Nanotechnology in Spain: from basic science to the market

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Summary

Over the last decade several initiatives were launched by the Government of Spain and its Autonomous Communities in order to fund excellence projects, and to establish forefront centres and infrastructures able to compete at the international level in the emerging fields of Nanoscience and Nanotechnology (N&N). Nowadays, Spain is one of the ten leading countries in terms of scientific production in such fields. However, this leading position of the Spanish scientists has little influence on the dynamics of a productive sector that is evolving with slow rhythm. As result, the number of large or companies showing activity in these research areas is quite small, making difficult the penetration of Spanish products in the extremely competitive nanotechnology global market.

1. International context: many applications, large investments

Nanoscience and Nanotechnology (N&N) are two already consolidated research topics that cover the discovery, understanding and application of novel properties that emerge or are improved from the control of the composition, shape and size of matter at the nanometer level. N&N exploit the novel properties of materials and devices that emerge when their characteristic dimensions moves down the nanoscale, i.e. a length interval ranging from one nanometer (1 nm) to few hundreds of nanometers (1). Nanoscale landscapes are populated by different kinds of nanostructures or nanoobjects which constitute the basis for synthesizing and fabricating novel materials and devices using a huge amount of top-down and bottom-up strategies that allow the control of matter at atomic and molecular scale, Such strategies are being developed from a suitable and synergistic convergence of many methodologies traditionally used in biology, physics, chemistry, computational sciences and engineering.

The multidisciplinary character of N&N will favour their impact in many economic sectors (2,3): health, environment, transportation, energy, biotechnology, agriculture, electronics, etc. Many N&N applications will allow the optimization of resources and diminishing environmental

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impact, in the direction of the sustainable economy paradigm. In addition, the convergence of N&N with other disciplines as biotechnology, cognitive sciences and information technologies will open a fruitful field of innovative applications (4,5) leading to a large scale invasion of N&N consumer goods, thus providing tangible results for the economy. The major consequence of these optimistic predictions has been the increase of funding, public and private, in N&N.

Currently, N&N represent one of the fastest growing areas of R&D worldwide (6-8). For instance, the US National Nanotechnology Initiative (NNI) budget allocated to the federal departments and agencies increased from US$ 464 million in 2001 to approximately US$ 1760 million in 2011 (9), accumulating ten billion US dollars over such period. Similar programs supporting the development of N&N have been established in Asian countries as Japan, South Korea, Taiwan, India, Iran, Malaysia, Singapore, or Thailand, promoting the use of N&N in local industrial sectors. European Union has also intensively promoted Nanotechnology (10,11) within the VI (FP6) and the VII (FP7) Framework Programmes through several thematic areas, as NMP ("Nanosciences, Nanotechnologies, Materials and new Production Technologies") or ICT ("Information and Communication Technologies"). For instance, over the period 2003-2006, the allocated budget for the NMP program added up to 1429 million Euros, increasing to 3475 million Euros over the FP7 (2007-2013). A major focus of UE initiatives is to improve the coordination and collaboration among stakeholders, and promote initiatives related with toxicology, ecological impact, metrology, standardization, regulation, dissemination and public engagement. Among the EU members, Germany, France and UK lead the N&N initiatives, including funding for human resources training, outstanding research centres and multidisciplinary campus of excellence. Similar initiatives have been launched in UK, the Netherlands, Austria, Italy, etc.

Other countries as Canada, Russia, Israel, Australia, Brazil, Argentina, and Mexico have mimicked the US or EU programs, incorporating particular aspects related with their own productive sectors. In this euphoric context, Spain has also implemented several initiatives that we describe below.

2. Nanotechnology in Spain: the impact of networking.

A very recent set of reports (12,13) released by the Phantoms Foundation (14) as coordinator of the Spanish Nanotechnology Network (NanoSpain) (15) provide a broad overview of the evolution and present situation of N&N in Spain. NanoSpain is currently formed by more than 330 groups from universities, research centers and companies, showing the strength of research in N&N in Spain. Figure 1 shows the distribution of topics as declared by the group members of the NanoSpain network, and illustrates the multidisciplinary character of nanotechnology. A shorter analysis on the current situation of Spanish N&N has been also published very recently (16). At the end of 1990´s, Spain lacked of specific institutional

programs intended to support and promote R&D activities in N&N. This was in contrast with the relative high world-wide impact of the Spanish scientific community working in N&N. The scientific community, leaded by the NanoSpain Network, played a leading role promoting several initiatives to raise the awareness of Public Administrations and private companies on this emerging field. The conference series "Trends in Nanotechnology" (17) and the ImagineNano event (first edition in 2011) (18) are two clear examples of the promotion of N&N from the scientific community, following a bottom-up strategy.

