# ACCIÓN CRECE

## Proposals by the Scientific Community to boost Science in Spain

COSCE

Confederación de Sociedades Científicas de España

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# Contents

# Preface

Spain is at a crossroads. It must decide whether its future will be built on a knowledge-based economy, in line with the agreements made by the European Council, in Lisbon, 2000, or whether it will renounce this path, and with it the opportunity to play a leading role in Europe and in the world in the next few decades.

The Spanish scientific community has long been aware of the need to improve its commitment to Spanish science and technology. Therefore, in 2004, it decided to bring its most representative scientific societies together into a higher body: the *Confederación de Sociedades Científicas de España*, COSCE (The Federation of Spanish Scientific Societies). The objectives of the COSCE are: to contribute to scientific and technological developments in Spain; to act as a qualified and unified interlocutor for scientists, communicating with civil society and representative authorities; and to promote the role of science and contribute to its dissemination as an essential ingredient of culture.

COSCE currently has more than 50 member scientific societies, which represent more than 30,000 Spanish scientists. The federation fully represents the scientific community and can therefore act as its interlocutor. It also aims to provide knowledge that may be of use to different economic, social, and political agents. COSCE approaches science from a global perspective, rather than one that is merely academic or theoretical. It is capable of generating expert information to actively promote, support, and contribute to developing science- and technology-related initiatives affecting both the public and private sectors. The aim of these initiatives is to strengthen science and technology in Spain as factors of economic and social progress. In view of this, COSCE has become a corporate instrument capable of: encouraging research, improving science education, disseminating the scientific spirit, and promoting social appreciation for scientific values. COSCE's members strongly and actively support the declarations made by European leaders in Lisbon: if Europe is to retain its position of privilege, the economies of its members must be based on the most competitive knowledge in the world. For this to happen, European society as a whole must be aware of the value of education and science as driving forces behind economic growth.

Science in Spain has made significant progress in the last 20 years. Nonetheless, a superficial analysis of the current situation suggests that this extremely positive growth has reached its limit, as clearly demonstrated by quantitative data obtained from the ministries involved and from different bodies devoted to assessing and monitoring Spanish research. Analysis of these data lead to the conclusion that the system itself should be thoroughly reconsidered, taking into account any other concomitant reforms that will be made. In response to these conclusions, COSCE initiated the first of several major lines of action, i.e. supporting the creation of five large committees of experts to carry out **Acción CRECE** (*Comisiones de Reflexión y Estudio de la Ciencia en España*, translated as *Committees to consider and study science in Spain*).

The five committees were charged with evaluating science in Spain from a totally independent position. Based on previously existing information and their own observations, they proposed actions that should contribute to strengthening the science–technology system in Spain and its links with all social agents. **Acción CRECE** has generated conclusions that were made concrete in the form of clear and workable proposals for revitalising, reforming and, if applicable, introducing structural changes to the Spanish scientific system. These proposals affect both fundamental aspects of the system and aspects related to its economic and social repercussions. Clearly, **CRECE's** conclusions and proposals are aimed at those ministries involved in the Spanish R+D system, as they are responsible for setting priorities, creating funding instruments, and developing assessment methods to ensure that resources are allocated appropriately. The conclusions and proposals are also directed at scientists themselves, as they propose and carry out scientific research and directly manage the allotted finances. In addition, CRECE's proposals send a clear message to other participants of the system, in particular to business sector and educators, and to society in general. This broadly directed approach is intended to ensure that scientific progress and technological innovation assume a greater presence in Spain.

Scientists, professionals, and experts in a wide range of fields have participated in the CRECE project. Their knowledge, experience, and prestige have enriched the project's contents, and provided the soundness and depth that CRECE's objectives need to guarantee the support and collaboration of Spain's public and private sectors. The leadership skills of the committee members and their ability to act have made **Acción CRECE** one of the strongest initiatives ever undertaken by the scientific community.

This venture's first success was that a group of scientists collaborated with other members of society to offer practical solutions to the current problem of updating the Spanish science and technology system. However, **Acción CRECE** goes beyond this: it has taken on an ambitious and daring task, one that is of major strategic importance to sustaining development in Spain and which must proceed in the presence of great international competition: strengthening science as a cultural factor and an economic driving force. Everyone involved in this project, and COSCE above all, are aware that making suggestions and proposing actions for an issue of such far-ranging implications are not without risks, due to the scope and complexity of the project, and to its importance. However, it is no less certain that ignoring the urgent need for this study would entail even greater risks.

JOAN J. GUINOVART
*President of COSCE*

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# Acción CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# The structures and instruments of science policy

# Summary

This paper considers the structures and instruments of Spanish science policy. It contains seven sections, in which many suggestions for improvements are presented. Nineteen of these suggestions are formulated as proposals.

The high figures involved in the public funding of research are discussed in the first section.
The proposals are:

- Maintain existing commitments and increase the central government's R+D budget by 25%. Moderate use of Chapter 8.

- Bring about comprehensive agreements between the different political forces to make science policy more stable.

- Make (triennial) *ex-post* evaluations of public R+D efforts.

Project policy is analysed in the second section. This is one of the basic instruments for government action in the research sector.
The proposals are:

- Increase project funds by a minimum of 25% per year over the next four years.

- Substantial improvements to project policy should be made by: increasing the rigour of *ex-ante* and *ex-post* evaluations, increasing the stability and publicity of calls for proposals, linking funding to the size and quality of groups, increasing overheads, increasing the flexibility of fund management by groups, encouraging interdisciplinarity, promoting European and International coordination.

- New kinds of more structural programmes should be created: strategic funding for consolidated groups, for centres and networks of (real) excellence, and for highly demanding doctoral programmes.

- Create a special programme for updating research infrastructures.

- Promote specific programmes that combine research with business innovation.

The third section looks at the public institutions that undertake research, including: CSIC, hospitals, and universities.
The proposals are:

- CSIC should be reformed to increase its scientific strength and its relationship with other agents in the Spanish science and technology system (particularly universities). The administration of CSIC's central structures has to be streamlined. In addition, its authority and management capacity should be significantly decentralised, giving more responsibility to centres and institutes, which should have their own legal status, boards, strategic plans, and clearly defined, strong scientific directions. Such centres and institutes should also be subject to periodic assessments by external scientific committees. CSIC researchers (of any nationality) should be offered indefinite employment contracts.

- Encourage research, and in particular clinical research, in the national health system's large university hospitals. A scientific career in hospitals should be defined and established. Funding programmes for clinical research should be developed and philanthropy encouraged. Thematic research institutes should be created, and research institutes connected to

the pharmaceutical industry. The role of the university should be increased, especially in postgraduate- and doctoral-level education

• Regarding research in a university context: teaching and research should be combined more efficiently, organisational structures should be made more flexible, overheads increased, and attention should be paid to the characteristics of consultancy activities and issues related to intellectual property.

• Aspects of funding for science parks should be considered.

In the fourth section, we propose giving impetus to policies for special programmes and large-scale facilities. The proposals are:

• A long-term policy of special programmes on scientific and technological subjects should be defined and developed. The subjects should be of strategic importance and have expert management.

• There should be a budget heading for the general programme of large-scale facilities.

• The *Comité de Grandes Instalaciones* (Large-Scale Facilities Committee) should be revitalised and strengthened.

The fifth section superficially analyses some of the important topics related to coordinating the central government's R+D policies with those of the regional governments.

The sixth section looks at National Plans and topics related to the organisation of the State's central government with respect to science policy. The proposals are:

• Consider attaching the CICYT to the President's office. At the same time, a vice-presidency occupied by the Minister of Education and Science (i.e. the ministry that has the predominant responsibility for research) could be introduced.

• The creation of a Ministry of Science, Technology, and Universities should be attempted in the medium-term.

• An advisory parliamentary office for Science and Technology could be created.

Finally, the seventh section proposes the immediate creation of a Research Funding and Evaluation Agency (or Committee). The aim of this is to avoid hampering the management of science policy and to follow international models. More specifically, the proposal is:

• Develop an agency (or committee) for evaluating and funding research as soon as possible. This agency would be dependent on the Ministry of Education and Science and include: the *Agencia Nacional de Evaluación y Prospectiva National,* ANEP (Evaluation and Long-Range Planning Agency), the *Comisión Nacional Evaluadora de la Actividad Investigadora,* CNEAI (National Committee for the Evaluation of Research Activities), the *Fundación Española para la Ciencia y la Tecnología,* FECYT (Spanish Foundation for Science and Technology). It would also assume responsibility for all the National Plan's project and human resources policies that are currently directly managed by the Ministry of Education and Science. In addition. it would be responsible for overseeing any new initiatives in these fields.

# Public funding of research

## R+D figures for Spain

The term "R+D" encompasses activities defined in the most developed countries as accounting for the main driving forces behind economic growth. The growth of a country depends to a large extent on its scientific and technological potential. This can be measured by different internationally standardised indicators. In general, such indicators consider both input into R+D activities and the results. Input indicators include: total R+D investment, relative R+D effort (measured by the number of scientists and technicians as a proportion of the workforce), or R+D investment as a proportion of GDP. Indicators of scientific output include documents and other such scientific products (particularly articles in internationally approved scientific journals), and patents.[1]

The ideal instrument for assessing a country's research potential would therefore be a list of indicators that together clearly reflect the level and variability in scientific input and output factors.

### *R+D investment*

The *Instituto Nacional de Estadística* (INE) is responsible for producing official data on R+D activities in Spain. Since 1964, it has regularly published a statistical study on R+D activities, in keeping with the criteria recommended by the OECD in the *Frascati Manual*.[2]

A general overview of Spanish R+D investments' high figures is presented below. These figures are based on INE data. Some of these figures have been simplified, and only a limited number of graphs and tables are presented. This was considered preferable, despite the resulting decrease in precision and detail.

Table 1 and Fig. 1 refer to actual amounts, whereas Fig. 2 and Table 2 refer to funds budgeted for by the central government.

Table 1 presents total R+D investment (we prefer this term to "expenditure", the word used by the INE) in 2003, the year in which the latest data were available. It differentiates between sectors executing the funds (companies, universities,

**Table 1.** Total investment in R+D (2003) by fund recipient and fund source (in millions of euros)

| Execution of funds | Source of funds | | | | | |
|---|---|---|---|---|---|---|
| | Companies | Government departments | Universities | Foreign Sources | PNP's | Total |
| Companies | 3 708 164 | 494 544 | 941 | 232 586 | 7 204 | 4 443 438 |
| Universities | 160 221 | 1 739 011 | 438 394 | 134 332 | 20 000 | 2 491 959 |
| Government departments | 97 163 | 1 053 703 | 3 342 | 102 903 | 4 652 | 1 261 763 |
| PNP's | 5 873 | 3 551 | 70 | 957 | 5 425 | 15 876 |
| TOTAL | 3 971 421 | 3 290 809 | 442 747 | 470 778 | 37 281 | 8 213 036 |

*Source:* INE. *Note:* The acronym PNP's refers to Private Non-profit Organizations[2]

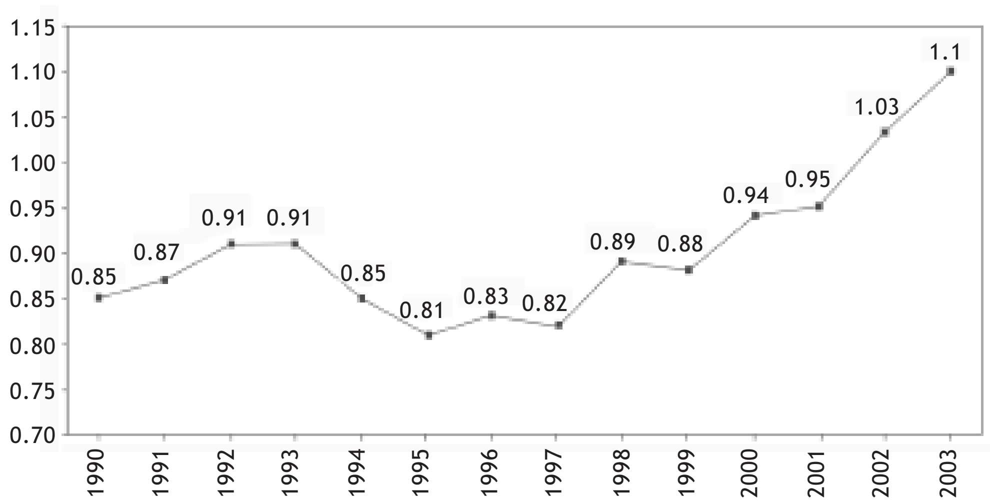


**Figure 1.** Changes in R+D investment, as a fraction of GDP (1990-2003)
*Source:* INE

research centres) and the source of the funds (companies, government departments, universities, non-Spanish institutions).

Table 1 shows that companies receive the largest percentage of total R+D expenditure: 54%, which represents almost 0.6% of GDP). Universities obtain 30% of the total expenditure. The general government gets 15.4%, whilst private non-profit organisations receive a marginal 0.2%.

Figure 1 presents a dynamic view of R+D figures. It shows changes in total R+D investment as a percentage of GDP between 1990 and 2003.

Table 2 presents the central government's R+D budget, separated into different items. The data are taken from the National Budget for 2002.

Finally, Fig. 2 gives a dynamic view of Spain's high R+D figures. Specifically, it shows changes in *Función 54* (R+D) of the National Budget. *Función*

**Table 2.** R+D budget by activity in the National Budget (2002)
(in millions of euros)

| Item | Total figures | | Chapter 8 (loans) | |
|---|---|---|---|---|
| | M euros | % total | M euros | Chap. 8/total figure (x100) |
| National R+D Fund | 340 | 9.0 | < 1 | not significant |
| CSIC and other MCYT PROs | 490 | 12.9 | < 1 | not significant |
| Ministry of Defence (including INTA) | 314 | 8.3 | < 1 | not significant |
| Department of Health (including Carlos III) | 121 | 3.2 | < 1 | not significant |
| Other Ministries | 103 | 2.7 | < 1 | not significant |
| Technological R+D | 1944 | 51.3 | 1640 | 84.4 |
| Information Society R+D | 412 | 10.9 | 349 | 84.7 |
| Science and Technology Management and General Services | 68 | 1.8 | < 1 | not significant |
| TOTAL | 3792 | 100 | 1990 | 52.5 |

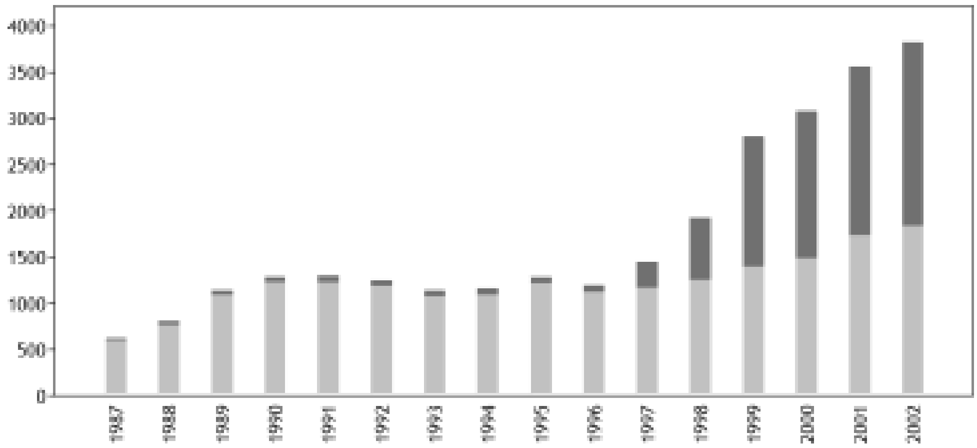


FIGURE **2.** Changes in Función 54 (R+D) in the National Budgets and the effect of chapter 8 (loans) on changes in Función 54 between 1987 and 2002 (in millions of euros)

*Source:* MINISTRY OF SCIENCE AND TECHNOLOGY (2004). *Memoria de Actividades de I+D+I 2002* (data from the National Budgets and the Treasury's *Intervención General de la Administración del Estado [General State Comptroller]*)

*54* is the section of the National Budget that includes details of all government funds devoted to research. In addition, Fig. 2 shows the impact of Chapter 8, i.e. loans, on *Función 54* between 1987 and 2002. This information is taken from the last Ministry of Science and Technology report (2004) on R+D+I (innovation) activities.

These figures and graphs require some additional comments:

*a)* The conceptual and actual difference between the budget figures and the funds that are finally made available should be kept in mind. For some items (especially Chapter 8), the received funds may be considerably lower than the budget figures.

*b)* Spanish R+D investment as a percentage of GDP is approximately half that of the European amount (15 European countries). The fluctuations observed during the time period examined (see Fig. 1) affirm that there is still no clear short- or medium-term convergence with the European average. Figure 1 also demonstrates that growth in Spain's total R+D investment has not been constant. Investment increased sharply during times of economic prosperity or when there was a specific political resolve.

*c)* The item corresponding to Chapter 8 (loans) has grown in a clearly disproportionate way in recent years, as seen in Fig. 2 (there has been no improvement in 2005). Loans accounted for more than half of the R+D budget in the last year shown in this figure. If we disregard the item corresponding to Chapter 8, the R+D budget for 2002 is no higher, in constant euros, than that for 1991.

*d)* In addition to the data given in Figs. 1 and 2, it should be stressed that the fraction of R+D corresponding to funds generated by the business sector is small compared to the European average. In 2003, Spain's public R+D funding was 0.57% of GDP, a percentage quite similar to that of Denmark. However, funding by Spanish businesses for the same year was 0.53% of the total. This is less than half the Danish percentage.

*e)* In the last 25 years, the governments of the regions have gradually assumed a leading role in stimulating R+D activities. They have developed a notable administrative infrastructure devoted specifically to managing scientific and technological policy. It is not easy to compare available R+D investment figures for the central government with those of regional governments. However, it can be estimated that, excluding universities and hospitals, the R+D investments of the regional governments are approximately 25% of the central government's *Función 54*.

***Publications***

R+D activities contribute to technological improvements in the long-term. In the short-term, their most tangible results are in the form of scientific publications (as well as patents, spin-offs, and other, similar products).

TABLE 3. Scientific production in Spain (1990 - 2003)

| | Number of articles | % of world wide production |
|---|---|---|
| 1990 | 10 688 | 1.6 |
| 1991 | 11 903 | 1.7 |
| 1992 | 13 824 | 1.9 |
| 1993 | 15 309 | 2.0 |
| 1994 | 16 214 | 2.0 |
| 1995 | 18 283 | 2.1 |
| 1996 | 20 080 | 2.2 |
| 1997 | 22 077 | 2.4 |
| 1998 | 23 783 | 2.5 |
| 1999 | 25 109 | 2.6 |
| 2000 | 24 984 | 2.5 |
| 2001 | 26 428 | 2.7 |
| 2002 | 28 526 | 2.8 |
| 2003 | 29 605 | 2.8 |

*Source:* INE

In general, several bibliometric indicators are used to measure and evaluate the quantity and quality of scientific production. These techniques can also be used to make forecasts, as they both enable innovative fields to be identified and verify the consequences and interest of scientific results.

Thus, Table 3 shows Spanish scientific production for 2003, measured in terms of the number of articles by Spanish authors that were published in international scientific journals. The figures are taken from the National Science Indicators (NSI) database, drawn up by the Institute for Scientific Information (ISI), Philadelphia. The data show that in 2003 Spanish scientific production was almost 3% of the world total.

## Proposals

In recent years, there has been a growing debate on the role of R+D investment in a country's economic growth. There is widespread agreement in the specialised literature that R+D investment is a crucial strategic factor in a country's increasing productivity and competitiveness, even though it represents only a relatively small percentage of total GDP. [3]

Public funding for research, which makes up a significant percentage of the total R+D funding in Spain, comes from a variety of sources. The main ones are the central government and the governments of de regions. The role of the latter has been gradually increasing, which is clearly a very positive factor. However, the main responsibility lies with the State, both in terms of the amount of funding involved and the central government's constitutional mandate to promote and generally coordinate research (Article 149 of the Constitution).

In view of: the analysis presented in the preceding paragraph –i.e. the consequences of the commitments made in Lisbon and Barcelona;[4] the fact that only 1.1% of GDP is invested in R+D (INE data for 2003), although the private commitment is even weaker– it seems clear that research funding by the central government should be considerably increased.

The government's commitment in its election manifesto was to increase research funding by 25% during each year of its term of office. It is only natural and right to insist that this firm commitment be fulfilled. This objective should not be achieved by disproportionate increases in Chapter 8, as was the case in 2005.

**Proposal 1**

*Maintain existing commitments and increase the central government's R+D budget by 25%. Moderate use of Chapter 8.*

In addition to increasing public research funds, it is essential that these increases should be allocated and spent correctly. The management, justification, and assessment of R+D investment should be improved. A budget increase would provide a significant opportunity to make reforms regarding the implementation of science policy. It would not be sensible to linearly increase all existing programmes. Instead, new programmes and instruments should be introduced to act as catalysts; these would, by example, give impetus to other aspects of the science and technology system. Extra funds should be put into such programmes. Moreover, such funds should only be invested in genuine R+D projects, not "defence projects".

The main direction of science policy for the short- and long-term should be firmly fixed. This would lead to the definition of specific medium-term objectives related to the provision of funds and to the design and size of the technology and science system (in particular, the number of researchers needed, which is of prime importance to defining a scientific career). (See the conclusions in the *Human Resources in Research* paper). For further discussion of these points, see the remarks in the sections on the promotion of special programmes and large-scale facilities, National Plans, and the organisation of the State's central government regarding science policy.

To achieve a certain level of stability in science policy, agreements on this subject should be fostered between the political forces of the government and the opposition. These agreements, which could perhaps take the form of widely backed parliamentary motions, would guarantee that science policy does not undergo traumatic transformations with every change of government.

**Proposal 2**

*Bring about comprehensive agreements between the different political forces, which would make science policy more stable.*

One aspect of these agreements should refer to increases in public funds, which should have medium-term forecasts and steadily rise. Ideally, an annual increase of 12% in this and the next two terms of office (together with moderate use of Chapter 8 funds) would be most appropriate. As such agreements do not exist, we recommend a 25% increase in funding during this term (proposal 1). It would, however, be a great pity if a trend of increase funding were to be cut short in the next term. A significant, sustained, and steady increase for 12 years is surely better than 4 years of considerable increases followed by a freezing of funds with no foreseeable end.[5]

In parallel with the growth in funds, triennial evaluations should be carried out. These would analyse the efficacy of the public effort and, in particular, whether investments by companies had grown at the same rate.

**Proposal 3**

*Make (triennial) ex-post evaluations of R+D public efforts.*

# Project policy

## Introduction

Policies concerning human resources and projects are the basic instruments for government action in the scientific and technological research sector. The paper *Human Resources in Research* covers general aspects of science policy with respect to human resources, and therefore focuses only on topics related to policies for supporting and promoting projects. The comments in this paper can be extended to all calls for publicly funded research proposals.

Project policy is defined as the policy of generally promoting research activities through public calls for proposals. The introduction of this policy in the 1980s represented a radical change in the Spanish science and technology system. In addition, project policy and the creation of the ANEP –one of the institutional structures arising from this policy– led to the development of a healthy culture of competitive calls for proposals.

These are thoroughly evaluated by the ANEP, and are almost the only option for obtaining public funding for research. No backward steps should be taken in this policy of competitive calls for proposals and rigorous evaluation. The only option is to progress.

A significant increase in funds is needed, as explained in the previous section. However, it should be stressed that the recommended increases are not proposed to justify "mysterious" figures, but have a well-defined objective. In fact, despite the fact that significant shortfalls can still be detected, an acceptably "buoyant" level of public sector research has been reached in Spain. This was confirmed in the above section, using the standard parameters of scientific publications. Thus, the time has come to take the qualitative leap needed to reach the levels of excellence of leading European countries. At the same time, the contribution of publicly funded research to the production sector should be substantially increased. To achieve this objective, there should be a considerable increase in the budget for project policy, to put it on a level with its counterparts (e.g. Germany and the UK) in the European research area. This is essential to Spain becoming competitive on a European scale.

Whatever the overall state of funding discussed in the previous section, we believe that a minimum increase of 25% per year over the next four years should be allocated to project proposals.

**Proposal 4**

*Increase project funds by a minimum of 25% per year over the next four years.*

## Necessary improvements

In this section we present a number of suggestions and recommendations aimed at improving the performance of project policy and increasing its efficacy.

***Rigour in ex–ante and ex–post evaluations***

To guarantee strict control over the use of funds, a rigorous evaluation must be carried out before they are awarded (ex–ante evaluation). Another evaluation should be carried out once the research project has been completed (ex-post evaluation).

ANEP's role and responsibilities should be strengthened to ensure that this objective is achieved (this topic is discussed in the section on the Agencia de Evaluación y Financiación de la Investigación). In particular, evaluations should be more informative than they are at present. Projects should receive more specific, detailed, and constructive criticism than they have received to date.

***Stability and publicity of public calls for proposals***

Calls for proposals should be stable, with a fixed schedule that is independent of political changes and budget fluctuations. The closing date for paying taxes is fixed, therefore the schedule for calls for project proposals should be too. This idea could be extended to the entire financial aid calendar. Calls for research projects should be held twice a year.

***Allocating funds by group***

Regarding the implementation of project policy, it is recommended that funds not be divided into miniscule parts or distributed evenly. Instead, we believe that the amount of funding for different projects should depend to a much greater extent than it does now on the size of the research group, the quality of its work, and on its productivity. In addition, some inflexible aspects of the current system should be removed, such as the restriction of only one project per principal researcher. If the projects are truly independent, researchers should be allowed to present several of them –two or even three. In addition, the career backgrounds of all researchers participating in a project should be acknowledged in the project evaluation, not just the track record of the principal researcher. These actions would prevent research groups from separating, and would encourage (or at least not discourage) the formation of research groups with many members.

***Improving overhead policy***

It is clear that the amount of money allocated to research projects should be increased (with additional funds). This increase would mainly serve to make universities and research centres fully aware of the importance of relying on extremely high-level research groups, capable of competing on national and international levels. These institutions should promote the formation of such research groups by helping them to overcome initial difficulties and by facilitating and consolidating the work of established groups. Of course, overhead policy should also lead to the establishment of a real commitment by universities and research centres to cover the operating needs of their research teams. They should, for example, take joint responsibility for the teams' maintenance expenses.

***Flexibility and greater efficiency of fund management***

Recipients of financial aid should have considerably more freedom to manage their funds. This could be done by eliminating fixed items or making expenditures more flexible. The current situation is so extremely rigid that it is sometimes difficult to manage expenditures adequately. Of course, increased flexibility must not adversely affect strict supervision of expenditures (preferably ex-post). In addition, we would like to register the scientific community's concerns about the 2003 *Ley de Subvenciones* (Subsidy Law). This law does not appear to be sensitive to the characteristics and needs of scientific and technological research. It should either be altered or extended to address these characteristics with sensitivity, common sense, and openness. [6]

***Stimulating interdisciplinarity***

It is very important to promote interdisciplinary collaboration. Above all, this should be encouraged in new areas related to science, technology, social science, and the humanities. Both researchers and technical personnel should be participate in collaborations.

***Promoting European and international cooperation***

Complementarity between the Spanish science and technology system and European programmes should be promoted. This could be achieved by: paying greater attention to the coordination of programmes within the European framework, conducting an in-depth study of the participation of Spanish groups in European programmes, promoting measures to improve the quality of participation, and not just the quantity of the returns. For more information on this topic, see the proposals in the section *Spain in Europe*. Coordination should also be encouraged –by signing international agreements– to facilitate joint projects with teams outside the European Union (US, Japan, etc), and to analyse plans and funding for Latin American cooperation (CYTED).

**Proposal 5**

*Substantial improvements to project policy should be made by: increasing the rigour of ex-ante and ex-post evaluations, increasing the stability and publicity of calls for proposals, linking funding to the size and quality of groups, increasing overhead, making fund management by groups more flexible, encouraging interdisciplinarity, supporting European and international cooperation.*

## New types of programmes

As more than 20 year's experience in project policy has now been accumulated, we consider that the policy of public calls for proposals could be extended such that a greater amount of structural funding is allocated.

***Strategic funding for highly consolidated groups and centres of excellence***

It is clear that funding highly consolidated groups of excellence creates particular problems. It seems appropriate for these groups of excellence to have funding (always through competitive calls for proposals) that enables them to make strategic medium and long-term plans for their activities.

This idea could also be extended to centres of excellence (public centres including those of the CSIC, other public research organisations, universities, and regional governments centres). We are referring to high-quality public research centres of a currently or potentially considerable size. In other words, centres that could play a leading role in Spain's impact on Europe.

Funding obtained by researchers belonging to these groups or centres that is directed at covering project overhead may not be sufficient, or sufficiently conditional to encourage groups or centres to take on this role. Therefore, it would be useful to initiate a policy of calls for proposals requiring medium- and long-term funding (presumably through contracts and programmes) of the research infrastructure of these groups or centres of excellence. Funding could be carried out in collaboration with the regional governments.

An essential aspect of this policy should be its competitive and open nature, combined with a rigorous and demanding evaluation process.

***Promoting coordination between research groups***

The aim is to expand and improve on recent (in the field of health research) or past (e.g. in the field of physics) experience and to systematically establish thematic networks that would help to publicise the productivity of Spanish groups and to maximise their utilisation. In addition, such networks would allow affinities to be created and increase mobility within Spain (it is absurd that it is sometimes easier to visit a European university or research centre than a Spanish one). These objectives could be attained by, for example, exchanges of personnel, summer schools, grant programmes, and workshops. However, we should add a cautionary note: the development of networks should not be used as an excuse, as is often the case, for ignoring evaluation and selection.

A network's nucleus should be made up of the groups and centres of excellence mentioned in the previous section.

***Financial aid for truly emerging or innovative groups and researchers***

The above measures do not exclude the fact that newly created (i.e. emerging) groups also stimulate the research process. While the Spanish science and technology system, which is still small, needs to expand, expansion should not be carried out indiscriminately. Instead, attention should be paid to the scientific worth of those researchers with new ideas and projects who have recently joined universities and research centres, due to the introduction of competitive programmes. Therefore, we propose that a specific budget item be created for newly formed groups. This would enable funds for a group's first two years to be allocated immediately. A reasonable level of funding should be provided, although the exact amount would depend on the field of knowledge. This first grant would be less competitive than the other types of funding. It would give a research group the opportunity to start-up efficiently and quickly, and to attain the preliminary data or results needed to obtain more competitive funding in the future.

