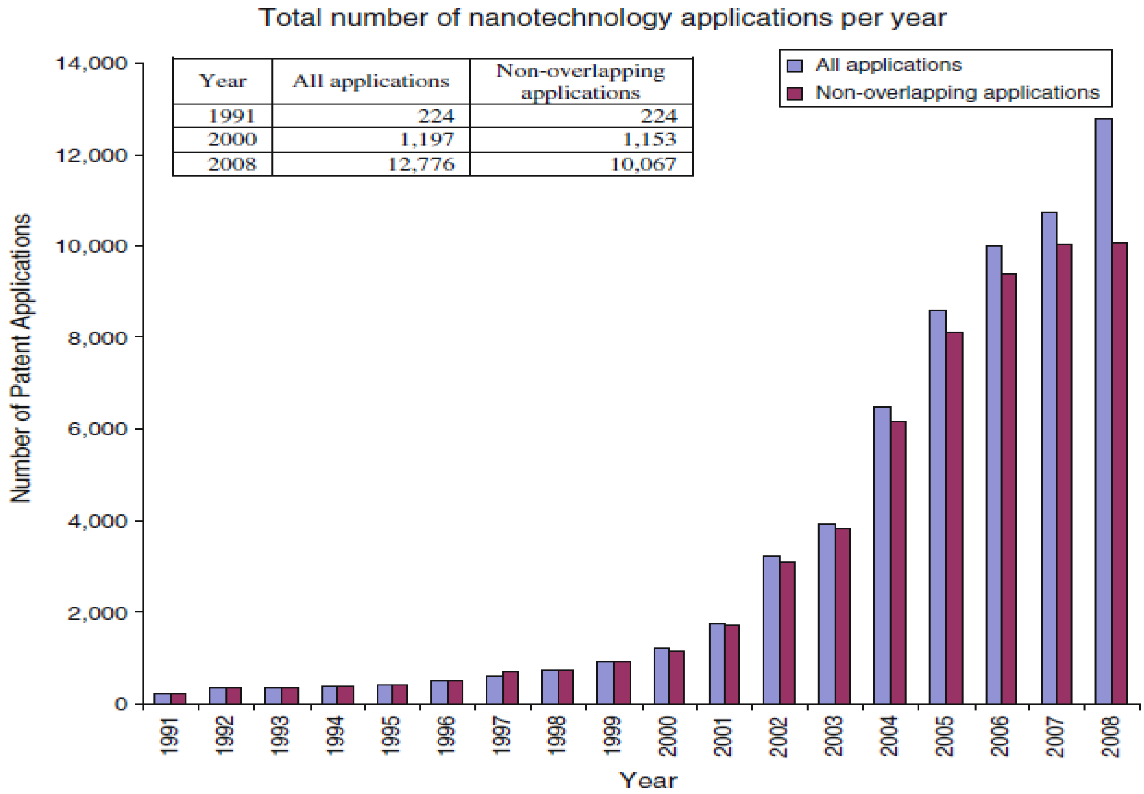


Fig. 1 Longitudinal evolution of the total number of nanotechnology patent applications in the 15 repositories per year (‘‘title abstract,’’ 1991–2008)

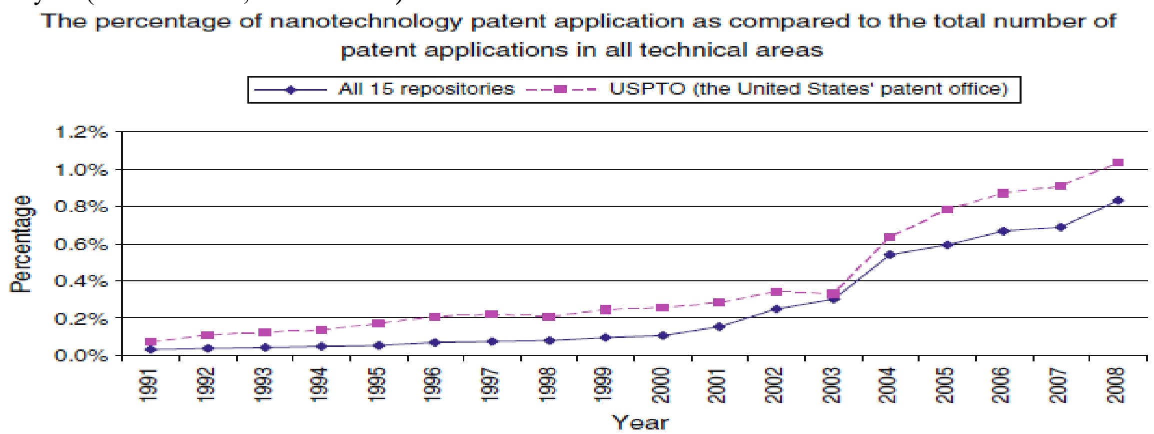


Fig. 2 Longitudinal evolution of the percentage of patent publications on nanotechnology versus all topics, in the repositories of leading 15 countries/regions and USA from 1991 to 2008 using keyword ‘‘title– abstract’’ search

The nanotechnology patent application percentages for the USPTO reported in the above figure are consistent with the data trends reported in previous studies (Huang et al. 2006; Hu et al. 2007) where the granted patents were searched by ‘‘title–claims’’ from 1991 to 2004. In that study, the percentage of granted patents reached 1.09% in 2004 versus 0.63% for patent applications in Fig. 2. Our previous studies also showed that the nanotechnology-granted patent percentages for ‘‘full-text’’ search was 4.85% in 2004 for the USPTO.

Number of patent applications per repository

Table 2 lists the numbers of nanotechnology patent applications published by each of the 15 countries/ regions' patent offices from 1991 to 2008. The USPTO examined and published the largest number of nanotechnology patent applications, followed by the patent offices of the PRC and Japan.