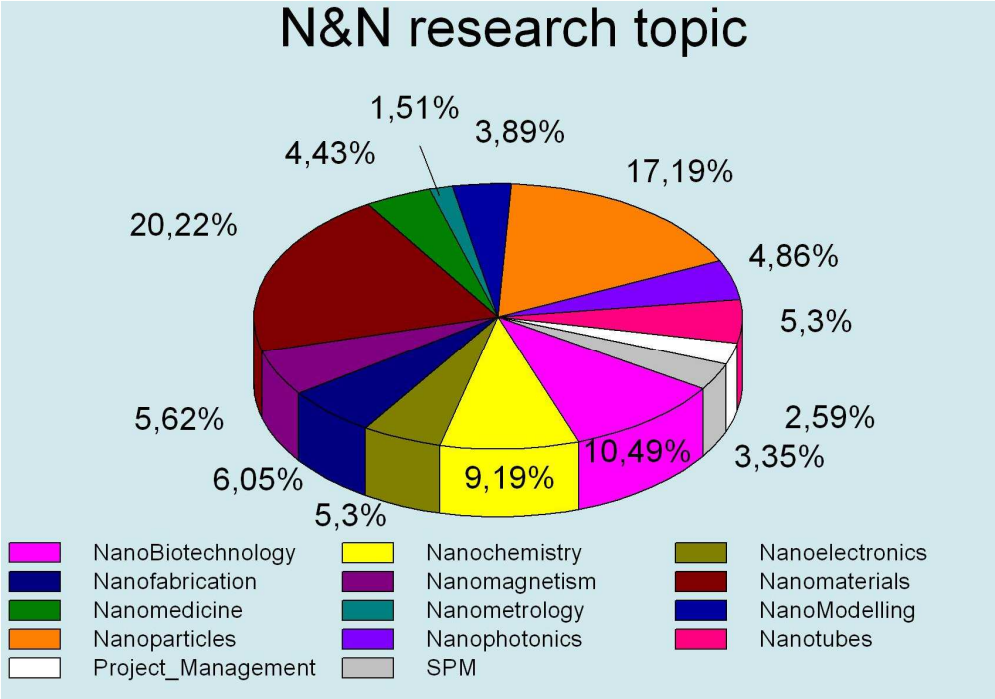

Figure 1. N&N research topics distribution corresponding to the 332 groups of the NanoSpain network (15).

As a consequence of the initiatives from the scientific community (networks, workshops, conferences) the National Plan for promoting R&D over the 2004-2007 and 2008-2011 periods included the so-called Strategic Action in Nanoscience and Nanotechnology (19). This Strategic Action allocated more than 324 million of Euros for funding R&D medium and large scale projects, building new R&D centers and technology platforms (see Figure 2). Under this funding scheme, the governments of Portugal and Spain have launched the International Iberian Nanotechnology Laboratory (INL), a joint centre aiming at playing a central role in Europe (20). We must mention the set of programs and centers promoted by the Autonomous (Regional) Governments or the Spanish National Research Council (CSIC) (21). A major effect of this wealth of investments has been the privileged position of Spain among the top ten countries around the world in terms of N&N publications (22,23). However, the budget for funding R&D activities has been decreasing from 2009 and, as consequence, the number of projects, fellowships and hired researchers has started falling. In the mid term, this reduction will impact negatively the Spain's position in the N&N publications world ranking.

