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NANOBIOTECHNOLOGY: TECHNOLOGY TRANSFER AND INNOVATION PERFORMANCE OF SCIENTIFIC PARKS IN SPAIN TOWARDS H2020

PARALLEL SESSION 5
STPs and AIs fostering technology-driven projects

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Nanobiotechnology: Technology Transfer and Innovation Performance of Scientific Parks in Spain towards H2020

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Executive summary

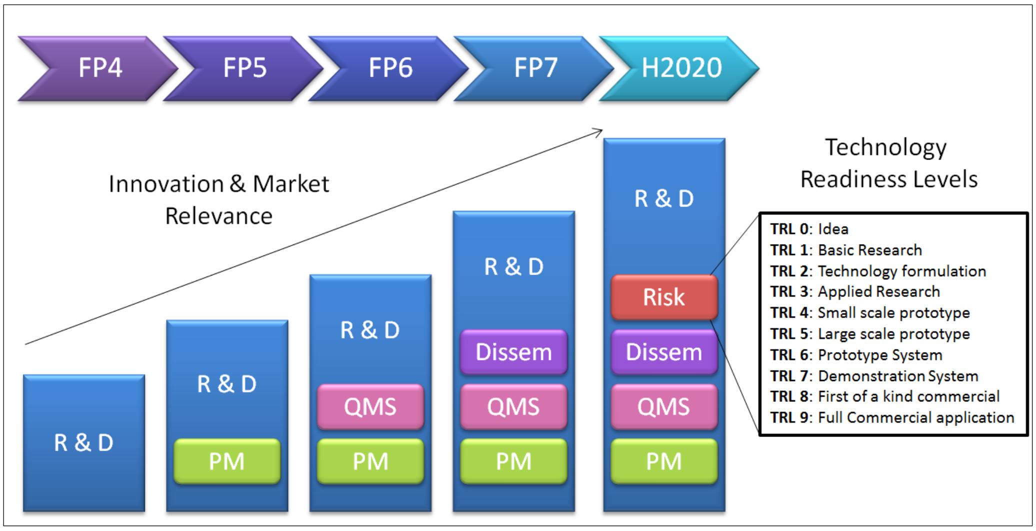
This document analyses the state of the art of the technology transfer and innovation performance of scientific parks in Spain, focusing on the research and development of Nanobiotechnologies as *crosscutting Key Enabling Technologies (cross*-KETs), which are among the priorities of the Horizon 2020 Framework strategy. Science and Technology Parks (STPs) and Areas of Innovation (AI) are now fostering technology and market driven projects with a risk management strategy at an early stage adjusted to the H2020 requirements. In this context, Bio&Health Nanotechnology will be analyzed by presenting available data on patents, publications, networks, related industry, and market projections as indicators of Technology Transfer and the Spanish Innovation Ecosystem. Nowadays, STPs have an important role in the leadership and coordination with universities and industry for H2020 projects in order to bend the curve of the “valley of death” for R&D commercialization.

Introduction

We are at the beginning of a new European Commission initiative. Horizon 2020 is the biggest financial programme for Research and Innovation implemented by the Innovation Union. It goes “*from fundamental research to market innovation*” involving the entire innovation chain. It is oriented to create the conditions for making Europe more competitive through research. The framework is focused on turning scientific breakthroughs into innovative products and services. This will provide economic growth by investing in job creation, competitiveness, improved quality of life and sustainable development, providing the background for solving some of the major societal challenges that the European Union is facing.[1,2]

This integrated programme will cover all research and innovation funding currently provided through the Framework Programme for Research and Technological Development, the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT), providing a simplification of existing innovation funding.[3,4] Novelties of the framework include the focus on societal challenges, the simplified access, and the coupling of research to Innovation in one single programme bringing together three separate past initiatives. Another novelty is the **Technology Readiness Level (TRL)** which addresses a corresponding risk at an early stage of the projects (**Fig. 1**). The objective of these TRLs is that all research projects must have a commercial application.

[1] Commission, E. Preparing for our future: Developing a common strategy for key enabling technologies in the EU. (2009).
[2] European Commission. *Regional Innovation Scoreboard 2012*. (2012). doi:10.2769/55659
[3] Kalisz, D. & Aluchna, M. Research and Innovation redefined. Perspectives on the European Union initiatives on Horizon 2020. *Eur. Integr. Stud.* (2012).
[4] European, C. *Eurostat regional yearbook 2013*. (2013).



PM = project management; **QMS** = quality assurance; **Dissem** = dissemination incl. standardization; **Risk** = risk management strategy

Fig. 1*: Evolution of the European Framework Programmes. (Source: European Technology Platform on Industrial Safety)*

H2020 has scheduled over 74 billion € for research funding emphasized in three fundamental pillars: 24.598 million € intended for **Scientific Excellence,** 31.748 million € for **Society Challenges** and 17.938 million € for **Industrial Leadership** (**Fig. 2**). The last one aims to support SMEs in the industrial development and application of *Key Enable Technologies* (KETs) which are considered crucial accelerators for innovation and competitiveness.

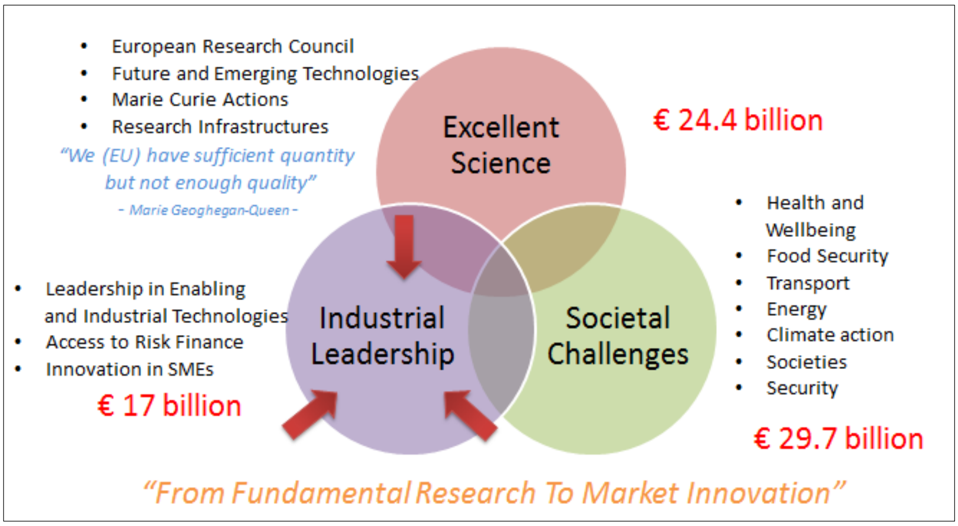


Fig. 2*: H2020 Fundamental Pillars and budget (Source: European Commission, 2014)*

Nanotechnology is one of the most promising KETs due to its economic and social growth potential, since it has been considered the greatest impulse to technological and industrial development in the 21st century and the resource for the next industrial revolution.[5,6,7,8,9] Scientific advances to date

[5] Genet, C., Errabi, K. & Gauthier, C. Which model of Technology Transfer for Nanotechnology? A Comparison with Biotech and Microelectronics. **4,** 205–215 (2012).
[6] Rothaermel, F. T. & Thursby, M. The Nanotech vs. the biotech revolution: sources of productivity in incumbent firm research. (2007).
[7] RNCOS. *Nanotechnology Market Outlook 2017*. (2013).
[8] European Commission. *Successful European Nanotechnology Research: Outstanding science and technology to match the needs of future society*. (2011).

have allowed us to manipulate a material atom by atom through the Nanotechnologies. The National Nanotechnology Initiative (NNI) defines Nanotechnology as research and development at the atomic, molecular, or macromolecular levels in the sub 100 nm range (˜ 1-100 nm) to create structures, devices and systems that have novel functional properties,[10, 11] with numerous manipulation advantages. Nanotechnology is not a new technology despite its definition having developed since the famous phrase "*There is Plenty of Room at the Bottom*" in Richard Feynman's historic 1959 lecture. Products based on nanotechnology are already in use; an example of these are the nanoscale carbon particles that have been used as a reinforcing additive in tyres for more than a century.[10] Nanobiotechnology is a rapidly advancing area of scientific and technological opportunity that provides advances in the food industry, energy, environment and medicine. This new discipline is placed at the interface of physical and biological sciences and has the potential to revolutionize medicine when tools, ideas and materials of nanoscience and biology are combined.