Rank	Patent office (repository)	No. of nanotechnology patent applications (1991–2008)	2000	2008
1	USA	19,665	405	3,729
2	PRC	18,438	105	5,030
3	Japan	10,763	328	1,744
4	South Korea	5,963	74	1,249
5	Canada	1,539	41	255
6	Taiwan	1,363	28	3
7	Germany	1,312	62	70
8	Australia	1,296	76	136
9	Russian Federation	859	45	162
10	Mexico	471	0	88
11	UK	412	14	68
12	France	390	8	38
13	Brazil	315	0	103
14	Ukraine	243	0	83
15	New Zealand	140	11	18

Table 2 Nanotechnology patent applications published in the top 15 countries/regions' patent offices in the interval 1991 to 2008 using keyword ''title–abstract'' search

The total number of nanotechnology patent applications published from 1991 to 2008 by authors from the US and PRC are estimated each at over 17,000. Over 20% of the US patent applications and 4% of the PRC's are in foreign repositories.

Figures 3 and 4 show the evolution of the numbers of nanotechnology patent applications published in different countries'/regions' patent offices by year. Since the patent offices of the US, PRC, Japan, and South Korea had many more nanotechnology patent applications, we present their evolution trends in Fig. 3. The evolution trends of the other 11 countries'/ regions' patent offices are shown in Fig. 4.

The patent offices of the US, PRC, Japan, and South Korea have significantly more nanotechnology patent applications than other patent offices, and all experienced larger increases especially after 2003. The PRC's repository surpassed the USA' repository after 2006. As shown in Fig. 4, the other 11 patent offices have experienced mostly increases but also decreased in recent years. The patent offices of the Russian Federation, Brazil, and the United Kingdom (UK) reached their peaks in 2008 with 162, 103, and 68 nanotechnology patent applications, respectively. The Ukraine's patent office peaked in 2007 with 87 nanotechnology patent applications, and the patent offices of Germany and New Zealand reached their peaks in 2006 with 164 and 21 nanotechnology patent applications, respectively. Canada's and Mexico's patent offices reached their peaks in 2005 with 274 and 94 nanotechnology patent applications, respectively. Australia's and France's patent offices peaked in 2003 with 343 and 57 nanotechnology patent applications, respectively. Taiwan's patent office had more than 200 nanotechnology patent applications per year from 2004 to 2007 with 2006 as the peak (343 applications); however, the number dropped dramatically in 2008 to only three nanotechnology patent applications probably due to a delay in collecting the 2008 Taiwan patent data by the esp@cenet ''worldwide'' database. In all following analyses, we used 2007 data for Taiwan's patent office instead of 2008.

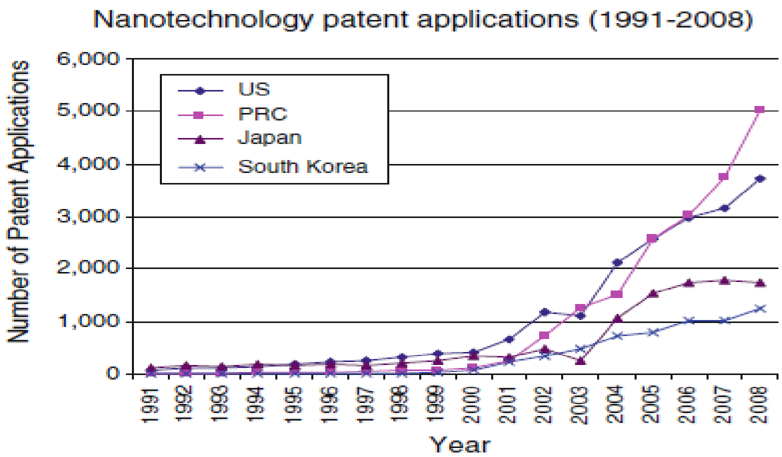


Fig. 3 The numbers of nanotechnology patent applications from all countries in the patent offices of the US, PRC, Japan, and South Korea using ''title–abstract'' search, from 1991 to 2008

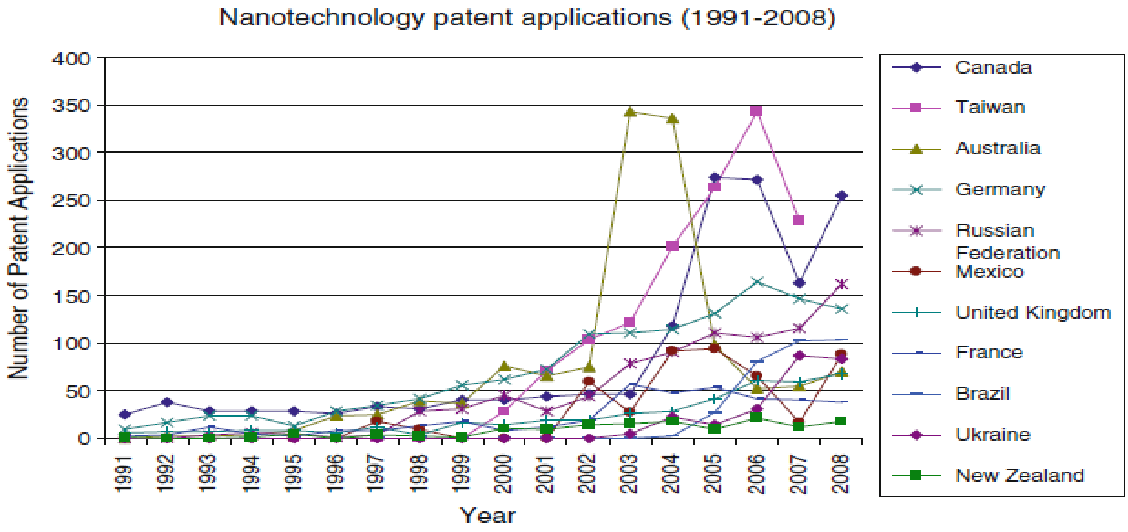


Fig. 4 The numbers of nanotechnology patent applications from all the countries in the remaining 11 patent offices using ‘‘title–abstract’’ search from 1991 to 2008.