***Financial aid for doctoral education programmes***

Doctoral education is essential to promoting research, as discussed in the paper *Human Resources in Research*. Here, we only wish to state that, apart from an indispensable policy of grants, there should also be a decisive policy (more than at present) of infrastructural and strategic support for doctoral programmes. This would provide at least a medium-term strategy, with support allocated to strong doctoral programmes that could have an international impact. Of course, the allocation of aid should be determined by competitive public calls for proposals. Doctoral programmes in the social sciences and in the humanities are different from those in the experimental sciences. The former are highly dependent on the availability of courses, whilst the latter heavily depends on laboratory work. This distinction should be kept in mind, as it implies that the most important form of infrastructural aid for the social sciences and humanities is that affecting course availability.[7]

**Proposal 6**

*New kinds of more structured programmes should be created: strategic funding for consolidated groups, centres, and networks of excellence, and for highly demanding doctoral programmes.*

### Additional infrastructure renovation

Shortfalls remain in the funding and, above all, the maintenance of university and public research centre infrastructures. These cannot be overcome by ordinary calls for project proposals.

Instead, the scientific–technological infrastructures of these organisations should be strengthened by introducing an action plan –a kind of *Plan Renove*– that would allow a significant proportion of scientific and technological facilities to be updated.

**Proposal 7**

*There should be a special programme for updating research infrastructures*.

### Strengthening research and technological development in economic sectors

Selective actions directed at strengthening the research and technological developments of companies should be promoted by the coordinated efforts of the different ministries and administrations. Such actions should have realistic funding targets, and results should be monitored and evaluated. A firm commitment must be made to combine research with business innovation in strategic sectors (software, proteomics, nanotechnology, sustainable chemistry, etc.). This could be achieved through specific programmes. The section titled: "The relation between central government and regional governments" also deals with this issue.

**Proposal 8**

*Promote specific programmes that combine research with business innovation*.

# Public institutions undertaking research

## General considerations

The two great pillars of research are universities and research centres. There is considerable overlap between the two that is likely to grow in the future. These two types of institutions are also becoming increasingly porous. It is therefore important that the basic principles of science policy are the same for both of them. The old contraposition between universities and research centres should be set aside.

The following are some principles that could be recommended for any type of research institution:

• They should have their own legal status, unless they are very small. In such cases, umbrella foundations could be useful. This frequently occurs in university environments, where the existence of small centres can be both valid and constructive.

• Research institutions should have boards (or councils). These could include many different institutions (e.g. universities) that are responsible for the research institution in question or have an interest in it.

• The institution's director should be appointed by the board after a comprehensive and open selection process. He/she should be responsible for medium-term science policy.

• The institution could have many types of personnel: employees, assigned civil servants, visiting scientists, etc. Of utmost importance is that the institution has a stable core of personnel, which is of an appropriate size to fulfil its objectives.

• The institution's administration should be made more professional by recruiting management professionals (e.g. trained, experienced managers).

• The recruitment of new researchers should be based on open and public selection procedures. Preferably, employment contracts should be offered.

• Periodic external inspections should be a basic requirement for research institutions of a certain size. In fact, all institutions should have an "external scientific council", which can be called on periodically to analyse the institution's situation in relation to international developments in the same field.

• Economic management should be dynamic and not subject to previous intervention. Of course, the statement of accounts should be rigorous.

• The institutions on the board should be in charge of basic funding. (Thus, in turn, any institution contributing to the institution's basic funding should to be a member of the board.) Basic funding could be subject to incentives (via contracts and programmes). Even if a policy of increasing overhead leaves significant funds in the hands of a scientifically strong institution, basic funding should cover at least all of the costs of the permanent staff. Preferably, it should also extend beyond these costs.

## The Spanish Council for Scientific Research (El Consejo Superior de Investigaciones Científicas, CSIC)

### *Introduction*

CSIC is unquestionably the main research organisation in Spain. Moreover, this indispensable and highly valuable organisation is present throughout the country. While, this committee does not intend to carry out a precise evaluation of CSIC or to present a detailed proposal for reforms, it will offer some reflections about the organisation and suggest some measures for improving it and for increasing its coordination with the Spanish science and technology system in general.

### *CSIC and the universities*

As a whole, Spanish universities (including university hospitals) carry out more research than does the CSIC, and their social and political influence are considerable. Consequently, development of the Spanish science and technology system should be based on trust and collaboration between the universities and the CSIC. If subsystems are isolated and shut off from each other, and a mutual lack of trust prevails, opportunities will be lost. This must not be allowed to happen. CSIC, based on its autonomous position and its legal status, should aim to make itself an asset and a source of opportunities for universities. When universities demand that the strength of the CSIC be increased, optimum conditions for research will be achieved. More specifically, we recommend encouraging programmes for collaboration (or interpenetration) between universities and the CSIC. Some examples of these are the following:

- Allow individual CSIC scientists to also carry out research in universities (departments, institutes, research centres linked to the universities, etc.), with some teaching obligations. This model is based on the *attachés* of the *Centre National pour la Recherche Scientifique*, CNRS (French National Centre for Scientific Research).

- Allow lecturers-researchers to be assigned for short or long periods to institutes linked to the CSIC.

- Facilitate the creation of joint research centres that have legal status and boards. These would take over from the existing model of mixed centres.

All of these programmes would also facilitate the coordination of truly joint careers. Lecturers-researchers would have a double affiliation. Throughout their careers, they would alternate between their dedication to research and their commitment to teaching.

### *CSIC's human resources*

The main goal in this area is to open doors, without reservations, to indefinite employment contracts (also to temporary employment contracts, but the real innovation lies in giving indefinite contracts). Employment contracts should be high-grade (obviously, this has implications for the salary structure). For more information on human resources, see the corresponding paper.

***The need for decentralisation: the role of the centres***

To clarify the terminology, the expression "decentralisation" does not in itself have geological implications. In this section, it refers to decentralising the capacity to manage and to take initiatives, giving more power to the centres. We believe that the management and responsibilities of the CSIC's current centres and institutions are insufficiently autonomous. The idea that CSIC could work well as a single, extremely homogonous organisation is condemned to failure (no matter how much the central organisation is streamlined, which is, of course, necessary). Currently, the organisation and administration of CSIC centres are inflexible and there is a lack of autonomy in their budgets. For example, the CSIC centres do not have funding that would enable them to award contracts to new groups and they tend to lack strategic plans. However, in this respect we have observed significant improvement and we commend the CSIC for this. Nonetheless, CISC centres also frequently lack a clear scientific direction.

Ideally, CSIC centres should have the following characteristics (in this case, the proposal is based on the German model):

*a)* Centres should have their own legal status. If this presents insurmountable legal difficulties, centres should be supported by institutions or foundations that already have appropriate legal status. Recently, new research centres have been created in Spain using a model that is freer and more independent than that of traditional CSIC centres. Most of these new centres are run as foundations, which enables them to hire personnel. They also have clear scientific direction, which is usually personified by a prestigious scientist. We consider that this formula of scientific foundations should be established as a model for creating new research centres, or for restructuring existing centres.

*b)* Centres should have management bodies that answer to the board and that have, and exercise, real scientific leadership capacity.

*c)* They should be appraised every five years by an international External Scientific Council made up of leading scientists in the research areas of the centres. The conclusions of these appraisals should be taken into account by the board and the management and have a bearing on the centre's strategic plans and scientific composition.

In many cases, new CSIC centres would be linked to universities. This would surpass the prevailing model of mixed centres in the way suggested in points *a, b*, and *c*.

***Administrative organisation:* ex–post vs ex–ante**

The administrative and financial management of the CSIC's central structures and institutions should be streamlined. If we had to summarise the direction that required reforms should take, we would say that the CISC has to advance towards a system characterised by greater autonomy and more responsibility for itself (e.g. CSIC should be able to take on debt, at least in terms of using Chapter 8). This should be complemented by rigorous control systems and a rendering of accounts that is not based on ex-ante evaluations but on ex-post audits.

***Relations with the regional governments***

The CSIC's collaboration with regional governments should be fluid and mutually advantageous. For the regional government, it should be a source of expert knowledge and open up new, global opportunities. For the CSIC it should represent a source of opportunities for realising its goals. Fortunately, the regional government are becoming increasingly active in promoting research and in allocating larger research budgets. Moreover, a policy of collaborating with the universities necessarily, and more or less automatically, involves dialogue and collaboration with the regional governments. The CSIC is the only research organisation that is established in the different regional government. As a result, it can play an important role with respect to developing and coordinating joint research programmes on a national scale with universities and, if applicable, companies.

**Proposal 9**

*The CSIC should be reformed to increase its scientific strength and its relationships with other agents in the Spanish science and technology system (particularly universities). Administration of the CSIC's central structures has to be streamlined. In addition, its authority and management capacity should be significantly decentralised, giving more responsibility to centres and institutes. Centres and institutes should have their own legal status, boards, strategic plans, and clear, strong scientific direction. They should also be subject to periodic appraisals by external scientific committees. CSIC researchers (of any nationality) should be offered indefinite employment contracts.*

## Other state organisations recognised as PRO by the *Ley de la Ciencia* (Science Law)

The *Ley de Fomento y Coordinación General de la Ciencia* (law for the promotion and general coordination of science), passed in 1986, confers the status of Public Research Organisations on several technological and scientific organisations that depend on the State government. Clearly, the general principles described above could also be applied to PROs, and, particularly to the research centres that depend on them. However, as this document does not aim to be exhaustive, we have not examined them in detail. We will only state that there is a great diversity between PROs. Although past proposals suggested joining them to the CSIC, we do not consider this to be a good idea. It would considerably distract both parties from their main tasks, and it is not clear whether a calculation of the losses and gains for all involved would come out positive. However, increasing the permeability between the CSIC and the other PROs would be extremely constructive.

Many PROs carry out research that is closely linked to the specific needs of particular sectors, such as fishing or energy. We should ask ourselves whether such PROs should depend administratively on the ministry closest to their research subject or whether all PROs should depend on the ministry responsible for science. Each model has its pros and cons, so that the choice is not obvious. A possible model of double dependency could be the following: each PRO would depend on the ministry that it is thematically closest to, but its budget would be annually approved by the *Comisión Interministerial de Ciencia y Tecnología* (see the section on National Plans and the organisation of the administration), in which the ministry responsible for science would have a predominant role. This would ensure coordination with other funds, and that an appropriate scientific–technical level was maintained. A tendency has sometimes been observed to shift the centre of gravity of PROs towards a kind of technical cabinet made up of the ministries they depend on. The above model would prevent such a shift. One particular case is that of PROs related to health. These have always been part of the Ministry of Health and Consumer Affairs. The double dependency model (and supervision) suggested above should also include these PROs.

## Other public research centres

There are a variety of public research centres in Spain, formalised under different legal statuses. These depend on the State, the regional governments, and even the provincial councils. Their presence in the system is recorded in the Science Plan that is currently in force. They appear under the name *Centro Público de Investigación* (Public Research Centres) (CPI).[8] These centres contribute significantly to the system. Under no circumstances (e.g. regarding calls for proposals) should they be treated any differently from the universities and PROs included in the *Ley de la Ciencia*.

## Hospitals

Biomedical research in hospitals is of enormous importance, and is a fundamental aspect of the Spanish science and technology system. Of course, the mission of large public hospitals' is to provide the population with high-quality health care. However, their mission is also to be centres for knowledge generation. These two tasks are inseparable. Research should be viewed as an integral part of the activity of hospital systems (not necessarily in each hospital, but definitely in, for example, university hospitals).

Research carried out by the international scientific community in the last two decades has shed light on the molecular bases of many pathogenic mechanisms. This knowledge has been used to design drugs directed at specific molecular targets. The next decade will see the development of drugs that will have to be tested on patients. As a result, translational research will expand greatly worldwide. Basic research in large centres has recently been encouraged by the creation of substantial research units. Now, the promotion of translational and clinical research in Spanish hospitals requires urgent attention. [9]

There are, however, reasons to be optimistic. In fact, conditions ensuring that hospitals do not miss the research boat are very good. As shown in a recent report by Camí *et al.* (2002), much of the scientific production in biomedicine and health sciences is carried out in large hospital centres. These results are not surprising, if the medical excellence of many of these centres and the opportunities that a national public health system offer are taken into consideration.

Certainly, research in Spanish hospitals still suffers from serious shortcomings when compared to that in countries in the vanguard of biomedical research, such as the United States, or, within Europe, the United Kingdom, and France. However, we consider that such shortcomings can easily be remedied, if they are overcome, Spain could be at the forefront of European biomedical research.

The organisation of research activity in hospitals should be based on services, departments, and, increasingly, on multidisciplinary programmes. As a result, the research itself will be linked to specific services, departments, or clearly-defined programmes, such as cancer, neuroscience, cardiovascular and other medical areas. However, there should be numerous formulae for structuring research activity. For example, hospitals associated with basic research centres might assign scientific personnel to both a basic science unit and a clinical service. Likewise, hospitals offering services with no research tradition could be encouraged to take on personnel with hospital research experience. Such personnel would strengthen research programmes that, in turn, could take advantage of the clinical services' research potential.

In our opinion, a combination of measures related to the budget and to the creation of dynamic administrative tools should be promoted immediately. These measures would optimise resources and support research in hospitals. Specific proposals are outlined below:

*a) Establish a scientific career pathway in hospitals*

This measure will probably do the most to help the development of translational research. The *Instituto de Salud Carlos III* could have an influential role in this process. Currently, many of the best researchers working in hospital environments lack incentives to devote themselves to research, so they orientate their careers purely towards health care, which pays a better salary and, more importantly, is a well-defined the career pathway. Hospital managements have limited resources, which should be devoted to health care. Establishing a research career pathway in hospitals, with the *Instituto de Salud Carlos III* and other institutions contributing financially, would enable quality researchers to be totally or partially freed from health care tasks. It would also provide full-time researchers with a clearly-defined professional horizon. This would be an unquestionably effective measure.

*b) Public funding of clinical research programmes*

It is widely known that almost all of the clinical trials and studies carried out in Spain are funded by the pharmaceutical industry. This sometimes leads to conflicts of interest, and essential clinical trials may not be funded. The recent *Instituto de Salud Carlos III* programme to create thematic networks for research centres should, in some cases, consider funding such trials. Of course, any funds should be awarded competitively and be subject to a periodic process of external appraisal.

*c) Philanthropy*

One unresolved matter in Spanish hospitals is how to attract philanthropic funds to build physical structures or finance research programmes. These funds make up an important part of project funding in other European countries. In fact, hospitals have the most opportunities to attract funds. We consider that government departments should consider how to establish incentive mechanisms that surpass existing ones (for example, co-financing using public and private funds).

*d) Creating thematic research institutes in hospitals*

It should be possible to establish thematic research institutes in hospitals, such as: cardiovascular institutes, institutes of neuroscience, oncology, medicine, etc. Such institutes should have their own legal status and capacity. Smaller hospitals should contain specific foundations that oversee all of their research. This structure's merit is that it provides a tool that enables research funds to be managed independently from the hospital's health care funds. Thus, research programmes could be encouraged and research personnel contracted. These institutes or foundations should have a board to approve their strategies and establish their research direction.

*e) Increasing the university's role*

University presence in university hospitals is frequently limited to teaching undergraduates. We consider that universities should go beyond this, strengthening medical–scientific careers and encouraging the creation of university qualifications, such as the Anglo-Saxon MD or PhD. In particular, doctoral programmes should be created within research institutes –obviously with the participation of the universities.

*f) Linking institutes and the pharmaceutical industry*

As in the great US and Asian research centres, we should strengthen collaboration with industry and create institutes for undertaking joint projects. Thus, in Spain, projects could be designed to research the preclinical development of new compounds, and to create facilities for the initial phases of clinical trials. Again, this opportunity is only open to hospital research.

**Proposal 10**

*Encourage research, and in particular clinical research, in the national health system's large university hospitals. A scientific career in hospitals should be defined and established. Funding programmes for clinical research should be developed and philanthropy encouraged. Thematic research institutes should be created, as should research institutes in conjunction with the pharmaceutical industry. The role of the university should be increased, especially in postgraduate and doctoral education.*

## Universities

Universities as a group are a vital research institution. It is therefore paradoxical that often, in the very heart of universities, research is challenged by teaching. Teaching is considered to be the true task of universities, but this idea should be reconsidered. The task of research is as essential as that of teaching, and the two are not in contraposition. Scientific research is an essential and inseparable aspect of the educational process. A second paradox is that insistence on the primacy of teaching is not always accompanied by an increase in teaching quality.

Below are some comments on the organisation of research in universities.

*a) Teaching and research are complementary*

As mentioned above, teaching and research are complementary university activities. All university lecturers (or researchers) should carry out research and teach (though not necessarily both year after year).[10] Rigorous evaluation mechanisms should be established for both teaching and university research.

*b) A wide variety of organisational forms*

Naturally, university research is organised in many different ways. However, the organisation of teaching and research in natural sciences has progressed in the last 10–15 years. In many cases, the current structure (independent faculties of biology, physics, chemistry, etc., each with their own departments based on specific areas of knowledge) could be complemented by improved interdisciplinarity. This would bring together research professors with complementary knowledge and training. Similar circumstances also arise in disciplines that require collaboration between the humanities and technology, such as: Natural Language Processing, digital libraries, etc.

*c) Increasing overhead*

The overhead of research contracts should be doubled over a reasonable period. In return, universities should acknowledge that stimulating and supporting research is one of their essential tasks.

*d) Consultancy contracts*

Consultancy contracts are not in themselves R+D, although they can occasionally involve this activity. In any case, they have a clear social use. Their presence in universities is acceptable (and given the financial shortfalls they are likely to be welcomed), but they must be carefully selected. Contracts should not amount to low-price offers that are implicitly subsidised by the university and have limited performance. In other words, universities should not provide routine consulting services that are already available in the market.

*e) Intellectual property*

Universities, regional governments, and the State should concern themselves, with a certain degree of urgency, about intellectual property issues. They should also promote the creation of companies from university environments. The idea is to make it as easy as possible for universities and their lecturers–researchers to make use of the value of their assets (or those they could have, with minimal extra effort) , for the benefit of all.

*f) Associated research institutes*

The most robust formula for organising university research would be an associated research institute. This would ensure the necessary degree of autonomy and management flexibility. It would also mean that institutes would have responsible boards (the university could serve on the board, with a proportional degree of influence).

**Propuesta 11**

*Regarding research in a university context: teaching and research should be combined more efficiently; organisational structures should be made more flexible; overhead should be increased; and attention paid to the specificities of consultancy activities and issues related to intellectual property.*

## Science parks

Science parks are one of several institutional innovations of the last 15 years. They have opened up a promising new way to create environments where universities, research centres, and government departments can interact. Existing science parks have still not adequately resolved one essential factor: a stable level of funding. While financial instability is a problem in itself, it also makes it difficult to attract and consolidate quality. It is therefore vital to maintain, from the beginning, a stable level of funding for the parks (the State, the regional governments and the private sector could perhaps contribute to this).

**Propuesta 12**

*Aspects of funding science parks should be taken into consideration.*

# The promotion of special programmes and large-scale facilities

## Special programmes

The time has come for Spanish science policy to take an important and decisive step in the European context: to launch special programmes in well-defined subjects that have a wide scope. Such programmes would enable quality research to be undertaken in the public sphere. They would also allow companies to become involved and/or crucial problems to be solved in areas such as health, the environment, or the information society. To achieve this, the budget has to increase beyond the "water mark". Future National Plans should devote particular attention to this matter. The idea is not to prescribe "more of the same", but to take advantage of the existing critical mass to mobilise the scientific community and to tackle well-defined objectives that require complex organisational structures (such as problems related to speech processing and language).

These special programmes should not be confined to merely announcing calls for applications and soliciting proposals (although this should also occur). In addition, shortcomings and priorities in the subject area should be identified. Adequate mechanisms (which must be open and competitive) should then be established to eliminate the shortcomings and develop the priorities. Companies should participate in these programmes from the moment they are defined, so that business needs can be incorporated from the outset. Funds allocated to basic, non-specific research should not be used for these programmes. Instead, programmes should be developed progressively in accordance with the increase in budget funds for R+D.

**PROPOSAL 13**

*A long-term policy of special programmes addressing scientific and technological subjects should be defined and developed. Such subjects should be of strategic importance and have complex management.*

## Large-scale facilities

Some of these special programmes would be associated with the promotion of large-scale scientific and technological facilities that would enable even more ambitious objectives to be reached. Research today, in some areas in particular, notably physics, requires facilities of such large magnitude that they cannot be situated in only one country. "Magnitude" refers to the cost (which is sometimes enormous) of investing in such facilities and maintaining them. However, it also refers to what is sometimes more important: the highly specialised team needed to effectively operate such facilities. Large-scale research facilities are an excellent vehicle for expanding R+D activities and a revitalising agent on a technological level for the associated industries. Let us take CERN (the European

Organisation for Nuclear Research) as an example. CERN's role in the development of high-energy physics is universally recognised (and a great example of the power of European collaboration). Nonetheless, many people are unaware of the extraordinary influence that CERN has also had on furthering technological developments, a result derived from the special instruments created to satisfy the laboratory's demanding requirements. An example of this is the omnipresent internet. This was invented by Berners-Lee in CERN as a medium for IT communication between high-energy physics research groups.

Regarding large-scale facilities in Europe, we could point out as an example the *Instituto Astrofísico de Canarias*. The most important astronomical facilities in the northern hemisphere (after Hawaii) are located in this Institute. A crucial step was taken with construction of the new large telescope Grantecán. Instead of simply providing the land and benefiting from the astronomical facilities, Spain participated actively in over 60% of the design and construction of this new telescope, with all the technological consequences created by this involvement. A second facility, the *Plataforma Solar de Almería*, has an enormous influence on the research and development of an energy source, i.e. solar energy, that is of interest to a country with climatic conditions such as those in Spain. The results obtained in the first phase of the Platform's operation have provided a solid base with which to analyse realistic approaches to solar energy in the future. The reactor *TJ-II*, a thermonuclear fusion pre-reactor installed in CIEMAT, has enabled important expert knowledge to be generated in this field. This knowledge will be of great use when the ITER programme begins. Finally, the synchrotron ALBA, in Vallés, is an important step for the development of the Spanish scientific community of synchrotron radiation users and for the high-technology companies participating in its construction.

The policy of large-scale facilities sometimes causes suspicion in the scientific community for fear that funding will be diverted from other, more modest projects. We consider that large-scale facilities should have their own budget heading (either within or outside the National Plan) which would help to clarify and pacify this sentiment.

**Proposal 14**

*There should be a budget heading for the general programme of large-scale facilities.*

For more than 10 years, Spain, like other countries in Europe, has had a Large-Scale Facilities Committee. This Committee is responsible for analysing the operation of existing facilities in Spain and the effectiveness of Spanish contributions to international large-scale facilities located in other countries. Likewise, it examines proposals for new facilities. This Committee should be revitalised and strengthened, and receive specific instructions for future activities. For example, it may perhaps be a good idea to carry out an analysis of current needs on a European level[11] and to examine the viability and appropriateness of locating new facilities in Spain. The Committee should also have a permanent organisational structure, which would enable it to effectively carry out advisory tasks on topics such as ways of managing large-scale facilities. To sum up, the Large-Scale Facilities Committee should be revitalised and given more organisational strength.

**Proposal 15**

*The Comité de Grandes Instalaciones (Large-Scale Facilities Committee) should be revitalised and supported.*

# The relation between the central and regional governments

In recent years, the regional governments, which are healthily heterogeneous, have increasingly facilitated the work of their most notable research groups. They have strengthened both the development of their research centres and technological development. They have also made a firm commitment to those priority research areas that are in keeping with their particular characteristics, natural resources, or other specific interests. The growing interest of the regional governments in research and their assumption of responsibilities in this area marks the beginning of a positive trend, which should be consolidated and expanded.

The relation between central and regional governments should be shaped by two basic principles: *collaboration* and *complementarity.*

*a) The principle of collaboration*

Central and regional governments should strive to reach agreements on coordinating the use of their respective R+D funds. Thus, they could try to jointly define objectives on a European, state, and regional scale. In addition, both central and regional governments should be represented –to an appropriate degree– on the boards of research centres, large-scale facilities, large installations. and projects that are of importance to the state but located in an regional government's territory.

*b) The principle of complementarity*

When an regional government duplicates state programmes, all kinds of dysfunctions arise. For example, regions funding ends up being concentrated on second class research, as it is incapable of competing with more extensive funds. In addition, one type of funding may be reduced in the presence of the other. It is better to reach a full agreement and specialise in complementary programmes. Regarding doctoral grants for example, it would be logical for the central government to award packets of grants to high-level doctoral and research programmes as an additional resource for carrying out these activities (i.e. the final selection and allocation of grants/contracts would be carried out in the recipient institutions). The regional government would focus on awarding grants to individuals. To give another example: in programmes for recruiting researchers, the state could focus in the first instance on fostering initial recruitment (along the lines of the Ramón y Cajal programme), and the regional government on permanent recruitment. Of course, all of this should be done with flexibility and without dogmatism.

# National Plans and the organisation of the State's central government regarding science policy

With regard to the State's central government, the promotion of science cannot be the exclusive responsibility of one ministry alone. Instead, all ministries should be involved, as they are today (the budget specifies this in its "famous" *Función 54*). The ministries of the different sectors (the Department of Health and the Environment Ministry are obvious examples) have specific tasks requiring solutions that frequently involve research activity. Ministries should therefore be able to directly promote research. As mentioned above, many ministries have their own PROs, although some of these are now dependent on the Ministry of Education and Science.

The wide variety of public agents undertaking research creates at least two problems: (1) drawing up the main points of a state policy that is consistent and has clear objectives, and (2) coordinating activities.

As regards the first problem, National Plans have been used as an instrument for defining the political authorities' strategic decisions. Moreover, they provide a framework in which agents involved in research can periodically meet, reflect on, and coordinate activities. They have functioned adequately in this role to date, and should be maintained. However, extensive experience with National Plans indicates that they require substantial external appraisals with international participation.

As far as the second problem is concerned, coordination between the different ministries in any country's science and technology system is an arduous assignment. A coordinating organisation is needed to prevent redundant research from being carried out, and to ensure that only high-quality research is promoted by the ministries. The alleged results of poor-quality research cannot be used. In this respect, it should be perhaps noted with concern that in the past some sector's ministries have demonstrated a certain tendency to use some of their PROs, despite the letter "R" in the acronym, as a kind of cabinet to give the ministry technical support rather than as true research centres (see the section on public institutions).

Broadly speaking, we consider that an Interministerial Commission of Science and Technology (CICYT), like the one currently in force in Spain, is a good solution. This organisation is responsible for the two above-mentioned tasks (drawing up National Plans and basic coordination). By Royal Decree 1864/2004 of September 6, 2004, the chairperson of this committee, which is attached to the Ministry of Education and Science, is the president of the government. The deputy chairperson is the vice president of the government and is in charge of the financial aspect (R+D has a significant financial impact). Committee members include ministers and high-ranking officials from those ministries involved in research (and high-ranking officials from the President's Office). The secretary is the Ministry of Education and Science's secretary of state for Universities and Research.

Clearly this Committee, which has an excellent design on paper, has to be more active and take more of a leading role in formulating science policy. We consider that it should be supported by an auxiliary committee, which would meet frequently and be chaired by the secretary of the CICYT. It would be made up of directors-general from the ministries involved and the director-general of the Budget. This Auxiliary Committee would have its own secretariat (like the current secretary-general of the National Plan for R+D). Another possible improvement is outlined below:

**Proposal 16**

*Consider attaching the Interministerial Commission of Science and Technology (CICYT) to the President's Office. At the same time, a vice presidency occupied by the Minister of Education and Science (i.e. the ministry that has the predominant responsibility for research) could be introduced.*

Moreover, corporate presence in the decision-making mechanisms of the National Plan for R+D should be increased. Currently, the existing CICYT is supported by an Advisory Board, which includes representatives from the business sector. However, both the composition of this board and the way it is run can clearly be improved. The way such improvements could be made requires serious consideration in the future.

An important issue is how to assign the central and most basic research responsibilities to the different ministries. There is no universally accepted model for situating support to science, and consequently science policy, within governmental structures. Within Europe alone, different countries can be seen to have different solutions. There are even various solutions within one country, as models may change repeatedly over time. France changed the position of its science system several times in the 1980s–from a Ministry of Education and Science, to a Ministry of Universities and Research, and finally to a Ministry of Science and Technology. Other countries, like the UK, do not have a specific ministry for this area.

Two approaches to this subject are described below:

*a)* The current assignment of responsibilities does not require many changes. In particular, it appears to be both important and preferable for the central government's jurisdiction over universities and research to be situated in the same ministry, as it is now.

*b)* A Ministry of Science and Technology should be given renewed consideration. The division of Science and Technology into two ministries does not help the science and application systems to converge, as they should. A ministry of this type would help to resolve the long-standing problem of where to situate innovation and how to coordinate it with supporting research.

   One operating advantage of having a Ministry of Science and Technology is that it would be easier to support those companies choosing to carry out real innovation (with all the risks this involves). This contrasts with the past tendency of ministries in charge of industry to subsidise companies mainly according to their financial needs and their impact on employment or the region. Moreover, if the most important PROs and the programmes for subsidising the research and development activities of companies were included in the same ministry, it would also be easier to organise and carry out projects that both parties agree on. In addition, the concerns of a Ministry of Education tend to be dominated by compulsory education.

A possible synthesis of approaches *a* and *b* would be to create a Ministry of Science, Technology, and Universities (which would include part of the current Ministry of Education and Science and part of the Ministry of Industry). This is our proposal for the future.

**Proposal 17**

*In the medium-term, the creation of a Ministry of Science, Technology, and Universities should be tried out.*

Another proposal would be to create a Science and Technology Advisory Office in Parliament. There are many precedents in other countries, where such offices contribute significantly to enriching the level of parliamentary analysis and discussion on legislative topics related to science and technology.

**Proposal 18**

*An Advisory Parliamentary Office for Science and Technology could be created.*

As we have repeatedly shown, the structure of regional governments has a notable bearing on political science and funding ability. The Science Council is the arena where central and regional governments meet and coordinate activities. Therefore, the Council be functional and much more than an authority, established by protocol, that deals with formalities.

Another highly significant structural innovation is proposed in the following pages.

# Research Funding and Evaluation Agency (AEFI)

The creation of an Agency (or Committee) for Evaluating and Funding Research (AEFI) is an urgent necessity for several good reasons: It would stop the administration and management of the Spanish public funding system for science from becoming stifled, and its launch would be an important sign of the maturity of the system. Moreover, it is also something that the Spanish scientific and technology community have fought for, and creating such an agency would fulfil the present government's election pledge to do so. The AEFI's function would be to manage the distribution of all or part of the resources allocated to implementing aspects of the National Plan. These include: projects, human resources, and, in general, any funding requiring public calls for applications (which should be the majority of cases).

There are already important European precedents for such an agency. Some agencies are already well-established, like those in the UK and Germany. Others, such as the *European Research Council,* are in the process of being set up. The design of such an agency should combine the following two requirements in the best possible way:

*a)* The AEFI should be autonomous, dynamic, impartial, stable, and rigorous. While it is not for us to declare what precise legal structure best suits the agency, it must allow it to have all of the above characteristics. In particular, we believe that the AEFI should render accounts ex-post, through ministerial audits and the National Audit Office. It should not be subject to ex-ante evaluations. Of course, it should also have the necessary personnel and means to operate effectively. It should not have its own centres for carrying out research (and probably no large-scale facilities). This would greatly help it to develop a reputation for impartiality.

