Biotechnology development in Spain: a change of paradigm?

Oliver Todt, Emilio Muñoz, Juan Espinosa de los Monteros, Victor M. Díaz

Corresponding author: todt@iesam.csic.es (Oliver Todt)

The authors are at the Science, Technology and Society Dept., Comparative Policies Unit (UPC), Spanish National Research Council (CSIC), c/ Alfonso XII, 18; 28014 Madrid; Spain; Phone: +34-91-521-9028; Fax: +34-91-521-8103

ABSTRACT *This article presents a quantitative and qualitative analysis of the Spanish biotechnology sector, including its scientific, business, policy and social aspects. The study differentiates two sub-sectors, considered to be the most representative: Biopharma and Agro-food. The results show that biotechnology development in Spain has entered a new phase. Traditionally, research and development in Spain followed an unstructured path built around regional spaces and driven by factors and influences external to Spain. However, the emergence of a fast-growing sector of spin-off companies from the public research system, specifically in the Bio-pharma sector, point to a change of model of development of the industry, on the national as well as the regional level. The data also show the key role played by public policy in creating a suitable framework for innovation and point to the need to analyze the influence of social and cultural factors on the development of the biotechnology sector.*

KEYWORDS: *biotechnology, innovation studies, Spanish biotechnology innovation, technology policy*

1. Introduction

The analysis of innovation patterns in biotechnology has shown the influence and importance of a wide variety of factors, social actors and processes. Among those factors are the national, regional and cultural environments in which innovation takes place. This article contributes to the study of national and regional biotechnology innovation processes with data on one country, Spain, a member state of the European Union (EU). The peculiarities of the situation in Spain, which have been addressed in previous studies, make the development of the biotechnology sector in this country a paradigmatic case study for innovation in industrialized economies with relatively low levels of innovation and research activity.[i]

There currently exists a lack of detailed data on biotechnology development. This situation applies even more to countries like Spain in which this technology was introduced rather late and in which its level of diffusion remains relatively low (compared to other industrialized countries). The lack of data is due, in part, to some of the specific dynamics of the biotechnology sector, particularly its horizontal character, the complexity of the scientific-technological and socio-economic base of the industry as well as the tendency to concentrate most analytic efforts on those countries and regions where the technology is best established. Most of the data available so far has been provided by a diverse set of organizations like the U.S. Bioindustries Organization (BIO), the University of Siena (especially through its Biotechnology Information Database – BID), national entrepreneurial organizations or the consultants Ernst & Young (through their Annual Reports on behalf of the European Commission[ii]).

On the other hand, several institutions which compile data on research and development (R&D) and innovation – like the OECD[iii] or EuroStat – have launched important initiatives for obtaining data on the biotechnology sector. The European Commission (EC) has funded projects aimed at obtaining information on biotechnology's socio-political environment in different member states.[iv] The EC also has created a Score Board on Biotechnology Innovation Indicators[v] which delivered its first results at the beginning of 2003.

In Spain, data on the biotechnology sector has been collected by different sources. One of the fundamental problems of analyzing the industry is the lack of comprehensive official statistics. In fact, the first compilation of biotechnology companies in Spain is only from 1997.[vi] In the compilation of OECD biotechnology statistics done by van Beuzekom[vii] this catalogue served as the Spanish country profile. The Spanish Association of Biotechnology Companies (ASEBIO) and Genoma, a public foundation dedicated to biotechnology development, are the organizations which have generated more recent and detailed data on the Spanish biotechnology industry (including detailed categorization of the biotechnology companies).

This article presents an analysis of the Spanish biotechnology sector, including its scientific, business, policy and social aspects. The analysis was guided by the data needs of the most important conceptual framework used for the analysis of innovation: National or Regional Systems of Innovation (NSI, RSI). The study differentiates two important sub-sectors, Biopharma and Agro-food, in which most of the Spanish

scientific and industrial activity in biotechnology is concentrated. The Biopharma sector includes biomedical, human health, pharmaceutical and similar biotechnology applications. Agro-food comprises agricultural, fishing, food production and processing as well as animal health applications. Other sectors (environmental applications, bioprocesses, services, etc.) are not very prominent in Spain.

The ultimate objective of the present analysis is a characterization of the recent transformations which the Spanish biotechnology sector has undergone. In the last few years, the development of the biotechnology industry in Spain has experienced a change of trajectory, on the national as well as the regional level. A new relationship between the system of Public Sector Research (PSR) and industry is rapidly emerging, equivalent to a change in culture of innovation. Spain, which is not prominent in the biotechnology industry in Europe (nor in most other innovative high-tech sectors[viii]), is entering a new paradigm of development in the biotechnology sector which has important implications for the general Spanish trajectory of technological innovation.

Díaz at al.[ix] propose a classification for the development of the biotechnology sector in different European countries. They differentiate four models:

Model 1: this is the trajectory of biotechnology development in the United Kingdom, similar to the U.S. trajectory (mainly spin-offs from other firms or public research institutions, dedicated entirely to business in biotechnology);

Model 2: a trajectory followed by countries like Germany or Ireland, characterized by the relative importance of dedicated biotechnology companies and an intermediate level of spin-off companies;

Model 3: the French trajectory, with relatively few spin-offs and relatively new but previously existing companies turning to biotechnology;

Model 4: a trajectory based mainly on the diversification of existing traditional industries, with an extremely low profile in the creation of spin-offs and the virtual absence of spin-offs from the PSR system.