Most patent offices generally publish the country of origin of the patent publications, with the exceptions of Japan, Australia, and New Zealand. Table 3 lists the top five countries where patent applications were filled from 1991 to 2008. For several of the other patent offices, a small portion of their patent applications may have incomplete applicant country information. In these cases, we manually verified the information. For each application having the applicant same as the inventor(s), we then used the country of the first inventor as its applicant country. As a comparison, we also list the numbers of nanotechnology patent applications published in 2000 (the year before the establishment of the US National Nanotechnology Initiative; Roco et al. 2000) and 2008 (the most recent year with data available for the whole year).

The USA was the most active internationally with the largest numbers of nanotechnology patent applicants published in other patent offices. It ranked first in three out of the 12 patent offices, including its own patent office, Canada’s, and Mexico’s patent offices; it ranked second in the patent offices of six other countries; and third in the remaining three patent offices. Japan, Germany, South Korea, and France are the most active internationally after the USA.

These results on country ranking generally are consistent with those reported in the previous study on granted patents at USPTO using ‘‘title–claims’’ search (Li et al. 2007), in which study the top five applicant countries of USPTO nanotechnology-granted patents published from 1976 to 2004 were the US (3,450 patents), Japan (517 patents), Germany (204 patents), France (156 patents), and South Korea (131 patents), with Taiwan being the seventh. In this study, the top five applicant countries identified were the US, Japan, South Korea, Germany, and Taiwan. However, the numbers of nanotechnology patent documents reported in this study are different from those reported by Li et al. (2007) due to three reasons. First, instead of using the granted patents as used by Li et al. (2007), we used the published patent applications as the data source in this study, because the esp@cenet ‘‘worldwide’’ database does not differentiate granted patents from published patent applications. Second, in this study involving 15 repositories we could not use the more complete ‘‘title/abstract/claims’’ used in previous study only for the USPTO. Third, our results are based on the data published from 1991 to 2008 while the numbers reported by Li et al. (2007) are based on the data published from 1976 to 2004. Many patent offices have published a large number of nanotechnology patents in recent years.

Table 3 shows that all the patent offices except those of Canada and Mexico had the largest numbers of nanotechnology patent applications published by applicants from their own countries. This indicates a ‘‘home advantage’’ effect. As defined in previous studies, the ‘‘home advantage’’ effect is the tendency of domestic applicants to file more patents with their home country patent office than foreign applicants (European Commission 1997; Ganguli 1998; Criscuolo 2005).

By comparing the numbers of nanotechnology patent applications published in 2000 and 2008, the tremendous increase in nanotechnology patent applications from each top applicant country can be easily perceived. Especially notable are the increases recorded by Mexico, Brazil, and Ukraine.

Table 3 Top five applicant countries in 12 countries/regions' patent offices based on the number of nanotechnology patent applications from 1991 to 2008

No.	Patent office/repository (no. of applications from all countries)	Rank	Applicant country	Number of nanotechnology patent applications (1991–2008)	2000	2008
1	USA (19,665)	1	USA	12,606	285	2,288
		2	Japan	1,866	42	308
		3	South Korea	1,272	6	343
		4	Germany	1,048	23	168
		5	Taiwan	839	7	175
2	PRC (18,438)	1	PRC	16,348	85	4,409
		2	USA	805	3	260
		3	South Korea	327	5	80
		4	Japan	301	2	64
		5	Germany	145	3	43
3	South Korea (5,963)	1	South Korea	4,087	41	967
		2	USA	461	15	151
		3	PRC	145	1	53
		4	Japan	138	4	39
		5	Germany	119	0	42
4	Canada (1,539)	1	USA	825	18	156
		2	Canada	192	4	28
		3	Germany	124	7	18
		4	France	57	6	7
		5	Japan	53	2	5
5	Taiwan (1,363)[a]	1	Taiwan	906	3	165
		2	USA	224	17	26
		3	Japan	113	3	17
		4	Germany	35	3	6
		5	South Korea	32	2	10
6	Germany (1,312)	1	Germany	1,182	56	124
		2	Taiwan	21	1	1
		3	USA	20	1	3
		4	South Korea	16	2	2
		5	Japan	15	0	1
7	Russian Federation (859)	1	Russian Federation	711	41	147
		2	USA	37	1	3
		3	Japan	17	0	3
		3	Germany	17	1	1
		5	France	16	0	2
8	Mexico (471)	1	USA	277	0	53
		2	Germany	30	0	5
		3	Mexico	28	0	4
		4	France	26	0	3
		5	Switzerland	20	0	2

Table 3 continued

No.	Patent office/repository (no. of applications from all countries)	Rank	Applicant country	Number of nanotechnology patent applications (1991–2008)	2000	2008
9	UK (412)	1	UK	162	5	27
		2	USA	109	8	15
		3	Germany	25	0	7
		4	Japan	20	0	3
		5	South Korea	19	1	5
10	France (390)	1	France	358	6	37
		2	Belgium	6	0	2
		2	Japan	6	0	0
		4	Taiwan	5	0	0
		4	USA	5	2	0
11	Brazil (315)	1	Brazil	116	0	42
		2	USA	99	0	32
		3	Germany	25	0	8
		4	Switzerland	21	0	4
		5	France	15	0	5
12	Ukraine (243)	1	Ukraine	221	0	78
		2	Switzerland	4	0	3
		3	Japan	2	0	0
		4	Switzerland	1	0	0
		4	USA	1	0	0