*b)* The Agency's administration should not be strongly dependent on the corresponding ministry (this is what the term "autonomous" refers to). Neither should it have close ties with the science and technology sector, which benefits from it. To guarantee these requirements, special attention must be paid to the design of the management bodies. This topic will be dealt with shortly.

One important question is the initial scope of the AEFI. Should it deal with all funds allocated to calls for applications and human resources? Or only those that are currently the Ministry of Education and Science's responsibility? Or all funds except those of the Health Ministry (and the *Instituto Carlos III* takes on the role of a Health Research Council)? Or all funds except those of the Health and Industry Ministries (and the CDTI adopts the role of an Industry Research Council)? We believe it would be sensible for the AEFI to initially take charge of programmes that are the responsibility of the Ministry of Education and Science. Its contact with the government would therefore be through this Ministry.[12] Of course, the AEFI should carry out the task of evaluation, and should include the *Agencia Nacional de Evaluación y Prospectiva* (ANEP; National Evaluation and Long-Range Planning Agency) and the *Comisión Nacional Evaluadora de la Actividad Investigadora* (CNEAI; National Committee for the Evaluation of Research Activities). The *Fundación Española para la Ciencia y la Tecnología* (FECYT; the Spanish Foundation for Science and Technology), which would almost certainly specialise in areas of communication and long-range planning, should also be accountable to the AEFI. It is also important to maintain diverse sources of funds. However, similar levels of requirements and evaluation methodology should be used. As a result, the ANEP should continue to carry out high-quality evaluations and to maintain its own legal status within the AEFI. It should offer services that go beyond the AEFI's sphere of activity.

Clearly, as the AEFI's administration becomes consolidated, the incorporation of other activities and programmes could be considered. This would be particularly relevant if a Ministry of Science, Technology, and Universities were created in the medium-term, as recommended in the previous section. The required concordance between the AEFI's objectives and the State's science policy would be guaranteed through contract-funding programmes with the Ministry of Education and Science, and by the participation of government representatives in the AEFI's bodies, as established by the its statutes and regulations. However, AEFI decisions on funding would be final (though there would, of course, be guarantees and appeal mechanisms).

Finally, we turn to the design of the AEFI's management bodies. This topic is essential to assuring that the agency maintains its dual autonomy. The following is one possible proposal:

- The highest management body would be a "Research Commission" –a name inspired by the Energy Commission or the Stock Market Commission, among others. This commission would be made up of 12 members, appointed by the government at the suggestion of the respective minister for 6 years with a turnover of two members per year. Appointment of new members should include a process of consultation and public calls for applicants. The appointment process would be organised by the Commission itself, and the President of the Commission would pass on the names of selected candidates to the respective minister. Most of the members of the commission would be highly prominent scientists and technologists. The Commission could also consist of additional members (no more than two or three) who are representatives of the administration. Of course, the Commission would put forward a director and a management structure.
- The Commission's president would also be appointed by the government for a given period, after a process of public and regulated consultations (call for candidates, etc). The position should be occupied by a widely respected scientist (from any discipline) with great scientific prestige. The successful candidate should also have experience in research management.
- The AEFI could also have an advisory body (the "Commission's Advisory Board") made up of representatives from the regional governments, universities, scientific organisations, etc.

**Proposal 19**

*Develop an Agency (or Commission) for Evaluating and Funding Research as soon as possible. This agency would be dependent on the Ministry of Education and Science and include: the National Evaluation and Long-Range Planning Agency (ANEP), the National Committee for the Evaluation of Research Activities (CNEAI), the Spanish Foundation for Science and Technology (FECYT). It would be responsible for all of the National Plan's project and human resources policies that are currently directly managed by the Ministry of Education and Science. In addition, it would include any new initiatives in these fields.*

# Notes

1 In general, the "family" of OECD manuals are used to measure R+D activities: the *Frascati Manual* (2002a); the *Technology Balance of Payments Manual* (1990); the *Patent Manual* (1994); the *Oslo Manual* (1997) and the *Canberra Manual* (1995), describing human resources devoted to R+D. The recommendations of other institutions such as Unesco should also be born in mind (UNESCO 1979a, 1979b; UNESCO 1984). However, the use of this kind of indicators could lead to some methodological problems. For example, the distinction between input and output indicators is not always clear. There are also more indicators of scientific production than scientific dissemination. Finally, there are countable calculation problems and problems in making international comparisons between the different indicators' magnitudes.

2 According to the last edition of the *Frascati Manual* (2003), PNPs include private non-profit organisations that are off-market. In general, they are funded by: taxes, contributions, their members' or patrons' donations, or by subsidies awarded by companies and government departments. They include professional associations, cultural societies, charitable organizations, aid organisations, unions, consumer associations, etc.

3 See: Griliches (1992), Fagerberg (1994). Different papers by Jones & Williams (1998) and (2000) give the most recent estimates of the long-term effects of R+D.

4 European Council, Lisbon, 23-24 March, 2000; European Council, Barcelona, 15-16 March, 2002.

5 If companies grew by another certain amount, it would enable them to reach the average European expenditure in a 12 year period, even accounting for 3% annual inflation.

6 The following ideas could be included in the regulations developed: Subsidies awarded to universities and research centres should be justified by a report of the work undertaken and a certificate issued by the university manager or centre director. This certificate would state that the subsidy had been registered in the accounts of the university or centre; that the funds received had been used to undertake the activity they were awarded for; and that the original documents confirming the expenditure were filed in the office of the university or centre.

7 Another specific initiative that would help to boost the Social Sciences and the Humanities would be a programme of encouraging the publication and dissemination of Spanish scientific activity in these fields in foreign languages, and particularly in English. This would help to break the isolation of these disciplines, and make the abundant, quality Spanish production more visible.

8 CICYT (2003a) vol. I, p. 115.

9 This kind of research has its own characteristics and requires specific organisation: ethical committees; epidemiology units; tissue banks; cryopreservation units; databases with confidentiality requirements; trial units; animal houses for larger species, etc.

10 In particular, periods abroad for university lecturers should be encouraged. This is often impossible, simply because departments do not have enough resources to cover teaching positions. This matter is closely related to the way university teaching staff are assigned. The unit of measure is exclusively related to teaching; by number of students/subject.

11 There should be a close relation between this committee and transnational institutes dealing with this topic. In particular such a relation should be formed with the European Commission and the European Science Foundation (ESF).

12 We believe that there are seven Research Councils in the UK.

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Confederación de Sociedades Científicas de España (COSCE)

# Acción CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Human resources in research

# Summary

The European Union aims to become the territory with the most competitive and dynamic knowledge-based economy in the world. Recent EU policy indicates that the number of researchers should be increased by 700,000. This measure should accompany an increase in research investment of up to 3% of GDP.

In the case of the Spanish science and technology system, the goal of qualitatively and quantitatively increasing human resources devoted to research is affected by several factors. These include: low motivation in the research profession, the low level of research and innovation in Spanish companies, the low level of scientific training of Spanish students. As a result, there are a series of structural problems in human resources for science and technology in Spain. These problems are set out below. For each one, several general measures are recommended.

*a)* Primary, secondary, and university education lack orientation towards scientific training. Education fosters passive attitudes rather than a positive predisposition to appreciating science.
The entire education system should improve its ability to provide education that: promotes creativity and reduces passivity, fosters a critical and constructive spirit, encourages curiosity to find out more about reality, creativity instead of dogmatic teaching, multidisciplinarity rather than compartmentalisation, and flexibility rather than rigidity.

*b)* Few young people are attracted to research and there is a low level of scientific culture in society.
Young people's motivation for engaging in research activity should be boosted. Such motivation is based on a desire to continue learning, to develop in-depth knowledge, and to apply this knowledge to the social and economic reality, in order to transform and improve it.

*c)* Professional uncertainties are associated with careers in science and technology at all levels, including researcher, technologist, technician, and manager.
Professional research jobs should be made more attractive to young people by increasing remuneration and strengthening the structure and prospects for progress in a career in the public sector and for being promoted within companies. In addition, the working environment and the social recognition of researchers should be improved.

*d)* Human resources and centres carrying out R+D need to be rigorously evaluated.
The continuous and rigorous assessment of individuals and groups devoted to research is both a mechanism for improving quality and a tool for structuring wage incentive schemes and professional promotion. All of these factors need to be encouraged.

*e)* The workforce of researchers is ageing.
In Spain, an effort is needed to qualitatively and quantitatively increase human resources devoted to research. This effort has to be accompanied by measures to facilitate the

regular, constant recruitment of new researchers. These would replace researchers who retire, and enable the qualitative and quantitative total mass of researchers to increase.

*f)* There is limited absorption of trained research personnel into the private sector, and a lack of communication and interaction between the public research sector and companies.
Perhaps the greatest efforts to bring about structural improvements should involve making it easier for the private sector to make use of research resources available to the public sector.

*g)* The research system has a rigid organisation that needs to be more adaptable. More flexible and dynamic ways of taking action need to be created.
The Spanish research system is mainly based on the civil service career, which favours individualism rather than team work. Introducing a more flexible alternative system – one that is based on the importance of collective tasks and subject to continuous assessment – would contribute to the system's agility and quality.

*h)* Groups of excellence in research have low visibility and limited support.

Researchers need to have stimulating environments in which to carry out their creative work. Designing measures to develop new human resources and grouping existing human resources into networks of excellence would considerably help to bring about an overall improvement in research quality in Spain.

## Proposals for action

- Implement measures in the education system that encourage younger generations to enter the research system.

- Create salary incentives that acknowledge the results of periodic appraisals of scientists.

- Promote the mobility of research personnel and develop other measures aimed at enabling research personnel in the university and health systems to increase their devotion to research.

- Create a programme of awards for excellent researchers. Give generous funding to centres of excellence that will allow optimum exploitation of human resources.

- Create a career structure in R+D based, at least in its final stages, on employment contracts for research (tenure model).

# Introduction

## Europe

This report is published taking into account the objectives of the European Union's recent R+D policy. This has been defined during the last five years, at the European Councils held in Lisbon (2000) and Barcelona (2002). In Lisbon, the Council proposed that Europe should become the region with the most competitive and dynamic knowledge-based economy in the world. In Barcelona, a target was set for increasing current research investment from 1.9% of GDP to 3%. This would reduce the gap between Spain and more advanced countries. In terms of human resources, it was estimated that an additional 700,000 European researchers would be needed to attain this objective. This would involve considerable effort, as new researchers would have to be recruited into the system and researchers leaving the system at retirement age would have to be replaced. Many papers have focused on the topic of human resources in Spanish and European research. The report *Increasing Human Resources for Science and Technology in Europe* (Brussels, April 2004) clearly set out the problems affecting human resources dedicated to science and technology in Europe. It stated the well-known fact that the number of researchers per inhabitant in the European Union is less than that in Japan and the US. It also indicates that Spain's position in the EU is unsatisfactory.

## Spain

Other significant problems affecting scientific and technological development are outlined in this document. Such problems have a particular impact on Spain. One widely recognised problem is that research jobs in science and technology are not particularly attractive to young people. This is because the following factors are less rewarding than in other occupations: remuneration, the career structure within the public sector and professional promotion in companies, the working environment, and social recognition. Other issues are population decline and young people's lack of interest in scientific-technical subjects in particular. These and other problems related to the approach used to teach certain subjects in the education system, have meant that to a certain extent, most students do not consider a scientific and technological education to be an attractive option.

Finally, two extremely significant problems should be pointed out. The first is the low level of research and innovation in Spanish companies. Consequently, few researchers and technologists are absorbed by the industrial sector and there is limited mobility of public sector researchers to the private sector. As a result, public-sector researchers try to become permanent staff, which saturates the system.

The second problem is the disproportionate percentage of highly qualified women who leave the system. This impoverishes scientific, organisational, cultural, and sociological aspects of the system.

### Demobilisation

We are immersed in a European society that has undergone profound and rapid changes, affecting the entire population's way of thinking. These changes are most apparent among the younger members of society – the future source of human resources for research – and can be seen in young people's passive behaviour. Young people are spectators of social creativity, and thus of research creativity, rather than actors. As a result, they are more attracted by financial incentives than by creativity itself. These trends are common to all European countries, but some specific additional characteristics apply to Spain. The OECD's PISA report recently revealed that Spanish students' have a low educational level in science subjects and in reading. This has an even more negative impact on motivation for research and worsens the overall situation.

All of this threatens to produce a loss of capacity and quality, and is in fact producing qualitative demobilisation and undercapitalisation of the European system of science and technology. This will have serious long-term consequences on Europe's ability to compete with the pressure from America and Asia. All things considered, society should pay more attention to the source of its most specialised and creative human resources, using a strategic approach to encourage a vocation for research, and giving this issue the priority it needs.

### Human resource policy in Spain

The basic principles of human resource policy in Spain were defined several decades ago. Since then, Spain has become part of a European society that has undergone profound and rapid changes. These have affected the entire population's way of thinking and that of young people in particular, as mentioned above. In the light of this situation, it appears that Spanish human resources policy is in need of urgent reforms aimed at bringing it in line with society's current needs for scientific and technological research. Reforms should take into account the complexity of research activity itself, learning from those examples in which carrying out research is supported by mechanisms that make working in the science and technology system more attractive. As a result, research would become an interesting option for more young people. People who are already employed within the system would be encouraged, and the ability to attract researchers and technologists from other countries would be increased.

Current scientific and technological research is carried out in a highly competitive environment. It requires considerable financial resources, has extremely complex structures for material and human resources, and must be supported and maintained by a very specialised and interdisciplinary education, with high levels of excellence and creativity. Research is a markedly professional activity, requiring a high level of motivation and teamwork ability. Therefore, the human capital devoted to research requires special attention.
These circumstances justify a more detailed consideration of this subject, which is the objective of the *Paper on Human Resources,* part of COSCE's CRECE project.

This aim of this report on human resources is to make realistic proposals that are compatible with the current science and technology system and able to improve it. Therefore, proposals that can only be implemented in the medium- and long-term, or proposals that involve considerably changing the current system's structure are not put forward. The problems that should be addressed, and which could be resolved include:

*a)* Primary, secondary and university education lack scientific orientation. Teaching methods favour passive activities and do not facilitate an appreciation of science.

*b)* Few young people are attracted to research, and research activity is not highly valued by society.

*c)* Professional uncertainties are associated with careers in science and technology at all levels, including researcher, technologist, technician, and manager.

*d)* Human resources and centres carrying out R+D need to be rigorously evaluated.

*e)* The workforce of researchers is ageing.

*f)* There is limited absorption of trained research personnel into the private sector and a lack of communication and interaction between the public research sector and companies.

*g)* The research system has a rigid organisation that needs to be adapted. More flexible and dynamic ways of taking action need to be created.

*h)* Groups of excellence in research have low social visibility and limited support.

# Science in the educational process

## Pre-university education

Young peoples' motivation for scientific research is based on a desire to broaden their knowledge and to apply this to the social and economic reality, in order to transform and improve it. Such motivation is *clearly* progressively decreasing and contrasts with an increasing interest in other activities that give greater, more immediate short-term rewards. This situation is related to behavioural norms, social appraisal criteria, and to the situation in the education system.

The social perception of research is not positive. Moreover, the education system does not foster the development of abilities that make children and young people curious about the phenomena occurring around them. The system does not encourage them to be creative, to take initiative, or to acquire the ability to confront a multitude of situations. Above all, it does not encourage them to continue to learn. In addition, the amount of time devoted to scientific education has decreased notably in pre-university education. However the main problem is not so much the content as the concept. For young people, science's main attraction is precisely its creative and practical nature. Therefore, a more suitable approach to transmitting these characteristics is needed. Such an approach should offer a view of science in which it appears to be something attractive, useful, and culturally important. Student should also have direct contact with the experimental aspects of learning.

Thus, it is important to encourage a mode of education that contributes to creating and developing abstraction mechanisms, provides the methods for shaping thought itself, and helps to stimulate questions. Education should encourage students to seek to understand reality and to systematise ideas. It should intellectually stimulate them. This would not only encourage research, but would also help to induce, through learning, the development of creative thought. This should be carried out in a comprehensive way, with awareness of the fact that some not strictly scientific education, for example music, fosters this capacity for integration.

Complementary activities should also be put into practice to bring young people at the pre-university level into contact with scientific environments. Measures needed to achieve this objective include specific publications, the Olympics, systems that encourage young people to pursue a research vocation, and support for exhibitions, thematic programmes, and museums.

Recent state and private efforts to familiarise young people with information technology through cyber games and the internet are of undeniably importance to their education. However, they also cause clear problems that have to be taken into account if they are to be overcome. One of these is that young people are becoming distanced from experimental, manual, and scientific play activities. Increasingly, the computer, and microelectronics in general, function as an almost magic black box, invented and manufactured by super-technologists and companies. Their indiscriminate use, from childhood on, tends to foster a total acceptance of their own technological inferiority and a submissive attitude to the dominant technology.

Therefore, we should not only encourage the use of technologies, but also take advantage of the opportunity to try to stop young people from being passive spectators of the technological developments and scientific-technical innovations achieved by others. They should become used to creating as they learn, through direct experimentation using their own hands and their own ingenuity and initiative, supported by appropriate means, stimuli, and teachers. Accordingly, it is particularly important for pre-university education establishments to have well-equipped laboratories.

Thus, the main objectives are to stimulate abstractive and analytical ability and to boost young people's creativity. This will contribute to establishing a favourable social climate that will lead to good citizens, good teachers, good scientists and technologists, good professionals, and good businesspeople. To achieve this, disciplines that encourage interest in scientific knowledge should be strengthened and made compulsory, as should those that develop the scientific method and increase the development of abstractive ability.

## University and doctorate education

University education in its current form does not resolve the problems created in primary and secondary education. Instead it consolidates them. At this level, it must be stressed that universities should set themselves the objective of providing an education that promotes multidisciplinarity rather than compartmentalisation, a critical spirit and uncertainty in knowledge rather than dogmatism, flexibility instead of rigidity. In short, education should be based more on practising and creating science or technology than on learning it.

The main exponent of participation in the educational process employed to train scientists and technologists is writing a doctoral thesis. The thematic diversification and specialisation that lead to a doctoral-level education comprises several different learning processes, depending on the needs and uses of the different disciplines.

The overall view of the doctorate is that its main task is to train researchers and academics. However, this focus has serious limitations. Firstly, the creation of an enterprising, innovative spirit and leadership ability, which should pervade the entire education system, should be strengthened even further during the doctoral stage of education. It is of prime importance for well-educated doctors to possess skills and abilities that enable them to tackle problems regardless of the environment in which they have to work. Secondly, it is hoped that future leaders of active research in the private sector will be doctors, technologists, and well-educated postgraduates. Thus, with regard to science and technology education, we have observed that:

- Experiments, workshops, games, and manual activities should be encouraged in primary and secondary education. The impact of science and technology on areas of personal and social life should be transmitted.
- Abilities and skills should be developed, and a method of education based more on stimulating curiosity and asking questions than on formally established knowledge should be encouraged.
- The teaching of scientific subjects should be strengthened in primary and secondary education.
- An interdisciplinary, experimental, and flexible university education has to be developed.
- Although doctoral education has diverse organisational structures in different disciplines, the ability to tackle and solve problems and the development of leadership skills should be encouraged.

# Training and selecting human resources

## General aspects

Sustained development of scientific and technological research depends on thorough knowledge of the general criteria guiding any measures to increase the quantity and quality of human resources in the science and technology system. These criteria should also be applied throughout the different stages of training of research staff and they should have a stable time framework. The number of researchers in the system must increase if Spain wishes to adapt to the recommendations defined in the Lisbon and Barcelona European Councils. It is estimated that the number of researchers in Spain needs to increase to 10 researchers per 1000 members of the population. However, this increase should correspond with a policy that takes into account the needs of the system in both the public and the private sectors. Moreover, such a policy should be implemented progressively. This would guarantee that researchers and technologists are incorporated into the system gradually, with the education required to ensure that the system's efficacy increases. The particulars of technological- or research-oriented training are considered below.

Furthermore, modern research cannot be considered to be an individual task; rather, it requires team work. Modern working groups should be made up of people with a variety of qualifications and capabilities. Research based exclusively on highly qualified researchers would be far from effective and would not be a high-quality activity. Technicians, managers, and technologists who are dedicated to obtaining a common objective of producing research that is of high-quality and competitive are needed.

## Training for technologists

Probably one of the biggest problems facing the Spanish science and technology system is that companies have limited human resources capable of innovating and incorporating technological advances into business activity. In particular, it is crucial for companies to have industrial researchers (highly qualified doctors and technologists) who can understand both the nature of scientific and technological advances and how to make good use of them for the company. Such researchers should also be able to foster and catalyse the innovation process in the business sector ,and they are essential to the ability of a company to become more competitive. Without such researchers, there is little use in increasing investments linked to infrastructures or acquiring technology. The idea is not only to increase the number of researchers in the business sector, though this continues to be essential, but also to contract more technologists. This means technical personnel who are highly qualified in different branches of engineering and applied sciences.

The public sector could contribute to improving human resources in companies, in order to encourage a culture of innovation as well as different types of technological development. Firstly, it could introduce reforms to the education sector, so that people are educated with abilities that motivate them and an enterprising spirit, as mentioned above. Secondly, a business focus should be encouraged as part of a researcher's education, and the insertion of researchers into the production sector facilitated. Thirdly, administrative barriers, which hinder researchers' mobility and exchanges between public institutions, innovation centres, and companies, should be removed.

Technologists are essential to corporate laboratories or research centres, and their training is one of the activities that define the industrial sector's ability to absorb and make use of researchers' efforts. A large numbers of technologists are also needed for processes involved in the construction and operation of large-scale facilities, many of which operate in a multinational environment. The idea is not to create watertight compartments between different kinds to activities; instead, the aim is to create overlap between research and technological development, with boundaries that are increasingly diffuse.

Specific training in advanced technologies should be undertaken, as it is in research, on the basis of recognising the need for continuing education throughout one's professional life. To date, only a few companies have collaborated closely with universities to offer specific postgraduate programmes. The establishment of a Higher Education Area (Bologna process) will lead to the establishment of postgraduate programmes. The opportunities that these programmes offer must be put to good use by universities and companies alike.

In Spain, specific instruments linked to jobs (*learning by doing*) have been used to train technologists. Examples of these are the programme for incorporating doctors into companies (Acción IDE) and subsequently the Torres Quevedo programme. The latter programme was initially directed at SMEs, but now has a wider field of action, including activities in science and technology parks. However, the effects of Acción IDE and the Torres Quevedo programme are limited, as the number of people involved is small.

In the Spanish public sector, human resources and grants for training research personnel are linked to projects of national programmes directed at universities and public research bodies. While this system has been highly valued for years, there is no comparable formula for projects funded through PROFIT (currently called *Ayudas al Fomento de la Investigación Técnica* – incentives for promoting technical research). If extra funding could be obtained on the basis of incorporating technologists under conditions similar to those in the Torres Quevedo programme, with no need for a specific call for applications, this could increase the appeal of PROFIT projects to Spanish companies.

Finally, mobility between the public and private sectors continues to be very limited. Activities linked to in-company end-of-degree-programme projects, which are common in some engineering studies, do not continue throughout a researcher's or technologist's professional life. University–business associations, which have recently increased in number, could act as an additional incentive if they are used to strengthen the factor of intersectoral mobility. The Framework Programme has tried to promote these processes as part of the networks of excellence. However, corporate participation in these networks is still very limited.

In any case, the goal is not just to have an administrative instrument provided by the budget, which would be a relatively simple scientific and technological policy decision. Instead, a change in mentality is required, and this needs time and perseverance. Adequate training and the availability of technologists are essential to catalysing the business sector's involvement in R+D activities. To attain this, the influence of human resources in activities funded by the authorities should be increased. Five different measures are proposed:

- Encourage a culture of technological and innovative development, especially during university and postgraduate education.

- Redesign the conditions for applying to the Torres Quevedo programme to make them more attractive to the business sector. The number and scope of programmes should be increased; in particular, so that new technology-based companies can take advantage of them.

- Improve tax conditions linked to training technologists, particularly when activities are undertaken in cooperation with the public sector.

- Fund the incorporation of technologists from the public sector into companies that have obtained a PROFIT project or an international programme (PM, EUREKA, ESA, etc.). The conditions would be the same as those of the Torres Quevedo programme. This would increase the role of the public sector as a generator of technologists.

- Increase funding for programmes that encourage mobility between the public and private sectors.

## Training and selecting researchers

The professional development of researchers in the Spanish public sector is defined by the legislative frameworks governing the different public institutions or centres responsible for such development. These include universities, the Spanish Council for Scientific Research (CSIC), and other public research organisations (PROs). The traditional career structure in public research centres is often based on a civil servant system. In this system, however, there is a lack of incentives and recognition to strengthen and reward research activity. In addition, the professional development of young researchers in Spain has been typified by a certain degree of instability and uncertainty, due to the periodic appearance of new recruiting strategies and/or grants that have been made available but without a stable time framework. This dynamics does not further the appropriate development of research activity. It also prevents a suitable pyramid of different ages from forming. Such a pyramid would ensure that there is a gradual turnover of research personnel.

To maintain the sustained growth of the science and technology system, any measures that are applied must take an overall view of the different stages in training research personnel and have continuity over time. According to the recommendations of the Lisbon and Barcelona European Councils, the number of researchers should be increased using a well-defined policy of progressive recruitment. A huge increase in the short-term would be detrimental to future generations and would be unlikely to enhance the system's efficiency. It would also be difficult to rapidly increase the number of researcher by using a selection process based solely on excellence and productivity. The objectives are therefore to strengthen the way the existing system is run and to recruit highly qualified researchers who can work in both the public and private systems. To achieve this, the first step is to define the criteria that should apply to all stages of the system:

| CRITERIA | |
|---|---|
| PRINCIPLES | INSTRUMENTS |
| Excellence | Appraisal |
| Professionalism | Incentives |
| Competitiveness | Mobility |
| Dynamism | |

The development of research activity in any scientific field should be based on training and on providing incentives to those researchers, technologists, and technicians who are qualified to carry out independent, innovative, and high-quality research. Job opportunities should be coordinated with the promotion of personnel.

Measures undertaken for the steady development of research should be inspired by a set of common principles. Such principles will ensure that researchers have the required background, regardless of the special characteristics found in the different scientific disciplines and technological fields.

## Principles

### *Excellence*

The mechanisms for selecting and appraising scientists and technologists should mainly be based on excellence. Excellence can be measured effectively using objective systems (bibliometric systems, impact indices, an index of citations in publications, patents, the creation of new technology-based companies, etc.) and/or by anonymous external appraisals (*peer review* committees). Such appraisals should generally take into account the international standards of excellence that are usually applied in the scientific-technological area to which the researcher belongs to.

### *Professionalism*

The aim of training and promoting scientists or technologists should be to attain professionals who are highly qualified and motivated to practise their profession. Salary bands and opportunities to receive other economic perks should form part of the incentives used to motivate professional and highly competitive activity.

### *Competitiveness*

The principle of competitiveness should be used to select and promote researchers. Thus, those who have the best research curricula, assessed in terms of excellence, will be promoted preferentially.

### *Dynamism*

The high level of specialisation and rapid advances in knowledge that typify the modern science and technology system calls for a high level of dynamism within the system itself. Continuous opportunities for training, and for perfecting, and specialising the skills of researchers and technologists require geographic, public-private cooperative, and thematic mobility from the predoctoral period onwards. This situation should be supported and fostered by different institutions, in particular those belonging to the public sector. Public sector institutions should encourage and promote the mobility of their personnel without any cost to the individuals involved. A high level of dynamism also calls for an increases in the permeability of institutions, so that researchers and technologists can come and go more easily. Mobility between the public and private sectors could be the best way to transfer results. Interdisciplinary, or thematic, mobility is now an essential factor in generating new knowledge.

## Instruments

### *Appraisal*

The professional promotion of scientists and technologists should be subject to a cyclical appraisal process. This would measure progress, stagnation, decrease, or decline in activity. Appraisal mechanisms should assess excellence above all. To achieve this, the parameters and standards of appraisal that are used should be internationally recognised. In addition, to encourage objective appraisals, the assessors should be totally independent, with no connection to the individuals.

A research system that is constantly being updated requires continuous assessment. This should be carried out by an agency. If not, the diversity that exists in Spain could give rise to different professional situations. The necessity of appraising groups of researchers will be dealt with at a later stage in this document. In such cases, it becomes even more important to have institutional tools that can undertake appraisals independently but homogeneously throughout the country.

Consequently, autonomous bodies that are relatively independent from the government are needed to carry out the processes of appraising or accrediting researchers or groups. Such bodies would manage and coordinate national research policy. The current ANEP should be the agency that is strictly dedicated to appraising the system's quality in terms of its researchers, programmes, or projects. Perhaps it should be divested of its long-range planning tasks, as these appear to be more in line with the work of other bodies. Moreover, the ANEP has not carried out much activity in this area to date. A new national agency focused on mediating opportunities also appears to be necessary. It would be responsible for appraising groups, establishing effective coordination with regional governments and managing national programmes.

### *Incentives*

Productivity and research excellence should be stimulated through a suitable incentive system. This objective has not been attained in the public system, as the salary bonuses that are currently in use are low and are awarded fairly indiscriminately. A more effective way of rewarding excellence would be to create a series of well-defined salary scales. Different grades could be obtained progressively according to the results of periodic appraisals.

### *Mobility*

The transfer of researchers to related occupations should be encouraged in order to foster the integration of research into society. Professional mobility refers mainly to personnel moving between research tasks and business activities involving science communication or management. The terms of researchers' contracts should favour their transfer to other, related activities. Research centres should be flexible enough to cope with this mobility.

Work regimes for researchers and technologists should include, on the part of public institutions, a commitment to sabbatical periods. These periods should not entail financial or professional costs to the individuals. The opportunity to take sabbatical years in other national or international research centres or companies, or to go on extended leave of absence, should be facilitated and supported. Likewise, any initiatives that contribute to increasing collaboration between PROs and companies should be stimulated and valued positively.

# Research incentives in the public sector

Research excellence in is an essential criteria in both the public and private sectors. This section proposes several measures aimed at individuals and others at creating high-quality research groups. The following two courses of action are considered:

- Propose measures to strengthen research in the public sector.
- Propose a model for a research career pathway that is flexible and complements the current one.

## Measures for personnel within the public research system

There should be a set of measures to give staff undertaking research tasks in public institutions incentives to carry out their activities to the full. (See the box-summary "Measures for stimulating the public research system".) Attention should be paid to two factors: (1) the individual and their career, and (2) the structure in which researchers carry out their activities. In this document, we propose some measures aimed at individuals, and others directed at encouraging groups in centres of excellence. In such centres, staff are able to carry out their work more efficiently, their activities are rewarded, and more resources and better methods can be attracted, all of which fosters quality research.