This last trajectory (model 4) was the one identified as the Spanish one, based on the situation of the biotechnology sector in the second half of the 1990s: most of the companies active in biotechnology were already existing large and medium-size enterprises from traditional industrial sectors which were applying

biotechnology to improve processes and products, with low levels of R&D investment and little cooperation with the public sector. Only very few spin-off companies existed at that moment. Most of the industry was located in just two regions, Catalunya and Madrid.

As this article shows, that situation has changed significantly in the last few years. The trajectory is now characterized by a large number of spin-off companies originating in the PSR system. In addition, the regional distribution of those companies indicates a geographically more evenly distributed development linked to the existence of research centers and universities.

2. Analyzing Biotechnology Innovation

2.1. National and Regional Systems of Innovation

Currently, several conceptual frameworks for analyzing technological innovation exist in the social and economic sciences. Their aim is to explain the process of innovation in one country or region, or in one specific sector as well as its repercussions (mostly on the economic level). The most widely used frame is the National and Regional Systems of Innovation (NSI, RSI) approach.

The NSI framework analyzes country-specific factors which influence the companies' innovative capabilities. The main idea of the approach is that a company's capability for innovation depends on its being able to interact with and coordinate a variety of external sources of knowledge (competitors, suppliers, scientific organizations, etc.) as well as internally generated knowledge from interdependent sources (like production, marketing or R&D).

NSI/RSI analyses are derived from quantitative and qualitative data on, among other, the production system, the structure and funding of R&D activities, regulation and public policy, property rights, inter-firm relationships (users-producers, industrial networks, etc.), the training and education system, relations between labor and capital, the firms' internal organization and dynamics as well as the financial system. Being based on a systems approach, NSI places emphasis on the relationship between processes of technology introduction and

diffusion, learning in companies (based on in-house as well as external knowledge) as well as nation or region-specific factors (public policy, social and cultural values, institutions, labor and financial markets, regulatory system and more, depending on how broad the framework is defined). The analysis encompasses formal (organizations) as well as informal institutions (like cultural values).

In the case of a RSI, the system's boundaries are defined by regional geographic limits. The regional perspective tries to overcome one of the main limitations of the NSI frame: the difficulties of establishing the boundaries of a "national" system in federal or multinational states as well as handling the socio-economic and cultural diversity existing within a nation. This is a crucial point for the analysis of the Spanish situation, given the important regional and cultural differences within the country.

While the NSI approach is based on one general framework, different authors stress distinctive elements of the system. According to Lundwall,[x] an innovation system is composed of the elements and relationships influencing the production, spreading and use of new and potentially useful knowledge. The essential elements of a system of innovation, according to this author, are the institutions and the production structure of the economy. Other authors have assumed the fundamental role played by the production system while placing distinct emphasis on the institutions. Nelson[xi] argues for the significance of the organizations involved in funding and support of R&D activities, whereas Edquist[xii] stresses the relevance of the informal ensemble of institutions (their social and cultural elements).

2.2. The analysis of innovation in the Spanish biotechnology sector: methodology

The present analysis centers on several of the elements proposed as key by the cited authors: the production system, PSR and R&D institutions as well as regulation and public policy. The evolution of those three elements was identified as the driving factor behind the recent structural changes experienced by biotechnology innovation in Spain. Most other factors were excluded from the analysis because of their relative unimportance for the new trajectory of biotechnology development but also because of the current lack of detailed data.

In fact, as already indicated, lack of consistent data collection has been a severe and general limitation of any analysis of the biotechnology sector in Spain. Among other, the rapid evolution of the biotechnology industry in Spain has resulted in difficulties in identifying and characterizing firms. The analysis therefore needs to draw on different data sources, combining quantitative and qualitative data.

Therefore, the present analysis is based on quantitative data as well as surveys from the different public and corporate Spanish sources indicated above. This information is complemented by (quantitative) data collected through questionnaires which allows to identify the role played by the key actors in the different areas characteristic of a system of innovation. In addition, (qualitative) data was gathered through research interviews with key actors as well as an analysis of Spanish biotechnology policy. All the data were collected during the 1998-2002 period.

3. Analysis of biotechnology development in Spain

The following sections will present data on three key aspects of biotechnology development in Spain: R&D, industry and public policy.

3.1. Spanish biotechnology research sector

In the areas of research related to biotechnology, Spain is well represented in the European Union as well as worldwide. In terms of the contribution to publications in journals indexed in the Science Citation Index (SCI), Spain holds the fourth place among European Union countries in the fields of biotechnology and applied microbiology (about 4% of the world-wide total SCI publications in those fields). At the same time, research in molecular biology, biotechnology and biomedicine in Spain has a slightly larger percentage of applied research (as compared to basic research) than the worldwide average.[xiii]

A comparison of human resources in research and teaching in the two main biotechnology sub-sectors shows a concentration in the Biopharma sector, which in some indicators more than doubles the Agro-food

sector (table 1). The traditionally strong position of Spanish research in the biomedical, biological and biotechnological sciences is reflected here. The science base in the Biopharma sector is very wide and strong, in terms of number of graduates, researchers and university teachers, but also in terms of research centers. Spanish scientific productivity (see above) is also dominated by this sector.