Applied Nanotechnology in biomedicine (nanobiotechnology and nanomedicine) is one of the areas of greatest projection of the future which is starting to show a promising impact in the health sciences including the diagnosis and treatment of diseases, as well as the development of new drugs and novel ways of administration.[12] The convergence of nanotechnology and biotechnology opens a challenging economic and scientific scenario leading to a huge market for nanomedicine-related products and services. Nowadays Nanotechnology and Nanobiotechnology constitutes an innovative breakthrough technology with high economic impact, so its analysis as a regional context is important to stimulate its progress.

Spanish Innovation Indicators

Innovation is a driving force in the development of S&T parks, organizations and institutions,[13] furthermore, to achieve the H2020 proposal objectives, innovation is considered the strategic element.[3] Innovation is a complex, diversified activity with many interacting components that results in any improvement on process or product.[14] Specifically, technology innovation and related capital and human investment shapes the National Innovation System (NIS) of a country by contributing to the nation's productivity, economic growth and standard of living.[15] NIS terminology was used for the first time in a Freeman publication about Japanese innovation in 1987. NIS is the set of business and institutional organizations within a given area whose activities and interactions initiate, import, modify and diffuse new technologies.[16] Innovation diffusion differs between countries depending on the relative position of each region with respect to different dimensions (spatial, institutional, technological, social and organizational).[17] Innovative activities also generate an added value for industries, contributing to strengthening a competitive scenario.

The research, development and innovation system in Spain is supported by national and regional authorities. At national level, the Secretary of State for Research, Development and Innovation of the Ministry of Economy and Competitiveness is responsible for the implementation of the research, development and innovation policies. Two agencies manage the funding: the recently created Agency for Science and Technology and the Centre for Industrial Technology Development.[18] The Spanish strategy for science, technology and innovation is aligned with Horizon 2020, to promote

[9] Flynn, T. & Wei, C. The pathway to commercialization for nanomedicine. *Nanomedicine* **1,** 47–51 (2005).
[10] Morrow Jr, Bawa, R. & Wei, C. Recent advances in basic and clinical nanomedicine. *Med. Clin. North Am.* **91,** 805–843 (2007)
[11] Nikulainen, T. & Palmberg, C. Transferring science-based technologies to industry—Does nanotechnology make a difference? *Technovation* **30,** 3–11 (2010).
[12] Fundación, O. P. T. I. Aplicaciones Industriales de las Nanotecnologías en España en el Horizonte 2020. *Minist. Ind. Tur. y Comer. Gob. España, Obs. Prospect. Tecnológica Ind.* (2008).
[13] Bellavista, J. & Sanz, L. Science and technology parks: habitats of innovation: introduction to special section. *Sci. Public Policy* **36,** 499–510 (2009).
[14] Commission, E. The Measurement of Scientific and Technological Activities Oslo Manual. *Communities* **Third edit,** 166 (2005).
[15] Milbergs, E. & Vonortas, N. Innovation Metrics : Measurement to Insight. *White Pap.* (2005).
[16] APTE. Estudio del Impacto Socioeconómico de los Parques Científicos y Tecnológicos Españoles. (2005).
[17] Marrocu, E., Paci, R. & Usai, S. Proximity, networking and knowledge production in Europe: What lessons for innovation policy? *Technol. Forecast. Soc. Change* **80,** 1484–1498 (2013).
[18] European Commission. *European Research Area Facts and Figures 2013.* (2013).

the active participation of Spanish agents in the European space. Promotion of excellent scientific and technological research, Industry Leadership in R&D&I and R&D&I oriented to outstanding challenges are the main goals pursued by the Spanish Strategy for Science, Technology and Innovation 2013-2020 and the National Plan for Scientific and Technical Research and Innovation 2013-2016, the main instrument to deploy the aforementioned strategy.[19]

Some innovation indicators such as the Global Entrepreneurship Monitor (GEM) 2013, catalogue Spain as an "Innovation-Driven Economy" as well as the US, Japan and the majority of the EU-28 countries, compared with other "Efficiency-Driven Economies" (Latin America and China for example) and "Factor-Driven Economies" (Africa and India principally).[20] However, Spain has been categorized as a "high-capacity/low-performance" country in terms of the Innovation Efficacy Index (IEI).[21] Furthermore, Spain has been classified by the OECD as an "innovation follower" rather than an "innovation leader" regarding the European Regional Competitiveness Index (RCI) 2012.[2] In 2013 Spain showed an RCI between -0.1 and 0, except for Madrid, that has values between 0.2 and 0.5 compared with other European countries (**Fig. 3**).[22] This asseveration states that the research produced does not always benefit society, but unfortunately the reason is not a consequence of the availability of appropriate resources. This data highlights the presence of a gap between R&D and what is really achieved for the market and the benefit of society,[21] so this is a concern that could be solved through an important key: innovation and technology transfer in the scientific parks.

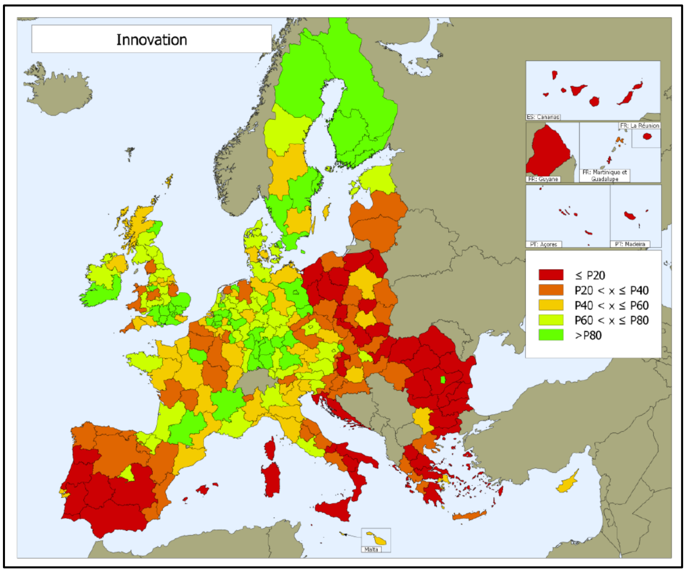


***Fig. 3**: Score distribution on the Innovation in Europe (Source: EU Regional Competitiveness Index, 2013)*

As stated by the COTEC 2013 report,[23] basic indicators of R&D activities show a clear decrease of invested resources in the National System of Innovation since 2011. Taking into consideration that the goal expenditure for Europe 2020 of Gross Domestic Expenditure on R&D (GERD) is 3%,[3] Spain had a value of 1.39% at 2010 before Italy and after the Czech Republic. This value falls to 1.33% in 2011. As a comparative overview, Finland has the highest value with 4% and Romania the lowest with 0.5%. The number of working personnel in R&D was also reduced in 2011 to 215 079 (full-time), which represents a fall of 3.1% about (222 022 people in 2010). Likewise, the Gross Domestic Product (GDP) per capita places Spain (31,573) below the average as compared with the EU-27 (31,748). The distribution of R&D spending by the business sector in Spain has still much lower weight compared with the EU-27 or OECD countries. In 2010 Spanish companies performed an R&D equivalent to 0.72% of GDP, the same level as in 2009, while in the EU-27 this effort was 1.17% and

[19] Zaldua, M., Kuittinen, H. & Minguela, L. R. MKETs-PL working document - Country report Spain. (2013).
[20] Amorós, J. ernesto & Bosma, N. *Global Entrepreneurship Monitor Report 2013*. (2014).
[21] Mahroum, S. & Al-Saleh, Y. Towards a functional framework for measuring national innovation efficacy. *Technovation* **33,** 320–332 (2013).
[22] Annoni, P. & Dijkstra, L. *EU Regional Competitiveness Index RCI 2013*. (2013).
[23] Fundación COTEC para la Innovación Tecnológica. informe cotec 2013. (2013).