### *General measures*

- Encourage the creation of: (1) active interfaces between universities and the CSIC, (2) university institutes that are combinations of research centres, or not, and (3) foundations, which facilitate cooperation and the creation of centres as private bodies and therefore flexible recruitment.
- Identify and strengthen high-level research groups in the public and private sectors, and make it easier to build bridges between them.
- Foster the creation of networks of researchers and centres that bring together researchers, technologists, resources, and projects. These networks would foster an environment of excellence in research, collaboration, and scientific communication.
- Promote the creation of centres of excellence on the basis of the current system's human resources. Supporting these groups will contribute to increasing quality in the generation of new human resources.
- Increase administrative and technical support for groups of excellence. In this respect, it is important to train professionals in research management. Such professionals could support researchers and groups in matters related to exploiting, protecting, and transferring results, and in their relations with companies.
- Create salary incentives to improve existing systems. New incentives should be based on periodic appraisals of the work undertaken, and act as a stimulus to researchers and technologists.
- Create a recognition of excellence, to be awarded to researchers with outstanding output. The performance of researchers in consecutive appraisals would determine whether the award was maintained.

- Facilitate sabbaticals in foreign centres.
- Support the mobility of researchers from public research organisations to enterprising technology-based initiatives that involve new, high-quality technological development and innovation. This could be achieved by measures permitting researchers to take temporary leave of absence in order to generate new companies.
- A national agency would assess the excellence of groups.
- Increase the permanent training of researchers.
- Increase the recruitment of women in the research field, and adopt measures that foster their dedication to research and their visibility.

***Specific measures for universities and the health system***

The university is an institution that has particular characteristics. Consequently, special attention and specific measures are needed to improve research in the university environment. Some of these characteristics significantly affect those human resources in the university that are devoted to research. The university's regime of teaching staff can act as a factor limiting the availability of human resources devoted to research. In addition, the double occupation of teacher and researcher frequently requires specific measures to facilitate research.

The health system has structural characteristics similar to those described above, as the main task is health care, and the system's personnel management is autonomous. Thus, in many cases, special measures are needed to increase human resources in R+D. We therefore propose a few specific measures in addition to those mentioned above:

- Support a temporary reduction in the teaching or health care work undertaken by excellent researchers. Such researchers should be allowed to preferentially devote their time to highly specialised health care or educational tasks. To achieve this, specific measures could be promoted that allow tasks to be distributed unevenly. Measures could also enable new personnel to be taken on so that excellent researchers are freed from their teaching or health care work.
- Offer intramural sabbaticals that favour periods of exclusive dedication to research work in universities and the health system.
- Create early retirement incentives for surplus teaching staff who are mainly focused on teaching. This would free up positions and enable the appointment of personnel who are mainly devoted to research.
- Include sabbaticals for researchers and technologists in the administration of these institutes.

**MEASURES FOR STIMULATING THE PUBLIC RESEARCH SYSTEM**

Support the creation of **quality scientific environments** (institutional interfaces, networks, centres of excellence, etc.).
Support the creation of **awards** as well as **reductions in teaching or health care tasks** for excellent researchers.
Establish **geographical sabbaticals and other measures to increase mobility** in the public and private sectors. These should have flexible management that does not cause researchers and technologists any unnecessary setbacks or personal financial costs. The government should manage this measure through open calls for applications and a minimum of three resolutions per year.
Create selective **salary incentives.**
Support **joint projects** between the public and private sectors.
Encourage the **recruitment of women into the research system.**

# A possible model for developing a scientific and technological career

This section proposes complementary measures adapted to the principles presented above and based on establishing contractual relations.

In Europe, there is a growing tendency to establish contractual relations. Moreover, such relations are beginning to be introduced within Spain, including the regio. The validity of a tenure-track model has been proved, as has its capacity to adapt to the changing situation of research in current society.

A proposal for a scientific career structure is presented below. The intention is not to substitute existing models, but rather to offer an additional model that is as compatible and complementary to existing models as possible. Thus, circumstances permitting, the entire model could be introduced as required, whereas in other cases only some parts of the model could be implemented. The key element of the proposed system is the continuous assessment of both researchers and institutions. This would help to create a scientific career structure in Spain that is suited to the needs of high-quality modern research.

In accordance with the above criteria, another objective of the proposed career is to foster the mobility of human resources devoted to the science and technology system. This would act as an instrument for increasing the system's competitiveness. Mobility could be between geographical locations, institutions, sectors, and areas of interest. It would encourage professional careers to be developed in those institutions that have positions allocated for use in this model.

Finally, another objective, which could become a proposal like the one made here, is to bring about the existence of contractual options. Once established, these could be funded by different administrations (the State, regional governments, CSIC, universities, etc.) as well as by private institutions, including financial corporations and companies. Any kinds of collaboration between these organisations would promote recruitment based on these concepts.

### Coordination of the model proposed for developing a scientific career structure

**Reasons for the proposal:**

The efficacy of similar systems in advanced countries has been proven.

There is a growing trend in Europe to use contractual relations.

The state and regional governments have begun to use a contractual approach.

The system is flexible and compatible with the existing model.

**Normative framework**

A normative framework may be needed to maintain the proposed system. Such a framework should be developed by the State, as it has jurisdiction in this area.

**Who contracts**

The proposed employment contracts could be made by any institution with its own legal status and responsibility in the R+D field.

**Who funds**

It appears that basic funding –the full amount and/or incentives provided by the system– should be the State's responsibility, at least during the initial phases. Subsequently, regional governments or those public and private institutions recruiting personnel could co-finance the model.

**Who is evaluated and who evaluates**
Research groups working on a single, consistent topic should be evaluated. Consequently, multidisciplinary institutions (such as universities or the CSIC) should not be appraised. Evaluations should be undertaken by a national agency (or the ANEP, if applicable) that would accredit groups that pass the personnel evaluation, enabling them to hire researchers.
**Location**
Those contracted using this system are not limited to a particular institution. All R+D institutions could have personnel contracted in this way.
**Relation to the current situation**
Current employment contracts in the Juan de la Cierva and Ramón y Cajal programmes are consistent, to an extent, with the system's associate postdoctorates and researchers, respectively. However, the concept of permanent researchers would be new. The Torres Quevedo programme reflects, to a certain degree, the proposals for transferring researchers trained in the public sector to the private sector.

## Characteristics of the new scientific and technological career structure

- These reflections on a **model for a career structure in** science and technology define a possible path for researchers approved by the consecutive appraisals. This career structure does not have to be pursued in the same centre, or separated from existing, traditional career structures. Instead, the researcher would be able to access and leave the suggested career structure in a flexible way.
- The proposed career structure would be pursued in the science and technology system with a **high level of mobility** between different geographical areas, institutions, and even sectors. Therefore, quality researchers from the private sector could be incorporated into the public system and vice versa.
- All stages of the career structure should be **open to researchers from abroad**, from their first educational phase to their continuance in the system. This requirement is a clear consequence of the aforementioned criteria of excellence, competitiveness, and professionalism. As a result, English should be accepted as another language in the system.
- An important aspect of this career structure is the issue of **salaries and complementary financial assistance,** such as funds and resources to support research and housing incentives for those stages in which geographical mobility is required or recommended. Attractive positions should be offered so that competent professionals do not opt to leave the system to work in more rewarding working conditions.
- This model is not meant to substitute approaches that already exist in public research institutions. Its aim is to create a career structure based on a **delocalised contractual system**, using appraisal as an instrument for validating excellence and professionalism. This is required for the system to be competitive. This model also aims to fits in with current structures.

### *Predoctoral research education*

- Public or private research projects could include the option of awarding grants and predoctoral contracts to researchers who are in this phase of their education.
- Proper attention should be paid to the education of doctoral students. Measures should be adopted to prevent grants and contracts from being awarded to groups that do not have the capacity to train such students.
- Under certain, justified circumstances, predoctoral training could be carried out in prestigious non-Spanish centres.
- Once the initial phase of predoctoral education has been completed (DEA, Masters, or

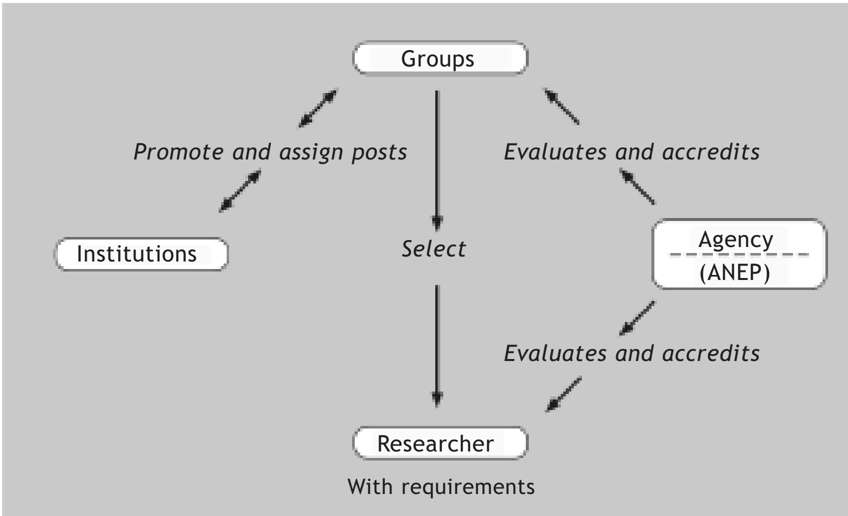


FIGURE 1 A diagram representing the mechanisms for promoting and evaluating centres and (permanent or associate) researchers

equivalent), the research undertaken could be supported by predoctoral contracts.

• Predoctoral researchers who are still studying should be attached to highly qualified groups and be assessed and selected by the heads of these groups (Fig. 1).

• Once students have finished their initial requirements, predoctoral funding should be awarded as quickly as possible.

• Predoctoral education should last at least four years.

• An enterprising and innovative spirit, and training for business leadership should continue to be encouraged throughout the predoctoral stage of education.

### *Postdoctoral researchers*

• Postdoctoral education should be attractive, so that highly skilled doctors choose this path of professional development.

• This period of education should be carried out at a centre different than the one in which the student's doctoral thesis was completed. It could be undertaken in a highly qualified group in Spain or abroad.

• The call for application and selection of these researchers should be organised so that there is no gap between the end of the predoctoral period and the postdoctoral stage.

• The postdoctoral period could be two years long initially. After appraisal by a recognised agency, this period could be extended to four years.

• The working conditions of postdoctoral researchers abroad should be such that, when the researchers are reincorporated into the Spanish system, their labour rights are recognised as if they had always worked in Spain.

### *Research associates*

• At least two years of postdoctoral research at other centres is required. Researchers should be (except in justified cases) less than 35 years old, have proven research ability and leadership talent, and a novel and interesting line of research. Applicants should also be capable of training younger researchers. These requirements should be evaluated and accredited by an agency that has recognised authority.

• Research centres that are accredited for their excellence should allot a minimum number of positions for research associates.
• Centres that have research associate positions will contract qualified researchers after an appropriate selection process that includes an interview conducted by the heads of research.
• Research associate contracts will be for an initial 5-year period. After 5 years, the research associate should be assessed by an independent committee. External evaluators with recognised research ability will comprise this committee. The appraisal will include an interview and a demonstration of the kind of work carried out. If the results of the appraisal are positive, a new 5-year contract will be awarded.
• Research associates could participate in training young researchers, i.e. they could have doctorate students attached to their group.
• Research associates should receive basic funding for their research for the duration of their contracts.

***Permanent researchers***

• The requirements for becoming a permanent researcher would be at least 7 years of quality research experience after completion of the doctoral degree and recognised, proven leadership ability. This ability would be evaluated by a recognised agency. Under special circumstances, less than 7 years of experience could be accepted, if justified by an exceptional evaluation result.
• Accredited and evaluated research centres should allot a specific number of positions for permanent researchers.
• Candidates should be capable of managing doctoral students and of including postdoctoral and associate researchers in their projects.
• Contracts for permanent researchers should be fixed and have different salary scales. An appraisal every 6 years would determine whether the researcher should be promoted to the next grade, stay at the same level, or have their contract terminated. The appraisal would include an interview with the researcher and would be conducted by a committee like the one used to evaluate associate researchers.

***Technologists***

After carrying out a comparative analysis of requirements in the technological field, it was found that the levels involving permanent contracts are in the hands of private initiatives. Therefore this report only deals with educational levels, an area in which public funding is able to participate (Fig. 2).

In this respect, and in connection with the phases in a professional research career structure, the stages in training research personnel in technology could be:

– **Training of technologists for research.** The kind of work these employees will do requires specific training in research and innovation technologies. However, in some cases, a doctoral degree may not be necessary.

– **Predoctoral training** This should be specifically provided for technologists who decide to begin a career that is devoted more to research. The contractual system
should be the same as that used for the general system.

– **Technological specialisation.** This is equivalent to postdoctoral research studies. The private sector has to be involved in its design and funding. The contractual system should be the same as that used in the general system.

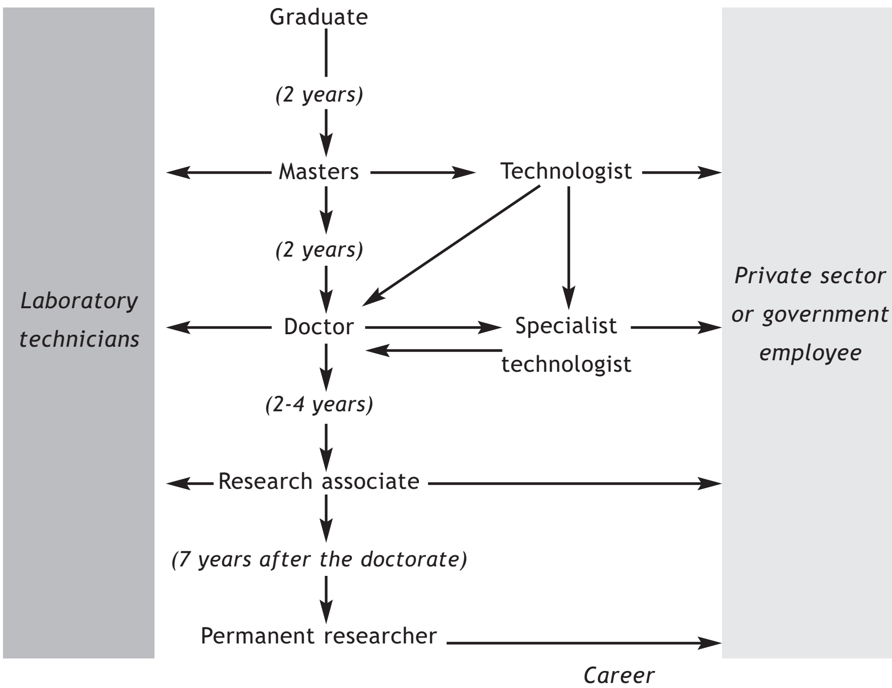


FIGURE 2. A diagram representing the proposed career structure in research, and the way this is linked to the technological research career in the private sector

***Technical personnel and other concepts***

• In addition to contractual approaches for researchers in the career structure described above, contracts should be created for highly specialised technical staff. These would be complementary to positions in a strictly research-oriented career. A technical career should also be attractive enough to recruit highly qualified professionals.

• The job of research technician could be a professional alternative for research personnel who have good training and technical experience, but who lack motivation or leadership skills.

• Contracts for work or services in research are useful employment approaches for temporary recruitment of both higher-level technicians and research personnel. Such contracts could offset temporary fluctuations in research activity.

• The need for specific, attractive training for research managers should be recognised. If managers were part of research teams, they could be authorised to manage the teams directly. In addition, they could oversee protection of intellectual property deriving from research results, and help to establish effective and fluid communication between researchers and the private sector.

• Public research centres should have research managers whose responsibilities include increasing technology transfer and the amount of collaboration with the private sector on research projects.

• More efficient organisational forms should also be adopted, so that researchers do not have to deal with all the phases of generating and distributing knowledge.

# Recommendations and proposals

## General recommendations

- Encourage social appreciation of science and research, particularly during the initial phases of education.

- Use the criteria of excellence, competitiveness, professionalism, and dynamism as principles on which to base the training and selection of researchers. Research should be accompanied by a constant process of evaluating researchers and research centres.

- Research excellence should be accompanied by wage incentives that encourage competitiveness and make scientific and technological research attractive.

- Encourage and facilitate topical, sectoral, and geographic researcher mobility using appropriate funding and regulations.

## Specific proposals

- Install active measures in the education system to encourage younger generations to enter the research system.

- Create salary measures that improve on existing ones and can be used to motivate researchers. Such measures would be based on continuous assessment of research results.

- Promote the mobility of research personnel and introduce measures that enable some research staff members in the university and health systems to increase the amount of time they devote to research.

- Create a programme of awards and recognition for excellent researchers.

- Apply the design of an R+D career structure based, at least in its final stages, on employment contracts for research.

- Establish mechanisms that permit and encourage a career in technological research.

- Link generous funding to networks and centres of excellence. This would enable the best use to be made of human resources.

- Encourage the recruitment of women into the research field.

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Confederación de Sociedades Científicas de España (COSCE)

# Acción CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Science and companies:
## Towards a dynamic ecosystem for innovation in Spain

# Summary

The current economic and social environment is marked by major changes and significant challenges. These have defined a high level of complexity and competitiveness for companies and countries within the international context. When faced with this environment, a society's ability to innovate becomes the main source of generating productivity, diversity, and value for companies, in addition to progress and well-being for society as a whole. This has occurred in many major periods of historical transformation.

The key to creating innovation is to connect science and business. Innovation can be defined as the practical application of technological developments and knowledge to meet specific business and social needs. It is the link in the chain that allows technology and scientific knowledge to be converted into useful and productive value. Awareness of innovation's strategic value, and of the connection between science and business, gave rise to the objective of this report: *to develop a proposal that contributes to improving the entire Spanish innovation system.* An analysis of the following factors is taken as a starting point: conditions that define an effective ecosystem for innovation, the Spanish innovative system's current situation, and the lessons learnt from a series of practical cases of innovation carried out by Spanish companies and institutions.

To this end, this report proposes creating a *Foro de Encuentro* (meeting forum), which would involve all the agents of the Spanish innovative system and be led by business. Mechanisms and plans for collaboration would be drawn up in this forum. Through specific and selective measures, these would enable the innovation model in Spain to take a qualitative and crucial step forwards.

The main goal of the meeting forum would be to develop a Spanish model of innovation. Specific innovation projects would be undertaken and used to analyse, document, and transmit guidelines for the different participants to follow. The model would be drawn up simultaneously. In addition, the forum's activity in itself would significantly contribute to creating an enterprising generation (researchers with a market mentality and business people with an innovative mentality) that fully embraces the new model.

### The ecosystem

Innovation is, more than ever, generated by the interrelation and convergence of many agents within an ecosystem. In a favourable social, legal, and cultural framework, this ecosystem can interpret the needs and challenges of business and society. It can then develop and apply knowledge and technology to meet these needs.

The ecosystem's main agents are: universities and research centres, government departments, financial corporations, and companies. These should interact as fluidly as possible with each other to encourage innovation, an enterprising spirit, and the generation of value for society as a whole.

Some key factors that would facilitate the general administration of the ecosystem are: developing the required talent; encouraging research centres to take a suitably enterprising approach and, conversely, incorporating innovation as a key element in business management; providing the system as a whole with the infrastructure and resources it needs to develop; and creating common areas for communicating and exchanging ideas.

## The current innovation system in Spain

The Spanish innovation system is not working effectively enough to ensure an adequate level of technological development and value generation, both of which are needed in the current competitive environment. Critical mass as well as human, technological, and financial resources are required to maximise optimisation of and productivity by the entire system. In addition, it is essential for the various components to be able to interact with each other.

According to CEOE (the Spanish Confederation of Employers' Organisations) data, only 6% of the current R+D expenditures of Spanish companies is allocated to contracting projects generated in Spanish universities and PROs.

Thus, the amount of investment in R+D+I (innovation) by Spanish companies is low, and there is only limited permeability between the public research system and corporate and social sectors. As a result of these two factors, among European countries, Spain registers relatively few patents (5 times less than Italy, 10 times less than France, 30 times less than Germany). The rate at which research effort is converted into real and useful innovation is therefore one of the lowest in Europe.

Consequently, there is significant room for improvement in many different areas. This report has identified a series of priority action plans. If these were applied to the ecosystem's main agents (companies, institutions, research centres, and government departments) the innovative capacity of each agent and of the system as a whole would be strengthened.

## Lessons learnt

Some initiatives and instances of collaboration between science and companies in Spain were analysed by this report's committee, as a way of understanding how the entire ecosystem works in practice. Overall, at least ten factors were found to be of value and should therefore be strengthened.

Among others, the following good practices were identified: (1) in each project the strategic value of innovation was recognised; (2) generating useful value for the market and society was the main driving force of the collaboration; (3) technology was transformed into practical solutions that could be applied to improving processes; (4) there were rigorous operating models to manage, adapt, and evaluate projects.

## Proposals for action

As a result of the analyses and reflections carried out for this report, a project is proposed that specifies how the Spanish innovation model should be redefined in the short-term.

Existing experiences can be used to devise an operating model that enables: the best professionals to be recruited, resources and existing experiences to be shared, flexible work plans to be coordinated, collaboration mechanisms between the different agents to be established, advice and recommendations regarding incentive and funding schemes to be given.

- The proposed project consists of *creating a meeting forum,* where all the agents comprising the ecosystem can meet. The forum would be led by business and would:

  – Define areas and sectors of priority action.
  – Establish all of the relationships that should be encouraged between the ecosystem's different agents and define the values that should be promoted.

– Promote the recruitment of the best researchers and managers.
– Coordinate all actions required to attain and share resources and experiences.
– Initiate a pilot project to test the innovation model proposed herein.

In conclusion, redefinition of the Spanish innovation model in the framework of the proposed forum, which is based on excellent relations between science and business, should be supported by two fundamental principles:

*a)* Companies within the *innovation ecosystem* will assume a leading role and work closely with the other participants. They will also be charged with coordinating mechanisms to develop and strengthen the entire model.

*b)* Legal, administrative, collaborative, communication, organisational, cultural, and financial barriers will be eliminated. This would enable the *innovation ecosystem* to function on its own.

Finally, we stress our firm belief that the Spanish innovative system's present situation is critical, and could jeopardise Spain's opportunities for future development. However, we are also convinced that if the proposed recommendations are applied immediately, the current situation can be rectified.

# Introduction

This document includes the main reflections of the *Science and Companies* working groups. Its objective is to make a proposal that will foster better use of Spanish scientific production, strengthening its connection to the business sector. This proposal should help to convert scientific production into a main source of productivity, competitiveness, and social and economic development.

The key to supporting innovation is to connect science and business. Innovation can be defined as the practical application of technological development and knowledge to meet specific business and social needs. Innovation enables technology and scientific knowledge to be converted into useful and productive value. The OECD defines innovation as using knowledge, and generating it if necessary, to create products, services, or processes that are either new to a company or improve on its existing ones. It states that success in the market is achieved in this way.

Clearly, innovation has been one of the basic guiding principles of human progress over time. In fact, a high concentration of innovation in certain situations and during distinct periods of time has always been a strategic catalyst, bringing about major social and economic changes. Everything seems to suggest that we are now in one of these periods. For example, several economic studies indicate that innovation is currently the main component in increasing productivity and the factor responsible for more than half the economic growth of advanced economies. For companies, innovation is a determining factor in generating the level of differentiation, competitiveness, and efficacy needed to operate in the complex and changing markets that make up the current international economy.

This report was put together keeping this outlook and an awareness of the importance of innovation in mind. In the first section, we analyse the determining factors in creating an environment that favours interrelation between research and development processes and social and business needs. Such interrelation generates innovation. In the following section, we examine the innovation process in Spain, highlighting the main aspects of its current form. We also recommend what kinds of actions the main agents in the innovation process should take. Next, using an analysis of different cases and the experiences of Spanish institutions and companies, we identify a series of practical guidelines characteristic of successful innovative projects. As a final result of this report, we present a proposal for action and a summary of the main conclusions. These contribute to the basic objective of making better and more comprehensive use of Spanish scientific production, so that it can be converted into value for business and research institutions, and into valuable innovation for society as a whole.

It is important from the outset to highlight the difference between large companies and small and medium-sized companies in Spain. Large companies have access to the best local and global research, whereas small and medium-sized one –the main components of the Spanish business sector– are less able to take advantage of the scientific capital at their disposal and thus become capable of innovation.

# A frame of reference and initial reflections: innovation as an ecosystem

We live in a time marked by continuous change, uncertainty, and significant social and economic factors, such as market globalisation and emergence of the knowledge society. It is a time of great overall complexity and a high level of competition in the economic environment. As a result, companies have to face increasingly difficult challenges. Countries' entire social and economic systems need to make continuous innovative efforts to maintain their ability to compete. New areas need to be opened up to create value, so that sustained and sustainable development can be maintained in an international context.

In these circumstances, scientific research and technological development and the practical applications of these activities are inseparable aspects of any effective innovation process. All agents involved in the innovation process must interact harmoniously, collaborate with each other, and be capable of maximising available resources. In this way, new knowledge, ideas, and technologies can be put to use by society. They can be converted into new products and valuable services for the market, which then generates wealth and well-being.

The group of agents involved in the innovation process and the interrelations between them are known as the *innovation ecosystem*. This system has its own internal dynamic. If we are to act on the innovation ecosystem, we must first unders-

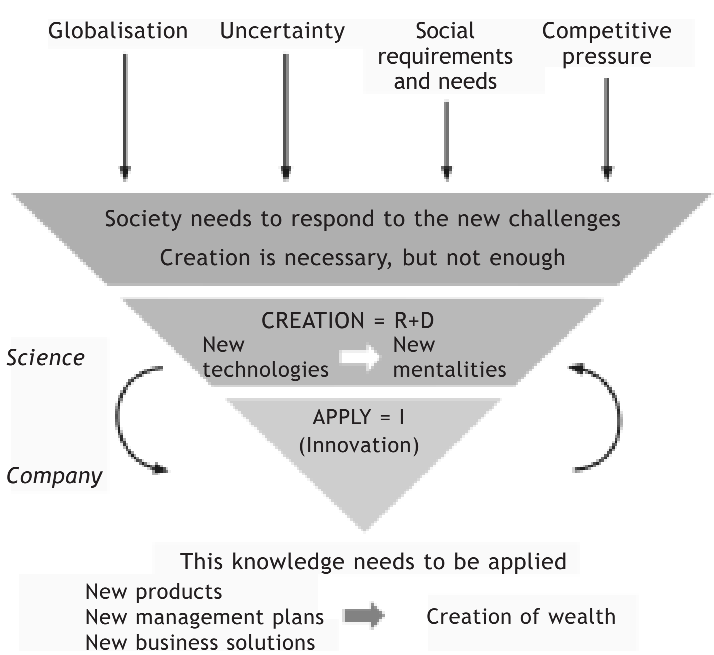



FIGURE 1. Harmonising the agents and factors involved in the innovation process.

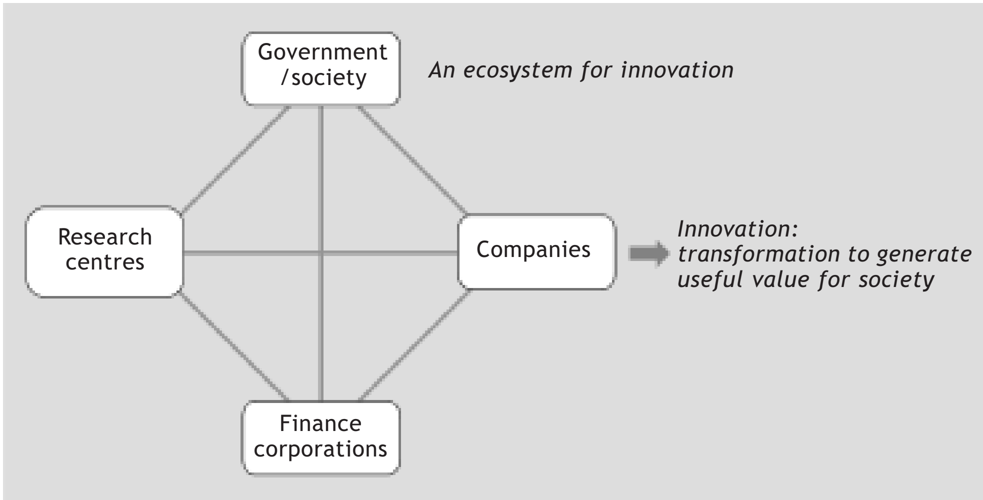



FIGURE 2. Innovation ecosystem dynamics

tand this dynamic, as it could either favour or hinder the innovation process.

The current innovation ecosystem is typically open, interdisciplinary, and competitive. This is in contrast to industrial society's characteristic unidirectional model, based on isolated R+D. Innovation in the current knowledge society is generated, above all, by the harmonious interrelation of the ecosystem's many agents and aspects, and is mediated by different institutions. Therefore, for this purposes of this report, the following components of the ecosystem should be briefly analysed: *a)* its basic structure, *b)* key factors in running it, and *c)* its main success factors.

## Basic structure

An innovation ecosystem's main agents and their basic functions are the following:

- Research centres devoted exclusively to generating scientific and technical knowledge.
- Educational institutions and universities, whose main tasks are to develop the talent needed for the system to work correctly, and to contribute to developing knowledge.
- Business, which is a key link in the process; to survive, it must transform knowledge and technology into the products and services required by the market. Thus, companies have a central responsibility for the ecosystem's operation.
- Institutes, innovation centres, and infrastructures that support research, and thus whose main task is to facilitate technological innovation in companies. This is accomplished by providing a variety of services and by creating environments that promote information transfer and communication between the system's different agents.
- Government departments, which must act to remove barriers to innovation and to support the ecosystem by providing it with economic and human resources that are outside the responsibility of business. The government should facilitate the creation of legal and social conditions that foster interaction and communication between all the agents of the ecosystem.

- Finance corporations, along with companies and government departments, whose task is to devise and implement ways of removing financial barriers so that innovation can advance.
- Society, whose needs and expectations are the system's true driving force and focal point.

## Key factors in running the ecosystem

The following factors are essential to the smooth functioning of the innovation ecosystem:

- Developing the talent needed to generate knowledge and convert it into real innovation. It is particularly important to encourage companies to recruit qualified researchers. It is also essential to foster not only the professional development of R+D+I teams, but also an innovative spirit among the board of directors.
- Having flexible organisations in the public and private sectors that act as trouble-shooters, i.e. they are capable of solving the problems that arise in a constantly developing and evolving system.
- Providing infrastructures that enable technological resources to be used efficiently and that encourage the different agents comprising the ecosystem to interrelate and collaborate. A system can only be effective if it provides opportunities for such meetings.
- Creating common meeting spaces where the different agents can communicate using a language understood by all. In this way, agents' interests would be smoothly incorporated into the system.
- Making financial resources available to facilitate each agent's activities. In particular, funds should be provided for activities related to knowledge generation and dissemination, and to knowledge transformation into wealth and well-being. It is essential for financial and other specialised agents to motivate and support enterprising activity in this way.
- Having a legal and fiscal framework that fosters innovation and stimulates organisations to take on the inevitable risks involved in any enterprising activity.