Table 1. Spanish science base (period 1991-1997) (own elaboration based on data from the Spanish National Institute of Statistics).

	Biopharma	Agro-food
Human resources		
• Potential		
Master Degrees (total 1991-1997)	129,621	117,300
Doctors (total 1991-1997)	17,190	9,150
• Real		
University professors (estimated)	3,039(staff)+2,602 (contract)	2,420(staff)+1,154(contract)
Researchers in projects	1,875	1,010
Researchers in other programs	700	450
Research Units		
Research Centers	2 (12 Depts., 130 units)	1 (3 Depts., 70 units)
Sectoral Research Centers	4	2
Functional units (projects)	357	178
Productivity		
Leading scientists (>3 projects)	9	5

As table 2 shows, the Biopharma and Agro-food sectors receive most of the public and private funds invested in R&D. Other biotechnology applications (environment, services, etc.) receive less money, in accordance with their relative lack of importance in Spain. The total sum of public funds spend on Biopharma R&D from 2000 to 2002 is less than half of what industry spend during the same period of time in that sector. In turn, in the Agro-food sector, public funds almost double private investment. Almost 90% of total private industry R&D funds are dedicated to Biopharma, 80% are spend by companies whose business activity is entirely dedicated to biotechnology in that sector. These figures show clearly that the Biopharma sector in Spain has entered a phase of self-sustaining development. Research and development in the Agro-food sector still depends heavily on public spending. In the Biopharma sector, most of the larger companies are now pharmaceutical laboratories, which account for the most part of the R&D investment.

Table 2. Total cumulative investment in biotechnology R&D for the period 2000-2002, millions of euros. (data: Ministry for Science and Technology and Genoma Foundation)

	Biopharma	Agro-food	Other
Total public R&D funds	**155**	**63**	**33**
Total private R&D funds	**352**	**37**	**14**
R&D funds of CEDB	306	28	9
R&D funds of CPDB	46	9	5

CEDB= Companies entirely dedicated to biotechnology; CPDB= Companies partially dedicated to Biotechnology

Compared to the total amount of public funds spend on R&D, the percentage allocated for stimulating innovation in biotechnology in private industry is very small (less than 5%). In addition, cooperation between

the private sector and the public research system is still incipient. Formal cooperation in terms of contracts and joint projects between companies and universities or public research centers remains limited. In 2002, about 800 such collaborative efforts for a total volume of 42 million euros were counted. This indicates that the level of cooperation between the private and public sectors remains low, in accordance to results from previous research (see at the beginning of the article).

Taking into account the fast growing number of spin-offs from the PSR system (see the following section), we must conclude that those spin-offs, even though originating in public research institutions, do not necessarily enter into cooperative agreements with such institutions. This is because most of those spin-offs, while headed and staffed by personnel trained in public research centers and universities and applying know-how directly from the PSR system, develop their own R&D activities. The ready availability of qualified personnel with research experience (see section 3.3.) permits a high level of R&D efforts within the newly founded firms, without necessity of recurring in all cases to collaboration with the public sector.

3.2. Spanish biotechnology business sector

The following classification of biotechnology companies in Spain was first proposed by Díaz et al.[xiv] A modified version will be applied here, akin to the one used by the Genoma Foundation. Three types of companies will be taken into account:

- Companies Entirely Dedicated to Biotechnology (CEDB): their main R&D efforts are located in Spain, they dedicate more than 80% of their activity to biotechnology and more than half of their total turnover is due to biotechnology;
- Companies Partially Dedicated to Biotechnology (CPDB): they also execute most of their R&D in Spain and a part of their turnover and business activity is due to biotechnology (but below 80% and 50% respectively);
- Companies Using Biotechnology (CUB): several of their principal lines of business are based on biotechnology applications while part of their turnover comes from biotechnology.

The following tables present the most important characteristics of those three kinds of firms.

Table 3. Structure of Spanish biotechnology business sector in 2003 and relative changes of different company types from 2000 to 2003 (data: Genoma Foundation)

	Percentage of type of firm in 2000 (%)	Percentage of type of firm in 2003 (%)	Number of firms in 2003	Avg. number of employees in 2003	Avg. turnover (millions of euros) in 2003
CEDB	20	36	71	21	1.8
CPDB	60	40	79	139	6.9
CUB	20	24	48	46	11.3

Table 4. Percentage of CEDB according to their year of establishment, in 2002 (data: ASEBIO)

Year of foundation	1900-1925	1925-1950	1950-1975	1975-2000	2001-2002
% of CEDB	5	5	10	40	40

Table 5. Distribution of size of firms (CEDB and CPDB) in 2001 (data: ASEBIO)

Size of firm (turnover)	Large (>€40m)	Medium (€0.3-40m)	Small (<€0.3m)
Percentage	9	32	59

Another important shift can be observed in the sectoral distribution (table 6). The distribution among the two dominating sectors (Agro-food and Biopharma) remained very stable through the end of the 1990s. Then, from 2000 onwards, the relative importance of the two sectors started to change rapidly.