1.58% in the OECD. This difference represents for Spain a significant obstacle on the road to a knowledge-based economy.[23]

Design and development of new nano products and systems will have significant social and economic impacts[24] in nearly all sectors in a relatively short amount of time.[5,9] For this purpose, there is a need for a well-established innovation strategy and measurement tools into the NIS. At the present, this is well recognized by most governments who believe that innovation is a key driver for economic development and a fundamental source of competiveness in the global marketplace.[21]

Innovative activities can be measured by R&D expenditure, number of researchers, patents, publications or the number of companies generated.[25,26] **Table I summarizes** the principal nano economic and innovation indicators in Spain. As can be seen, funding and investment indicators place Spain in 19th position. Ranking is better regarding patents and publications; most recent nano patent data from 2013, ranks Spain at 16th position and in 9th position regarding total citation to nano-articles. Also highlighted is a good position regarding the number of researchers per million people showing the existence of concern about the human capital.

TABLE I
Economic, R&D and Nano Innovation Indicators in Spain

Indicators	Quality	Position	Year
Funding and Investment			
R&D expenditure (% of GDP)	1.39	19th	2010
Human Capital			
Population	46.217,96	25th	2012
Researchers in R&D (per million people)	2.922	17th	2010
Science			
Nano-articles per Millon people	74.19	20th	2012
Average citation per article	2,20	11th	2012
Total ISI articles	48.350	9th	2012
h-index of nano-articles	24.00	8th	2012
Total citations to nano-articles	7.560%	9th	2012
International collaboration in nanoscience generation	58.24%	72th	2012
Local share in nanoscience generation	7.09	41th	2012
Technology			
Nanopatent publication (UPSTO)	107	20th	2012
Nanopatent (EPO)	31	16th	2013
Share of Nanopatent publications	0.39	-	2012
Industry			
GDP (ppp)	1.484,95	14th	2012
GDP	1.349,350,7	13th	2012
GDP per capita (ppp)	32,129	21th	2012

Source: Nano Statistics, Nano Science, Technology and Industry Scoreboard (www.statnano.com)

Nano-patenting Activity

[24] Juanola-Feliu, E. The nanotechnology revolution in Barcelona: innovation & creativity by universities. *Manag. Int.* **13,** 111 (2009).
[25] Mohnen, P. & Dagenais, M. Towards an Innovation Intensity Index : The Case of CIS 1 in Denmark and Ireland. (2000).
[26] Zucker, L. G., Darby, M. R., Furner, J., Liu, R. C. & Ma, H. Minerva unbound: Knowledge stocks, knowledge flows and new knowledge production. *Res. Policy* **36,** 850–863 (2007).

The number of patents registered in each region and each year is an approximation of the knowledge production[27] invention,[4] technological novelty[28] and creativity,[24] as well as an indicator of applied research and technological development.[29] Up to 2010, Spain had 31.3833 total patent count in the nanotechnology field. **Fig. 4** shows the most productive regions in terms of PCT nano patent applications-count in 2010 positioning Madrid (9.1333), Barcelona (7.2833), Valencia (4), La Coruña (2), Albacete (2), Cádiz (1), Granada (1), and Málaga (1) as host spots of this category.[30]

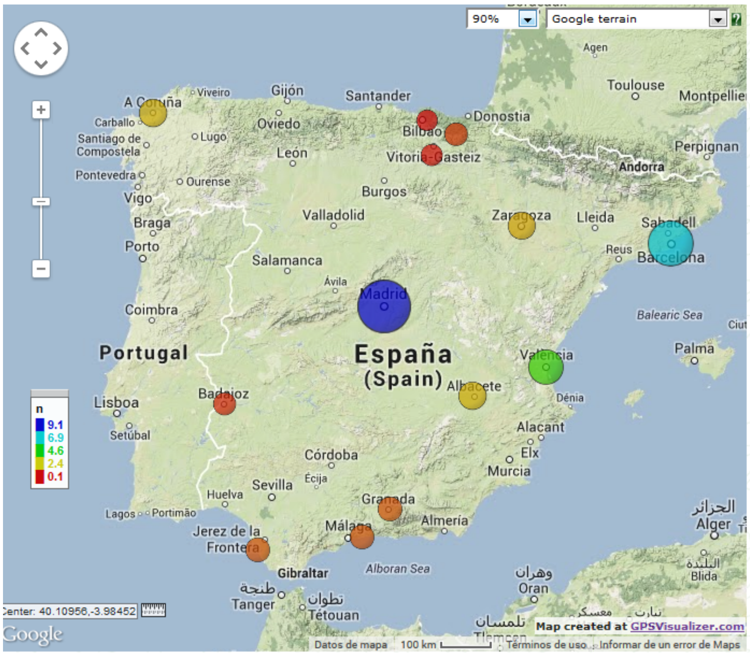


Fig. 4: *Map of Spain based on the number of nanotechnology patent application in 2010 by the OECD.stat. Circles diameter indicates the PCT patent application density of principal regions. GPS Visualizer Tool (http://www.gpsvisualizer.com/).*

In a global comparison, major contributors in Nanotechnology patent applications during the last decade are USA, Japan, Europe, Korea, and China. European patent applicants 2000-2010 involve institutions distributed as follows: Academia (12%), Research Institutions (18%), and Companies (70%).[31] Concerning the significance in total patent applications of KETs in Spain, lowest values correspond to Photonics, Micro/Nanoelectronics and Nanotechnology with a patent activity less than 2% of the total patent activity compared with 3.8% of the Industrial Biotechnology (**Fig.5**). Furthermore, Nanomaterials, Nanomanufacturing, and Nanoelectronics have a low Revealed Technological Advantage Index (RTA),[32] meanwhile nanobiotechnology has the lowest rate in the EU, revealing a weak competitiveness in this research field.[33] These data show the importance of performance measurement and evaluation of science parks, which are imperative in order to get

[27] Lee, I. H., Hong, E. & Sun, L. Regional knowledge production and entrepreneurial firm creation: Spatial Dynamic Analyses. *J. Bus. Res.* **66,** 2106–2115 (2013).
[28] Breschi, S., Malerba, F. & Orsenigo, L. Technological Regimes and Schumpeterian patterns of innovation. **110,** 388–410 (2013).
[29] Schmoch, U., Heinze, T., Hinze, S. & Rangnow, R. Mapping Excellence in Science and Technology across Europe Nanoscience and Nanotechnology. 1–113 (2003).
[30] National Institute of Stadistics. (2011). at <http://www.ine.es/>
[31] European Commission. *Observatory NANO Factsheets March 2011*. (2011).
[32] OECD. *OECD Science, Technology and Industry Scoreboard 2011*. (OECD Publishing, 2011).
[33] Miyazaki, K. & Islam, N. An empirical analysis of nanotechnology research domains. *Technovation* **30,** 229–237 (2010).

better insight into how to obtain an effective approach and improve these values through an adequate technology transfer process.