## Success factors

To ensure the success of the innovation ecosystem, society needs to support and encourage the following practices:

- Attain the commitment and leadership of business people, professionals, politicians, and researchers whose attitude and personal motivation will help them to identify and develop new plans of action, to connect the different agents, and to make them advance towards a common objective.
- Use excellence and creativity to guide actions and to achieve natural dynamics for work. Cases in which excellence has been actively sought and attained should be considered as blueprints for success.
- All the agents involved should be capable of critically assessing scientific and technical activity, knowledge development, and innovation generation .
- The creation of value should serve as a permanent reference point and key factor in guiding relations and collaboration between the system's different agents.
- The innovation ecosystem should be continuously monitored, measured, and assessed to identify which agents and actions add the most knowledge and value to the chain of creating products, and generate the most wealth and well-being for society as a whole.

# An analysis of the Spanish innovation ecosystem

The current Spanish innovative system's considerable challenge is to build an ecosystem with the conditions it needs to become rooted in the innovation process. In its present form, the Spanish ecosystem is still far from running well enough to ensure sustained economic development in the current complex, competitive international environment.

Many studies and reports have highlighted both the shortfalls in the Spanish R+D sector (in terms of investment and availability of resources) and the difficulties it has, compared to other European countries, in joining with the productive system to generate innovation (R+D+I). In 2003, Spanish companies' investment in R+D represented 0.52% of GDP, compared to an EU average of 1.28%. Spain is even behind countries that recently joined the EU, such as Slovenia or the Czech Republic. Measurements of the interrelation between the public research and development system and the Spanish production sector are not very positive either. According to CEOE data, only 6% of R+D expenditure by Spanish companies is allocated to contracting projects generated in Spanish universities and PROs.

Thus, investment by Spanish companies in R+D+I is low, and there is only limited permeability between the public research system and the corporate and social sectors. As a result, among European countries, Spain registers relatively few patents (5 times less than Italy, 10 times less than France, 30 times less than Germany). The rate at which research effort is converted into real and useful innovation is therefore one of the lowest in Europe.

If these data are taken as a frame of reference, it is clear that the Spanish innovative system has undeniable room for improvement. An analysis of this system's situation reveals the following shortcomings:

- Very few companies that carry out research have the capacity to produce goods with a high technological value.

- Spain has to continue to make an effort to approach the percentages of R+D investment typical of the most developed countries. However, the main problem lies in the business sector's inability to make good use of the results generated by research activity. This situation is worsened by the difficulties the entire ecosystem appears to have in identifying action plans that could contribute to improving companies' productivity and competitiveness.

- The innovative system's ability to recruit staff with higher levels of education could clearly be improved. In Spain, there is limited recognition of scientific work in terms of financial benefits. Therefore, both tangible and intangible incentives should be strengthened to attract more and better talent.

• Current scientific and technological policy encourages the pure transfer of resources to the productive environment. However, there is no concern for gauging and strengthening the innovative culture in the companies that receive these resources.

• There is a lack of continuity in public policies. There is no established aid agenda in which the medium- and long-term objectives are well-defined and in which actions are continuously assessed using precise measurements.

• The Spanish economy is directed more at public services than at R+D aid for these services. Information and communication technology, which can optimise business processes and public services, is not widely used as a tool for innovation and transformation.

• Managing research and innovation is increasingly costly in terms of time and resources. To a large extent, this is due to the difficulties involved in obtaining a cost–benefit analysis of innovative activity. It is also a result of administrative management problems that arise when submitting proposals calling for grant applications.

• Moreover, it appears that there are no standards of measurement for analysing the implications and results of decisions taken. Such standards would help to manage innovation processes with more knowledge and effectiveness.

# Action plans for the Spanish innovation ecosystem's agents

Better use of Spanish scientific production –converting it into value for companies and therefore for society as a whole– can only be made if the *innovation ecosystem* runs smoothly. Several factors are required to achieve this: Existing barriers need to be eliminated. All of the agents' functions should be strengthened considerably and adapted permanently. Conditions should enable the ecosystem to develop, change, and adapt itself to any new situation that may arise. State intervention should be avoided so that the ecosystem can enter a productive phase. In addition, actions should be oriented towards creating conditions that favour the active participation of all agents.

This report's working group has identified some priority courses of action for the innovation ecosystem's main agents. These are listed below.

## Business

• Innovation should be at the top of business leaders' agendas in large-, medium-sized, and small companies.

• The innovation process should be incorporated in a structured way into companies' management models.

• Business people should take a leading role in the innovation process to ensure that better use is made of existing scientific and technical knowledge. This should be done in collaboration with centres of research excellence and other ecosystem agents. To achieve this:

– The business sector should be equipped with technological and human resources that give it enough capacity to create innovative products, services, and management.
– It is vital for the ecosystem's agents to collaborate in forums, in order to identify and promote priority lines of research.
– Companies' technological backgrounds have to be improved, so that advantage can be taken of every opportunity to collaborate and exchange information and knowledge. This is absolutely essential.

• It is crucial for companies to recruit doctors, R+D professionals, and technologists. These professionals are qualified to detect scientific advances and to facilitate their use according to the company's interests. They would also build bridges and communication channels between the research world and the company.

• The aim of changing the criteria used for assessment and internal recognition should be to increase the internal prestige and professional development of staff involved in innovation.

• Large innovative corporations could promote programmes to form new innovative companies. They could also generate funds and act as specialised bodies to assess venture capital projects that are closer to their enterprising nature than to the interests of financial corporations.

• Business organisations should foster collaboration between small and medium-sized enterprises (SMEs) and other agents, such as technological centres. In this way well-defined, specific priorities and the most appropriate lines of research can be coordinated.

## Institutes and centres

• Universities and PROs should compete on the basis of excellence and quality of knowledge. They should also be aware that they need to do this in a global environment. Thus, obtaining resources and participating in R+D programmes should be based on competition with other national and foreign centres.

• These centres should have flexible and dynamic organisations that are closely linked to the rest of the system. They should encourage improvements in scientific production (both in quantity and quality) and better use of research results.

• Universities and PROs should make an effort to:

– Better understand business needs and link research effort more closely to business challenges.
– Participate in seminars with the business sector and technological centres in order to identify priority lines of research that would contribute to boosting innovative activity in companies and in the system as a whole.
– Promote excellence in all of their activities.

• Innovation centres could play an extremely important role in the process of finding employment for researchers in the production sector, particularly in SMEs.

• For the ecosystem to run smoothly, universities, PROs, and business should be brought closer together by:

– Forming research teams focused on projects that are defined by companies and funded by public and private resources. These would act as a driving force for smaller companies.
– Creating joint centres in which the public sector and business institutions participate.
– Supporting active business participation in science and business parks. The parks would thus become knowledge nodes, capable of attracting the best companies and research centres, and therefore focuses for disseminating innovation in the production sector, particularly in the case of SMEs and the public sector itself.
– Joining together universities, research centres, SMEs, and large (national and multinational) companies with major public and private clients to work on cutting-edge technological projects. Such projects would be led by companies. These kinds of actions could be complemented by government procurement policies that would help to support innovative areas and establish some bases for consolidating emerging areas.

• Bringing different agents together should result in some existing areas of knowledge being selected. It would also lead to a commitment by innovative companies and centres of research excellence to concentrate their funds and efforts. Public and private institutions would also give their support. Consequently, development would occur in areas that promote the ecosystem's growth. These actions could become a benchmark for the entire ecosystem.

## Government departments and society

The public sector could contribute to:

• Improving human resources in companies in order to boost their culture of innovation and technological capital in different ways. Firstly, procedures could be introduced into the education sector to help people to develop abilities that give them initiative and an enterprising spirit. Secondly, a business orientation should be promoted in research education. The production sector should be encouraged to recruit researchers, using financial aids and incentives that are attractive to both researchers and companies. Thirdly, the administrative barriers to mobility and to the exchange of researchers between public institutions, innovation centres ,and companies should be removed.

• Facilitating and encouraging the identification and promotion of innovation in sectors of priority interest to the Spanish economy. In turn, this would lead to:

– The active participation of exceptional companies active in these sectors.
– The collaboration of research centres that are recognised for their quality.
– The joint establishment and development of lines of research by centres and companies.
– The provision of aid by public institutions qualified to evaluate risk/benefits and dynamic, flexible management procedures.

• Improving the technological sophistication and existing training in the Spanish business sector, so that the use of scientific and technical knowledge truly becomes a medium through which innovation is created.

• Facilitating collaboration with large companies to co-finance projects.

• Promoting both spaces for the ecosystem's agents to meet and the development of technology-based business activities.

• Avoiding use of the subsidy system as a general standard. Instead, an the ecosystem different components should be encouraged to obtain loans on the basis of competitiveness criteria. The public sector could guarantee loans for innovation using guarantee funds.

• Fostering an enterprising spirit in companies, so that they lead and guide innovation processes, by looking for new ways to increase competitiveness and meet society's needs.

• Promoting a permanent forum where the different agents can exchange ideas, discuss problems, solutions, and share opportunities.

• Amending the policy of incentives and tax concessions to encourage innovation of products, services, and management models.

• Boosting standards for measuring the degree of innovation in companies. Economic and/or tax concessions should be allotted according to an organisation's position, as determined by a scale that measures fairly objectively the level of innovation.

• Eliminating the legal and non-legal barriers that hamper the smooth running of the ecosystem.

# Cases of collaboration and lessons learnt

Some initiatives and instances of collaboration between science and companies in Spain were analysed by this report's committee, as a way of understanding how the entire ecosystem works in practice. The aim was to identify good practices and key factors that promote value and that should be strengthened in the future.
Some of the reference cases were:

- The Parc Científic de Barcelona model
- The Joint Institute CSIC/Universidad Politécnica de Valencia
- The Universidad Politécnica de Cataluña
- IBERDUERO Research Projects
- The promotion of emerging technologies through the creation of collaborative networks, such as those established for the Fundación Genoma.

All of these cases represent different models of collaboration between the science and business sectors. Such models contribute to increasing the wealth and well-being of Spain, through the tangible results obtained and the learning process and knowledge developed in the experience. An analysis of these cases has resulted in a series of guidelines that serve as a reference for future actions that can improve the Spanish innovative system. The following guidelines are considered to be the most relevant:

• The leaders in the cases described consider innovation to be a strategic element in development. Their high level of scientific and technical education enables them to process existing information and to make optimal decisions for the smooth-running of their organisations.
*The presence of leaders with scientific and technical education within organisations is one of the key elements for improving collaboration between the different agents of the innovation ecosystem.*

• The aim of establishing links and groups among the ecosystem's different agents has been to make good use of research results and the system's existing knowledge, or to promote lines of research that are directly linked to companies' needs.
*The actions of those in charge of public and private institutions reveal the following strategic elements: they make good use of research results and existing knowledge, promote and strengthen lines of research that are directly linked to companies' needs.*

• All of the institutions in each of the above-cited cases have a clear operating model that has been stable over time and is flexible enough to adapt to the specific needs of the projects tackled.
*Collaborations should establish a clearly defined framework for action that is flexible and stable over time, and that ensures efficiency and efficacy.*

• The companies have known how to make good use of research, and how to encourage, guide, and even lead it. Seeking high practical applicability of research results is compatible with the agents being able to generate knowledge and to learn.
*The encouragement and leadership of companies has helped make applying research results compatible with the generation of knowledge and learning.*

• Sufficient technological capacity in terms of human resources and technological capital is needed to establish efficient communication channels. Such channels help tackle innovation processes. However, possessing technology is not enough on its own. Companies must also be able to use technology appropriately in order to transform it into useful solutions that add value to the processes it is applied to.
*The availability of technology in companies is not enough to identify the type of knowledge that should be converted into added value for the company. Researchers, technologists, and managers are also needed, to effectively evaluate technology, and to use and transform it in an innovative way.*

• Public and private incentives and funding instruments are fluid enough to be able to channel and set up different initiatives.
*Initiatives in which public researchers and companies collaborate should have an incentive system as well as a financial engineering plan that helps combine resources from the public and private sectors.*

• Flexible management and organisational strategies are developed that can be adapted to the special characteristics and changing needs of each situation.
*Management procedures have to be made more flexible so that they do not become a barrier to developing innovative activities from the outset.*

• The development of systems for measuring results has led to results-focused management and the continuous search for higher degrees of excellence.
*Results have to be monitored and evaluated using a comprehensive and balanced scorecard, made up of indicators that are suited to the characteristics of the projects. This will ensure excellence of results.*

• A positive environment, in which rewards and recognition are offered by each one of the agents involved, is an incentive that fosters the development of successful activities. In this respect, a culture of innovation should be developed and strengthened in the hearts of those companies and organisations that make up the ecosystem.
*The system of incentives for internal recognition, promotion, and professional development of staff working in companies and other organisations in the ecosystem should be well-designed. It should always be closely linked to creative and innovative capacity.*

• A meeting place where researchers, technologists, and companies can communicate with each other is essential. Such places have a crucial role in coordinating all key aspects of the development of innovative programmes.
*There should be places and forums where researchers and technologists from the public sector and business can develop a common language. These meeting places would ensure that groups interrelate, and would encourage them to collaborate in a constant and fluid way.*

# Proposal for action

One of Spain's clear challenges is to bring innovation within the country into line with that of other European countries. A constant, considerable effort, one that is sufficient to revitalise the present capacity of the innovation system, must be made to attain this goal. . All actions should take into account the entire ecosystem and their impact on its development. If not, they could risk being inefficient and may fail to attain the degree, depth, and speed of progress required. The Spanish innovative system is faced by an extremely important challenge. We therefore consider that measures should be implemented throughout the entire ecosystem. These would trigger a dynamic that would help the Spanish innovative system to become productive and highly successful.

> *We propose setting up a* ***Meeting Forum****. This would not interfere with other existing forums that have different specific aims. Its actions would be totally flexible, its conception plural, its organisation dynamic, and its administration inexpensive. We consider that the private system –made up of a group of innovative companies– now has the ability and the motivation to promote such an institution.*

The main objective of the Meeting Forum would be to develop a Spanish model of innovation. Specific innovation projects would be undertaken and used to analyse, document, and transmit guidelines for the different agents in the innovation ecosystem to follow. The model would be drawn up simultaneously. In addition, the Meeting Forum's activity in itself would significantly contribute to creating an enterprising generation (researchers with a market mentality and business people with an innovative mentality) that fully embraces the new model.

The specific design of the Spanish innovation model would be defined in the Meeting Forum. This operating model would help to: attract the best professionals, share existing resources and experiences, coordinate flexible work plans, establish mechanisms for collaboration between the different agents, and recommend the best incentive and funding schemes. It would develop dynamically and be based on the specific, successful experiences that are obtained.

An outline for the Meeting Forum's design is presented below:

Firstly, a group of companies should be established as leaders. These would act as the Meeting Forum's promoters and should include companies selected for their marked innovative nature and their possible influence on the ecosystem. This team of promoters would decide on the Meeting Forum's communication infrastructure, mechanisms for collaboration, and management structure.

Secondly, the team of promoters should use published studies and papers to analyse the different interrelations between the ecosystem's agents. They will select and incorporate other elements of demonstrated importance into the Meeting Forum. One such element could be the recruitment of researchers and technologists who have proven excellence and the most experience in collaborating in the chosen production sectors. Thirdly, when the Forum is operative, the following tasks should be undertaken:

*a)* Analyse the guidelines and specific characteristics needed by the ecosystem. These should enable the ecosystem to define which interrelations should be developed and encouraged in order to generate innovation.

*b)* Design a pilot project that will seek to analyse and then model the interrelations that occur. The objective of this would be to work out the details of the Spanish innovation model.

*c)* Monitor the pilot project to assess, and where necessary change, the guidelines established in a and the model's details worked out in b.

As guidelines for action become consolidated through the pilot project, in accordance with a new Spanish innovation model, the Meeting Forum could:

- Promote into the ecosystem the incorporation of other agents that support the newly established projects.

- Pursue the creation of a venture capital fund to finance these innovative projects. This fund should use business rather than subsidy criteria; that is, failed projects should not be bailed out by successful projects. Instead, each project should be treated as an independent management unit.

- Encourage the creation of equivalent organisations that use the same principles but act independently. This would ensure the maximum level of expansion, create a multiplier effect, and help to avoid unnecessary bureaucracy.

- Aim to establish a training process to impart in-depth knowledge regarding: research quality, exploiting results, and the intellectual property system. Advice, help, and support would be given throughout this process.

- Support a revision of the legal framework for insolvency, i.e. the legal consequences of failure. These consequences are a barrier to the development and promotion of innovative business projects.

The Meeting Forum will act as a promoter and an influential group, striving to attain social recognition for innovative work. It is neither a lobby nor is it hierarchical. As a result, one of its advantages is that its members will be people who are convinced of innovation's potential and the need to improve the existing situation.

# Conclusions

The Spanish innovation system is not working effectively enough to ensure the level of future development and generation of value needed in the current competitive environment. It lacks both the critical mass and the human, technological, and financial resources required to maximise optimisation and productivity throughout the system. In addition, its agents do not interact optimally. However, we believe that if appropriate action is taken (in terms of intensity and effectiveness) the opportunities for improvement and progress are considerable.

We also believe that the innovation system has to be interpreted dynamically, in terms of sustainable development. Therefore we use the term *innovation ecosystem* to refer to the necessity of developing an environment with the following characteristics:

- The ecosystem is made up of different agents that should be interconnected (like nodes) through communication and collaboration processes that enable resources and knowledge to be used efficiently.

- It should be provided with staff who are adequately trained in research and management.

- It should be supported by public and private financial resources. In particular, private financial corporations should assume a greater risk in exchange for the potential to achieve greater profitability and provide suitable tools for funding innovative initiatives available to companies (venture capital).

- Companies should lead the innovation process within the ecosystem, in collaboration with other agents. They should promote the modernisation of organisations and ensure that valuable knowledge is generated.

- Government departments should act as facilitators, helping to create conditions that allow the ecosystem to evolve and reducing the barriers to innovative activity.

- The interrelation between society and agents generates a certain dynamic. Like any complex feedback system, this can enter into cycle of productivity, competitiveness, and generation of social well-being, or deteriorate into a vicious circle that cannot sustain progress.

- A monitoring system should continuously assess the vitality of the ecosystem and enable it to be managed proactively.

To make the most effective use of existing resources, we consider that this ecosystem should first be developed in sectors that are defined by their potential and their characteristics as priority areas.

In order to advance as far as possible, and taking into account existing limitations, we propose undertaking a project that will specify how to redefine the Spanish innovation model in the short-term.

This project will include the creation of a forum for all of the ecosystem's agents, which would be led by the companies and research centres, and would:

– Define priority action areas and sectors.
– Establish all of the relations that need to be encouraged between the ecosystem's different agents and define the values that should be promoted.
– Promote the recruitment of the best researchers and managers.
– Coordinate all of the actions required to attain and share resources and experiences.
– Initiate a pilot project to test the proposed innovation model.

In conclusion, redefinition of the "Spanish innovation model" in the framework of the proposed Meeting Forum should be supported by two fundamental components:

• The leadership of companies within the *innovation ecosystem*. Companies will work closely with other agents, and will coordinate the mechanisms for developing and strengthening the entire model. They will seek ways to work and collaborate that are based on excellence.

• The elimination of legal, administrative, collaborative, communication, organisational, cultural, and financial barriers. This would enable the *innovation ecosystem* to function on its own.

Finally, we stress our firm belief that the Spanish innovation system's present situation is critical, and could jeopardise Spain's opportunities for future development. However, we are also convinced that if the proposed recommendations are applied immediately, there is sufficient time to turn the current situation around.

Confederación de Sociedades Científicas de España (COSCE)

# Acción CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Spain in Europe

# Summary

The countries of the European Union, which Spain joined in 1986, have created a system of collective institutions and mechanisms of action that make it impossible to consider the Spanish reality without putting it into a European context. One of the areas in which the dynamics of European integration is clear is that comprising research policies, technological development, and innovation.

The European Union has recently moved various aspects of research and technological development (R+TD) and innovation further up its action agenda. For example, the idea of a European Research Area is one of the priorities of the EU political agenda. This serves the *Lisbon Competitiveness Strategy and the Barcelona Objectives for Investment in R+D+I.* Research, technological development, and space are fundamental aspects of the EU's internal policies in the *Treaty Establishing a Constitution for Europe*. To this should be added the European Commission's proposal for the *Seventh Framework Programme for Research and Technological Development (2007–2013).*

Within the framework of the European Research Area, the EU member states recently unanimously declared themselves in favour of supporting basic research. The European Commission has given this course of action visibility, budgetary treatment, and specific management in its proposal to create a *European Research Council (ERC)* within the Seventh Framework Programme. The programme itself highlights the need to pay greater attention to high-quality basic research. Around 10% of the programme's total budget will be allocated to basic research, and managed independently.

In the European context, Spain should become a key player in R+D aspects of the integration process. This would help Spain's specific characteristics to be taken into account.

Moreover, Spain's national R+D policies should also be placed into this European context. They would then be strengthened, coordinated, and integrated, instead of moving in a different direction –as often occurs. The role of companies is also crucial, but they have serious shortfalls and therefore require the most attention.

## Proposals

### *General proposals*

- Spain is no longer one of the member states with the lowest per capita salaries. As a result, the level of competitiveness needed to successfully face challenges arising in the international market should be based mainly on its capacity to *create, adapt, and apply knowledge*. Consequently, other essential factors are: a good education, excellent scientific research, innovative technological development, an enterprising industrial sector, and investment capital that is used more than revenue.

• The implementation of the Bologna process in universities will be of fundamental importance to European integration. Spain should make good use of this opportunity to readapt university structures so that they can contribute appropriately to increasing R+D development.

• Spain should endeavour to become a key player in the development of the European integration process in the R+D field. To achieve this, it should develop an active European R+D strategy. In addition, national and regional R+D policies should be put into a European context, so that they can be strengthened, coordinated, and integrated.

• The main European arena for *transnational research* has been defined by the Seventh Framework Programme. Therefore, funding agencies, Spain's research organisations, and officials and agencies responsible for scientific and technological policy need to immediately adopt measures that enable active and effective *participation in the formal decision-making processes* of *European institutions* in a way that makes use of the country's expert knowledge. Measures should also give *organisational, technical, and financial support to those research groups and innovative companies* that could participate in future European Union R+D initiatives.

• A legislative, organisational, and normative framework is needed to successfully develop a policy regarding international, cooperative scientific research, technological development, and industrial innovation. This framework would help the system's administration to become specialised, dynamic, flexible, and independent, and ensure that actions are coordinated.

## Specific proposals

• A 25% increase in the average annual real investment in scientific research and civil technological development in Spain (see Chaps. 1-7) is needed over the next 4 years, if the country's R+D+I commitment is to converge with that of other European countries and approach the Barcelona objective of 3% of GDP. The proposal to double the Framework Programme's budget is an excellent opportunity for Spanish science and technology. To make effective use of it, Spanish budgets should be increased simultaneously and their management structure reformed.

• The best way to attain sufficient quality and quantity of human resources, and to counteract the negative effects of mobility, is to increase funding and researchers' social prestige. This can be achieved by raising public awareness of a career in research and improving working conditions for researchers. Spain should support the *European Charter for Researchers* and the *Code of Conduct for the recruitment of researchers*. The latter document presents a series of recommendations, including:

– Recognise the research profession at the postgraduate level.
– Establish a clear framework for the professional and personal career of scientific researchers and technologists.
– Favour the mobility of research staff' between universities and research organisations.

– Provide lifelong learning opportunities for researchers.
– Establish stable and transparent methods– in the public service or not– for recruiting trained researchers into the system, according to their merits and abilities.
– Develop training programmes for techniques that support research.

• Adopt measures, along the lines of a Commission initiative, aimed at creating a *virtual community*. This would aid in the development of mutually beneficial initiatives for transnational scientific cooperation between the community's different groups and organisations. At the same time it would keep the knowledge assets and scientific reference resources of excellent Spanish researchers, in Spain and abroad, active.

• Optimise use of large-scale research infrastructures in which Spain participates by strengthening related thematic areas.

• Business competitiveness has to be increased to strengthen Spain's role in an emerging Europe and to further its population's social well-being. The following elements, among others, are needed to achieve this. Each is complementary to transnational collaborative research:

– Design an incentive system to increase the participation in European programmes of large companies that have technological capacity and connections with SMEs.
– Promote the creation of science and technology parks and participation in scientific *euro-regions* (geographic groups).
– Introduce a policy for research infrastructures that is consistent with the following economies of scale: international, European, and that of the member states.
– Establish effective and complementary European and national programmes to support SMEs.
– Create synergies with other European initiatives, such as EUREKA, COST, European Science Foundation (ESF), and other science federations and associations (EIROFORUM, FEBS, EACS, etc.).

• The EU has established a fund of 2bn per year to support basic research in all disciplines. This provides an opportunity to reduce brain drain and increase the competitiveness of a knowledge-based economy. Spain should make maximum use of this fund.

• The instruments for participation proposed in the Seventh Framework Programme are not excessively different than existing ones. However, they do aim to strengthen the major scientific networks and industrial technology platforms. Small research groups and a limited number of Spanish innovative companies will participate in this seventh programme, taking on a more significant role of scientific, technical, and organisational leadership than in the current programme. These groups and companies should be provided with appropriate administrative, legal, and financial support.

• *Technology platforms* are set up under the leadership of industry. Their aim is: to define the medium and long-term research agendas of industry, increase investment in industrial R+D, and gear the activity of publicly funded applied-research towards business priorities. Spain should be represented on all the technology platforms, with authority and decision-making capacity. It should be able to lead some of the platforms (or some work areas) and make use of the definition process to launch national technology platforms that have appropriate funding and the participation of the public and private systems.

• Management instruments are needed to initiate actions for strengthening regional presence (in the Seventh Framework Programme proposal this is known as *regions of knowledge*).

• A *system for assessing and monitoring science* should be set up to analyse the presence of Spanish universities, research groups, and companies in European R+D programmes and actions, and to assess the results obtained and their impact on the Spanish system.

• Support the creation of scientific and technological reference and/or advisory bodies that would give Spain a more active and effective presence in the international field, particularly in Europe.

• The government's ministries, regional governments, and research funding agencies should be coordinated to improve the integration of R+D efforts. This would improve the European presence of Spanish research groups and companies and help obtain results. Such coordination is even more important in the case of technological innovation, as EU structural funds are used and the regional governments have increased their jurisdiction in this area.

• Supporting action is needed to help promote the participation of Spanish groups in international programmes, particularly in the EU's Framework Programme. This action would be aimed at training researchers in aspects of project management. It would also make some management units available to universities and research organisations, to provide them with the services they need. Other, complementary actions would be:

– Encourage the preparation of proposals by providing direct aid to groups or management units (if such units are created).
– Award additional aid to approved projects to cover expenses related to: protecting and exploiting results, OEPM (the Spanish Patent and Trademark Office) state of the art searches, costs of registering patents in Spain when they are not covered by the Framework Programme, actions fostering the creation of industrial prototypes with the collaboration of a Spanish company, drawing up business plans to create technology-based companies, etc.
– Encourage the approval of new mechanisms and procedures in the EU for administering and managing resources allocated to promoting research in all disciplines. These would avoid the excessively bureaucratic systems that are currently in use.

# Introduction

During the last 15 years, an extremely significant, rapid process of political, economic, and social changes has taken place in Europe. The old Soviet Union disappeared and the majority of its members have joined the Atlantic Alliance and the European Union. The single market and single currency were established successfully and economic migration has occurred. In the last 5 years alone, the number of immigrants has risen to over 5% of the Spanish population.

At the same time, large industrial and financial groups have formed, such as: Daimler Benz-Chrysler, BMW-Rolls Royce, Sandoz-Ciba Geigy-Aventis, Rohne-Poulenc-Hoetcht, or the banks Bilbao-Vizcaya-Argentaria (BBVA) and Santander-Central-Hispano (BSCH). In addition, ambitious projects involving scientific and technological coordination, have been initiated, for example: the Large Hadron Collider, human genome sequencing, ALMA, ITER, Ariane V, the European module of the international space station, EADS, and Galileo. Finally, the treaty establishing a Constitution for Europe has been adopted, and the ratification process has started in the member states. Research, technological development, and space form part of the EU's internal policies in the Constitution.[1]

These examples show that it is essential to encourage the convergence of resources and activities from different sources to attain common objectives. The great importance of such objectives goes beyond the available resources of one political or institutional body alone. In this respect, the EU has recently moved various aspects of research and technological development (R+TD) and innovation further up its action agenda. For example, the idea of a European Research Area places science, technology, and innovation at the top of the political agenda of the EU's member countries. [2]

To this should be added the European Commission's proposal for the *Seventh Framework Programme for Research and Technological Development (2007–2013).*[3] In the next decade, this will influence programme contents, priority lines of research, and modes of action for research initiatives in member countries, scientific and technological institutions, and business. The Programme's budget is doubled in this proposal; its period of validity is extended to 7 years; and some management changes are introduced. Moreover, the proposal strengthens several *support actions for: excellent research, training and mobility of researchers, research infrastructures, and company research.*

In the past, the Spanish government considered the Framework Programme to be a supplementary mechanism for funding national R+D, in which the indicator par excellence was "financial returns". This view of European research policy traditionally relegated Spain to a secondary role in shaping and designing the Programme. In contrast, Spain has played a more decisive role on a European scale in other policies, such as those for cohesion or structural funds. Despite Spain's involvement in the Framework Programme and other multilateral cooperation mechanisms, the inherent internationalisation and europeanisation of R+D has not been a significant factor in Spanish R+D policy. It has not guided either national policy or policy in the majority of the regional governments . In general, project funding, training, and human resources policies have lacked even the slightest perspective of internationalisation and European integration.

Therefore, it is time for Spain to become a key player in the R+D aspects of the European integration process. This would help Spain's specific characteristics to be recognised. Spain's national R+D policies should also be put into this European context– allowing them to be strengthened, coordinated, and integrated, instead of moving in a different direction, as has often occurred.

Spain needs to participate more actively in designing the EU's scientific and technological policies –and those of other R+D organisations and institutions. This participation should be on a par with the involvement of numerous Spanish research groups and companies in over 30% of the R+D projects approved by the V Framework Programme. As a result of this involvement, networks of multilateral and bilateral scientific and technological relations have been formed that have strengthened domestic efforts.

Investment in research and technological development in advanced countries in no longer merely a superficial part of the budget. However, the EU's Sixth Framework Programme[4] allocates almost €5000 million per year to R+TD. This represents only 6% of the member states' total investment in these policies. Both the authorities and the broader society are demanding –with increasing determination and urgency– to know exactly how these investments contribute to resolving economic, social, and labour-related problems.