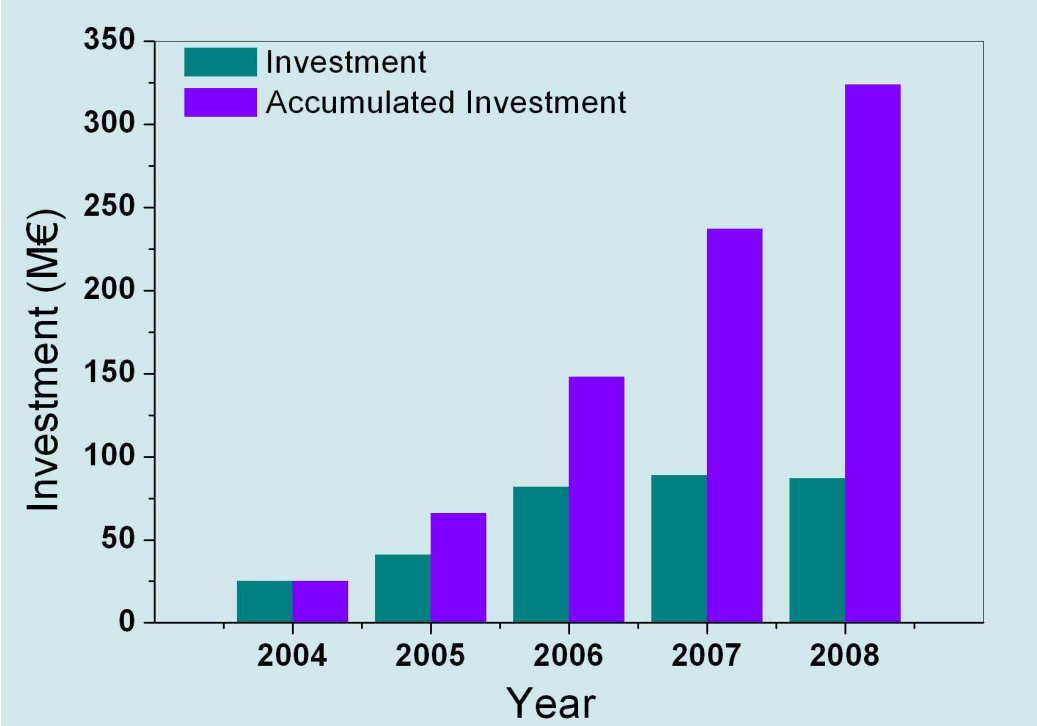

Figure 2. Spending of the Government of Spain (per year and accumulated) in the promotion of Nanoscience and Nanotechnology activities over the period 2004-2008.

3. Spanish "nanotech" companies: an emerging sector.

The outstanding situation of Spanish science has nothing to do with the market impact of the Spanish nanotech companies. National and regional governments have implemented several programs and actuations to enhance the technology transference of basic and applied knowledge born in the laboratories to the companies' productions plants (16). These programs include the funding of large scale public-private consortia leaded by Technology Centers (24), spin-off companies located in Science and Technology Parks (25), or Technology Platforms (26). These strategies for generation and transfer of knowledge have been reinforced by some complementary activities aimed at the internationalization and commercialization of N&N products obtained by Spanish companies. The Spanish Institute of Foreign Trade (ICEX) (27), through its Technology Plan in Nanotechnology (coordinated by the Phantoms Foundation (14)), has encouraged many international promotion activities, enabling the participation of more than fifty Spanish companies in several international exhibitions as Nanotech Japan (2008-2012), US NSTI fair (2009), Taiwan Nano (2010) or RusNanoTech (2011). Figure 3 shows a snapshot of the Spain Exhibition Area in the Nanotech 2012 event. Over the last 5 years more than 40 different companies and institutions have exhibited their products, patents portfolios and services under the ICEX-Phantoms plan for promoting Spanish N&N abroad.

Figure 3. Spain Area in the Nanotech Tokyo 2012 event. Fotography courtesy of Dr. J. Maira, Deputy Vicepresidency for Knowledge Transfer, Spanish National Research Council (CSIC).

In spite of the large amount of public initiatives aimed at increasing the number as well as the economic impact of Spanish companies, the share of the global N&N market by these N&N companies is negligible, following the same trends noticed in those Spanish sectors based on intensive R&D activities. From long time ago, national and regional Governments have implemented several programs devoted to increase the knowledge transference from universities and public research institutes to the productive sectors. However, these programs have achieved limited success as shown by the evolution of several indicators (28,29,30) as number of filed patents per resident, volume of high-technology exports, number of R&D staff, etc. Therefore, Spain faces a serious challenge in order to be considered as a relevant worldwide economic player. The only way to reach this status is to take several steps, including a noticeable increase of the funding of R&D activities, an improvement of internal coordination among regional and central administrations, the change towards a new educative model focused on a culture of innovation and efficiency, etc. If these conditions are set, those companies that currently are developing their activity in N&N would play a major role in Spain economy. However, this goal will be achieved in one or two decades.