Table 6. Relative distribution of firms by sectors, considering all three categories of biotechnology companies (CEDB, CPDB and CUB) (data for 1998-2001: ASEBIO; data for 2003: Genoma Foundation)

	Avg. 1998-2000 (%)	2001 (%)	2003 (%)
Agro-food	58	50	44
Biopharma	25	34	43
Other	17	16	13

As can be seen from the table, the importance of the Agro-food sector (in terms of number of firms) has decreased, while the percentage of companies in the Biopharma sector almost doubled in three years. This trend

is clearly confirmed by the development of turnover of the CEDBs. From 2000 to 2002, turnover rose from about 35 million euros to over 110 million euros in Biopharma, while it actually decreased from about 10 million euros to just about 4 million euros in the Agro-food sector during the same period of time. In other words, in terms of turnover, the sector of companies entirely dedicated to biotechnology is dominated by a very large margin by the Biopharma line.

In other words, the Spanish biotechnology sector is experiencing a distinct change: small, recently founded companies, mainly in the Biopharma sector, whose business is completely dedicated to biotechnology, with high R&D investment and mostly national ownership are now characteristic of an industry which until 2000 was dominated by the model 4 referred to in the introduction (large multinationals from traditional fields with few R&D activities in Spain which generate part of their business from using biotechnology applications).

Notably absent in this development is risk capital. Traditionally, this is not an important source of funds for business development in Spain. Despite the rapid development of spin-off companies since 2000, risk capital does not play any significant role. Biotechnology represents less than 1% of all the risk capital raised in Spain (compared to 10-20% in the U.S. and Europe).[xv]

3.3. The importance of the PSR system for the newly founded companies

An additional analysis of the newly founded companies reveals another important fact: the large majority are spin-offs originating in public sector research. The analysis of the companies entirely dedicated to biotechnology (CEDB) founded between 2000 and 2002 shows the importance of the PSR system as a source of entrepreneurs. In the present form, this constitutes an entirely new phenomenon not only in the Spanish biotechnology sector but for the entire Spanish economy.

Only 18% of all newly founded CEDB were spin-offs from private industry. In turn, 82% of all such companies were established by researchers from a public university or research center (in the Biopharma sector this percentage was even slightly higher, 88%). Those entrepreneurs include permanently employed, mostly senior researchers (civil servants or researchers on a permanent contract) who took on the foundation of a company parallel to their research jobs as well as researchers in an unstable employment situation without clear

perspective (short-term contracts without possibility of renewal) who decided to start a company as a more promising employment alternative (usually with the active support of established senior researchers from within the institution they were previously employed by). This shows the key importance of the availability of trained PSR personnel for the emergence of this new trajectory of the Spanish biotechnology sector.

In fact, the most important source of qualified personnel for the spin-off companies are researchers trained in the public research sector but forced to abandon it for lack of contracts and long-term career plans. While Spanish universities and public research centers are increasingly training personnel through pre-doctoral and post-doctoral scholarships and short-term contracts, the rate of permanent absorption of qualified personnel into the Spanish PSR system consistently remains much lower than the number of graduates and personnel trained in the public sector.[xvi] This surplus of researchers which the Spanish PSR system – because of its generally low level of R&D spending[xvii] – is unable to absorb, has clearly influenced the significant rise in startup companies. Newly founded companies mean a new source of employment in Spain for many researchers, doctors and young scientists who otherwise would have to look for work outside of Spain.

The dominance of the Biopharma sector among newly founded companies can be seen from table 7.

Table 7. Distribution according to sector of CEDB founded between 2000 and 2002 (own elaboration, based on data from ASEBIO)

	Biopharma	Agro-food	Other
% of companies originating in PSR	70	25	5
% of companies origi-nating in private sector	44	33	23
Total %	**65**	**27**	**8**

Two-thirds of all spin-offs were in the Biopharma sector, while about one-fourth was in the Agro-food sector. Biopharma and Agro-food together sum up about 90% of all companies created, with Biopharma dominating by a factor of 2.5. As table 7 shows, the spin-offs from the private sector are much more evenly distributed among sectors than on average: only slightly more spin-offs were in Biopharma (44%) than in Agro-food (33%), with about one fourth dedicated to other activities (services etc.). In turn, among the companies

originating in PSR, the Biopharma sector clearly dominates the Agro-food sector by a 3:1 margin, with almost all PSR spin-offs dedicated to either of the two sectors.