Science and technology constantly influence the daily life of the population; hence, citizens should be informed about research advances.[5] In this respect, the Treaty on European Union calls for wide consultation on all areas of the Union's activity, in a clear, constant dialogue that is open to civil associations.[6]

## Knowledge

Scientific research, technological development, industrial innovation, academic education, and professional training lead to the development of new ways of thinking, working, and living. These factors also determine the population's capacity for social participation.

Knowledge is the basis of the actions that constitute most of the new markets and public policies in strategic sectors, such as health, telecommunications, transport, the environment, and natural and technological disaster impact reduction.

Now that Spain is no longer one of the European countries with the lowest salaries, and given its lack of natural resources, the basis of its competitiveness lies mainly in its ability to create, adapt, and apply new knowledge. Therefore it also stems from a quality education, excellent scientific research, innovative technological development, an enterprising industrial sector, and capital that is geared to investment rather than to obtaining short-term profits. Efforts must thus be made to: bring national R+D+I investment closer to the Lisbon target,[7] improve the effectiveness of public spending, establish more and better incentives of business innovation. In addition, the number of young researchers and the quality of their training must be increased, while improving their motivation and permanent recruitment into the R+D+I system, particularly in the private sector.

In this respect, the investiture speech of the Spanish President of the Government, held on 15 April 2004, was encouraging. He committed the government to centring its activity on improving economic development supported by education, research, and innovation. This is one of the government's five main focuses of action. To attain this objective, the President announced a 25% increase in the annul budget for these items, which "signifies, definitively, putting science at the centre of our priorities". In the Chamber of Deputies, on 6 April, 2005, the President reiterated that there would be an "immediate increase" of R+D in Spain and Europe.

However, to achieve these objectives, there must be an immediate increase in efforts aimed at adapting the organisational structure, size, production capacity, and application of research results, technological development, and innovation to Spain's economic, social, and cultural reality.

Scientific research and technological development are essential to improving the living and working conditions of the population, contributing to their social and economic well-being, and increasing business competitiveness. To achieve this, the following aspects need to be promoted:

- High-quality research at all levels. The Bologna process could become a blueprint for making necessary changes in higher education so that it becomes more competitive.
- Excellent basic research and a high level of creativity.
- An attractive work environment and promising career prospects for the best researchers.
- A policy for research infrastructures that is consistent with the different economies of scale: international, European, national, and regional.
- Effective and complementary European and national programmes to support innovative SMEs; synergies with other European initiatives, such as EUREKA, COST, the European Science Foundation (ESF), and with other science federations and associations (EIROFORUM, FEBS, etc.).

## Cooperation

In recent decades, stable links between different organisations –the basis for building relational social capital– have been considered to form a fundamental source of strategic and operational enrichment for the parties involved. This has led to the recognition that technological and other knowledge is generated by a process of sharing. Self-sufficiency has been shown to be an inefficient strategy of action in the present globalised and extremely dynamic environment.

While this principle is applicable to all organisations, it acquires fundamental value as a guiding strategic principle in organisations associated with knowledge generation and transfer. The idea is not just to generate and transfer knowledge to another institute. Instead, organisations must be able to share information, supporting each participant's specialisation to improve the overall efficacy and efficiency of their actions.

In this context, international cooperation in research and technological development is closely related to the wider trend of internationalisation of the science and technology systems of developed countries. Both public and private institutions understand the importance of a global strategy, and this has profoundly changed the conduct of all involved (see the box: "Types of international cooperation"). A global strategy both predates and has been accelerated by globalisation.

### Types of international cooperation

The problems arising in today's' advanced societies are highly complex and of enormous importance. Similarly, undertaking scientific and technological projects requires: major economic resources, significant scientific facilities and infrastructure, combined knowledge with a high level of excellence in a wide variety of disciplines, and a dynamic, flexible, and efficient management and organisational capacity.
International cooperation is required in many cases; however, regardless of its level of development, a country cannot undertake such projects alone. The following are some examples of cooperation:

a) Large scientific projects and technological infrastructures that mainly serve what is known as "big science": ITER, CERN, Institut Laue-Langevin, ESRF, the ESO's ALMA project, X-FEL (free-electron lasers), and the European Southern Observatory.

b) Alliances between large industrial corporations– some with public participation– such as: EADS, ESA, and Galileo.

c) The chemical and pharmaceutical industries, such as ZENECA, AVENTIS, BAYER, and NOVARTIS, have undertaken cooperation in basic physical chemistry and biotechnology: . Such collaboration could take place in the near future also in the field of information and communication technology, when silicon is replaced by nano or bio-system technology.

d) Extensive networks of SMEs and networks connecting these with large companies and research organisations to generate shared knowledge.

e) The integration of economic and intellectual resources in interdisciplinary and emerging areas: nanoscience and nanotechnology, genomics, among others.

f) International collaboration between multidisciplinary research groups to advance knowledge and find solutions for problems that have a social impact: climate change, biodiversity conservation, bovine spongiform encephalopathy (BSE), genetically modified food (GMO), antenna radiation, etc.

g) *Programa Iberoamericano de Ciencia y Tecnología para el Desarrollo,* CYTED (the Ibero-American programme for the development of science and technology).

In the Spanish public system, the number of papers by Spanish researchers that were published in international journals or at conferences has increased. Specifically, international collaborations rose from 29.57% in 1988 to 33.68% in 2002.[8]

A brief analysis reveals that co-authorship rates (by scientific field) have increased significantly in recent years. Although patterns vary in the different specialities, this is a general trend.

From another perspective, a study of trends in different types of collaboration highlights the various scientific communication norms used by researchers. A high proportion of papers in the Spanish science system are still produced with no collaboration whatsoever. Collaboration would be particularly useful in the less-developed regional governments, where it could be supported by those communities with more significant development and more consolidated systems.

In terms of the *private system,* many Spanish companies have globalised their marketing networks and/or the supply of components for their products or processes. They have done this by reaching agreements with companies located in other countries and by extending their own network of offices. However, there has been considerably less participation in international networks for knowledge generation. Obviously, globalisation has affected multinational companies based in Spain, but SMEs have been affected to a much lesser extent.

From a historical perspective, public and private participation in existing European R+D programmes –those of the EU (R+D Framework Programme) and other organisations (such as ESA)– has helped catalyse international cooperation. This could be considered to be very positive for the Spanish research and technology system. In addition, some of these programmes require the joint participation of public and private institutions (the concept of a "consortium" is commonly used). This has fostered an increase in mutual R+D knowledge and better cooperation between these institutions.

Paradoxically, existing national policy instruments have not facilitated this process. The problems encountered in setting up mechanisms like the ERA-NET scheme, which was accepted and promoted by the Spanish government, demonstrate the practical difficulties. It is also very difficult to fund international industrial programmes, such as EUREKA, through national programmes (like PROFT) when there is collaboration with public institutions. This situation is seriously aggravated by inadequate distribution of the research and technological development budget between the Ministry of Education and Science and the Ministry of Industry, Trade, and Tourism.

The objective of creating a true European Research Area is still far from being fulfilled. However, it is essential to contribute fully to this goal by eliminating barriers to mobility, so that projects can be carried out with funding flows that cross borders. This would facilitate the recruitment of researchers from other countries into Spain. Germany and the United Kingdom have agreed on a specific, bilateral implementation of the "money follows people" principle for projects that are already funded in their respective countries. If Spain does not follow suit, it will lose a historic opportunity and run the risk that others will do the same, leaving the ERA highly fragmented.

Even so, the Spanish science and technology system is gradually losing the strong self-sufficient character it has maintained for too many decades. It is becoming involved in the process of opening-up, promoting cooperation with other countries, and embarking on a path of growth through knowledge. However, there is still some inflexibility in R+D administration and management that hinders internationalisation and cooperation with other countries, both of which are essential to maintaining Spain on a path of steady growth. In this respect, and notwithstanding the differences, examples provided by the EU member countries Ireland and Finland should be considered.

Likewise, by virtue of the Spanish process of political decentralisation, mechanisms also need to be established that will ensure the required degree of coordination between regional, national, and international R+D+I plans.

An international dimension has become indispensable to scientific, technological, and industrial development. At the same time, another fundamental factor for growth involves interactions between innovative companies, universities, research laboratories, and local and regional development agencies in close *geographic proximity*. These have become known as "regional innovation clusters". Regional approaches to R+D are responsible for: determining the region's capacities for research; maintaining and generating scientific, technological, and specialised infrastructures; strengthening links with industrial development areas, science and technology parks;

supporting groups and centres of excellence; and promoting training and mobility of researchers.[9]

Regional R+D and industrial innovation policies are more efficient when they are formulated and developed in coordination with interregional, state, and international policies, i.e. when the maxim *think globally, act locally* applies.

This leads to the successful coordination of R+D programmes through cooperation, occurring in the framework of federal-type planning. It also brings about the identification of "variable geometry" actions, the opening up of regional programmes, and the participation of organisations and institutions from other regions, in a search for the scientific excellence needed to resolve problems arising in each region.

Salvador Barberá's article, "El futuro del sistema nacional de ciencia y tecnología" (The future of the national science and technology system), published in *Boletín SEBBM* (2004; 142: 5-12), gave an excellent update on such important topics as: human resources, infrastructures, project funding, and funding agencies. It also discussed the relation between the state, the regional governments, and the scientific community.

The international dimension of actions in science and technology is closely linked to the programmes, priorities, ways of participating, and funding instruments for initiatives developed within the framework of national R+D+I policy. Therefore, the greater the consistency between the Spanish and international frameworks of action, the more effective the development of synergies and the integration of Spanish R+D with that of its European partners.

Individual regions tend to play increasingly important roles in research and innovation activity. They benefit from European and national resources that enable them to set up a series of alternatives and plans for interregional cooperation and to form different types of networks.

# Scientific cooperation in the European Union

In a meeting on 24 November 2004, the EU's Competitiveness Council (Internal Market, Industry, and Research), with the support of the Spanish delegation, recognised the key role of national actions in achieving the Lisbon objectives. It also stressed the importance of member states' commitment to advance and carry out this process in the best way possible, with a view to attaining the Barcelona objective of raising internal investment in R+D to 3% of GDP by 2010. Two-thirds of this investment is to come from the private sector.

Five years on from the Lisbon strategy, European institutions confirmed that the entire Union, and its member states individually, have encountered difficulties in putting this strategy into practice. There have been changes in policy and in the economies of the member countries. These measures call for some changes in direction, such as creating a European institute of technology, and developing guidelines for state aid to stimulate companies, innovation, and research.[10] The main EU instrument for building a European Research Area (ERA) is the Framework Programme. Related actions involve setting in motion mechanisms to progressively open up national programmes, and processes of mutual learning associated with the "open method of coordination" (OMC). Member states are responsible for the OMC, although its impact is still very limited. In this respect, it should be taken into account that the Framework Programme accounts for only 5% of the total resources used in the different states.

An examination of the Spanish response to the ambitious Barcelona objective reveals a stark reality. Modest Spanish domestic spending on R+D has increased slightly, from 0.98% of GDP in 2001 to 1.1% in 2003. In parallel, Spain's ability to contribute to the EU budget –which funds the Framework Programmes for scientific research and technological development– has been increasing, as shown in Tables 1 and 2. This leads to the paradoxical situation that Spain is a net beneficiary of the EC budgets, but a contributor to the proportional part of the funds destined for R+D policies. That is, whilst the Spanish contribution to the EU budgets between 1999 and 2002 (a period coinciding with the duration of the Fifth Framework Programme) reached an average of 7.9%, funds returned for scientific research and technological development activities were less than 6.2%.

Of course, the Spanish balance of payments with the EU is positive, due to returns from agricultural, structural, and cohesion policies, among other factors. However, this argument should not satisfy Spain, given the greater ability of R+D to revitalise and strengthen culture, education, quality of life, working conditions, the economy, and industry. Moreover, as mentioned above, this situation will change rapidly with the entry of new

**Table 1.** Spanish contribution to the European Union's international budgets

| | Execution 1999 | | Execution 2000 | | Execution 2001 | | Execution 2002 | |
|---|---|---|---|---|---|---|---|---|
| | Amount | % | Amount | % | Amount | % | Amount | % |
| Germany | 21,069.0 | 25.5 | 21,774.9 | 24.8 | 19,727.2 | 24.4 | 17,582.2 | 22.6 |
| Spain | 6,231.3 | 7.6 | 6,445.4 | 7.3 | 6,591.5 | 8.2 | 6,551.2 | 8.4 |
| France | 13,993.8 | 17.0 | 14,510.9 | 16.5 | 14,471.3 | 17.9 | 14,152.3 | 18.2 |
| Italy | 10,765.8 | 13.0 | 10,999.9 | 12.5 | 11,612.5 | 14.4 | 11,279.5 | 14.5 |
| United Kingdom | 11,081.5 | 13.4 | 13,857.0 | 15.8 | 7,743.4 | 9.6 | 10,152.8 | 13.1 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... |
| TOTAL | 82,530.8 | 100.0 | 87,959.1 | 100.0 | 80,718.1 | 100.0 | 77,698.0 | 100.0 |

**Table 2.** Spanish contribution to multilateral European programmes 2002*

| | Percentage of participation | Contribution m Euros |
|---|---|---|
| European Space Agency (ESA) | 4.9 | 117.2 |
| European Organisation for Nuclear Research (CERN) | 6.9 | 45.7 |
| European Molecular Biology Laboratory (EMBL) | 6.7 | 4.0 |
| Institut M. V. Laue-Paul Langevin (ILL) | 3.0 | 2.6 |
| European Synchrotron Radiation Facility (ESRF) | 4.0 | 2.5 |
| European Molecular Biology Conference (EMBC) | 6.5 | 0.7 |
| Gran-Sasso neutrino experiment (CERN) | - | 0.7 |
| European Science Foundation (ESF) | 6.1 | 0.4 |
| TOTAL | | 173.8 |

*Source MCYT*: I+D+I activities report 2002. Different Spanish companies participate in industrial and technological developments in fields such as: civil engineering, structures, instrumentation, antennae, electronics, software, etc.

* One of the key aspects for European research policy for the period 2007-2013 will be the significant increase in funds allocated to European Union R+D, as recommended by the European Commission - from a total of €17,500m in the Sixth Framework Programme to €10,000m annually. This proposal is quite far removed from what the major countries seem willing to support.

member states and future financial redistributions.[11]

This has become increasingly obvious as the objectives and the structure of the Framework Programmes have become oriented towards concentrating available resources on a few lines of industrial research. In some cases, a policy of subsidising specific industrial sectors has emerged (e.g. aeronautics, information technology, and bio-health).

The Framework Programmes have not been directed towards stimulating the development of a European production sector, which would comprise 98% of SMEs –that is, the enterprises that are the largest generators of employment, particularly in Spain. Likewise, the public system's participation is heavily concentrated on a small number of institutions and regional governments.

Generally, the role of Spanish groups/companies is to act as suppliers of knowledge. They have limited capacity to access most of the knowledge generated in the consortium, and even less ability to transform it into useful innovations.

Nevertheless, the Spanish research and productive system has obtained many benefits since1986, when it began participation in the EU Framework Programmes for Research and Development. Significant funds have been received –amounting to almost 10% of the total investment in national programmes during the same period– and a culture of international collaboration has been generated. In addition, Spain has been able to become involved in projects that are much more scientifically and technologically ambitious than projects that could be undertaken domestically. It has had access to the results and highly significant industrial uses of such projects, and has learned to better organise and manage its research and innovation.

Spanish participation in European R+D programmes does not end with the Framework Programmes. In fact, there are other arenas for scientific and technological collaboration, established by international agreements with some EU member states and other countries.

Of these, the following should be mentioned: EUREKA (a framework for the pre-commercial technological development of projects on any subject); COST (a framework for coordinating research actions, guided by "à la carte" participation objectives); the European Space Agency (ESA), which offers a dual programme of "obligatory" activities (mainly the scientific research programme) and "à la carte" activities in the areas of space transport and applications (Galileo); CERN (organisation for European cooperation in particle physics); the European Science Foundation (ESF) which brings together 65 organisations from 22 countries and manages programmes (mainly through coordination) and networks in a wide range of areas; the European Southern Observatory; the EADS Group; the European Molecular Biology Laboratory (EMBL); etc.

In their respective fields, the creation of these institutions represents a fundamental initiative in terms of European scientific and technological cooperation, training, mobility and exchange of researchers, dissemination of research results, and the provision of scientific advice for society.

Before these intergovernmental cooperation initiatives were established, R+D was considered to be a national activity, with the borders between the different national systems being relatively impermeable. Research involving trans-European cooperation was seldom, for researchers and for companies. In fact, European countries cooperated more actively with the United States than with each other. While this may still be the case, this tendency is slowly changing.

Spain's participation in European Union R+D programmes and programmes resulting from intergovernmental agreements can no longer be brought about only by research groups and companies acting on their own. There should be an institutional strategy, supported by governments (both regional and national), to ensure a framework of action. This strategy should also commit the national resources needed to make better use of international participation efforts. Interaction between the different regional, national, and EU levels is particularly important in the areas of infrastructure and human resources.

Regardless of the state of the international environment producing the most significant scientific and technological advances, Spain needs to:

– Participate in international R+D forums and programmes.
– Increase its active participation in international decision-making bodies.
– Participate in major global industrial technology projects.
– Foster international cooperation with competitors, suppliers, and clients, as this is a source of technological innovation.

In addition, given the limited resources, the policy of international scientific and technological cooperation should have a selective focus. Priority should be given to actions in a limited number of thematic and geographic areas.

Political and objective details of the European Commission's proposal for the Framework Programme of 2007–2013[3] are defined in the communication "Building the ERA of knowledge for growth".[12,13] In this proposal, the programme's budget is doubled and its period of validity extended to 7 years. In addition, support actions for excellent research, training and mobility of researchers, research infrastructures, and company research are strengthened. These specific aspects will be dealt with later.

## Basic research

During the last 4 years, there have been European discussions on the challenges facing basic research, and the most appropriate ways to meet them within the framework of the ERA.[14,15] The EU member states have unanimously declared themselves in favour of supporting basic research, and the European Commission has given it greater visibility, budgetary consideration, and specific management in its proposal for the Seventh Framework Programme. This programme highlights the need to pay greater attention to high-quality basic research. Around 10% of the programme's total budget will be allocated this area and managed independently by the European Research Council (ERC).

According to the report on the creation of the ERC, a fund of an estimated two billion euros per year should be established within the Framework Programme to support all aspects of knowledge. This fund would be managed by the ERC, which would be autonomous, rigorous, transparent, and have administrative flexibility. It would use already-existing European scientific institutions of recognised quality.

The creation of the ERC was approved by the European Commission on 23 March 2005, in Brussels, in a meeting of heads of state and government. The ERC Identification Committee presented an interim report on 21 March 2005 that began: "Support of frontier research will form an important component of the Commission's forthcoming proposal for the Seventh Research Framework Programme". A ERC, with an executive council made up of scientists, will provide a distinctive and independent mechanism for putting this "frontier" scientific research programme into practice. The Identification Committee will assess candidates in May 2005 and present a final report in June 2005. The Committee has also presented suggestions on "working methods" for the ERC's executive council or administration. These cannot be defined precisely until the European Parliament, the Council of Ministers, and the Commission make the appropriate legislative decisions.

In the beginning of April 2005, the European Commission made its financial proposal for the period 2007–2013. The amount allocated to research was 67.8 billion ( 11.3 billion per year), which represents an increase of 6.6% of the total relative to the last Framework Programme (2000–2006). On 25 March, the president of the European Commission, José Manuel

Durao Barroso, published an article in which he gave the reasons why education, research and innovation are the keys to increasing productivity in the EU. The percentage of GDP allocated to R+D in Europe is 1.96% compared to 3.12% in Japan, and 400,000 Europeans who have studied science and technology currently live in the United States. Three quarters of students born in the EU who do their doctoral or postdoctoral studies in the US prefer to stay there after finishing their studies.

The *EIROforum* is made up of the seven European intergovernmental research organisations with the most modern infrastructures (CERN, EMBL, EFDA, ESA, ESO, ESRF, ILL). In a recent publication (*EIROforum report*, 2004), it identified cooperation prospects as Europe's best way to achieve the Lisbon objectives. The value of the Marie-Curie grant programme was stressed, as was the potentially enormous importance of establishing a European Fund for Research Excellence. The ERC should manage this fund with independence and flexibility in order to bring about competitive research on a global scale.

Basic research is a field of action of general interest, in which government investments yield high social, economic, and cultural returns. Support for basic research is justified, given that:

*a)* It has a high impact on business competitiveness, economic growth, and social well-being.

*b)* Its cost and complexity are growing due to the multidisciplinarity of its activities, and the private sector cannot be expected to assume this expense.

*c)* It guarantees that results become public property.

*d)* It helps to advance knowledge about the causes of certain illnesses (e.g. cancer, cardiovascular and cerebrovascular diseases, neurodegenerative conditions, AIDS, and multiple sclerosis), and seek solutions for specific problems.

*e)* Without it there are no high-quality teachers, without such teachers there is no high-quality education, and without education there are no high-quality teams of professionals or managers.

*f)* It helps to ensure sufficient empowerment, so that the most recent and complete information on the latest advances can be accessed and assimilated. Moreover, as a result, it brings about participation, however modest, in the consortiums that generate these advances.

*g)* If scientific culture is lost, people become both distanced from the places where decisions are made and less independent.

However, as the economic needs of basic research groups increase, those in charge of the res publica have instead chosen to reduce budget items funding actions in areas that can best withstand the pressure of different social influences. One of these areas is investment in intangible assets, such as basic research, as the results are uncertain, and quantifiable effects are most often achieved only in the long-term, beyond the duration of an electoral mandate.[16]

Spain's spending on basic research in relation to GDP is one of the lowest of OECD member countries (it is only above that of Mexico and Slovakia). It has remained at 0.15% of GDP in recent years, while the OECD average reached 0.34% in 2001. However, scientific production and research potential indicators are positive, despite the drop in the rate of productivity and the almost 30% increase in the cost per publication. In general, it could be said that productivity per

Spanish researcher is dropping because the number of researchers is increasing faster than the number of papers published. In addition, the average number of Spanish authors per paper has risen. However, the indicator of researchers per 1000 inhabitants is not as far from the European average as that of the expenditure per researcher. Thus, *"there is a need to create a more attractive basic research environment, supported by high quality education, appropriate research funding, research infrastructure, and science-innovation links, where excellent researchers are recognised and can excel, thereby strengthening Europe's performance in basic research."* (Conclusions from the Irish Presidency's Symposium: "Europe's Search for Excellence in Basic Research", Dublin, February 2004).

## Mobility

The Acción CRECE paper *Human Resources in Research* provides an in-depth analysis of specific aspects of human resources. However, in this section, some brief comments will be made about the researchers' roles as a fundamental (and indispensable) resource for knowledge transfer in any activity related to scientific and technological cooperation, and their effectiveness in training young researchers.

The mobility of researchers between different scientific disciplines, research groups, and national borders is one of the most important factors in successfully developing a research policy for the EU, as has been observed over time. The resolutions and communications of European institutions have spelled out different initiatives in this field.[17] In practical terms, there has also been a steady increase in the economic resources allocated to mobility by the six Framework Programmes[18] implemented since 1985 (Single European Act).

One of the main objectives of the European Commission's proposal for the Seventh Framework Programme is to develop and strengthen human resources in research with respect to training, mobility, and development of research careers.

Publication of the Commission's recommendation concerning the European Charter for Researchers and the Code of Conduct for the recruitment of researchers represents an important step in this direction.[19] The objective of both the Charter and the Code of Conduct is to contribute to the development of a European labour market for researchers that is attractive, open, and sustainable. The market's conditions should favour high-level performance and productivity. These are Commission recommendations to the member states, who are invited to apply them voluntarily. The recommendations will be revised periodically, using the open method of coordination.

There is an urgent need for training and recruiting young researchers into the European R+D+I system. Specifically, 1.2 million research staff are needed to fulfil the Barcelona objective by the year 2010; of these, 70,000 should be researchers.[20] Additional staff would be needed to replace researchers who have reached retirement age and leave the system. Concurrently, there has been an overall population decrease and a drop in the number of students in scientific and technical disciplines essential to effectively developing business innovation.

In turn, the Bologna process presents an excellent opportunity for reforming the university system. The creation of the ERC is deemed necessary to strengthen the research mission of universities. Training and a research career are important for

European education and research. Therefore, the aim is to create more synergies between these two components, by promoting improvements in the organisation and structure of European doctoral programmes.[21] Joint programmes between European universities and the recognition of a European Doctorate are also essential.

As a result of these circumstances, initiatives need to be launched to attract excellent researchers to Europe. At the same time, changes need to be introduced to adapt the current legislative and institutional framework (entry and promotion conditions, economic and labour regime, immigration, etc.) to the new situation. Supportive services should be made available for visiting researchers, staff, and their families.

As stated in other sections of this report, knowledge-based societies are dependent on their capacity to produce, use, and transfer knowledge. These activities require the mobility of all kinds of resources and of researchers themselves within an international research framework. Likewise, the mobility of researchers between complementary disciplines and institutions (universities or research laboratories, companies, and vice versa) not only fosters knowledge transfer, but also gives impetus to cooperation among research groups, and between these groups and industry.

The scientific community is well aware of the importance of mobility, as its mobility rate is approximately 5% compared to the active population, whereas it is 2% for other professional groups. Nevertheless, this rate is not high enough to cover current scientific research and business innovation needs.

International mobility is a fundamental factor in staff promotion, although its relative importance varies greatly depending on the area. Moreover, this mobility is strongly asymmetrical. The outward flow to other countries (towards the US more than Europe) reflects the Spanish public system's lack of appeal to researchers from abroad. This is reinforced by a lack of adequate instruments and a certain inscrutability with respect to selection processes and job stability.

In the business sector, the importance and degree of international mobility of R+D staff is less than in the public sector– if we discount mobility in multinational companies that have internal staff-rotation programmes linked to promotion. The spread of other R+D centres to Spain or competition from other companies with their own staff is limited, and does not change the general opinion given here.

Spain currently has 83,000 researchers (EDP) (4.5 per 1000 of the active population, compared to a European Union average of 5.7) according to the OECD and EUROSTAT. It needs to make even greater efforts in this area. The former Ministry of Science and Technology contributed by launching the Ramón y Cajal programme in 2001. This programme's objective is to recruit 3000 young, high-level researchers (of any nationality) into Spanish public research organisations in 4 years.[22] To date, three calls for application have been made (see Table 3).

The results of this programme highlight, among other things, that many Spanish researchers living abroad (there are estimated to be about 2000 in the US alone) are interested in being reincorporated into the Spanish research system (21.4% out of a total of 1978 contracted). There are 171 researchers from other European countries in Spain (8.6% of the total number contracted).

Researcher mobility is generally advantageous, but it does entail some risks. Negative effects of

TABLE 3. Ramón y Cajal Programme

| ***Basic characteristics of the doctors selected for the Programa Ramón y Cajal by year*** | | | | | |
|---|---|---|---|---|---|
| | | 2001 | 2002 | 2003* | Total |
| Number of candidates selected | | 774 | 498 | 706 | 1978 |
| Number of foreign candidates selected | | 105 | 99 | 130 | 334 |
| Number of Spaniards contracted who live abroad | | 108 | 114 | 202 | 424 |
| Average age of candidates contracted (years) | | 35.8 | 35.5 | 35.4 | 35.5 |
| Distribution by gender of candidates contracted (%) | Men | 63% | 66% | 63% | 64% |
| | Women | 37% | 34% | 37% | 36% |

Note: * provisional data
*Source:* Ministry of Science and Technology

| ***Programa Ramón y Cajal Objectives*** **(% of the total number of people contracted)** | | | | |
|---|---|---|---|---|
| | 2001 | 2002 | 2003 | Total |
| To bring back Spanish researchers | 14.0 | 22.9 | 28.6 | 21.4 |
| To attract foreign researchers | 13.6 | 19.9 | 18.4 | 16.9 |
| To improve employment conditions and career prospects | 72.4 | 57.2 | 53.0 | 61.7 |

*Source:* Ministry of Science and Technology

| ***Distribution of contracts by research area*** | | |
|---|---|---|
| | No. | % |
| Sciences (physics, chemistry, mathematics, earth and space sciences) | 683 | 34.8 |
| Life science and technology (plant biology, agriculture, livestock and food technology) | 383 | 19.6 |
| Animal and molecular biology | 304 | 15.5 |
| Medicine and physiology | 220 | 11.2 |
| Engineering, information and computer technology | 190 | 9.7 |
| Social sciences (economics and law) | 67 | 3.4 |
| Humanities (pedagogy, philosophy, art and education sciences) | 113 | 5.8 |
| TOTAL | 1960 | 100 |

mobility can arise in countries such as Spain that have an excellent level of higher education, but no equivalent technological development. One such effect is the loss of quality human capital *(brain drain)* or inadequate use of education *(brain waste)*. To avoid this, current entry conditions for research and teaching staff need to be brought into line with those of countries that have outstanding R+D.

The brain drain could be limited if the measures established by the Lisbon Council in 2000 were adopted nationally and by the ERA, and if the European Fund (ERC) favoured the return of personnel.
Current Spanish entry conditions for research and university teaching staff should be immediately brought into line with those of countries that have outstanding R+D.

European higher education guidelines should be applied to higher education and doctoral programmes (European doctorates), and the European Charter guidelines applied to researchers.
The best way to combat the negative effects of mobility is to increase social prestige (by raising public awareness) and improve the conditions of the research career. Researchers should be recognised as professionals after the postgraduate degree. The recommendations established by the European Researcher Charter and the Code of Conduct for recruiting researchers should be adopted to achieve these goals.
Measures aimed at creating a kind of "virtual community" should be established that would keep active both shared knowledge assets and scientific resources of excellence. It would also help establish and develop effective initiatives for transnational scientific cooperation between excellent organisations, groups, and researchers both within Spain and abroad, for the mutual benefit of all.
Effective recruitment of researchers from within and outside the Spanish R+D+I system requires a legislative, organisational, information, and management framework that is efficient and readily available.

***Infrastructures***

Research infrastructures provide increasingly important support for the advance of basic and applied knowledge, technological development, innovation, and socio-economic competitiveness. In the European Union, the term "research infrastructures" refers to facilities that provide essential services to the scientific community for research in different fields. Examples include: libraries, databases, biological archives, clean rooms, communication networks, and synchrotrons. They may be located in one place, distributed, or virtual.
In addition, infrastructures are:

– Focal points for technological innovation, in areas such as instrumentation and rapid data acquisition.
– Hubs for regional growth, particularly for less-developed regions, thereby improving competitiveness (research and innovation, information technology, and human capital).
– Centres for training and mobility of researchers during graduate or postdoctoral education.

All of this is particularly relevant in view of the next Framework Programme, given that the Commission Communication on the EU financial perspectives for the period 2007–2013 refers to research infrastructures as a key element to advance European scientific and technological development. Developing research infrastructures of European interest is one of the six main objectives in the Commission Communication on the future of European Union research policy[23] and the Seventh Framework Programme.