What kinds of companies are leading this change in the productive sectors? Next paragraphs are devoted to shortly describe the profile of such innovative companies. However, we must mention that there is little information on the number of “nano-companies” since there is no easy access to available public information on these issues. Using several sources (13, 15, 16) we have identified 78 companies working in nanotechnology. More than half of this number

corresponds to companies created in the period 2005-2011. Figure 4 shows the evolution of the number of N&N based companies. It is worth say that the number of Spanish companies with some kind of activity in N&N is very low in comparison to that of US, Japan, Taiwan, Germany, UK or France. The most appealing fact is that the average growth rate (6 companies per year) is constant even over the period 2009-2011, which corresponds to the deep crisis suffered in particular by the Spanish economy. From the analysis of the set of 78 companies we conclude that: (i) in general N&N companies are extremely small since they have been recently established and they did not find economic resources to expand their activities; (ii) these N&N companies invest in R&D activities as a fundamental basis of their respective businesses although the R&D department is really small (1-2 people on average); (iii) traditional industrial sectors are not aware of the competitive advantages that nanotechnology could provide to their businesses. In general, we found that many companies are start-ups or spin-offs, leaded by few highly qualified researchers who are members of universities or research centres, and physically located in one of the Science and Technology Parks scattered across the country. It is very interesting to notice that Madrid, Basque Country, Aragon and Andalusia accumulate more that 50% of the Spanish N&N companies.

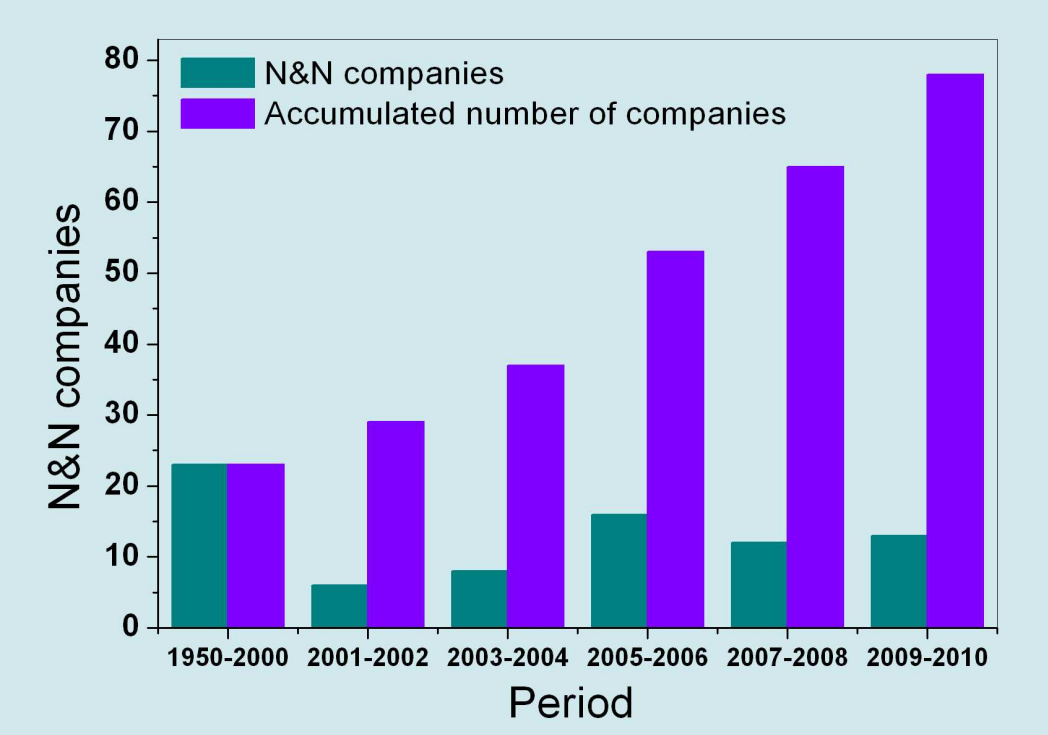

Figure 4. Evolution of the number of companies with activity in N&N over the 1957-2010 period.

Figure 5 shows the distribution of Spanish N&N companies among several economy sectors: (i) Agro-food & cosmetics, (ii) Health & biotechnology, (iii) Nanomaterials providers, (iv) Electronic devices, instrumentation & equipment, (iv) Automotive & Aerospace, (v) Construction & civil infrastructures, (vi) Energy & environment, (vii) Software, and (ix) Consulting & project management. It is worth mention that the most important sectors are Health & Biotechnology and Nanomaterials. These areas fit well to the most representative activities of Spanish R&D

groups (see Figure 1). Notice that dimension of Spanish electronics industry is not so large in comparison to that of other UE countries, and that in consequence, the number of N&N companies with activities in electronics or electronic equipment is small.