[a] As noted previously, data from 2007 was used for Taiwan's patent office, rather than 2008

Top applicant institutions

Table 4 lists the leading five applicant institutions per repository that includes large companies, universities, and research centers. In each of the patent offices of the PRC, South Korea, Germany, Russian Federation, France, and Ukraine, all of the top five applicant institutions were from the home country. In contrast, all the top five applicant institutions in Australia's patent office came from the USA. Four out of the top five application institutions in both Canada's and Mexico's patent offices were from the USA. In addition, none of the top five applicant institutions in New Zealand's patent office was from its home country. Some internationally active applicant institutions that ranked among the top five in different countries'/regions' patent offices included IBM (from the US), the University of California (from the USA), Samsung Electronics Co. Ltd. (South Korea), Hon Hai Prec Ind Co. Ltd. (Taiwan), Industrial Technology Research Institute (Ind Tech Res Inst; Taiwan), Hyperion Catalysis International Inc. (USA), and General Electric (USA).

In the USA's patent office, IBM ranked first, followed by the University of California and Samsung Electronic Co. In Japan's patent office, the National Institute for Materials Science (Nat Inst for Materials Science) ranked first followed by the National Institute of Advanced Industrial Science and Technology (Nat Inst of Adv Ind & Technol) and Matsushita Electric Ind Co. Ltd. In PRC's patent offices, all the leading applicants are academic or academy research institutions.

Compared with 2000, there is a general increase in the number of nanotechnology patent applications published by the top institutions in 2008. Among the top five institutions, in each of the patent offices of the USA, PRC, and Australia, the institution with the largest numbers of nanotechnology patent applications from 1991 to 2008 also ranked first in 2000.

Table 4 Top five applicant institutions in the 15 patent offices based on the number of nanotechnology patent applications from 1991 to 2008

No.	Patent office/ repository	Rank	Applicant institution	Country of the institution	Number of nanotechnology patent applications (1991–2008)	2000	2008
1	USA	1	IBM	USA	277	11	54
		2	Univ California	USA	209	11	29
		3	Samsung Electronics Co. Ltd.	South Korea	172	0	69
		4	Hon Hai Prec Ind Co. Ltd.	Taiwan	157	0	54
		5	Ind Tech Res Inst	Taiwan	106	3	15
2	PRC	1	Chinese Academy of Science[a]	PRC	1,155	14	312
		2	Univ Zhejiang	PRC	464	3	129
		3	Univ Tsinghua	PRC	461	2	91
		4	Univ Shanghai Jiaotong	PRC	409	3	75
		5	Univ Fudan	PRC	317	3	81
3	Japan	1	Nat Inst for Materials Science	Japan	334	0	60
		2	Nat Inst of Adv Ind & Technol	Japan	322	0	69
		3	Matsushita Electric Ind Co. Ltd.	Japan	263	6	37
		4	Fujitsu Ltd.	Japan	247	13	48
		5	Canon Kk.	Japan	222	11	26
4	South Korea	1	Samsung Electronics Co. Ltd.	South Korea	327	1	82
		2	Korea Inst Science Technology	South Korea	253	3	57
		3	LG Electronics Inc.	South Korea	153	2	26
		4	Samsung Sdi Co. Ltd.	South Korea	144	1	12
		5	Seoul National University	South Korea	120	0	46
5	Canada	1	Xerox Co.	US	27	0	18
		2	Nantero Inc.	US	25	0	0
		3	Nat Res Council	Canada	23	1	1
		4	Hyperion Catalysis International Inc.	USA	21	0	3
		5	Nanosys Inc.	USA	18	0	0
6	Taiwan[b]	1	Ind Tech Res Inst	Taiwan	201	0	23
		2	Hon Hai Prec Ind Co. Ltd.	Taiwan	78	0	51
		3	Univ Nat Cheng Kung	Taiwan	32	0	2
		4	IBM	USA	25	3	28
		5	Univ Nat Chiao Tung	Taiwan	17	0	3
7	Germany	1	Infineon Technologies AG	Germany	55	0	0
		2	Fraunhofer Ges Forschung	Germany	44	4	4
		3	Siemens AG	Germany	36	2	10
		4	Henkel Kgaa	Germany	31	5	0
		5	Hahn Meitner Inst Berlin Gmbh	Germany	20	0	0
8	Australia	1	Univ California	US	37	3	5
		2	Univ Northwestern	US	18	1	0
		3	Hyperion Catalysis International Inc.	US	16	3	4
		4	Nanosphere Inc.	US	15	0	1
		5	Harvard College	US	14	0	1
9	Russian Federation	1	G Obrazovatel Noe Uchrezhdenie	Russian Fed.	45	0	22
		2	Zao NT MDT	Russian Fed.	11	4	1
		3	Boreskova Inst Kataliza Sibir	Russian Fed.	10	1	3
		3	Inst Fiz Tverdogo Tela Ran	Russian Fed.	10	0	6
		3	Inst Ehlektrofiziki Ural Skogo	Russian Fed.	10	6	0