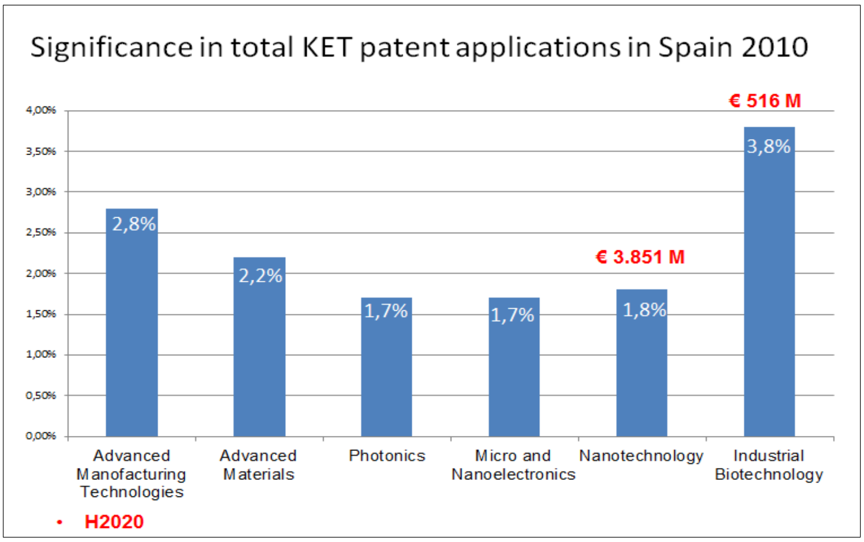


Fig. 5: Significance in total KETs patent applications in Spain and H2020 funding (source: European Commission KETs observatory https://webgate.ec.europa.eu/ketsobservatory/)

Nano-publication Activity

Scientific publications in the nanotechnology sector have also grown exponentially over the last two decades. Since 1998 nano-publications have grown from almost 4 thousand to 100 thousand in 2009.[31] Islam and Miyazaki (2007) performed a cross-country comparison of scientific nanotech related publications, which places Spain inside the 26% that the European Union represents as global leader after the United States (27%), Japan (15%), and Greater China (11%).[34] In a European sectorial Publication Analysis, Spain is in fifth position after Germany, which is leading the group, France, the UK, and Italy in the Health, Medicine and NanoBio sector **(Fig. 6).**[31]

[34] Islam, N. & Miyazaki, K. Nanotechnology systems of innovation—An analysis of industry and academia research activities. *Technovation* **27**, 661–675 (2007).

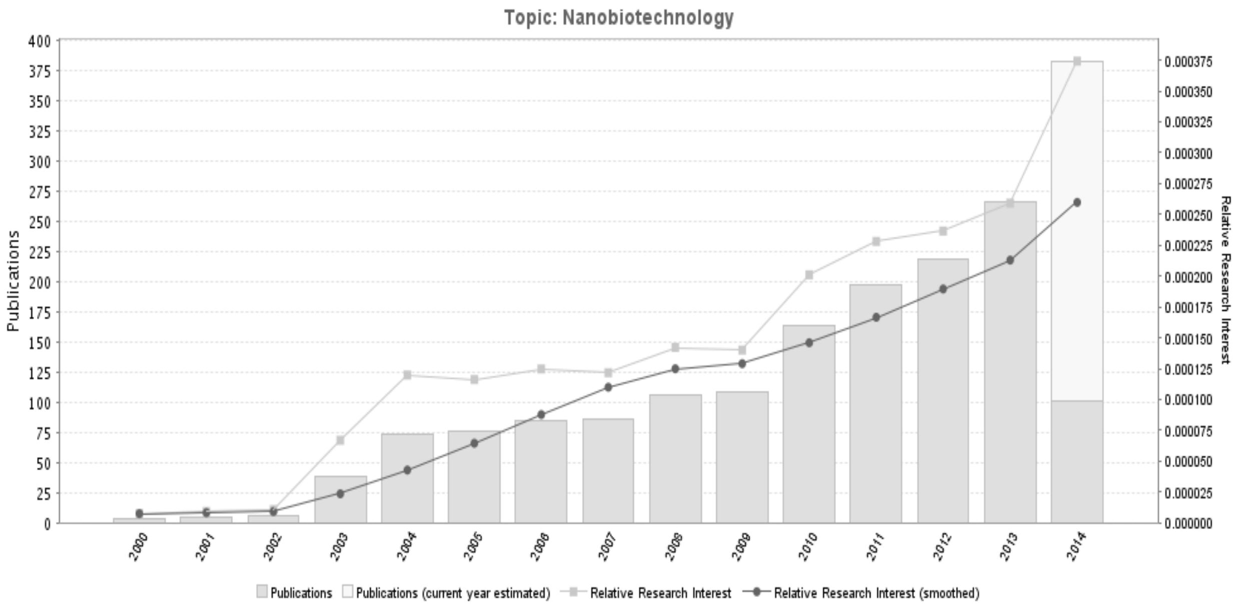


***Fig. 6**: Worldwide Nanobiotechnology Publications over time (Source: www.gopubmed.com)*

The Asia Nano Forum Report (2014) revealed that China, USA, South Korea, India, Germany, Japan, France, the Islamic Republic of Iran, England and **Spain** were the top 10 countries in Nano Science and Technology publications for 2012. [35] From gopubmed.com, some facts and figures of nanobiotecnology publications are presented in Box1:

Box1. Nanobiotechnology Scientific Publications: Facts and Figures

There are 1.559 documents worldwide regarding "Nanobiotechnology". Last year (2013) it has been published 266 articles regarding Nanobiotechnology. Top countries are United States with 328 publications, India (123), China (104), Germany (94), Japan (85), United Kingdom (77), Austria (73) and Spain in 8th place with 60 publications in this area.

Top Cities are Vienna (72), Baltimore (71), Tehran (51), Vellore (46), and in 5th place Tarragona (44).

Top Journals in this field are J. Nanobiotechnology (271), let Nanobiotechnol. (121), lee proc Nanobiotechnol. (102), Langmuir (31), Plos One (26), Acs Nano (21), Small (18), and Lab Chip (17).

Top terms are: Nanoparticles (484), Proteins (470), Humans (426), Nanotechnology (397), Animals (312), Nanostructures (280), Pharmaceutical Preparations (278), Research Report (259), DNA (257), and Microscopy (233).

35 Hongfang, J. & Lerwen, L. *Asia Nano Forum Annual Report 2013*. **2013**, 67 (2014).

Nanobiotechnology in Spain

Nowadays, the emerging sector of applied nanobiotechnology is basically addressed to the biomedicine and nanomedicine sectors. Research findings suggest the start of a promising impact on the health sciences and, specifically, in three main areas: Diagnostics, Therapeutics and Regenerative Medicine. Nanomedicine is considered a long-term play in the global market; in fact, it is anticipated to grow around 25% each year. The expected market size related to radical innovation-based nanomedicines will be 1.000 M€ in 2020 and 3.000 M€ in 2025.[36] In this context H2020 will spend 9.7% of the total budget in Health, Demographic Change and Wellbeing; specifically, the program will invest 3.851 M€ in Nanotechnology and 516 M€ in the Biotechnology Industry.

Nanobiotechnology will make a difference in medicine, for pharmaceuticals and diagnostics, in countless industrial processes, agriculture and food industry. In Spain, Nanobiotechnology represents 10% of all nano research fields, and Nanomedicine is growing as a differentiated portion showing its increased importance (**Fig. 7**)

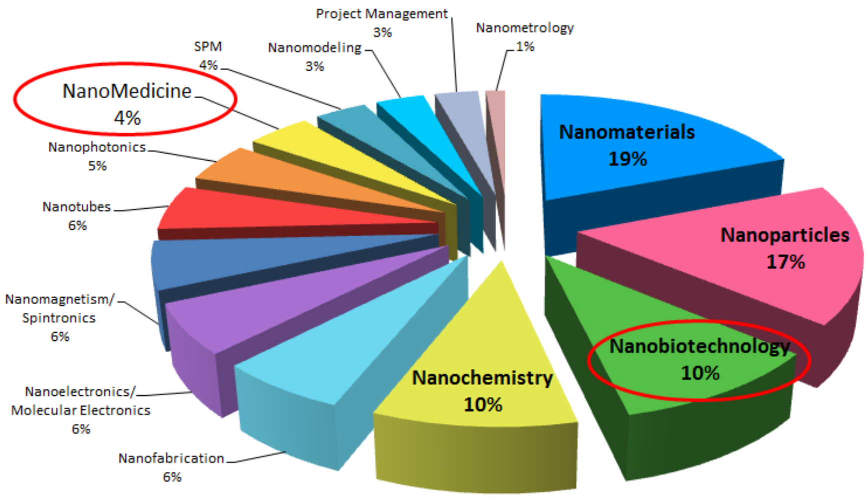


Fig. 7*: Distribution of nanotechnologies in Spain (Source: Phantoms Foundation, 2011)*