European research infrastructures' medium- to long-term requirements include devising a 10- to 20-year plan that would be drawn up in a continuous process, involving periodic updates and revisions.[24] The European Conference on research infrastructures has established that there is wide consensus, in scientific and political circles, on the need for a European focus for key research infrastructures.[25,26]

The Spanish infrastructure roadmap is in the process of being formulated and should take into account the European roadmap's tasks. It should also consider Spanish participation in existing or planned international infrastructures linked to the international scientific and technological organisations of which Spain is a member. Participation costs are considerable (see Tables 1 and 2), but essential if Spain is to be situated in the international scientific context to which it belongs. Participation also produces important industrial returns in the form of contracts and *know-how*.

In this respect, Spain should take part in new large-scale European scientific facility projects from the outset. It should establish national complementary actions to optimise subsequent use of the facilities, and also to contribute to their construction by supplying instruments, equipment, and components.

Spain already has some important scientific facilities and participates in a growing number of major international facilities (CERN, ESRF, EMBL, ILL, GBIF, etc.). Spanish groups and companies need to boost their use of these facilities both quantitatively and qualitatively. At the same time, a process of building several major scientific facilities has been initiated in just a few years. Among these are: the development of a 10-m (diameter) segmented telescope, in the Observatorio del Roque de los Muchachos on the island of La Palma, a 3.5-GeV synchrotron in Barcelona, a new 30.m oceanographic vessel, and a supercomputer with a 40-TFLOPS processing capacity in Barcelona. All of these have been created in response to a completely new policy that differs greatly from its predecessors.

This process of increasing Spain's global presence can also be seen in its 10.5% contribution to the Galileo programme, in which Spain's fixed contribution to ESA is 5%. In addition, negotiations on Spain's participation in ESO have begun. Spain's participation in the ALMA project has already been decided upon by an agreement with ESO. However, use of major international infrastructures should also be optimised and related thematic areas strengthened.

Scientific and technological infrastructures are a fundamental factor in Spain's scientific, technological, and socio-economic development. Building, improving, and maintaining them requires considerable financial investments. Therefore, in addition to the benefits drawn from the construction and scientific use of the facilities, it is important to ensure that interested communities make use of them.

The Spanish Ministry of Education and Science has begun to devise a national roadmap to promote these initiatives, providing Spanish scientists and technologists with tools to advance knowledge over a 15-year period. The roadmap's design should be coordinated with that of the European scientific infrastructures roadmap and with the plans of the regional governments in this area.

Use of the major international infrastructures in which Spain participates has to be optimised. To achieve this, lines of research and training activities in related thematic areas should be strengthened, among other measures. This would bring about optimum use of the facilities.

## Business

Business plays a crucial role in the process of European integration, but it also has the most serious shortfalls and therefore requires the most attention. According to data provided by EUROSTAT, R+D spending in Spain reached 1.11% of GDP in 2003. However, companies contributed only 48.9% of the expenditure in 2002. This is a long way from the recommendations of the Lisbon Strategy stating that business should contribute two thirds of the R+D spending by the year 2010.

These data reflect the Spanish business sector's past weakness in R+D activities. This is due to several factors, for example: the industrial sector is made up of many small companies in traditional production sectors with a low technological input, and buying essential technology abroad is a common strategy. Thus, companies are not involved in creating or developing technology.[27]

Many Spanish companies, in particular financial and service companies, have a globalisation policy that involves creating marketing networks and networks for supplying components. Less effort is made to participate in international networks for generating, developing, and integrating new knowledge.

In addition, large companies with technological capacity lack clear incentives to participate in European R+D programmes. The network of stable links with other companies, European and national public centres, has an inadequate structure. In the European Union's Fifth Framework Programme, 50% of Spanish returns went to a relatively small number of companies in the business sector. The Sixth Framework Programme, which is currently being implemented, has similar figures.

Priorities have been focussed on a small number of technological areas that are far from the interests of Spanish companies. In general, programmes have long-term perspectives. Many existing programmes are ill-equipped for SMEs, which are given a marginal treatment to appease consciences; but this does not contribute to solving the problem. In addition, Spanish companies have a relative lack of interest in existing priorities, as their direct involvement in EU matters is negligible. Unlike large European business groups, very few Spanish companies are directly represented in Brussels. Consequently, they have almost no influence in devising programmes.

We should analyse the impact of the incorporation of large multinational companies into Spain, and consider how to increase the involvement in R+D of the most visible financial institutions, i.e. those with the highest turnover.

Research groups do cooperate with companies in the Framework Programme. However, Spanish companies are absent from almost 50% of the projects. Moreover, their participation in projects does not necessarily lead to their ability to make good use of the technology generated by the public system. It is difficult to estimate to what degree this is true, but in any case the carry-over effect is limited.

However, something is changing. Some Spanish companies with an international orientation and technological capacity cooperate with research centres all over the world. There is a process of improving technology access networks, as demonstrated by the acquisition (or control) of technology-based companies.

Moreover, government initiatives to boost science and technology parks, not just as urban planning projects, but as instruments for competitiveness and business development, could contribute to increasing the innovative activities of companies.

The position of Spanish companies in the major European R + D consortiums needs to be consolidated and they should participate in setting up the Seventh Framework Programme's technology platforms. Among others, the following measures should be taken to achieve these objectives:

– Link national resources to participation in European programmes.
– Strengthen collaborative activities between companies and research groups.
– Create centres that have European competence in R+D, sufficient critical mass, and technological capacities.
– Continue to support the presence of SMEs in consortiums for all European projects.

The internationalisation of SMEs should also be supported, by developing their technological access and marketing networks as well as through agreements reached with other strategic technological partners.

# Comments on the Seventh Framework Programme

On 6 April 2005, the European Commission presented its proposal for the Seventh Framework Programme (2007–2013). It is too early to know the results of the European Council and Parliament's final *co-decision*. However, comments can be made about the foreseeable impact of the Programme on the Spanish science and technology system. Thus, to contribute to the formation of the Spanish government's opinion, and to prepare collectively for tackling this new initiative, key aspects of the Commission's proposal are listed below:

• There is a proposal to double the Framework Programme budget. This is good for the Spanish science and technology system, even though this budget will cover a 7-year period instead of the usual 4 years.
The higher the EU budget, the more opportunities to attain economic returns, particularly if the Spanish budget is increased and its administrative structure reformed at the same time.

• The proposal states the importance of excellent basic research in all scientific fields, and allocates it a considerable budget of 1.5 billion. In addition, the proposals of individual research teams, human resources, and researcher mobility will be independently analysed by peer review, and coordinated by the European Research Council.
The term *research team* does not necessarily imply that its members work in the same country.

• To resolve the problem of the current Framework Programme's highly bureaucratic administration, the idea of outsourcing is supported, using a model of executive agencies (one or several). This is applicable to the European Research Council, human resources and mobility programmes (Marie Curie actions), and actions geared towards SMEs.
The decentralisation of programme management and/or modes of action should not ignore or diminish decisions made by the European Commission, as the budget authority, which take precedence over decisions reached by the European Parliament, the member States, or independent expert opinions given during the evaluation of proposals, Adequate recognition must also be given to the research itself and the impact of its results.

• Proposed instruments for participation are not very different from those currently in use. Proposals can make use of the instrument best suited to the characteristics of the activity to be undertaken.
However, no less than 50% of the budget is allocated to funding research and technological innovation activities in the same fields as in previous programmes, although major scienti-

fic networks and technological-industrial platforms are strengthened. This means that small research groups and the limited number of Spanish innovative companies that could participate in this programme will find it more difficult to assume a role of scientific, technical, or organisational leadership than under the current Framework Programme. To tackle this situation, measures will have to be introduced to give the administrative, legal, and financial support required.

• *Technology platforms* are formed under the leadership of industry. Their objective is to define medium- and long-term research agendas, to increase industry's investment in R+D, and to direct the activity of the public applied research system towards business priorities. Specific legal structures could be created, like those intended for Galileo and Hidrógeno, among others.

Spain should participate in all the technology platforms, with authority and decision-making capacity. It should lead some of these platforms (or some work areas). It should also have enough critical mass to be able to use the definition process to launch national technology platforms that have appropriate funding and the participation of the public and private systems.

• The process of progressively opening up national programmes needs to be strengthened, in order to contribute to creating the ERA. Accordingly, the Commission has proposed new initiatives of interest to Spain, such as: ERA-NET PLUS (funding through joint calls for proposals), high-risk loans granted by the European Investment Bank, and a new approach to the relation between the Framework Programme and structural funds that enables actions to be taken with a strong regional presence (called *regions of knowledge* in the proposal).

# Programme and project management

The effective development of a policy covering scientific research, technological development, and innovation, in the context of international (and national) cooperation, requires a legislative, organisational, and normative framework that would enable administration of the research system to become specialised, dynamic, flexible, and independent. This is particularly important in an R+D+I system like Spain's. The Spanish research system has three levels of governance (international, national, and regional). In addition, ministerial and independent competences coexist and are strongly rooted in services. All of these must be coordinated to ensure that resources are allocated effectively.

It seems likely that the Spanish government will soon pass a Law for State Agencies[28] to deal with this and other similar situations. Such agencies will be specialised administrative bodies, with organisational autonomy. Their task will be the decentralised management of public services that are independent from services provided by companies and private interests.

This organisational initiative will, in principle, require a determined political commitment. Agencies must be given a well-defined legal and public status, especially if they are to become bodies that unite public actions for promoting science. They could, for example, manage all or a considerable part of the national R+D+I plan, particularly those activities related to the public system.

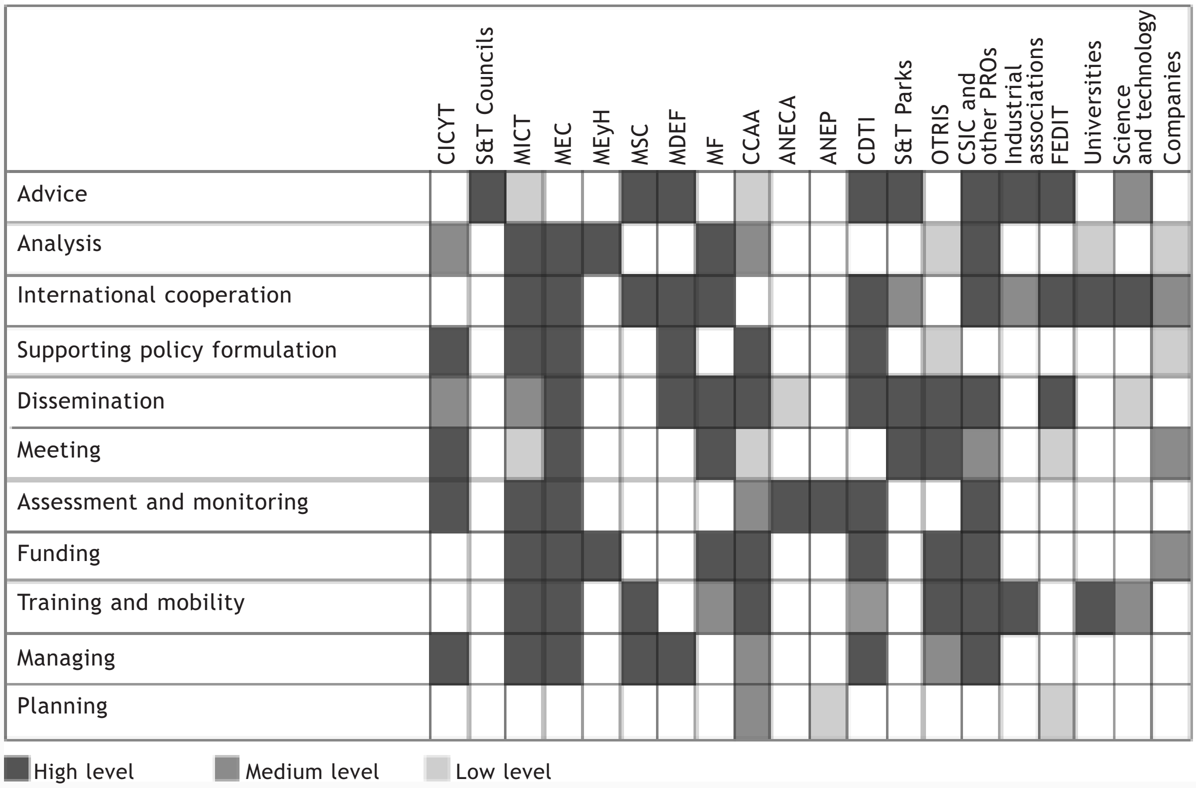
Jurisdiction as well as the budget for research are distributed between the ministries executing the national R+D+I plan. Consequently, it is important to decide whether, in this context of decentralised research management, there should be one agency or several, perhaps one for each ministry involved.

Turning now to the execution of research, the operating capacity of universities and PROs has to be increased immediately. This would enable them to manage projects from international R+D programmes, particularly those connected to the EU. The aim would be to stop Spanish groups from withdrawing from such projects. Groups avoid taking on leadership tasks due to the administrative and management responsibilities they currently involve. If the EU truly wants to encourage scientific research and lead a "dynamic knowledge-based economy", it should make its characteristically rigid, intrinsic bureaucracy more flexible.

Figure 1 lists the main authorities and institutions making up the Spanish R+D system, and their degree of involvement in different activities.

Improvements in the Spanish research and technology system must be attained in the area of effective, agile, and flexible management of its plans and programmes. The EU also needs to be given the mechanisms and procedures it needs to avoid the current administrative labyrinth.

A national agency should be created to assess proposals, programmes, and scientific and economic impacts. Such an agency would evaluate, fund, and exploit research and technological development plans to be carried out over a period of several years.




Comisión Interministerial de Ciencia y Tecnología,
CICYT (Interministerial Commission of Science and Technology).

General and Advisory Councils for science and technology
Ministerio Industria, Comercio y Turismo,
MICT (Ministry of Industry, Commerce and Tourism).

Ministerio de Educación y Ciencia, MEC
(Ministry of Education and Science).

Ministerios de Economía y Hacienda,
MEyH (Ministry of Economy and the Treasury).

Ministerio de Sanidad y Consumo
MSC (Ministry of Health and Consumption).

Ministerio de Defensa, MDEF (Ministry of Defence).

Ministerio de Fomento, MF (Ministry of Development).

Regional I+D+I Systems, CCAA.

Agencia Nacional de Evaluación de Calidad y Acreditación, ANECA
(National Agency for Quality Assurance and Accreditation).

Agencia Nacional de Evaluación y Prospectiva,
ANEP (National Evaluation and Long-Range Planning Agency).

Centro para el Desarrollo Tecnológico Industrial,
CDTI (Centre for the Development of Industrial Technology).

Asociación de Parques Científicos y Tecnológicos de España,
APTE (Spanish Association of Science and Technology Parks).

OTRIS

CSIC and other Public Research Organisations (PROs)

Asociación Española de Normalización y Certificación, AENOR
(Spanish Association for Standardisation and Certification).

Federación Española de Entidades de Innovación y Tecnología,
FEDIT (Spanish Federation of Innovation and Technology
Organisations).University

**Figure 1.** The main authorities and institutions in the Spanish R+D system and their activities

# Conclusions and proposals for action

As a result of the considerations and data set out above, we propose a series of measures that could contribute to improving Spain's position and effectiveness in Europe:

- Spain is no longer one of the member states with the lowest salaries. As a result, the level of competitiveness needed to successfully face challenges arising in the international market should be based mainly on its capacity to *create, adapt, and apply new knowledge*. Consequently, other essential factors are: a good education, excellent scientific research, innovative technological development, an enterprising industrial sector, and the greater use of investment capital compared to revenue.

- Implementation of the Bologna process in universities will be of fundamental importance to European integration. Spain should make good use of this opportunity to readapt university structures so that they can contribute appropriately to increasing R+D development.

- Spain should endeavour to become a key player in the development of the European integration process with respect to R+D. To achieve this, it should develop an active European R+D strategy. In addition, national and autonomous R+D policies should be put into a European context, so that they can be strengthened, coordinated, and integrated.

- The main European arena for *transnational research* is defined by the Seventh Framework Programme. Therefore, funding agencies, Spain's research organisations, and those responsible for scientific and technological policy need to immediately adopt measures that enable them to effectively participate, using their expert knowledge, *in the formal decision-making processes of European institutions.* Measures should also give *organisational, technical, and financial support to research groups and innovative companies* that could participate in future EU R+D and demonstration initiatives.

- *A legislative, organisational, and normative framework* is needed to successfully develop a policy regarding scientific research, technological development, and industrial innovation in the context of international cooperation. This framework would help the system's administration to become specialised, dynamic, flexible and independent, and ensure that actions are coordinated.

## Proposals for action

- A 25% increase in the average annual real investment in scientific research and civil technological development in Spain (Chapters 1–7) is needed over the next 4 years, if R+D+I in Spain is to converge with the European goal stated in the Barcelona objective of 3% of GDP. The proposal to double the Framework Programme's budget is an excellent opportunity for Spanish science and technology. To make effective use of it, Spanish budgets should be increased simultaneously and its management structure reformed.

• The best way to optimise the quality and quantity of human resources, and to counteract the negative effects of mobility, is to increase funding as well as the social prestige of researchers. This can be achieved by raising public awareness about a career in research and by improving working conditions for researchers. Spain should support the *European Charter for Researchers* and the *Code of Conduct for the recruitment of researchers.* The latter document presents a series of recommendations, including the following:

– Recognise the research profession beginning at the postgraduate level.
– Establish a clear framework for the professional and personal career of scientific researchers and technologists.
– Favour the mobility of research staff between universities and research organisations.
– Provide lifelong learning for researchers.
– Establish stable and transparent methods– whether in the public service or not– for incorporating trained researchers into the system, according to their merits and abilities.
– Develop training programmes for techniques that support research.

• Adopt measures, along the lines of a Commission initiative, aimed at creating a *virtual community*. This would aid in the development of initiatives for transnational scientific cooperation between the community's different groups and organisations, for the mutual benefit of all. At the same time, it would keep the knowledge assets and scientific resources of excellent Spanish researchers, in Spain and abroad, active.

• Optimise use of the large-scale research infrastructures in which Spain participates by strengthening related thematic areas.

• Business competitiveness has to be increased to strengthen Spain's role in an emerging Europe and to improve its population's social well-being. The following elements, all of which are complementary to transnational collaborative research, are among those needed to achieve this:

– Design an incentive system to increase the participation in European programmes of large companies that have technological capacity and connections with SMEs.
– Promote the creation of science and technology parks and participation in scientific *euroregions* (geographic groups).
– Introduce a policy for research infrastructures that is consistent with the following economies of scale: international, European, and that of the member states.
– Establish effective and complementary European and national programmes to support SMEs.
– Create synergies with other European initiatives, such as EUREKA, COST, European Science Foundation (ESF), and other science federations and associations (EIROFORUM, FEBS, EACS, etc.).

• The EU has established a fund of € 2 billion per year to support basic research in all disciplines. This provides an opportunity to reduce brain drain and increase the competitiveness of a knowledge-based economy. Spain should make maximum use of this fund.

• The instruments for participation proposed in the Seventh Framework Programme do not excessively differ from existing ones. However, they do aim to strengthen the major scientific networks and industrial technology platforms.

Small research groups and a limited number of Spanish innovative companies will participate in this Seventh Programme, taking on a role of scientific, technical, and organisational leadership that is more significant than in the current programme. These groups and companies should be provided with appropriate administrative, legal, and financial support.

• *Technology platforms* are set up under the leadership of industry. The aim of these platforms is: to define industries' medium- and long-term research agendas, increase investment in industrial R+D, and gear the activity of the public applied research system towards business priorities. Spain should be represented on all the technology platforms, with authority and decision-making capacity. It should be able to lead some of the platforms (or some work areas) and make use of the definition process to launch national technology platforms that have appropriate funding and the participation of the public and private systems.

• Management instruments are needed to initiate actions for strengthening regional presence (in the Seventh Framework Programme proposal this kind of action is known as *regions of knowledge*).

• A *system for assessing and monitoring science* should be set up to analyse the presence of Spanish universities, research groups, and companies in European R+D programmes and actions, and to assess the results obtained and their impact on the Spanish system.

• Encourage the creation of scientific and technological reference and/or advisory bodies that would give Spain a more active and effective presence in the international field, particularly in Europe.

• The government's different ministries, regional governments, and research funding agencies should be coordinated to improve the integration of R+D efforts. This would enhance the European presence of Spanish research groups and companies and help obtain results. Such coordination is even more important in the case of technological innovation, as EU structural funds are used and the regional governments have increased their jurisdiction in this area.

• Support action is needed to help promote the participation of Spanish groups in international programmes, particularly in the EU's Framework Programme. This action would be aimed at training researchers in aspects of project management, and would make some management units available to universities and research organisations, to provide them with the services they need. Other complementary actions would be:

– Encourage the preparation of proposals by providing direct aid to groups or management units (if such units exist).
– Award additional aid to approved projects to cover expenses related to: protecting and exploiting results; OEPM (the Spanish Patent and Trademark Office) state of the art searches; costs of registering patents in Spain, when they are not covered by The Framework Programme; actions fostering the creation of industrial prototypes with the collaboration of a Spanish company; drawing up business plans to create technology-based companies, etc.
– Encourage the approval of new mechanisms and procedures in the EU for administering and managing resources allocated to promoting research in all disciplines. These would avoid the excessively bureaucratic systems that are currently in use.

# Notes

1 Part III, Title III, Article III, Section 9ª on *Research and technological development and space* of the Treaty establishing a constitution for Europe.

2 European Councils held in Lisbon in 2000 and Barcelona in 2002.

3 Seventh Framework Programme for research, technological development and demonstration activities. COM (2005) 119, 6 of April, 2005.

4 The European Commission has proposed an annual budget of €10,000 M to finance the Seventh Framework Programme (2007-2013).

5 Science and Society Action Plan. Com (2001)714.4, Dec. 2001.

6 Treaty on European Union. Art. I-47 (democratic participation).

7 At the Lisbon European Council on the 23 and 24 March, 2000, Heads of State and Government set the following as a new EU objective for 2010: “to become the most competitive knowledge-based economy in the world, capable of sustained economic growth with more and better jobs and greater social cohesion”.

8 Fundación Española para la Ciencia y la Tecnología: Bibliometric indicators of Spanish scientifc activity, (1998-2002). Madrid, 2004.

9 CDTI: “Resultados y evolución de la participación española en el Programa Marco”. 27.01.2005 and 05.11.2003.

10 “Growth and jobs: a new Start for the Lisbon strategy”, a speech by President Durao Barroso to the European Parliament. Strasbourg, 09.03.2005.

11 Financial perspectives 2007-2013: 1,025,000m, of which 1% of European GDP ( 10,000m) will be allocated to R+D (Com (2004) 101 final).

12 Building the ERA of knowledge for growth. COM (2005).

13 “El Espacio Europeo Común de Conocimiento en la Unión Europea”. A Spanish approach to the problem. Emilio Muñoz et Al. Academia Europea de Ciencias y Artes, Spain, 2005.

14 A high Level Advisory Group proposal on the creation of the European Research Council (ERC). December 2003/January 2004.

15 European Commission communications on Basic Research. January and May 2004.

16 Spain’s spending on basic research in relation to GDP is one of the lowest of all the OECD member countries (it is only above Mexico and Slovakia). It has remained at 0.15 % of GDP in recent years, whilst the OECD average reached 0.34 % in 2001.

17 COM (2003)436. Brussels, July 2003: “*Researchers in the European Research Area: one profession, multiple careers”.*

18 The *Human Resources* budget in the 6th Framework Programme (2002-2006) is 1.58bn. It is therefore almost 10% of the budget for non-nuclear activities (€16.27bn).

19 A commission recommendation [2005/251/CE], 11 March, 2005, relating to the European Charter for Researchers and the Code of Conduct for the recruitment of researchers. DOUE L 75/67 22.3.2005.

20 “Europe needs more scientists”, report by the High Level Group on Increasing Human Resources for Science and Technology in Europe. April 2004.

21 Conclusions and Recommendations from the Bologna Seminar on “Doctoral Programmes for the European Knowledge Society”. Salzburg, 3-5 February 2005.

22 L. Cruz-Castro y L. Sanz Menéndez: “*Human resources. Bringing science and technology human resources back in: the Spanish Ramón y Cajal Programme”,* Science and Public Policy. February 2005.

23 Science and Technology, the key to the future of Europe. (Com (2004) 353 of 16.6.04.

24 Commission services document, 29.10.04.

25 The conference presentations can be found at: http://www.cordis.lu/improving/infrastructure/events.htm.

26 European Strategy Forum on Research Infrastructures (ESFRI) created three groups in: Physical Sciences and Engineering, Biological and Medical Science, Social Science and Humanities, and a fourth group in e-Infrastructures. These have been in existence since the end of 2002 (eIRG, a group of Ministry delegations to tackle GEANT and Grid topics).

27 According to Eurostat, companies’ contribution to R+D spending in Spain - out of a total of 1.11% of GDP - was only 48.9% in 2002. This percentage is a long way from the objective of two thirds by 2010 recommended by the European Council in Barcelona.

28 «ORDEN del Ministerio de Administraciones Públicas/3017/2004», of 16 September, in which a commission is formed to study and prepare the draft for the «Ley de Agencias Públicas».

# ACCIÓN CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Science and society

# Summary

The section *Science and society* analyses some of the central problems in the interaction between scientific advances and social structures. In particular, it looks at how individuals and social groups (the public) receive scientific advances in Spain. In addition, it includes a study of the influence that the appreciation of science by the public and society as a whole has on science itself. This summary highlights some of the section's most representative observations, conclusions, and recommendations.

Nowadays, most scientific areas and their social applications are not a problematic issue for the majority of the public. Indeed, many such areas are seen as clearly beneficial. However, an overview of Spanish society's recent perception of science and technology reveals one aspect that is different than that of other European societies. This is important when formulating programmes for bringing science and society closer together and for establishing a dialogue between the scientific community and the public. This aspect is outlined below:

*a)* Studies carried out by the European Commission and private institutions concur in characterising Spanish society as one of the most optimistic, with the least reservations about science.

*b)* Spanish society's optimistic, unproblematic profile is accompanied by a low level of scientific knowledge among the population (knowledge of science's central concepts and ways of operating). It is significantly lower than the level in the majority of advanced European societies. In other words, Spain's open attitude to science is, in fact, passive. It is not linked to personal efforts to take an interest in science or to become informed about it. Science is not seen as an essential aspect of society's culture.

In this respect, the proposals are:

• In Spain, more than in other European societies, lasting and effective initiatives should be introduced to increase society's knowledge and general interest in both the scientific foundations of culture and the contribution of science to cultural development. This would also encourage young people to choose scientific careers.

• Efforts by public and private agents to communicate science to the public should be considerably increased. In addition, the results of these efforts should be scrutinised and assessed. In particular, it should be compulsory to assess the results of implementing public science-related policies.

The number of researchers involved in bringing science closer to society is almost negligible. This activity does not form part of researchers' normal concerns. Many researchers consider that it is outside their role, and even contrary to their interests. Therefore, the following proposal is made:

• The scientific community and scientific institutions with competence in political science should make a clear and explicit commitment to assess and stimulate science communication by researchers.

Obviously, the best results of educational efforts are attained within the formal education system. It is extremely important to dedicate special attention to generating and maintaining university students' interest in research.

• Institutions of higher education should find new ways to support and recognise members who stand out due to their special efforts in stimulating science and reforming the curriculum. The latter will allow phasing out of unimaginative teaching methods that dampen interest in research. In addition, students should be encouraged to find out about research activity of the teaching staff.

• In primary and secondary education, all teaching-staff initiatives directed at increasing interest in science and its applications should receive special attention and support from the universities, the CSIC, and scientific organisations. This would help to draw the attention of the corresponding education authorities to the importance of basic scientific education. There are currently serious shortcomings in this area. Such support would also highlight the lack of encouragement, incentives, and resources of the teaching staff.

Like the rest of Spanish society, the Spanish political class is not in close contact with scientific knowledge, and, unlike the majority of countries in Europe, there are no official and transparent channels for offering scientific and technological advice to the government or parliamentary representatives. Examples of such channels are: scientific advisory offices for the presidency; permanent Parliament and Senate scientific commissions; scientific advisors in embassies, and international organisations.

• It is essential to institutionalise the channels for managing and applying scientific knowledge, so that public interest can be handled on a daily basis, not just in crisis situations.

The scientific community cannot remain indifferent to Spanish society's view of science and its level of acquisition of scientific culture. Thus:

• Spanish researchers have to be aware of those concerns and attitudes in the social environment that are relevant to their work. Likewise, the scientific community should take advantage of any opportunity to inform society about how public concerns, preferences, and requirements are incorporated into research work.

• It should be clear to the scientific community that using public resources entails some indissoluble, inherent principles of reciprocity. Among others, these include explaining the efficient use of resources in terms that can be understood by the society that provides them.

The position of scientific information in the Spanish media is on a par with its situation in the country, in terms of effort and scientific level. It lies somewhere between that of the most advanced countries and the least developed. The small size of the Spanish science and technology system; the lack of leading scientists and authorised spokespeople; the limited social and political influence of scientists; and the absence of a scientific tradition in Spain are factors that have a negative effect on the social appreciation of science, despite the level reached in the last two decades. Thus:

• All agents in the science and technology system should be aware of the importance of keeping society well-informed of their activities through many channels, with a special emphasis on the media. The heads of public institutions should adopt appropriate measures to achieve this aim.

Bridges need to be built, and connections improved, between the scientific community and the media in order to bring about this flow of information. Both groups must play a part in this process. However, science will have to continue to earn its presence in the media by generating interesting news, being open and transparent to the media, and offering quality up-to-date information.

• Specialised personnel or scientific communicators –ideally, journalists with scientific training or scientists with journalistic training– should be involved and work first and foremost in this area. The public system should stimulate training of these professionals.

The most reliable data regarding the amount of science shown on television reveal that science has a relatively low impact on TV programming in Spain (0.001–0.01% on TVE).
Therefore we propose that:

• Public television channels dedicate both more attention and time slots that attract much larger audiences to popular science programmes, even if they are not immediately successful. Children's' programmes with a science content are a clear investment in the future. Meetings between scriptwriters and news and scientific editors should be coordinated so that they views on science and society can be exchanged.

Since the early days of the internet, science has sought and found its place in the resources of the World Wide Web. This has raised the prospects of moving science closer to the interests of society. Scientific organisations and associations, hospitals, universities, companies undertaking research, government departments, museums, etc., have created an enormous arena for learning and communicating science. However, the limited number of internet portals for science communication and information in Spain are often of a low quality and have only marginal influence. If the overall effects are considered, it is clear that the internet has changed the situation, in science as in other fields, from a chronic lack of information and knowledge, to one in which the problem is the individual management of an overabundance of information. In turn, the traditional mechanisms for "filtering" or separating verified from spurious knowledge have been weakened.