Table 4 continued

No.	Patent office/ repository	Rank	Applicant institution	Country of the institution	Number of nanotechnology patent applications (1991–2008)	2000	2008
10	Mexico	1	Procter & Gamble	USA	23	0	2
		2	Elan Pharma International Ltd.	Ireland	9	0	9
		2	Hyperion Catalysis International Inc.	USA	9	0	0
		4	Kimberly Clark Co.	USA	8	0	1
		4	Rohm & Haas	USA	8	0	0
11	UK	1	Toshiba Res Europ Ltd.	UK	13	1	4
		2	Hitachi Europ Ltd.	UK	9	0	0
		3	Gen Electric	USA	8	1	0
		4	Intel Co.	USA	7	0	3
		5	Waters Investments Ltd.	USA	6	0	0
12	France	1	Centre Nat Rech Scient	France	58	0	5
		2	Commissariat Energie Atomique	France	41	1	3
		3	O'real	France	27	0	0
		4	Rhone Poulenc Chimie	France	10	0	0
		5	Arkema Sa	France	8	0	0
13	Brazil	1	Unicamp	Brazil	13	0	1
		2	Comissao Nac de En Nuclear	Brazil	8	0	1
		3	Gen Electric	US	6	0	2
		4	Du Pont	US	5	0	5
		5	Gomes Uilame Umbelino	Brazil	5	0	1
14	Ukraine	1	Kaplunenko Volodymyr Heorhiiov	Ukraine	99	0	53
		1	Kosinov Mykola Vasyliovych	Ukraine	99	0	53
		3	Shulzhenko Oleksandr Oleksandr	Ukraine	6	0	0
		4	Lytvynenko Yurii Mykhailovych	Ukraine	5	0	0
		5	Lviv Polytekhnika Nat Universi	Ukraine	4	0	1
15	New Zealand	1	Eastman Kodak Co.	US	4	0	0
		2	Snow Brand Milk Prod Co. Ltd.	Japan	3	1	0
		3	Smithkline Beecham Co.	USA	2	0	0
		3	Technologies Avancees & Membra	France	2	0	0
		3	Univ Johns Hopkins	USA	2	0	0

[a] In our data collection, Chinese Academy of Sciences had variations of its name in English and it also has several affiliated organizations. We manually checked and came up with 27 different institution names which are all essentially Chinese Academy of Sciences. The number reported in the table is the sum of all the nanotechnology patent applications published by these 27 institutions

[b] As noted previously, data from 2007 was used for Taiwan's patent office, rather than 2008

Top technology fields

We used the International Patent Classification (IPC) class instead of the European Patent Classification (EPC) class to indicate technology fields in Table 5 because the EPC class information is incomplete in some patent offices (repositories). Among the top five technology fields in the 15 patent offices, there were 19 unique IPC classes, 10 of which ranked among the top five in more than one patent office:

– ''Semiconductor devices; electric solid state devices not otherwise provided for'' (H01L) ranked among the top five in 11 patent offices (except in those of Mexico, Brazil, the Ukraine, and New Zealand)

– ''Preparations for medical, dental, or toilet purposes'' (A61K) ranked among the top five in 11 patent offices (except in those of Japan, South Korea, Taiwan, and the Ukraine)

– ''Non-metallic elements; compounds thereof'' (C01B) ranked among the top five in 11 patent offices (except in those of Germany, Mexico, Brazil, and New Zealand)

– ''Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus'' (B01J) also ranked among the top five in nine patent offices

– ''Investigating or analyzing materials by determining their chemical or physical properties'' (G01N) ranked among the top five in seven patent offices

– ''Nano-structures manufacture or treatment thereof'' (B82B) ranked among the top five in six patent offices.

In the USPTO, ''Semiconductor devices; electric solid state devices not otherwise provided for'' (H01L) ranked first, followed by ''Preparations for medical, dental, or toilet purposes'' (A61K). In addition, ''Investigating or analyzing materials by determining their chemical or physical properties'' (G01N) and ''Layered products, i.e., products built-up of strata of flat or non-flat, e.g., cellular or honeycomb'' (B32B), which ranked third and fifth, respectively, in this study, ranked fifth and fourth, respectively, in the previous study (Li et al. 2007). However, ''Non-metallic elements; compounds thereof'' (C01B), which was also among the top five, did not appear among the top 10 technology fields as reported by Li et al. (2007).

In Japan's patent office, ''Semiconductor devices; electric solid state devices not otherwise provided for'' (H01L) ranked first, followed by ''Non-metallic elements; compounds thereof'' (C01B), ''Nano-structures manufacture or treatment thereof'' (B82B), ''Investigating or analyzing materials by determining their chemical or physical properties'' (G01N), and ''Electric discharge tubes or discharge lamps'' (H01J). All these technology fields ranked among the top 10 in the previous study (Li et al. 2007). Except ''Nano-structures manufacture or treatment thereof'' (B82B), which ranked eighth in Li et al. (2007), they all ranked among the top five as well.

Compared to 2000, there were many more nanotechnology patent applications in the top five technology fields in 2008 for different patent offices, including the patent offices of the USA, PRC, Japan, South Korea, Canada, Germany, Russian Federation, the UK, Mexico, France, Brazil, the Ukraine, and New Zealand. Since the patent offices of Mexico, Brazil, and Ukraine did not have nanotechnology patent applications in 2000, there were no applications from their top five technology fields in 2000. In addition, none of the eight applications in France's patent office in 2000 belonged to its top five technology fields. In 2008, almost all the top five technology fields in each of the 15 patent offices had nanotechnology patent applications.

For the patent offices of the USA, Japan, Taiwan, Australia, and New Zealand, the technology field that ranked the first in each of them based on data from 1991 to 2008 also had the largest number of nanotechnology patent applications in 2000. In 2008, there were 13 patent offices (excepting the patent offices of PRC and France) for which the technology field which ranked first based on data from 1991 to 2008, also had the largest number of nanotechnology patent applications in 2008 (Taiwan in 2007).