For nanomedicine in Spain, biosensors, biochips, cellular chips, active implants, bioreactors for cellular bi and tridimentional growth, tissue engineering, drugs administration, and genetic sequencing are considered consolidated areas of specialization. Particularly tissue engineering and genetic sequencing seems to have a high expectation of market commercialization by 2020 (since 2015 and from 2016-2020 consecutively). At present, biosensors, biochips, and cellular chips are in the prototype stage, while the other technologies are mostly in industrial development. However, the development of applications in this area will not reach the level of industrial development until 2020. Spain will also be in a foreign technological dependence in all these topics.[12] Nanofotonics, nanobiology and nanomedicine (molecular diagnosis), and photovoltaic energy are fields with less external dependence at the industrial level, however the dependence is high regarding nanobiology and nanomedicine (diagnostic imaging).[37] Despite these predictions, experts have considered that these technologies in Spain have a major attraction both scientific and in market position equivalent or even better than that of neighbouring countries according to the scientific capabilities. Nonetheless exterior dependence will decrease to 34% in 2020 and to 25% beyond 2020.[12]

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[36] Commission, J. E., Nanomedicine, E. T. P. & Report, E. Radmaps in Nanomedicine Towards 2020. (2009).
[37] Fundación, P. *Nanociencia a y Nanotecnología en n España Nanociencia y Nanotecnología en España*. (2008).

It is expected that Nanotechnology could be the fastest-growing industry in history,[10] so new opportunities in the marketplace are also expected.[38] In fact, there are some nanotech products that are already in use, thus analysts anticipate that markets can grow by hundreds of billions of euros during the present decade.[24] The global nanotechnology market is anticipated to grow around 19% each year from 2013 to 2017 (**Fig 17**.). It is expected that the annual global market for nano-related goods and services will top $3 trillion in 2020.[39]

Spanish STPs Performance

An insight of the "real mission" of an STP can be obtained through a performance evaluation.[40,41] Even if it is difficult to measure the effectiveness of STPs due to the diversity in stakeholders' objectives and expectations and the performance criteria,[42] different approaches have been examined under some headings: employment growth, sales growth, profitability,[43] geographic proximity to universities,[22,44,45,46] the context where a science park is located and operates, the life cycle[40] and technology-based firms located within science parks and off park.[42,45,47,48]

Geographic proximity to universities is also a determinant that affects technology and knowledge exchange facilitating networking activities and generating costs advantages. Proximity to the STPs improves success in obtaining extramural funding and improves a university's doctoral graduates' prospects for jobs.[49] However, some studies show that Off-park firms achieve a higher level of employment than comparable on-park firms, thus indicating that science parks even obstruct the development of high-tech firms.[48] Westhead (1997) also found no statistically significant difference between the two types of firms in terms of R&D intensity, R&D spending and the research capability to introduce new products and patents.

Despite the fact that there are not many quantitative analysis to estimate the results that have been achieved through these years in Spanish STPs,[42] it is known that there is a positive impact for small companies regarding the location in the parks, rather than large companies, due to small companies benefitting from support from large companies.[50]

Spanish STPs have more than two decades of history. Since 2000, they and their companies have begun in a phase of expansion and rapid growth. In 2007 there were 25 parks associated with the Spanish Association of Science Parks in Spain (APTE), becoming one of the main tools of technology policies at this regional level.[50] Currently, there is a total of 49 park partners representing 61,25%,

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38 Flynn, T. & Wei, C. The pathway to commercialization for nanomedicine. *Nanomedicine* **1,** 47–51 (2005).
39 Roco, M., Mirkin, C. & Hersam, M. Nanotechnology research directions for societal needs in 2020: summary of international study. *J. Nanoparticle Res.* (2011).
40 Bigliardi, B., Dormio, A. I., Nosella, A. & Petroni, G. Assessing science parks' performances: directions from selected Italian case studies. *Technovation* **26,** 489–505 (2006).
41 Wright, M., Phan, P. H. & Siegel, D. S. Science parks and incubators: observations, synthesis and future research. *J. Bus. Ventur.* **20,** 165–182 (2005).
42 Hansson, F., Vestergaard, J. & Husted, K. Second generation science parks: from structural holes jockeys to social capital catalysts of the knowledge society. *Technovation* **25,** 1039–1049 (2005).
43 Löfsten, H. & Lindelöf, P. Science Parks and the growth of new technology-based firms—academic-industry links, innovation and markets. *Res. Policy* **31,** 859–876 (2002).
44 Chan, K. F. & Lau, T. Assessing technology incubator programs in the science park: the good, the bad and the ugly. *Technovation* **25,** 1215–1228 (2005).
45 Siegel, D. S., Westhead, P. & Wright, M. A ssessing the impact of university science parks on research productivity : exploratory firm-level evidence from the United Kingdom. **21,** 1357–1369 (2003).
46 Narasimhalu, A. Science and Technology Parks as an Open Innovation catalyst for Valorization. *Res. Collect. Sch. Inf. Syst.* **1672,** (2012).
47 Westhead, P. R&D "inputs" and "outputs" of technology-based firms located on and off Science Parks. *R&D Manag.* (1997).
48 Monck, C. & Peat, M. Science parks and the growth of high technology firms. (1988).
49 Link, A. N. & Scott, J. T. U.S. science parks: the diffusion of an innovation and its effects on the academic missions of universities. *Int. J. Ind. Organ.* **21,** 1323–1356 (2003).
50 Barge-Gil, A., Vásquez, Á. & Modrego, A. El Impacto de los Parques Científicos y Tecnológicos Españoles sobre la Innovación Empresarial según los tipos de Empresas. *La Innovación como factor Compet. la Empres. española- ICE* 73–88 (2011).

and 31 affiliated parks with a 28,75%. The majority of parks are located in Cataluña (20), Andalucía (14), Comunidad de Madrid (8), País Vasco (7), Comunidat Valenciana (6) and Castilla y León (4)[51] (**Fig. 8 A**). The first five regions concur with the most productive regions in terms of PCT patent applications-count and the majority of high and medium-high technology industries. On the other hand, the number of nanotechnology companies by autonomous communities differs from the number of scientific parks (**Fig. 8 B**).[52]
The main business sectors that are developed in the Spanish science and technology parks have been identified in 11 categories in which the most outstanding ones are the TICs (23%), Engineering, Consulting and Advisory, which engaged 16% of the entities, 7% for medicine and healthcare and 4% of technology centres.[53]

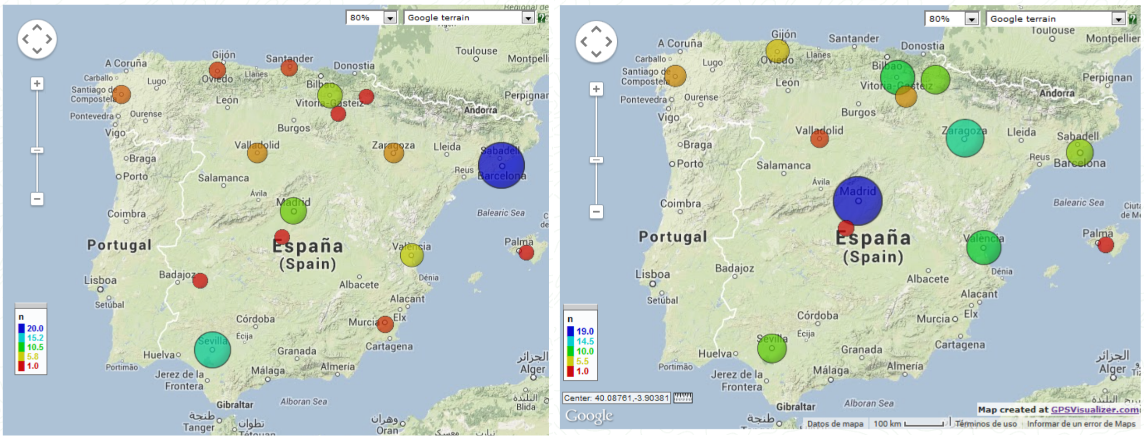

Fig. 8: *A) Number of Scientific Parks by Autonomous Communities*
B) Number of Nanotechnology Companies by Autonomous Communities.