3.4. Regional patterns in the Spanish biotechnology business sector

The geographic distribution of the newly established CEDB also shows a new pattern emerging. The data[xviii] indicates that almost two-thirds of all companies (CEDB, CPDB and CUB) are located in just two Spanish regions, metropolitan Madrid (38%) and Catalunya (25%). Andalucia (9%), the Basque Country (7%) and Valencia (6%) are next. If only taking into account the CEDB, the concentration in Madrid is even more pronounced: 46% of all CEDB are located in Madrid, 16% in Catalunya (Andalucia: 11%; Basque Country: 7%; Valencia: 7%). Comparing the two most important regions, it can be seen that almost half of the entire Spanish industry exclusively dedicated to biotechnology is located in just one region, metropolitan Madrid. Catalunya is more important in terms of the other two types of companies, CPDB and CUB.

This regional concentration is related to Madrid and Catalunya being, by a large margin, the two dominant Spanish economic and industrial regions. Previous research[xix] already identified this regional concentration of biotechnology companies in Catalunya and Madrid, even though until the end of the 1990s, the biotechnology industry was centered on Catalunya: 37% of all companies entirely or partially dedicated to biotechnology were located there, but only 16% in Madrid. In addition, Madrid followed – already then – a different model of development, more akin to model 1 than to model 4, while Catalunya, then dominant, distinctively presented a model 4 trajectory. In the rest of Spain, model 4 also dominated the biotechnology industry.

However, turning to the CEDB newly created in 2000-2002, the regional distribution is much less concentrated on Madrid (31%) and Catalunya (20%). Relatively more CEDB spin-offs can be found in the other regions: Valencia: 13%; Andalucia: 11%; Basque Country: 6%. Even more important, other regions which are not very prominent in terms of the biotechnology industry, show an important rate of spin-offs: Galicia, which only contributes to about 3% of all biotech companies as well as about 3% of all CEDB, holds 8% of all newly created CEDBs. While Madrid and Catalunya still dominate (about half of all start-ups are

located there), other less important regions show rates of company creation which almost double (Valencia) or triple (Galicia) their relative importance in the Spanish biotechnology industry.

In other words, while the start-ups still tend to be located in those regions which traditionally are economic and industrial centers in Spain, they are more evenly distributed. This is directly related to the way those companies are created: from the PSR system. While industry in general is heavily concentrated in just a few regions in Spain, research centers and especially universities tend to be more evenly distributed. This explains why a region like Galicia, which is less industrialized and generally shows lower income levels than the Spanish average, can have a relatively high rate of biotechnology PSR spin-off creation. At the same time, even in highly industrialized regions like Madrid or Catalunya, the percentage of private spin-offs is low, and not significantly higher than the Spanish average, indicating the low importance of established private industries for the new biotechnology trajectory.

3.5. The role of policy

The observed changes show the key role played by public policy. On the one hand, from the mid-1990s onwards, the national and many regional competent authorities passed a large number of laws and regulations which, for the first time, created a stable legislative and regulatory framework for the Spanish biotechnology sector. Among those initiatives on the national level were the laws and regulations to transpose and develop several European Directives on the regulation of Genetically Modified Organisms (GMOs) and novel foods (including the creation of a National Biosafety Commission), the Spanish regulatory frame for the marketing of genetically modified (GM) crops (which included one of the first authorizations conceded in the EU on GM crop planting), regulations regarding the protection of workers and legislation on assisted reproduction. Several regional governments passed laws regulating GMOs (including the creation of regional biosafety committees), their cultivation and the control of possible negative environmental effects.

On the other hand, specific policy instruments were created to foster company creation. A new policy instrument is the Neotec network which aims at establishing physical and virtual support for aiding the creation and consolidation of new high-technology firms. The program gives priority to entrepreneurial initiatives

derived from R&D results of public universities and research centers. On the regional level, several Spanish regions have started their own initiatives in the last years. The Madrid government set up programs to help in the founding of technology-based companies, while Catalunya is fostering the creation of science and technology parks. The Valencian government is sponsoring the creation of a biocluster. The combined effect of all those efforts was the shaping of a legislative, regulatory and policy framework for biotechnology innovation.

In addition, a number of new policies were introduced in recent years to facilitate the mobility of researchers from PSR to the private sector, thereby overcoming, in a way, the R&D policy problems identified in previous research.[xx] One of the most important changes is the possibility given recently to researchers from the public sector to create their own companies. Before, researchers employed by public research institutions as well as university professors from public universities were banned from certain economic activities (like founding companies) while maintaining their state employment. Since 2001, they are allowed to do so. In addition, several R&D policy initiatives were started to foster their participating in firms. Since 2002, researchers can leave their public employment for up to four years to dedicate themselves to private companies related to the PSR system. However, there still exist significant hurdles for an efficient application of these measures, especially due to highly bureaucratized procedures in the application of the norms throughout the Spanish PSR system.[xxi]

The main drivers for the creation of new companies between 2000 and 2002 were the recognition of the biotechnology sector in public policy and administration (with the creation of a general regulatory framework) as well as in the private sector (with the founding of the Spanish Association of Biotechnology Companies in 1999), jointly with the availability of trained personnel. The facilitation of mobility of PSR personnel between the public and private sectors, while playing a key role in fostering company creation originating in PSR, occurred in parallel to the rapid growth in spin-offs and can be considered, at least partially, an accompanying or even reactive policy measure.