Table 5 Top five technology fields in the 15 patent offices based on the number of nanotechnology patent applications from 1991 to 2008

No	Patent office/ repository	Rank	IPC class	Class name	Number of nanotechnology patent applications (1991–2008)	2000	2008
1	USA	1	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	4,203	76	743
		2	A61K	Preparations for medical, dental, or toilet purposes	1,974	51	367
		3	G01N	Investigating or analyzing materials by determining their chemical or physical properties	1,754	36	230
		4	C01B	Non-metallic elements; compounds thereof	1,453	23	187
		5	B32B	Layered products, i.e., products built-up of strata of flat or non-flat, e.g., cellular or honeycomb	1,400	15	444
2	PRC	1	A61K	Preparations for medical, dental, or toilet purposes	1,549	9	370
		2	C01B	Non-metallic elements; compounds thereof	1,501	14	392
		3	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	1,311	11	388
		4	C08L	Compositions of macromolecular compounds	1,247	7	349
		5	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	1,095	4	350
3	Japan	1	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	2,324	81	367
		2	C01B	Non-metallic elements; compounds thereof	1,994	55	292
		3	B82B	Nano-structures manufacture or treatment thereof	1,599	35	229
		4	G01N	Investigating or analyzing materials by determining their chemical or physical properties	1,123	47	89
		5	H01J	Electric discharge tubes or discharge lamps	1,031	58	82
4	South Korea	1	B82B	Nano-structures manufacture or treatment thereof	1,280	5	417
		2	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	1,094	29	238
		3	C01B	Non-metallic elements; compounds thereof	409	5	103
		4	C08K	Use of inorganic or non-macromolecular organic substances as compounding ingredients	374	0	88
		5	H01J	Electric discharge tubes or discharge lamps	361	7	30
5	Canada	1	A61K	Preparations for medical, dental, or toilet purposes	328	8	47
		2	G01N	Investigating or analyzing materials by determining their chemical or physical properties	169	7	9
		3	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	148	10	8
		4	C01B	Non-metallic elements; compounds thereof	144	2	23
		5	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	123	4	22
6	Taiwan[a]	1	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	367	11	47
		2	C01B	Non-metallic elements; compounds thereof	114	1	14
		3	H01J	Electric discharge tubes or discharge lamps	112	1	9
		4	C23C	Coating metallic material coating material with metallic material surface treatment of metallic material by diffusion into the surface, by chemical conversion or substitution coating by vacuum evaporation, by sputtering, by ion implantation or by chemical vapor deposition, in general	78	2	13
		5	G01N	Investigating or analyzing materials by determining their chemical or physical properties	71	0	15

Table 5 continued

No	Patent office/ repository	Rank	IPC class	Class name	Number of nanotechnology patent applications (1991–2008)	2000	2008
7	Australia	1	A61K	Preparations for medical, dental, or toilet purposes	295	22	19
		2	C01B	Non-metallic elements; compounds thereof	212	12	7
		3	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	209	9	11
		4	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	177	10	12
		5	G01N	Investigating or analyzing materials by determining their chemical or physical properties	163	15	4
8	Germany	1	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	165	7	17
		2	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	135	13	10
		3	B82B	Nano-structures manufacture or treatment thereof	121	3	16
		4	G01N	Investigating or analyzing materials by determining their chemical or physical properties	111	3	13
		5	A61K	Preparations for medical, dental, or toilet purposes	103	6	8
9	Russian Federation	1	B82B	Nano-structures manufacture or treatment thereof	118	2	55
		2	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	88	4	13
		3	C01B	Non-metallic elements; compounds thereof	75	2	16
		4	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	69	6	15
		5	A61K	Preparations for medical, dental, or toilet purposes	58	1	12
10	UK	1	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	83	2	16
		2	G01N	Investigating or analyzing materials by determining their chemical or physical properties	58	2	15
		3	B01D	Separation	30	2	2
		4	A61K	Preparations for medical, dental, or toilet purposes	29	0	7
		5	C01B	Non-metallic elements; compounds thereof	28	0	2
11	Mexico	1	A61K	Preparations for medical, dental, or toilet purposes	109	0	26
		2	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	60	0	0
		3	C08K	Use of inorganic or non-macromolecular organic substances as compounding ingredients	58	0	8
		4	C08L	Compositions of macromolecular compounds	52	0	3
		5	C09D	Coating compositions, e.g. paints, varnishes, lacquers; filling-pastes; chemical paint or ink removers; inks; correcting fluids; wood stains; pastes or solids for coloring or printing; use of materials therefore	45	0	8
12	France	1	A61K	Preparations for medical, dental, or toilet purposes	69	0	2
		2	H01L	Semiconductor devices; electric solid state devices not otherwise provided for	61	0	6
		3	B82B	Nano-structures manufacture or treatment thereof	55	0	7
		4	C01B	Non-metallic elements; compounds thereof	47	0	7
		5	A61Q	Use of cosmetics or similar toilet preparations	45	0	2

Table 5 continued

No	Patent office/ repository	Rank	IPC class	Class name	Number of nanotechnology patent applications (1991–2008)	2000	2008
13	Brazil	1	A61K	Preparations for medical, dental, or toilet purposes	65	0	21
		2	C08K	Use of inorganic or non-macromolecular organic substances as compounding ingredients	30	0	7
		3	C08L	Compositions of macromolecular compounds	28	0	6
		4	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	28	0	8
		5	B82B	Nano-structures manufacture or treatment thereof	24	0	12
14	Ukraine	1	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	52	0	25
		2	C01B	Non-metallic elements; compounds thereof	24	0	3
		3	B22F	Working metallic powder; manufacture of articles from metallic powder; making metallic powder	21	0	4
		4	C12N	Micro-organisms or enzymes; compositions thereof	19	0	16
		5	C02F	Treatment of water, waste water, sewage, or sludge	18	0	4
15	New Zealand	1	A61K	Preparations for medical, dental, or toilet purposes	62	4	8
		2	A61P	Therapeutic activity of chemical compounds or medicinal preparations	28	1	3
		3	B01J	Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus	20	2	4
		4	B01D	Separation	18	1	3
		5	C07K	Peptides	17	0	3