In 2010, APTE STPs members had a total of 1805 registered patents, as reported by 34 parks. In the same year, 3669 patents were requested compared with 189 patents requested by in-park companies. This means that only 5% of requested patents are from these entities and the 95% remaining are from other entities. The Autonomous Community with the most patents registered is the Basque Country, where there are 599 parks' patents in 2010, representing 33.2% of all patents. In a second group, four other regions, by number of patents, are Andalucía, (14.7%), Navarra (13, 6%) Valencia (10%), and Madrid (9.9%). Autonomous communities with the lowest percentage are Asturias (7%), Castilla y León (5.6%) and Catalonia (2.7%). The other regions have percentages below 1%.[51]

Science Parks provide an important resource network for new technology-based firms (NTBFs), and stimulate technological spillovers,[45] and have a crucial role not only in the formation of new companies but also in their organizational survival and development.[43] In this context, in Spain, there are 6119 companies registered in the STPs, 368 focused on medicine and health. The number of researchers reached 146 669 workers in 2012, resulting in a decrease of 5% over the previous years. There were 29,296 performing tasks of R&D. APTE members and the 7 Parks which have reached a relative maturity, generate 0.65% of GDP and 5.8% of R&D jobs in Spain.[51]

STPs are helping to improve the reality of the R+D+i of the Spanish system, increasing the interrelationships between Universities, Technology Centres and Business, favouring the creation of new technology-based companies, and promoting continuity and increased intensity of the R+D+i in companies. STPs are extremely cost-effective elements of the Public Sector.[16]

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51 Asociación, A. & Científicos, D. P. Memoria APTE 2012. (2012).
52 Phantoms Foundation. *Catalogue of Nanoscience & Nanotechnology Companies in Spain*. 1–88 (2013).
53 APTE. Estadísticas de la Actividad de los Parques Científicos y Tecnológicos Miembros de APTE de 2010. (2010).

STPs in the Nanobiotechnology TT and Industry

Scientific Parks are important providers of technical, logistical, administrative, and financial infrastructure to help young enterprises[54] generating sustainability and facilitating innovation.[55] In the nanotechnologies, knowledge transfer is also important, therefore transfer offices play a key role[56] and are considered central hubs in the regional relationships.[57] SPTs and incubators are important links in the entrepreneurial value chain at the national or environmental level of analysis.[5] In Science and Technology Parks, the term *valorization* is often referred to the process of creating value through transferring knowledge.[46] S&T parks present a wide variety of value models in response to the many different contexts in which they operate.[13]

The transfer improvement from research and science communities to commercial stakeholders should also include research centres, institutions, governmental bodies and industries.[3] STPs that embrace the Triple Helix Model appear to be ideal candidates to play the role of catalysts for successful valorization. This model posits that three sectors (helices), university-government-industry (UGI), communicate with one another and can occasionally, and partially, take on each other's role.[58] It can be seen as a way of providing greater insight into the complex dynamics between the government, business and knowledge centres, influencing the creation and the diffusion of knowledge, the production of value added with its attendant market dynamics, and regulation.[59] However, in the Nanobiotechnology sector, a Five Helix Model, where University-Hospital-Industry-Administration and Citizens should emerge for economic growth and social benefits, with an important role of STPs in all these engines.[56] Nowadays, STPs are conceived as a mechanism by which academic researchers commercialize their outputs and where firms can locate in order to access academic expertise, becoming the "linker" between academic science and the market. Science and Technology Parks thus represent an infrastructural mechanism to bridge the gap between academia and industry. [60]

According to the Phantoms Foundation (2013), there are 94 Nanoscience and Nanotechnology companies in Spain. They are mostly situated in Madrid, Aragon, País Vasco, Comunidad Valenciana, Navarra, Andalucía and Cataluña **(Fig. 8B).** In Spain, 12.62% of companies are involved as main research areas in Nanomaterials, 9.89% in Nanocomposites, 8.53% in Nanoparticles, 7.84% in NanoBio and 7.16% in Nanomedicine. A lesser percentage of research domains are Carbon Nanofibres, Microsensors, Nanotoxicology and Nanophotonics.[52] **Fig. 9** shows all research lines and the number of Spanish companies that are currently developing these areas.

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54 Lai, H.-C. & Shyu, J. Z. A comparison of innovation capacity at science parks across the Taiwan Strait: the case of Zhangjiang High-Tech Park and Hsinchu Science-based Industrial Park. *Technovation* **25,** 805-813 (2005).
55 Erdélyi, T. D. Science Parks as the Facilitators of Sustainability The Case of IDEON Science Park and its Lightfoot Academy. (2011).
56 Juanola-Feliu, E., Colomer-Farrarons, J., Miribel-Català, P., Samitier, J. & Valls-Pasola, J. Market challenges facing academic research in commercializing nano-enabled implantable devices for in-vivo biomedical analysis. *Technovation* **32,** 193–204 (2012).
57 Resende, D. N., Gibson, D. & Jarrett, J. BTP—Best Transfer Practices. A tool for qualitative analysis of tech-transfer offices: A cross cultural analysis. *Technovation* **33,** 2–12 (2012).
58 Hyun Kim, J. A Hyperlink and Semantic Network Analysis of the Triple Helix (University-Government-Industry): The Interorganizational Communication Structure of Nanotechnology. *J. Comput. Commun.* **17,** 152-170 (2012).
59 Van Looy, B., Ranga, M., Callaert, J., Debackere, K. & Zimmermann, E. Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect? *Res. Policy* **33,** 425–441 (2004).
60 Quintas, P., Wield, D. & Massey, D. Academic-industry links and innovation: questioning the science park model. *Technovation* **12,** 161–175 (1992).

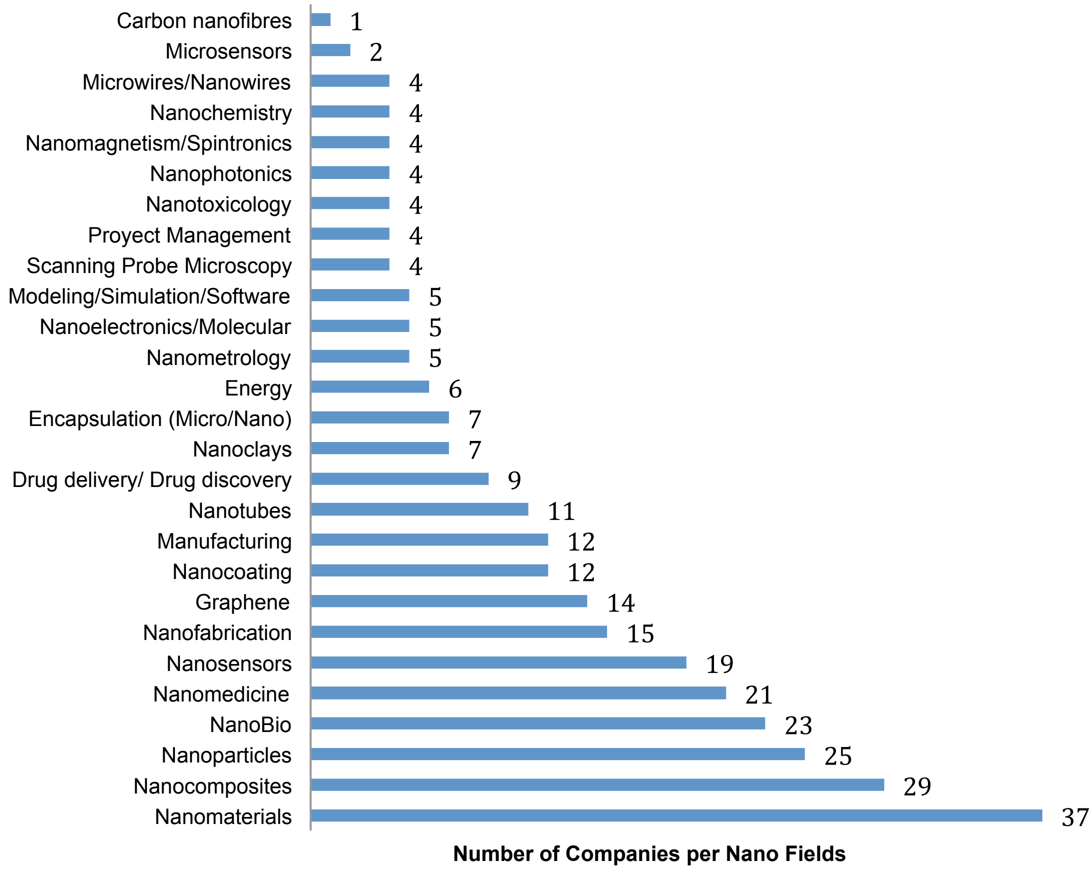

Fig.9: *Number of Nanotech companies by research fields (Phantoms Foundation, 2013)*