. Analysis: a new pattern of development

In general terms, the amount of human and economic resources dedicated to research, development and innovation in Spain is very low, compared to other industrialized countries. Private funding of R&D is even lower, if compared to EU and OECD standards.[xxii]

As already mentioned above, until the end of the 1990s, biotechnology in Spanish industry was characterized by a lack of startup firms and dominated by established companies from different sectors applying this technology for improving production processes. Most importantly, those companies did not have any significant R&D activities, at least in Spain. Only the – traditionally very small – percentage of innovative biotechnology firms was found to be different. These usually were firms totally dedicated to biotechnology. They were spending above average on R&D, maintained well-established and productive links with the public research sector and expressed trust in the standards of the Spanish science base. They also tended to cooperate above average among themselves.[xxiii]

Even though collaboration among firms as well as between firms and the PSR system is slowly growing, it still remains low. The main reasons for this situation can be found in the respective cultures of the business and research sectors as well as in deficits in the Spanish educational and training systems. Another factor is the gap between the objectives and activities (projects, knowledge, data, etc.) of public research and the industry's expressed demands.[xxiv]

However, a clear change of trend can be observed between 2000 and 2002, implying a change of model of development. Overall, biotechnology in Spain has started to shift from model 4 to a regionally differentiated mix of models 1 and 4 (see the classification at the beginning of the paper). The model 1 trajectory of development (characterized primarily by startup companies, as in the UK), which at the end of the 1990s was only present in one region (Madrid), has expanded all over Spain. At the same time, the type of companies representative of the model 4 trajectory remain important regionally, as in Catalunya.

The number of startups dedicated to biotechnology has risen significantly. At the same time, the field of activity is shifting. While before, biotechnology was mostly identified with the Agro-food sector (due to the predominance of established firms from that sector which used biotechnology to improve existing processes

and products), now it is shifting to biomedicine and pharmaceutical applications. This is because of the startups which operate mostly in those sectors. In other words, the dynamics of the biotechnology sector, at least in the short and mid-term, will be dominated by pharmaceutical and biomedical applications. And this despite the traditionally important Spanish agro-food industry: the domestic Spanish Agro-food market (26 billion euros in 1998) is about five times as large as the Biopharma market (about 6 billion euros, 1998).

The overall composition of the biotechnology sector is shifting towards spin-off, smaller size firms whose activities are based on intensive links with the PSR system in terms of interchange of personnel (in terms of R&D collaboration, the situation has not yet changed significantly). The new firms tend to have mostly national Spanish capital and local R&D strategies. Given that the recent startups are all exclusively dedicated to biotechnology, an emergence of a dedicated biotechnology sector in Spanish industry can be observed. This contrasts with the model predominant until 1999: large, mostly multi-national companies with non-Spanish capital and R&D activities located outside of Spain which use biotechnology only as far as it permits a gradual improvement of their products and production processes located in Spain.

This observed shift constitutes an important change in innovation patterns in Spain in general. Biotechnology is one of the first sectors in Spain to break free from the traditional patterns predominant in Spain, with few relation between industry and the public research sector. While the previous dynamics and deficits in innovation linger, the recent changes are staking out a new trajectory for the Spanish biotechnology industry but also for innovation in Spain in general (at least in certain sectors and regions).

The growing importance of the pharmaceutical and biomedical sectors can be linked, among other, to the size of the university and research sectors. Both in terms of personnel, students, R&D activity and public spending, Biopharma is dominating Agro-food. This dominance reflects a historical focalization of Spanish universities and research in those sectors. It also means that there is a comparatively larger number of researchers and trained personnel available, and searching for job opportunities.

5. The "social factors" question

The development of biotechnology, at least in its Agro-food applications, has been influenced profoundly since the 1990s by social debate, especially in Europe. This raises the question of the influence which social factors might have in the current development of the biotechnology trajectory in Spain. While the NSI approach does not give prominence to those factors, the case of the development of genetic engineering (especially in the agro-food sector) during the 1990s and the public debate related to its regulation[xxv] indicates that the economic, policy and PSR factors of an NSI-analysis can only give a partial picture of the process of innovation. In fact, the influence of "social factors" like public perception, acceptance, the role of civil society, consumer demand and the structure of emerging markets proved to be paramount in the development of genetic engineering during the 1990s.

Technological optimism in Spain is consistently the highest in the entire EU. This also applies to biotechnology and genetic engineering. According to studies of public perception,[xxvi] Spaniards are more optimistic with respect to Agro-food applications of biotechnology than the rest of EU citizens, while in Biopharma applications they are close to the European average. However, agro-biotechnology in Spain is experiencing similar problems of acceptance as in the rest of the EU. The social debate over genetically modified foods during the second half of the 1990s affected the introduction of this technology in Spain in the same way as in other European countries. Even though Spain is the only EU member state where GM crops (maize) have been cultivated for several years, GM foods did not enter the food market (as in the rest of the EU) as the Spanish agro-food industry turned away from GM ingredients.[xxvii] The development of the Spanish Agro-food biotechnology sector was conditioned by this social debate, by heightening uncertainty over consumer behavior and business opportunities.