[a] As noted previously, data from 2007 was used for Taiwan's patent office, rather than 2008

__*Patent family analysis within each patent office*__

Table 6 lists the numbers of nanotechnology patent applications published in single patent office, two or more patent offices, and three or more patent offices. For example, 2,939 patent applications that were published in the US patent office had been also published in at least one other patent office. Among those patent applications, 741 had been published in three or more countries'/regions' patent offices. The patent offices of Japan, the PRC, and South Korea also had relatively larger numbers of nanotechnology patent applications published in multiple patent offices.

For each patent office, we also identified other patent offices with which it shared the greatest numbers of nanotechnology patent applications for the interval between 1991 and 2008. For example,

– The top five patent offices sharing nanotechnology patent applications with the USPTO were Japan (1,258), PRC (725); South Korea (636), Taiwan (353), and Canada (350). Our analysis shows that all other patent offices (except for Brazil's patent offices) shared the largest numbers of nanotechnology patent applications with the USPTO.

– The top five patent offices sharing nanotechnology patent applications with the PRC repository were those of the USA (725), South Korea (624), Japan (416), Taiwan (68), and Canada (40).

– The top five patent offices sharing nanotechnology patent applications with the JPO were those of the USA (1258), South Korea (450), PRC (416), Taiwan (107), and Canada (106).

Table 6 Numbers of nanotechnology patent applications published in single patent office, two or more patent offices, and three or more patent offices (1991–2008)

No.	Patent office (repository)	No. of patent applications published in total	No. of patent applications published in a single patent office	No. of patent applications published in ≥2 patent offices	No. of patent applications published in ≥3 patent offices
1	USA	19,665	16,726	2,939	741
2	PRC	18,438	17,079	1,359	490
3	Japan	10,763	9,084	1,679	614
4	South Korea	5,963	4,731	1,232	491
5	Canada	1,539	988	551	160
6	Taiwan	1,363	900	463	123
7	Australia	1,312	926	386	91
8	Germany	1,296	1,229	67	21
9	Russian Federation	859	785	74	31
10	Mexico	471	228	243	96
11	UK	412	291	121	32
12	France	390	339	51	17
13	Brazil	315	167	148	70
14	Ukraine	243	231	12	6
15	New Zealand	140	68	72	38

V. Conclusions

Key findings from the longitudinal analysis of nanotechnology patent applications between 1991 and 2008 are:

• The worldwide growth rate of the number of nanotechnology patent applications between 2000 and 2008 is about 34.5% (Fig. 1). This rate is larger than the corresponding rate of increase for International Citation Index articles of about 25%. The baseline growth rates of the number of patent applications for continuing topics are 16.14 and 12.57 times in the interval from 1991 to 2008 for the USPTO and the top 15 nanotechnology patent repositories, respectively. The new nanotechnology topics in 2008 as compared with 2000 represent 92% in the USA and 68% for top 15 repositories. The baseline growth rate is significant in the PRC patent office, but the data available in 2000 are too limited to generate a content map in that year for comparison with 2008. The largest number of nanotechnology patent applications, as well as of the patent application families, are at the patent offices of the USA, PRC, Japan, and South Korea.

• A higher number of nanotechnology patent applications are published by applicants from their own countries/regions, indicating significant ''home advantage'' effects. The USA, Japan, Germany, South Korea, and France were the largest contributors in patent offices other than its repository. The top 15 patent offices except for Brazil's patent office shared the largest numbers of nanotechnology patent applications with the USPTO. Japan is the USPTO's largest partner cosharing 1,258 nanotechnology patent applications.

• Applicant institutions with large international activity are illustrated by IBM (from the USA), the University of California (from the USA), Samsung Electronics Co. Ltd. (from South Korea), Hon Hai Prec Ind Co. Ltd. (from Taiwan), and Industrial Technology Research Institute (Ind Tech Res Inst; from Taiwan), Hyperion Catalysis International Inc. (from the USA), and General Electric (Gen Electric, from the USA).

• The ranking of the most productive institutions and the categories of the lead technology fields in patent repositories have had relatively small changes over time, and few institutions or categories of technology fields were able to break into the top ranks. However, specific topics within various technology field categories changed rapidly after 2000. Topics that increased in 2008 in most of the 15 patent offices included: ''Composite materials,'' ''Deionized water,'' ''Gate electrodes,'' ''High purities,'' ''Metal nanoparticles,'' ''Organic solvents,'' ''Particle diameters,'' ''PH values,'' ''Quantum dots,'' and ''Semiconductor Devices.''

• Several top technology fields (represented by IPC class) were shared by multiple repositories. ''Semiconductor devices; electric solid state devices not otherwise provided for'' (H01L) was among the top five technology fields in 11 out of the 15 patent offices. The following fields ranked among the top five in multiple repositories: ''Preparations for medical, dental, or toilet purposes'' (A61K), ''Non-metallic elements; compounds thereof'' (C01B), ''Chemical or physical processes, e.g., catalysis, colloid chemistry; their relevant apparatus'' (B01J), ''Investigating or analyzing materials by determining their chemical or physical properties'' (G01N), and ''Nano-structures manufacture or treatment thereof'' (B82B).