Networks also have an important access to opportunities for growth and profit.[61] In this context several initiatives have been promoted to strengthen research and support in nanotechnology from the late 90's in Spain, since there wasn´t any institutional framework or initiative pointed towards the support and promotion of R&D in nanotechnology. This fact pushed the scientific community to promote several initiatives to strengthen research in nanotechnology and, at the same time, to raise the awareness of public administration and industry.[62] Some of the important research networks and institutions are presented in **Box2.**

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[61] Ebers, E. & Powell, W. W. Biotechnology: Its origins, organization, and outputs. *Res. Policy* **36,** 433-437 (2007).

[62] Correia, a., Pérez, M., Sáenz, J. J. & Serena, P. a. Nanotechnology applications: a driving force for R&D investment. *Phys. Status Solidi* **204,** 1611-1622 (2007).

Box2. Spanish Nanotechnology Networks

Research Networks and Institutes:

- Nanociencia
- NanoSpain Spanish Nanotechnology Network (coordinated by the Phantoms Foundation)
- CSIC (Spanish National Research Council)
- TNT Trends in Nanotechnology conferences
- IBEC "Catalan Bioengineering Institute
- Instituto Catalán de Nanotecnología
- INA Instituto de Nanotecnología de Aragón
- Unidad de Nanotecnología de la Universidad de Oviedo
- Círculo de Innovación Tecnológica en Microsistemas y Nanotecnologías de la Comunidad de Madrid"
- NanoGalicia
- Saretek
- The Madrid Institute of Advanced Studies in Nanoscience (IMDEA-Nano)
- New International Iberian Nanotechnology Laboratory (INL)
- Spanish Foundation of Science and Technology (FECyT)
- Spanish National Research Council (CSIC)
- Aitex Nanotechnology Group
- Modelling for Nanotechnology - M4nano
- Nanogune
- Red Nanoenergía
- Spanish NanoMedicine Platform

Technological Centers approaching Nanotechnology:

- TEKNIKER, INASMET, CIDETEC, IKERLAN, LABEIN

Nanobiotechnology: a cross-cutting KET fostered by STPs

In September 2009, the European Commission published its Communication *"Preparing for our future: Developing a common strategy for key enabling technologies in the EU"*. This strategy identifies the need for the EU to facilitate the industrial deployment of Key Enabling Technologies (KETs) in order to make its industries more innovative and globally competitive. KETs are one of the key factors to realize the overall policy objectives of Europe 2020, due to the importance of these technologies for the competitiveness and innovation of European enterprises as well as for the development of sustainable products and processes.[1]

Six KETs have been selected according to the economic criteria, economic potential, capital intensity, technology intensity, and their value adding enabling role (**Box 3**).[63]

Box3. Key Enabling Technologies KETs

1. Nanotechnology,
2. Micro and Nano Electronics,
3. Photonics,
4. Advanced Materials,
5. Biotechnology Industry, and
6. Advanced Manufacturing Systems

The first KET, Nanotechnology, is expected to make a rapid impact on society[64] through the creation of future economic scenarios, the stimulation of productivity and competitiveness, the converging of technologies, and in the new trends in education and human development. The increasing speed of the changes in markets, products, technologies, competitors, regulations and even in society means important structural variations that modify what is strategic for organizations.[65] Evidence for the rapid impact of nanotechnology can be gleaned from figures for government investment in nanotechnology R+D activities, facilities and workforce training. Analysts expect markets to grow by hundreds of billions of euros during the present decade. After a long R+D incubation period, several industrial segments are already emerging as early adopters of nanotech-enabled products and findings suggest that the Bio&Health market is among the most promising for the coming years.

Nanotechnology is considered to be heterogeneous, multifaceted[66] and interdisciplinary because it combines and blurs disciplines such as physics, chemistry and bio/medical as subfields (**Fig. 10**).[10,38] Furthermore, it is considered multidisciplinary since it is not restricted to the realm of advanced materials, extending also to manufacturing processes, biotechnology, pharmacy, electronics and IT, as well as other technologies.[34,67] These characteristics allow the connection to a diversified set of industries,[11] implying that nanotechnologies can be involved directly or indirectly in the other five remaining KETs. This could be evidenced by the nanotechnology-based products that are now entering the consumer market, which have had a huge impact on almost every industrial sector.[7,38]

63 ECSIP consortium. Study on the international market distortion in the area of KETs: A case analysis. (2013).
64 Roco, M. C. & Bainbridge, W. S. Societal implications of nanoscience and nanotechnology: Maximizing human benefit. *J. Nanoparticle Res.* **7,** 1–13 (2005).
65 Teece, D. Capturing Value from Knowledge Assets: The New Economy, markets for know-how, and intangible assets. *Calif. Manage. Rev.* (1998).
66 Libaers, D., Meyer, M. & Geuna, A. The Role of University Spinout Companies in an Emerging Technology: The Case of Nanotechnology. 443–450 (2006).
67 Porter, A. & Youtie, J. How interdisciplinary is nanotechnology? *J. Nanoparticle Res.* (2009).

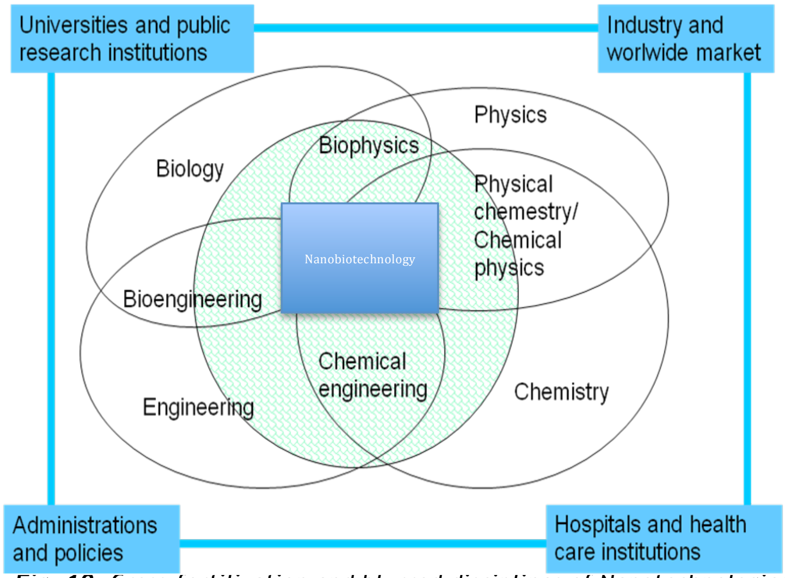

Fig. 10: Cross-fertilization and blurred disciplines of Nanotechnologies. Source: (Juanola-Feliu et al., 2012).