Additional studies, which complement the analysis of the factors presented before, are needed to judge the possible role which social factors, including acceptance, might play in the development of the spin-off companies in Spain. Acceptance, in addition to the economic, policy and structural factors identified above, might influence the predominance of Biopharma firms among the spin-offs.

6. Conclusions

The analysis shows that the previously predominant trajectory of biotechnology development in Spain is giving way to a new model. The emergence of a biotechnology industry entirely focused on applications and business opportunities deriving from that technology and fueled by trained personnel originating in the PSR system means a shift in trajectory which moves innovation patterns in Spain closer to those of other European countries. At the same time, the new trajectory maintains some dominant Spanish characteristics: the traditional dominance of the public sector in R&D in Spain is now turning into the emergence of a spin-off sector almost exclusively fueled by the PSR system. And the predominant importance of the Biopharma sector in Spanish PSR (as compared to the Agro-food sector) contributes to the dominance of that sector among the spin-offs. But this development also reiterates the important role of public policy. The shift in the biotechnology trajectory is directly linked to national and regional policies, backed by which facilitate the participation of PSR personnel in private companies.

Acknowledgements

This article is based on the research project "European Biotechnology Innovation Systems" (EBIS), project no. EU-SOE1-CT98-1117, as well as the project "Estudio y análisis prospectivo de la biotecnología y su aplicación en la industria española", financed by the CEFI Foundation.

Este trabajo ha sido publicado en la revista: Technology Análisis & Strategic Management

Vol. 16, Nº 3, 415 – 429, Septiembre 2004

References

1 V. Díaz, E. Muñoz & J. Espinosa de los Monteros, 'Un primer mapa del sector biotecnológico en España', *Sistema*, no. 161, 2001, pp. 87-101. On Spanish efficiency in innovation, see: J. Molero, *Industrialisation and Internationalisation in the Spanish Economy, An ESRC Research Programme on one Europe or Several. Working Paper 28/01* (Brighton, Sussex European Institute, 2001); J. Molero, 'Nuevos temas de la innovación tecnológica en una perspectiva comparada: diversidad y eficacia de las empresas españolas', *Cuadernos Económicos de Granada*, 14, 2002, pp. 85-108.

2 Ernst & Young (eds.), *8. Annual European Life Sciences Report* (London, Ernst and Young, 2001).

3 OECD, *Biotechnology indicators and public policy* (DSTI/EHS/STP/NESTI, 2002, 8)

4 See, for instance, the Inventory of Public Biotechnology R&D Programmes in Europe: European Commission (ed. by Senker, J.), *Inventory of public biotechnology R&D programmes in Europe*, *volume 1 (Analytical Report), volumes 2 and 3 (Natural Studies)* (Luxembourg, Office for Official Publications of the European Communities, 1999/2000).

5 European Commission, *Score Board on Biotechnology Innovation Indicators*, 2003 (http://trendchart.cordis.lu/Scoreboard2002/html/download_area/download_area/html).

6 CICYT (Interministerial Committee for Science and Technology) [A. Albert (ed.)], *Spanish Research Groups and Enterprises Working in Biotechnology* (Madrid, CINDOC, 1997).

7 B. Van Beuzekom, *Biotechnology Statistics on OECD Member Countries: Compendium of Existing National Statistics* (OECD STI Working Papers 2001/6, 2001).

8 AEPC, *Ciencia y tecnología en 2002 – Anuario 2003 de la Asociación Española de Periodismo Científico* (Madrid, AEPC, 2003).

9 V. Díaz, E. Muñoz, J. Espinosa de los Monteros & J. Senker, 'The socio-economic landscape of biotechnology in Spain. A comparative study using the innovation system concept', *Journal of Biotechnology*, 98, 2002, pp. 25-40.

10 B. Lundvall (ed.), *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning* (London, Pinter, 1992).

11 R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis* (New York, Oxford Univ. Press, 1993).

12 C. Edquist (ed.), *Systems of Innovation: Technology, Institutions and Organisation* (London, Pinter, 1997).

13 Genoma, *Avance del Estudio Estratégico de la Biotecnología en España* (Madrid, Fundación Genoma, 2004).

14 Díaz et al., op. cit., Ref. 9

15 Díaz et al., op. cit., Ref. 1

16 Genoma, op. cit., Ref. 14

17 E. Muñoz, 'Veinticinco años en la evolución del sistema', *Quark*, no. 22-23 (10/2001), 2001.

18 AEPC, op. cit., Ref. 8

19 Genoma, op. cit., Ref. 14

20 see Ref. 1

21 Díaz *et al*., *op. cit*., Ref. 1

22 E. Muñoz & O. Todt, *¿Es posible construir un espacio común de innovación? – Work Document AECYA 1-04* (Madrid, UPC, 2004).

23 AEPC, *op. cit*., Ref. 8

24 Díaz *et al*., op. cit., Ref. 9

25 E. Muñoz, 'The Spanish System of Research' in: P. Laredo & P. Mustar (eds), *Research and Innovation Policies in the New Global Economy. An International Comparative Analysis*, (Cheltenham, E. Elgar Publ., 2001, pp. 359-397).