REFERENCES

[1.] NSTC, 2000, "Nanostructure Science and Technology", Chapter 8: Research Programs on Nanotechnology in the World, pp. 131-150.
[2.] M.C. Roco, 2001, " International Strategy for Nanotechnology Research and Development", Journal of Nanoparticle Research, Kluwer Academic Publ., Vol. 3, No. 5-6, pp. 353-360.
[3.] M.C. Roco and W.S. Bainbridge, eds., 2001, "Societal Implications of Nanoscience and Nanotechnology", Kluwer Academic Publishers, Boston, pp. 3-4.
[4.] Survey of EU Member States R&D funding for nanotechnology carried out in the Council of the European Union (response from Austria).
[5.] Survey of EU Member States R&D funding for nanotechnology carried out in the Council of the European Union (response from Belgium).
[6.] *Australian Nanotechnology: Capability and Commercial Potential*, Invest Australia Report (2005) http://www.investaustralia.gov.au/
[7.] Survey of EU Member States R&D funding for nanotechnology carried out in the Council of the European Union (response from Denmark).
[8.] *Final Report of the International Dialogue on Responsible Research and Development of Nanotechnology*, Questionnaire Responses and Background Information (2004) http://www.nanoandthepoor.org/Attachment_F_Responses_and_Background_Info_040812.pdf
[9.] Survey of EU Member States R&D funding for nanotechnology carried out in the Council of the European Union (response from Finland).
[10.] India, China front-runners in nanotech research, A. Vaidya, The Times of India, January 24 2005 http://timesofindia.indiatimes.com/articleshow/999932.cms.

[11.] *Presentation of Training Initiatives within Asia-Pacific Programmes*, L. Liu, Nanotechnology Research Institute (AIST), Japan, Workshop on Research Training in Nanosciences and Nanotechnologies: Current Status and Future Needs, April 2005, Brussels *Irish Council for Science, Technology & Innovation Statement on Nanotechnology*, July 2004
[12.] *Presentation of Training Initiatives within Asia-Pacific Programmes*, L. Liu, Nanotechnology Research Institute (AIST), Japan, Workshop on Research Training in Nanosciences and Nanotechnologies: Current Status and Future Needs, April 2005, Brussels
[13.] *Nanotechnology in* Asia 2003, Asian Technology Information Programme (AITP) April 2003
[14.] *Nanotechnology and the Poor: Opportunities and Risks*, Meridian Institute, January 2005
[15.] *Nanotech business entering Singapore too* (report on a presentation of H-G Lee of LG Electronics), L. Liu, Asia Pacific Nanotech Weekly (2004/11/ 2 #40)
[16.] Response to questionnaire on nanotechnology (for the Royal Society and Royal Academy of Engineering study on nanotechnology), A. Pacholak, British Embassy Warsaw (2003)
[17.] European Commission, *Towards a European Strategy for Nanotechnology*, COM(2004) 338.
[18.] Albert R, Barabasi AL (2002) Statistical mechanics of complex networks. Rev Mod Phys 74:47–97
[19.] Andersen PH, Drejer I, Waldstrøm C (2006) In the eye of the storm—knowledge appropriation and the globalization of regional competencies. In: The proceedings of the annual meeting of the Academy of Management
[20.] Chen H, Schuffels C, Orwig R (1996) Internet categorization and search: a machine learning approach. J Vis Commun Image Represent 7(1):88–102
[21.] EPO (2008) Global patent data coverage. Available in European Commission (1997) Second European report on S&T indicators. European Commission, Brussels
[22.] Ganguli P (1998) Intellectual property rights in transition .World Pat Inf 20(3–4):171–180
[23.] GarfieldE (1955) Citation indexes for science: a newdimension in documentation through association of ideas. Science 122: 108–111
[24.] Hingley P, Park W (2003) Patent family data and statistics at the European Patent Office. WIPO-OED workshop on statistics in the patent field, Geneva
[25.] Hu D, Chen H, Huang Z, Roco MC (2007) Longitudinal study on patent citations to academic research articles in nanotechnology (1976–2004). J Nanopart Res 9(4):529–542
[26.] Oldham P, Cutter AM (2006) Mapping global status and trends in patent activity for biological and genetic material. Genomics Soc Policy 2(2):62–91
[27.] Kathyrn J A (2009), 'Constructing Nano Business: The Role of Technology Framing in the Emergence of a Commercial Domain" A PhD DISSERTATION in Department of Management and the Graduate School of the University of Oregon
[28.] Roco MC (2005) International perspective on government nanotechnology funding in 2005. J Nanopart Res 7(6):707–712
[29.] Roco MC, Williams RS, Alivisatos P (2000) Nanotechnology research directions. Springer, Dordrecht
[30.] Seymour EH, Borges FC, Fernandes R (2007) Indicators of European public research in hydrogen and fuel cells—an input–output analysis. Int JHydrogen Energy 32:3212–3222
[31.] Tolle K, Chen H (2000) Comparing noun phrasing techniques for use with medical digital library tools. J Am Soc Inf Sci 51(4):352–370.
[32.] House of Commons Science and Technology Committee, *Too little too late? Government Investment in Nanotechnology*, 2003–04, March 2004,
[33.] Fifth Report of Session Information presented on the MATNANTECH initiative at NANO 2003 meeting, Japan (2003).
[34.] **Nanotechnology and business opportunities: scenarios as awareness instrument by** W.H.C. Knol; Qeam Vierde Binnenvestgracht 19 - 2311 NT - Leiden - the Netherlands;Erik.Knol@Qeam.com - www.Qeam.com ;Presented paper published in the proceedings of the 12th Annual International Conference 'High Technology Small Firms',
[35.] Enschede, the Netherlands, May 24 - 25, 2004, pp. 609 – 621