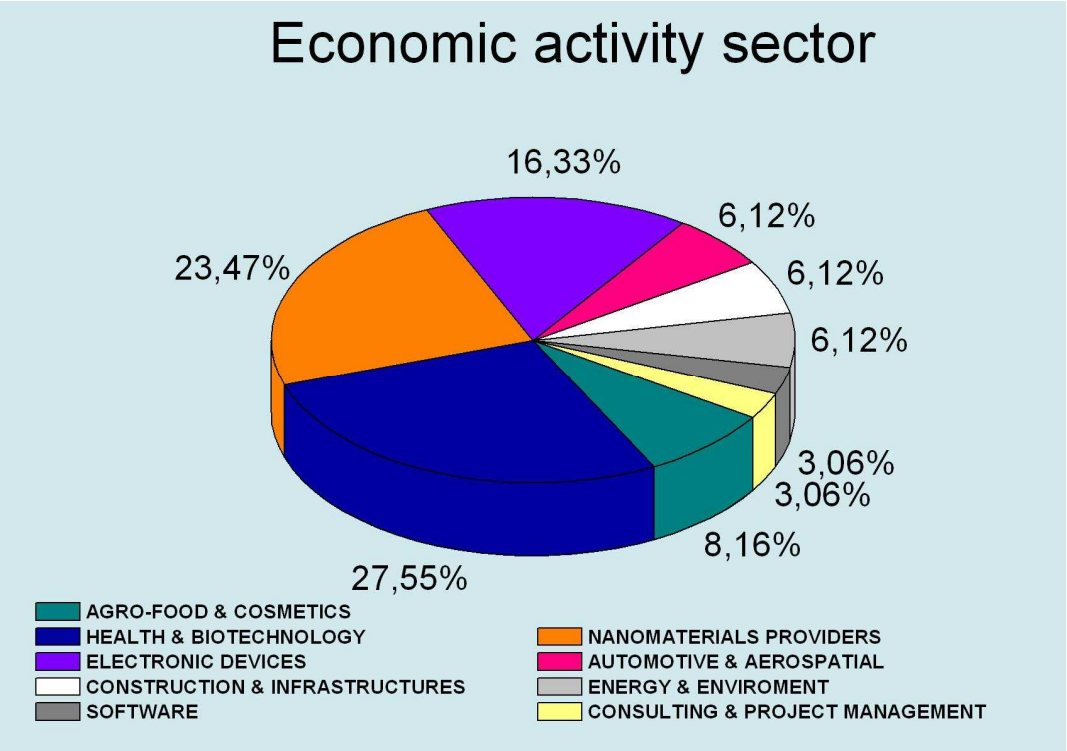

Figure 5. Economy sector distribution of Spanish companies with activity in N&N.

4. Conclusions

Nanoscience and Nanotechnology represent scientific-technical areas that in less than two decades have gone from being in the hands of a reduced group of researchers who glimpsed their great potential, to constitute one of the recognized pillars of the scientific advance for the next decades. The expected impact of Nanotechnology in many sectors has made possible the increase of public and private investment in N&N, and several countries are competing to lead the “nano-revolution”. Spain can be included in the group of privileged countries that are moving towards the knowledge-based society paradigm. However, in order to keep the pace with other advanced countries, it is necessary: (i) to increase the levels of R&D investment in N&N programs, in spite of the economy crisis context; (ii) to stimulate the dialogue and cooperation between national and regional governments, (iii) to take into account existing scientific networks in the design of scientific policies; (iv) to enhance the coordination of universities, research centres, and large scale infrastructures in order to optimize the access to scientific services of public and private research groups; (v) to enhance public-private cooperation through Technology Platforms, Industry Networks and Science and Technology Parks; (vi) to provide access to funding and logistic support to small N&N emerging spin-offs; (vii) to improve multidisciplinary research through specific training programs (Master and PhD

courses); and (viii) to involve the society through well designed dissemination activities using classical (science museums, television programs) or emerging (internet, social networks) approaches. We are at a critical crossroad, the next decade will confirm us whether we have chosen the right way.

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