26 O. Todt, 'Regulating agricultural biotechnology under uncertainty'*, Safety Science*, 42, 2004, pp. 143-158.

27 European Commission, *Eurobarometer 58.0: Europeans and biotechnology* (Luxembourg, European Commission, 2002); J.L. Luján & O. Todt, 'Perceptions, attitudes and ethical valuations: the ambivalences of the public image of biotechnology in Spain', *Public Understanding of Science*, 9, 2000, pp. 383-392.

28 O. Todt & J.L. Luján, 'Spain: commercialization drives public debate and precaution', *Journal of Risk Research*, 3 (3), 2000, pp. 237-245.

---

i V. Díaz, E. Muñoz & J. Espinosa de los Monteros, 'Un primer mapa del sector biotecnológico en España', *Sistema*, no. 161, 2001, pp. 87-101. On Spanish efficiency in innovation, see: J. Molero, *Industrialisation and Internationalisation in the Spanish Economy, An ESRC Research Programme on one Europe or Several. Working Paper 28/01* (Brighton, Sussex European Institute, 2001); J. Molero, 'Nuevos temas de la innovación tecnológica en una perspectiva comparada: diversidad y eficacia de las empresas españolas', *Cuadernos Económicos de Granada*, 14, 2002, pp. 85-108.

ii Ernst & Young (eds.), *8. Annual European Life Sciences Report* (London, Ernst and Young, 2001).

iii OECD, *Biotechnology indicators and public policy* (DSTI/EHS/STP/NESTI, 2002, 8)

iv see, for instance, the Inventory of Public Biotechnology R&D Programmes in Europe: European Commission (ed. by Senker, J.), *Inventory of public biotechnology R&D programmes in Europe*, *volume 1 (Analytical Report), volumes 2 and 3 (Natural Studies)* (Luxembourg, Office for Official Publications of the European Communities, 1999/2000).

v European Commission, *Score Board on Biotechnology Innovation Indicators*, 2003 (http://trendchart.cordis.lu/Scoreboard2002/html/download_area/download_area/html).

vi CICYT (Interministerial Committee for Science and Technology) [A. Albert (ed.)], *Spanish Research Groups and Enterprises Working in Biotechnology* (Madrid, CINDOC, 1997).

vii B. Van Beuzekom, *Biotechnology Statistics on OECD Member Countries: Compendium of Existing National Statistics* (OECD STI Working Papers 2001/6, 2001).

viii AEPC, *Ciencia y tecnología en 2002 – Anuario 2003 de la Asociación Española de Periodismo Científico* (Madrid, AEPC, 2003).

ix V. Díaz, E. Muñoz, J. Espinosa de los Monteros & J. Senker, 'The socio-economic landscape of biotechnology in Spain. A comparative study using the innovation system concept', *Journal of Biotechnology*, 98, 2002, pp. 25-40.

x B. Lundvall (ed.), *National Systems of Innovation. Towards a Theory of Innovation and Interactive Learning* (London, Pinter, 1992).

xi R. Nelson (ed.), *National Innovation Systems: A Comparative Analysis* (New York, Oxford Univ. Press, 1993).

xii C. Edquist (ed.), *Systems of Innovation: Technology, Institutions and Organisation* (London, Pinter, 1997).

xiii Genoma, *Avance del Estudio Estratégico de la Biotecnología en España* (Madrid, Fundación Genoma, 2004).

xiv Díaz et al., op. cit., Ref. 9

xv Genoma, op. cit., Ref. 14

xvi E. Muñoz, 'Veinticinco años en la evolución del sistema', *Quark*, no. 22-23 (10/2001), 2001.

xvii AEPC, op. cit., Ref. 8

xviii Genoma, op. cit., Ref. 14

xix see Ref. 1

xx Díaz *et al*., *op. cit*., Ref. 1

xxi E. Muñoz & O. Todt, *¿Es posible construir un espacio común de innovación? – Work Document AECYA 1-04* (Madrid, UPC, 2004).

xxii AEPC, *op. cit*., Ref. 8

xxiii Díaz *et al*., op. cit., Ref. 9

xxiv E. Muñoz, 'The Spanish System of Research' in: P. Laredo & P. Mustar (eds), *Research and Innovation Policies in the New Global Economy. An International Comparative Analysis*, (Cheltenham, E. Elgar Publ., 2001, pp. 359-397).

xxv O. Todt, 'Regulating agricultural biotechnology under uncertainty'*, Safety Science*, 42, 2004, pp. 143-158.

xxvi European Commission, *Eurobarometer 58.0: Europeans and biotechnology* (Luxembourg, European Commission, 2002); J.L. Luján & O. Todt, 'Perceptions, attitudes and ethical valuations: the ambivalences of the public image of biotechnology in Spain', *Public Understanding of Science*, 9, 2000, pp. 383-392.

xxvii O. Todt & J.L. Luján, 'Spain: commercialization drives public debate and precaution', *Journal of Risk Research*, 3 (3), 2000, pp. 237-245.