This strong interdisciplinary character, combined with the possibility of manipulating a material atom by atom, opens up unknown fields and provides an endless source of innovation and creativity. Nanotechnology qualifies for having a major impact on the world economy, because nanotechnological applications will be used in virtually all sectors.[68]

While each of the KETs already has huge potential for innovation individually, their **cross-fertilization** is particularly important to offer even greater possibilities to foster innovation and create new markets (**Fig. 11**). The concept of cross-cutting KETs refers to the integration of different key enabling technologies in a way that creates value beyond the sum of the individual technologies for developing innovative and competitive products, goods and services that can contribute to solving societal challenges. Cross-cutting KETs activities will in general include activities closer to market and applications. The global market volume in KETS is 646 billion euros and substantial growth is expected of approximately 8% of EU GDP by 2015 (Ro-cKETs project conference, Brussels 2-3 April, 2014)

[68] Hullmann, A. The economic development of nanotechnology - An indicators based analysis. (2006).

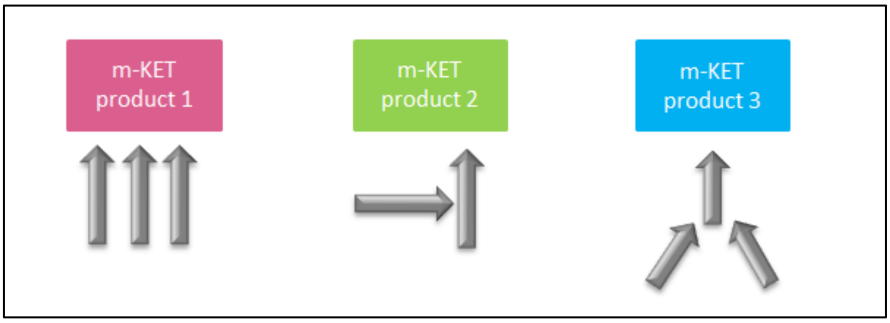

***Fig. 11**: Multi-KETs production (Source: Ro-cKETs project conference, Brussels 2-3 April, 2014)*

The integration of different Key Enabling Technologies (KETs) represents a vital activity in Horizon 2020. About one third of the budget assigned to KETs will go to supporting innovation projects integrating different KETs (European commission page web, 2013). Multi-KETs are the sum of at least two KETs and an Advance Manufacturing Systems (AMS) environment (High tech manufacturing environment). In this context two of the six KETs: Nanotechnology and Biotechnology Industry can be fused into one: *Nanobiotechnologies*.

STPs in Spain have not yet estimated the distribution of KETs within the parks. Similar sectors by number of companies in the STPs members of the APTE are: Agro and Biotechnology 4%, Energy and Environment 4.3%, Industry 3.5%, and Health and Medicine 6.1%.[69] STPs are boosters of multi-KETs as they allow the convergence of all the KETs in one place. This is a facility for companies that intend to research, develop and commercialize multi-KETs products.

Future challenges for STPs

Despite the fact that the nanobiotechnology industry is growing, it still has to overcome some barriers. According to Linton & Walsh (2008), much of the science and technology developed in research labs isn't commercialized.[70] Particularly, nanomedicine firms have focused primarily on the science and less on the commercial applications resulting in difficulty in bringing products to market.[38] This discontinuity constrains a complete development of nanotechnologies in industry. Spanish innovation indicators show that this could be attributed to the so called "***European paradox***" phenomenon[2,71] which explains the presence of a gap between high levels of scientific performance on one hand and the minimal contributions to industrial competitiveness and new venture entrepreneurship on the other.[21,38,71,72] The EU has difficulties in translating its knowledge base into goods and products, as for example; R&D projects implemented in FP6 and FP75 frameworks have successfully delivered a lot of new nanomedicines but few products on the market. In this context, The Commission states that bridging the so called "Valley of Death" to upscale new KET technology based prototypes to commercial manufacturing, often constitutes a weak link in the successful use of KETs potential. This is meant to be the "European industrial Renaissance" by covering the whole value of chain Lab-to-Market as the principal aim of H2020 where market is the main starting point.

The overcoming of this barrier is what Flynn et al., (2005) called "*Crossing the chasm to commercialization*", [38] and STPs are the key players in the improvement of the technology transfer for this gap reduction. One important pre-requisite for successful implementation of the identified roadmaps will be an improved knowledge and communication between academics, SMEs and

69 APTE, A. & Científicos, D. P. Memoria APTE 2012. (2012).
70 Linton, J. D. & Walsh, S. T. A theory of innovation for process-based innovations such as nanotechnology. **75,** 583-594 (2008).
71 Debackere, K. Managing academic R&D as a business at K.U. Leuven: context, structure and process. *R D Manag*. **30,** 323-328 (2000).
72 Linton, J. D. & Walsh, S. T. Acceleration and Extension of Opportunity Recognition for Nanotechnologies and Other Emerging Technologies. *Int. Small Bus. J.* **26,** 83-99 (2008).

especially large industry,[36] since very little is still known about nanotechnology transfer from universities to companies.[11]

Nanomedicine belongs to those emerging sectors in which business development methods have not been established yet. Some of the barriers to innovation and growth for SMEs are access to finance additional to public support, knowledge and skills shortage, weakness in networking and cooperation with external partners (open innovation) and Internationalization. For that reason, some of the challenges for NanoBio and Nanomedicine Spanish SMEs include adopting a market perspective, which means starting from the demand side (demand analysis, identification of technological opportunities, mapping market requirements), featuring highly qualified jobs and highly skilled people, finding partners, or looking for associations with research groups so they can combine efforts in generating qualified projects for H2020. All these SMEs challenges are also challenges for STPs as they are the guides of innovation in the value chain.

Also STPs will have an important role in the new multi-KET *pilot production*, which is between technology and commercialization. Pilot scalability is considered a **bottle neck** in the way to commercialization, even more in the Health domain where the scalability is complex. Most high tech pilot production problems are inherently multi-KETs. SMEs diversity of technologies requires flexibility for needs and solutions in this process. Companies would need access to facilities and access to a production mentality, which requires manufacturing expertise found in STPs.

Last but not least, as a consequence of industry growth, human capital will be essential in the future (human resources management). Roco (2003) estimated that about 2 million nanotechnology workers will be needed worldwide by 2015. A distribution of nanotechnology workers will also be needed for approximately 0.3 and 0.4 million professionals in Europe. Consequently, trained personnel, skilled workers, and high level educational degrees must be considered as a key challenge.[73]

Conclusions

Due to the rapid evolution of Nanotechnologies, the identification of new trends, challenges, and principal stakeholders is required. Nanotechnology is considered the engine of the next industrial revolution so it's necessary to know the state of the art and progress in this field for an adequate positioning at the industrial and economic levels. This enables improvement over the shortcomings and taking advantage of funding frameworks such as the Horizon 2020.
Healthcare nanotechnologies, named nanobiotechnologies and nanomedicines, need to have special considerations due to their impact in social and economic areas. As innovation indicators showed that Spain is a country with high capacity, policies should focus most on improving technology transfer process (adding value process) as well as networking and innovation diffusion activities to achieve a high performance status. These activities are fundamental to STPs, so their evaluation and performance analysis is needed.

In this document we have had a closer look at the two main quantifiable indicators of scientific and technological excellence and innovation in a region: patents and publications. Patents reflect the ability to translate scientific results into technological applications, identifying most promising fields and actors in terms of human capital, organizations, or countries. Also they are evidence of the translation of the science, R&D and innovation to the market. As the total KET patent applications in Spain shows that Nanotechnology is less than 2%, there is still more to do in this field.

Universities, companies, administrations and citizens, as a Five-Helix Model fostered by STPs, need to establish new methods of cooperation to take advantage of the European Union Horizon 2020 project. To achieve this goal, especially in Spain, it is needed to increase the integration of the research results into the market. Universities and companies must cooperate in entrepreneurship

[73] Roco, M. Converging science and technology at the nanoscale: opportunities for education and training. *Nat. Biotechnol.* (2003).

and attracting talent to analyse together the market demand which is one of the fundamentals of the H2020 objectives. STPs are also encouraged to strategically position themselves in the downstream (market) side of the second axis of the Strategigram, and not only in the upstream portion (technology stream).

In conclusion, Technological and Scientific Parks are an essential element of innovative systems for important projects but also they have an important role in the leadership and coordination in the H2020 framework to reduce the gap between science and market.