• Institutes and scientific organisations should exploit the revolutionary possibilities of new internet resources more professionally and intelligently, in order to communicate their research activities to society. It is vital to educate the population regarding the criteria for selecting and recognising the cognitive value of information available on the internet. Consequently, they will be able to access and use the vast digital library of verified knowledge that currently exists on the internet.

Intellectual access to science and other information is seriously limited by the fact that reading habits have changed for the worse and reading comprehension has decreased, particularly among schoolchildren. Recovering and strengthening these capacities should be compatible with the emergence of new media and formats. In addition, the production of scientific and popular science books is very low in Spain. The major scientific magazines (in all forms and at all levels) have only a limited role. They are better represented and established in other European countries.

- There are very few science books in public libraries, and those that are found tend to be out-dated; thus, sustained plans are needed to increase their availability. In addition, joint publication agreements for popular science works of clear social interest should be reached, and a carefully thought-out plan implemented to provide support for magazines covering popular science and scientific culture.

Currently, Spain has a notable group of centres devoted to the communication of science. These include: museums and interactive science centres, specialised museums, planetariums, aquariums, botanical gardens, and zoos. All of these centres are essential to improving scientific knowledge and the public's perception of science. In addition, they promote public education about the characteristic attitudes and skills of scientific research, aid in understanding scientific concepts linked to current affairs, and suggest ways to incorporate such concepts into culture.

- Society and the authorities should recognise the growing impact and diverse functions of science museums (including planetariums, aquariums, botanical gardens, and zoos) in disseminating scientific knowledge. Human and financial resources as well as museum space should be considerably increased to improve the educational function of the National Museums of Natural Sciences and of Science and Technology. The contribution of these institutions to the dissemination of scientific knowledge should be systematically assessed.

The presence of women in the Spanish education and research system has increased considerably in the last two decades. However, it has not yet had a significant effect on the number of women on the higher rungs of a teaching–research career.

- To address a problem of this complexity, reliable and systematic data should be obtained immediately. Such data would be used to statistically analyse in detail all of the variables involved in gender inequality in the Spanish science and higher-education system.

However, some actions can be taken before the results of these analyses are obtained. A series of measures can be implemented that contribute to halting both the loss of women from the Spanish R+D system and their massive demotivation due to the additional barriers they encounter in pursuing a competitive research career and achieving excellence. The following measures stand out:

- Mechanisms for harmonising professional, private, and family life should be created or strengthened. These could include: flexitime, public social services to look after dependants, tax incentives that favour these mechanisms, and other similar incentives that facilitate researcher mobility and the return to a scientific career or part-time work after periods of maternity leave.

# Science and society at the turn of the century

One of the strongest driving forces in the global and complex society of today's world is the continuous advance of scientific and technological knowledge. Such advances have become a kind of "life-support system". For any society, its collective possibilities, and those of the planet as a whole, are a function of its capacity to continue to expand the scientific image of the world and of its ability to better understand and more effectively design "the artificial", which is the objective of technology and engineering.

Science and technology's current pre-eminence has emerged amid tension with other conceptual constructs and institutions. In the last three decades, indicators of "cultural unease" and resistance to scientific change have appeared. Groups and associations have arisen that fight for greater control or an external orientation of science. They also demand a redefinition of the rules of the "implicit contract" between the scientific community and society (Guston and Keniston, 1994). In recent years, regulators, public officials, and members of the scientific community have formed the view that we are faced with a widespread crisis of confidence in science and its most characteristic institutions. Recommendations and action plans have taken this diagnosis of the science–society relation as a basis for their responses. In reality, neither the diagnosis nor the treatment is entirely new. In fact, they have reoccurred in a cyclical manner since at least the end of the 1970s. A brief look at the course of the science–society relation from the perspective adopted in this report could assist in identifying new factors in this interaction in relation to other periods of time.

Science has been increasingly connected to a large number of institutions and social practices, in the context of a more general process of modernisation. In parallel, it has become formalised as the exclusive activity of a professional group. This has given rise to a sharp demarcation between the scientific and public communities, clearly visible since the end of the nineteenth century. Along with this *scientific–public community* demarcation arose what is known as the *implicit contract*, regulating the interactions of the two communities. This has been in effect since the end of World War II. By virtue of this tacit agreement, the scientific community attained autonomy (in selecting objectives and carrying out research) and an increasing volume of financial and human resources. In exchange, it contributed to the production of a stream of material goods and services (among which those in the field of health care stand out), and the transformation of the average person's education and cultural facilities. Through its spokespeople, society accepted– with little argument– the assumption that material support and non-interference, added to how the scientific community operated, even if this appeared to be esoteric and unnatural, would sooner or later improve the quality of life and create more choices for most of society. There has been unbroken confidence in the existence of this link between scientific theory and material progress (and, less explicitly, cognitive and educational progress) throughout the central period of the modern age. The undesired effects of scientific advances were generally viewed as temporary episodes that could be resolved by more science and more technology (Pardo, 2001).

In areas of the world where the science–industry complex became rooted, the source of legitimisation of science lay more in its practical effects or applications (levels of well-being increase steadily and become widespread) than in its strictly cognitive aspect (a greater capacity to construct representations of the natural and social world, which are constantly revised and have growth potential, unparalleled by other forms of higher culture). This utilitarian function of science was expressed most clearly in modern medicine (Handlin, 1972: 260).

This situation changed dramatically after the demonstration of devastating nuclear power in World War II. It was also affected during the 1970s by the environmental effects of the partnership between science and industry. The visibility of the unwanted consequences of applying scientific knowledge underwent a change of such magnitude that the erudite optimism of the scientific community, and the belief in science-based progress that is characteristic of modern societies, could no longer get around it.

The dramatic confirmation of the dual nature of scientific knowledge, "creating new parameters of risk and danger [while] offering beneficent possibilities for humankind" (Giddens, 1991), led to an erosion in public confidence in the link between scientific advances and social progress (Marx, 1988). The culture of critical and alternative movements at the end of the 1970s attributed a wide spectrum of undesired effects to science and technology, which were criticised for: being a causal agent in the processes of alienation and dehumanisation. Intuitive images of the world supported by common sense were allegedly being replaced with fragmentary and abstract representations unconnected to the way most people visualised the world from daily life. These un turn gave rise to artificial and "unnatural" lifestyles, seriously alterations in the seasons and environmental equilibrium, and support of the nuclear arms industry.

The scientific community viewed outside criticism as inciting regulation by state agencies, or even the direct intervention of the public in matters that were thought to be reserved for scientists. Sensitivity to this criticism led, in the mid-1970s, to a sense of alarm, expressed by media and scientific institutions, who feared for the ability of science to survive the attacks being launched against it. The idea of a *crisis regarding the legitimacy science* took shape, and indirectly contributed to increasing the then modest level of research into public perceptions of science. It also resulted in initiatives to improve "public literacy". Until the end of the 1980s, this task was led by the National Science Foundation in the United States. The NSF analysed a biennial series of science and technology indicators measured since 1972. At the end of the 1980s, the European Commission and other nationally based private institutions joined in the mapping public perceptions of science.

This area of research is known on the other side of the Atlantic as *scientific literacy,* and in Europe as *public understanding of science* (Miller, 1983). The above context helps to understand why the focus of this research agenda has been measurement of the degree of public approval of science and the scientific community, and why it has continued to be the focus of such surveys. The main hypothesis of this research programme is that (favourable) attitudes to science are a function of the public's level of scientific knowledge. The public's cognitive deficit, documented using an extensive series of surveys in advanced countries, has been taken to be the variable that is related to the occurrence of criticism or resistance to certain scientific and technical applications. There is no formal or statistical evidence to support this hypothesis, and it has been subjected to scrutiny only in recent years (Evans and Durant, 1995), with unclear results.

With the perspective of time, the seriousness of the supposed *crisis regarding the legitimacy of science* can be re-evaluated. A second examination of the data gives a more qualified opinion, although we should bear in mind that while the best-documented case is that of the United States., it cannot be directly applied to European societies. Despite this cautionary note, available empirical and historiographic evidence shows that the fears of the scientific community, from the mid-1970s until the end of the following decade, only partially corresponded to reality. More specifically, those fears were mainly based on the attitudes and behaviour of a few, quite active minorities, and on the mass media's disproportionate coverage of a few critical episodes involving science and technology. These were given a weight that was disproportionate to their actual social impact. This disparity illustrates that public opinion cannot be directly inferred from either opinions disseminated by the mass media, or the demonstrations and actions of pressure groups (Pardo, 2001).

According to data from surveys undertaken in the US between the end of the 1950s and the beginning of the 1970s, analysed by Karen Oppenheim and Amitai Etzioni (1974), the public's overall assessment of science's role was positive. People rejected openly anti-scientific viewpoints and had high regard (prestige and trust) for professional scientists. Even so, these positive perceptions were based, above all, on the instrumental (practical effects) rather than the cognitive (explanatory capacity) dimension of science .

The constant dissemination of information regarding the undesired effects of science- and technology-based progress opened the way for sceptical attitudes and criticisms of technological advances. Paradoxically, a higher level of knowledge brings with it a greater awareness of the risk factors, as remains the case today. Thus, a constantly expanding list of risks has been generated that has gradually taken the form of the current culture of *zero tolerance* (at least on a symbolic or declarative level), which frequently conflicts with the fearless, personal acceptance of some preventable risks in daily life.

Therefore, there is a dividing line between the widespread trend of optimism and confidence in science up to the beginning of the 1970s, and the culture of criticism, or at least ambivalence, in the face of progress and science that marked the end of the decade. This occurred in the context of a more general crisis of confidence in modern society's main institutions (Lipset, 1987). Despite this erosion of confidence, the scientific and medical communities continued to be highly favourably viewed. Moreover, in contrast to the conventional idea that the relative loss of confidence in science occurred in the most educated sectors, an analysis of the data shows that the opposite was true.

The emergence of environmental consciousness is one of the changes in modern societies that has had the most enduring effects and the greatest influence on perceptions of science. The historian Leo Marx (MIT) pointed out that the optimistic Euroamerican view of progress has eroded during the last three decades. The main contributing factor to its decline has been growing pessimism about the role of humans in nature; i.e. an awareness of the serious, undesired effects of the industrial productive system and the modern age in general on the global ecosystem. Such effects are sustained by science and technology

(Marx, 1998). Extensive, concurring evidence indicates that late modern age societies are aware of negative environmental developments, such as global warming, the greenhouse effect, and species extinction. Simultaneously, improvements in the standard of living and lifestyles fostered by the transference of scientific and technological advances to society via the productive system are taken for granted, nor does the public seem willing to relinquish these advances. Thus, the public's ambivalence to science at the turn of the century has largely arisen from these two opposing vectors.

An overview of the public's perceptions of science and technology in recent years is typified by the following points. These are useful when formulating programmes for bringing science and society closer together, and for establishing dialogue between the scientific community and the public:

• *Most scientific issues and their social applications are not a source of problems for the majority of the public*. *Many such issues are seen as being clearly beneficial.* Typically, scientific and technological advances are quietly integrated into the basis of the complex manner in which the public's needs are collectively satisfied. To a lesser extent, advances are also incorporated into conceptual schemes used to interpret the world and to order daily experiences.

• In general, outside the scientific community, only limited, brief attention is given to these advances. In other words, *scientific issues must now compete for the attention of a public that can choose between an enormous number of sources of information such that its "interests" multiply beyond the limits of its cognitive capacities and available time*. The population segment referred to as the *attentive public* (satisfying the set of conditions for being "interested in" and "informed" about science) is around 10% of the adult population of more advanced countries.

• *Only limited resistance to scientific and technological change is present in the current climate. As a rule, such resistance does not involve a generalised critical attitude to science.* In the second half of the twentieth century, resistance and controversy were mainly related to the undesired impacts (observable or supposed) of some aspects of science and technology, such as: the natural environment, central cultural values, views on human identity, and the demarcation between species.

• *Studies aimed at determining trends within the general public regarding their attitude to science* (measured, for example, using questions about the expected effects of a wide range of scientific and technological areas over the next 25 years) *show that, overall, it is optimistic.* In addition, analyses of the public's confidence in groups and institutions reveal that there is a favourable opinion of scientific institutions remains, although confidence has decreased since the 1970s.

• *This overview correlates with reserves and anxiety concerning some areas of science,* and some specific applications of biotechnology in particular. These are the focus of concern and debate within a wide range of institutions (e.g. the church), associations (these are often religious, although advocacy groups for patients with specific illnesses –the potential beneficiaries of new biochemical advances– often act as a counterweight to such groups), the general media, the media and institutions representing the scientific community, and, of course, regulatory agencies. The most rigorous studies show that *the level of public understanding of modern genetics is extremely low*, and confusion and erroneous beliefs abound. However, there is also evidence of *legitimate moral concerns* linked to developments in genetics and their applications. The scientific community generally tackles these issues inadequately, making dialogue between researchers, the public, and regulatory agencies difficult.

• It is also clear that the *public distinguishes between degrees of acceptability of different applications, even in the absence of exact information.* The "approval" of a specific application is mainly based on judgement of its end use. However, in other notable cases (such as stem cell research) the *means* are also extremely important (e.g. opinions about embryonic stem cells and cells from adult tissues differ). In general, while there are relatively few conflicts between public attitudes to science and religious beliefs, the latter are much more relevant in cases such as the noted above. Therefore, the scientific community and regulatory agencies should be sensitive to these differences of opinion and be able to approach the moral debate without reservations (Solter *et al.*, 2004; Pardo, Midden and Miller, 2002).

• A series of analyses of public perceptions of science appeared in the second half of the 1990s and at the start of the new century. These questioned the effect of scientific knowledge or familiarity on attitudes (acceptance or resistance) to science. A theory developed in literature until 2 or 3 years ago claimed that, in general, a high level of scientific knowledge has no effect on favourable attitudes to science. Variants of this theory stated that its effect is contrary to previous beliefs, i.e. more knowledge leads to more critical and sceptical attitudes to science. As this theory spread among political leaders, particularly in the European Commission but also in some European countries, it led, after an initial period of disorientation, to a change in strategy, in which the goal of scientific dissemination and communication was replaced by the aim of establishing a dialogue with the public as well as public participation in resolving scientific–technological controversies (using mechanisms such as consensus conferences).

Empirical evidence from the Eurobarometers was used as the basis for criticism of the *scientific literacy* ("knowledge matters") paradigm. A new, more detailed examination of this evidence has helped to re-establish, in a more elegant and unequivocal way, the differential effect of the public's familiarity with science on their inclinations towards it (Pardo and Calvo, 2002; Muñoz, 2003; Sturgis and Allum, 2004). Hardly any significant gaps could be found *in the theory linking higher levels of knowledge and more favourable public attitudes to science.* The few gaps that do exist are confined to science's prospects in areas that could be classified as "science–technology miracles". Logically, together with other matters directly and deeply involving ethical principles, these have been rejected by the well-informed public.

These new analyses have formed the basis for the renewed effort during the last decade at increasing the number of scientific communication activities. At the same time, other general variables (world views), such as those on nature and "natural" and ethical orientations, have played a supporting role in significantly influencing the general population's view of science. Without denying the effect that specific public-participation has on the formation of opinions regarding controversial issues, two conclusions have arisen in this recent period. First, the *public and private efforts to communicate science to the public should be considerably increased. The results of these efforts should be subject to scrutiny or assessment* (i.e. it should be compulsory to assess the results of implementing public policies). The number of researchers involved in bringing science closer to the public is still negligible, as this activity does not form part of researchers' normal concerns and many researchers consider that it is outside their role, and even contrary to their interests. The effectiveness of different approaches and means of communicating science to the public needs to be rigorously evaluated. Second, *the scientific community should pay increased attention to legitimate questions from the public about the ethics and values of its activities*, or the results of these activities. This should lead to: better training of researchers in this area, the drawing-up of guidelines up by scientific institutions, and constant attention being paid to the concerns and sensitivities of pluralistic societies like the Spanish one.

- *Studies carried out by the European Commission and private institutions concur in characterising Spanish society as one of the most optimistic, with the least reservations about science.* This is even the case in areas (such as biotechnology) that are problematic in countries with a similar religious orientation (such as Italy and Poland). The scientific community is highly valued and ranked only just behind another highly valued group, the medical profession. The fast pace of socio-economic change experienced in Spain during the last three decades, the development of a markedly pluralistic democracy, and the country's full incorporation into Europe seem to have eroded or even pushed aside all traditions and principles perceived as obstacles to innovation, pluralism, and greater well-being. Nonetheless, *this optimistic and unproblematic profile –one that distinguishes Spanish society from those with a long scientific and pluralistic tradition– is accompanied by a level of scientific knowledge among the population that is significantly lower than the level in the majority of advanced European societies.* In other words, Spain's open attitude to science is, in fact, passive. It is not linked to personal efforts to take an interest in science or to obtain information about it. Even "second stage" university students have little knowledge of such activities. Thus, more than in other European societies, science in Spain needs to be brought much closer to the interests of its citizens by increasing the amount and accessibility of information and sustaining the public's interest in the dynamics and results of research activities. This is even more urgent than illustrating the benefits of certain areas of research and their applications, which is a worthwhile objective but one that should be carried out in a realistic way, with no "oversell".

These points describe the both the general and Spanish background to the more specific considerations set out in the next sections.

# Science for society: the social responsibility of scientists

Science is an intellectual adventure in which the ideas of creativity and progress are inherent. It is an essential part of modern culture and has revolutionised our notion of the world and of ourselves. The main function of science is to construct verifiable knowledge, which is constantly open to confirmation or rejection. When scientists transmit this knowledge to society they contribute to generating ideas and concepts. These help people to live in the current, changeable, global society with greater rationality, security, and freedom. In addition, the applications of science have profoundly transformed daily life, to the extent that science and technology are now essential components of a country's economic development. For these reasons, *the scientific community cannot remain indifferent to Spanish society's view of science and its level of acquisition of scientific culture.*

It is usually taken for granted that the knowledge characteristic of experimental sciences is ethically and morally neutral. However, some aspects of it go beyond strictly cognitive (theories, empirical evidence) and involve elements related to values and ethics. In advanced democracies, scientific and technological activities can, either directly or indirectly, affect societies' collective ideas, values, interests, preferences, needs, and opportunities, to varying degrees. These activities include the selection of priority areas of research, how research is undertaken, and the technological developments arising from it. In Spanish society, most scientific research is carried out in public institutions or using public funds (universities, PROs, technological centres, regional research institutes, health system centres, etc.). Therefore, scientific researchers have an additional commitment to the social environment they belong to and depend on. At present, the attitude of the Spanish scientific community does not generally appear to recognise society's influence on the direction of its work. It is therefore important to focus on incorporating an attitude of recognition into research culture. We propose some channels by which Spanish scientists can be motivated to accept this social commitment.

In addition, a significant effort in education and the dissemination of science is needed for society to be able to take an interest in and fully appreciate the nature and objectives of science; its applications (generated much more rapidly than in the recent past), and the uncertainties associated with its uses. This effort should be made at all educational levels, and outside of the formal channels of education. The current contribution of Spanish scientists to this effort is minimal. There is ample space for growth and improvement in the effectiveness and visibility of science. These, and other related aspects that typify the relation between scientists and their social environment in Spain are described below.

## The researcher in society

*As mentioned above, most members of Spanish society appreciate that scientific and technological advances contribute to improving their well-being. However, this perception is not linked to a view of science as an essential element of society's or of each individual's culture.* The scientific community should not "overreact" to the uncertainty and even resistance with which society sometimes responds to scientific or technological developments. Instead, it should try to understand the basis and the meaning of such reactions, by creating an open, non-paternalistic dialogue with the public.

Some segments of the public do not appreciate with clarity that there is no absolute certainty in scientific theories and models (i.e. results that are immune to being changed by subsequent theories). Likewise, they do not understand that "zero risk" is unattainable (as much as risk is, and should be, reducible to socially acceptable levels). Scientists, on their part, all too frequently seem to be disconcerted by ethical debates on research, and often attribute them merely to the public's lack of information. The effect of the combination of these two attitudes on controversial science-related subjects could erode the "intangible asset" of the public's confidence in the scientific community.

Spanish researchers have to be aware of concerns and attitudes in the social environment that are relevant to some aspects of their work. They should take advantage of any available opportunities to inform society of how researchers incorporates the public's concerns, preferences, and requirements into its work and decision-making. There are different ways of implementing researchers' social contracts, including numerous European initiatives (such as the European Group on Ethics in Science) and some Spanish ones. These should be acknowledged, evaluated, and generalised as appropriate. Postgraduate and doctoral programmes should include the opportunity to confront young researchers and technologists in training with ethical questions and the importance of social responsibility. Administrations in charge of funding research could, with little extra effort, provide guidelines on general ethical principles for the researcher (such as the well-known pamphlet *On Being a Scientist. Responsible Conduct in Research*, compiled in 1989 by the National Academy of Sciences and the National Institutes of Health, USA). These could be complemented by other, more specific guidelines for those scientific areas of specialisation that have a greater capacity to affect society's values and ethical principles. The state-wide establishment of CSIC has facilitated the important task of raising public awareness, thereby promoting debates and informative meetings on these aspects. Science academies and societies offer a particularly appropriate framework for presenting and debating scientists' social responsibilities.

As mentioned above, another important aspect of researchers' social commitment relates to the public origin of the funds used for their work. It should be clear to the scientific community that using public resources entails certain indissoluble, inherent principles of reciprocity, such as explaining the efficient use of resources in terms that can be understood by the society that provides them. This information task could be carried out by research organisations (universities, CSIC, PROs), through activities such as: open-house days; electronic information resources; disseminating reports of activities undertaken and outlining researchers' principles of conduct. This institutional support would in no way substitute for the responsibility of individual researchers.

## The researcher as a teacher and spokesperson

It is extremely important, even urgent, to make a lasting and effective effort to increase Spanish society's knowledge and general interest in culture's scientific foundations and science's contribution to their development. This may also encourage more young people to choose scientific careers. Initiatives should tackle many aspects, such as:

*a)* Providing an intelligible and attractive description of the creative function of scientific knowledge and the impact of scientific and technological advances on growth and well-being in Spain.

*b)* Stimulating scientific interest and scientific knowledge at all educational levels, according to the specific characteristics of each level (in a programme similar to that developed by the American Association for the Advancement of Science, called *Science for all Americans*. AAAS, 1981, 1993).

*c)* Communicating information about the methods and elements that typify scientific research, such as: curiosity and a desire to understand the world, the role of doubt, attention to empirical evidence, uncertainty, risk, perseverance, and critical analysis of the arguments of others, and, more importantly one's own arguments, etc.

It is true that a growing number of Spanish scientists participate in popular science programmes and initiatives. However, they are not usually given incentives or recognition for this work, and levels of organisation and support are low. Research institutions and government departments themselves do not fully appreciate the value of disseminating information about the scientific advances generated within them. A clear and explicit commitment to valuing and encouraging researchers' work in this area has to be made by the scientific community and the scientific institutions with competence in the area of science policy. They should provide specific, professional, and financial incentives to researchers carrying out this task. These incentives must not impinge on the criteria of selection and excellence in communicating scientific knowledge, as the negative effects of shortcomings in this area are well-known. University institutions and research organisations should make more extensive and efficient use of the opportunities information technologies provide to spread scientific information. Such technologies are generally absent, or the content is limited, in these institutions' Web pages and internet portals.

While the task of communication scientific information is on the official agendas of many Spanish scientific societies and academies, in general, sustained and efficient plans are lacking. Some societies composed of professionals and enthusiasts with the common objectives of research, knowledge preservation, and dissemination have attained a notable and active social presence. They illustrate by example the important role that scientific organisations could assume.

Obviously, educational efforts can attain the best results within the formal education system. At the university level, it is essential to dedicate particular attention to generating and maintaining students' interest in research. Judging by some recent studies, the framework of higher education brings students into only limited contact with the research world. This is a matter for concern, as they are thus deprived of one of the strongest incentives for choosing a research career. In addition, this approach does not help to transfer information about the central core of research activity (which is not just its results). This is such an important issue that it is dealt with in a separate point, based on the Fundación BBVA study *Los estudiantes universitarios españoles* (Spanish University students) (Fundación BBVA, 2004).

According to this study, 35% of "second stage" university students considered the possibility of a research career at some time. This percentage dropped to 11% if only those students who actually mentioned research as the career they would most like to pursue after their studies were included.

An important aspect of Spanish university students' perception of science is the image they have of the researcher. This is true of students as a whole, and the subset planning on pursuing a research career. It is interesting to confirm that all university students perceive a career in research as demanding and not financially attractive. They also believe that the authorities do not support researchers. Among the positive aspects is the belief that researchers are increasingly necessary for social and economic development, and that it is a prestigious career (Fig. 1).

The 11% of students who mentioned research as the career they would most like to pursue had the same image of the researcher. However, the difficulties did not seem to affect their choice of profession. The reasons and motives for their choice seemed to be based on other factors, such as their university experience, their general attitude to science, their motives and interests at the beginning of their studies (significantly influenced by their experience during secondary education, family influences, and their "reference group" during that time).

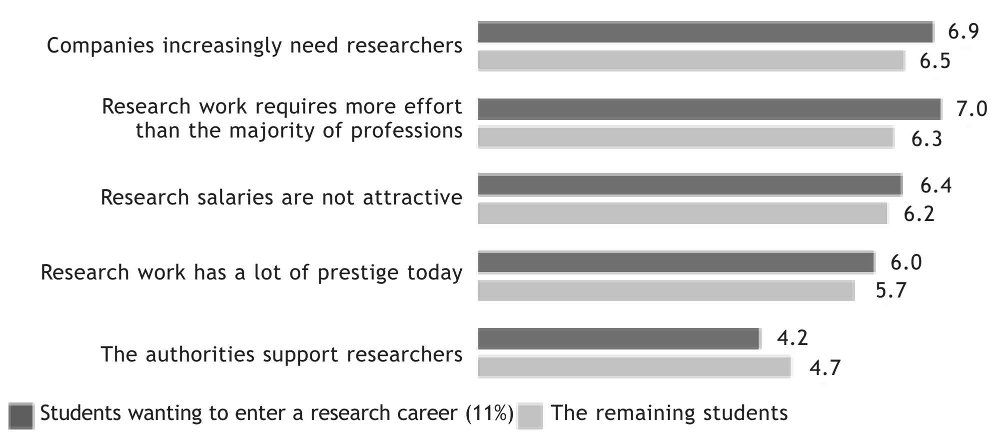



**Figure 1.** Level of agreement with each phrase

*Base:* Total cases (3000) average on a scale of 0 to 10 (0 indicates total disagreement and 10 total agreement)
*Source:* Fundación BBVA

**TABLE 1.** Evaluation of research

| | Want to pursue a research career (11%) | Remaining students |
|---|---|---|
| ***Do you know of any research programmes or projects being carried out in your faculty?*** | | |
| Affirmative response | **46%** | 20% |
| ***Evaluation of research being carried out in your university*** | | |
| Average (on a scale of 1 to 10) | **6.7** | 5.9 |
| Very positive evaluation (scores of 7 to 10) | **57.3** | 36.2 |
| ***Agreement with statements about research in your university (average on a scale of 1 to 10)*** | | |
| Research has nothing to do with me or my studies | 2.6 | **4.5** |
| Professors encourage students to go into research | **4.8** | 4.1 |
| Professors usually talk about their research in class | **4.5** | 3.9 |
| My university offers resources so that students can do research | 4.7 | 4.5 |

*Base:* Total number of cases (3000). *Source:* Fundación BBVA

This study of Spanish university students suggests that university experience has a significant effect on students' expectations of research. Those who wish to go into research when they finish their studies are more familiar with research carried out by their faculty (46% knew about a research project of their faculty). They have a more favourable view of the development of such projects (57% considered that it is very positive). In contrast to those who are not interested in a research career, they more highly value the contact they have with professors on research topics (Table 1).

It is also important to note the perception (shared by students who want to pursue a research career and by most students in general) that lecturers do not encourage research and that there is a lack of university resources for students to carry out research.

An analysis by branch of knowledge shows that students of experimental sciences are clearly differentiated by their greater familiarity, interest, and career orientation towards research. Forty-five percent of experimental science students knew of a particular research programme or project by their facility, compared to 23% of the total university student group. In addition, experimental science students are the most aware of the relation between their studies and research. Students of social sciences and law are the least aware of this link.

Likewise, 67% of experimental science students had at some time considered pursuing a research career, and 35% stated that research was the career they would most like to pursue when they finished their studies. Among the remaining students, this percentage was no higher than 11%.

The segment of students wishing to pursue a career in research after graduating tends to have different plans than the group of university students as a whole. The most notable difference is that those students in the research group planned to complete a doctorate, which they viewed as the "ticket" to enter a professional research (25% compared to 5% in the rest of the student group).

TABLE **2.** Contact with and evaluation of science according to a profile of subject area and professional orientation

| | Scientific area (experimental and health sciences) | | Other areas (humanities, social, legal and technical sciences) | |
|---|---|---|---|---|
| | Want to pursue a research career (5%) | Remaining students (13%) | Want to pursue a research career (6%) | Remaining students (76%) |
| Watches TV programmes on scientific and technological topics | **71** | 54 | 49 | 40 |
| Reads popular science magazines every month | **31** | 17 | 23 1 | 0 |
| Watches videos about scientific and technological subjects | **55** | 41 | 40 | 27 |
| Scientific and technological subjects are frequently and quite often part of their conversations | **60** | 42 | 49 | 27 |
| Has been to a natural science museum in the last 12 months | **49** | 36 | 33 | 27 |
| Interest in scientific subjects (on a scale of 0 to 10) | **8.2** | 7.1 | 7.2 | 6.0 |
| Information on scientific topics (on a scale of 0 to 10) | **6.3** | 5.8 | 5.8 | 5.0 |

*Source*: Fundación BBVA

Moreover, the group who declared their interest in a research career also clearly held more favourable attitudes to science. There are two significant differences between students in terms of those attitudes:

- The first of these is related to *the different fields of study.* Students of experimental and health sciences are the most involved in science. Not surprisingly, they have the most favourable attitudes to science and the most favourable image of scientists.

- The second is related to *professional orientation.* There is a more favourable attitude to science among students who are more interested in academic careers, such as research.

The interaction between the two variables produces the subset of students with the most positive inclinations towards science, i.e. the group of health and experimental science students who intend to pursue a research career. The indicators in Table 2 show that these differences can also be observed in other forms of contact with science and research.

The above results provide evidence of the shortcomings in students' awareness of the research work of lecturers-researchers. Academic institutions should thus find new ways to support and recognise members who stand out due to the special efforts they make in stimulating science and reforming the curriculum. The latter aids in eliminating unimaginative and demotivating teaching methods. The process of adapting Spanish qualifications to the European Higher Education Area began recently, and offers unique opportunities for this reform process. Maximum advantage must be taken of these opportunities, such as collaboration between university teaching staff, CSIC scientists, and other research organisations.

In primary and secondary education, all teaching staff initiatives directed at increasing interest in science and its applications should receive special attention and support from the universities, the CSIC, and scientific organisations. This would help to draw the attention of the corresponding education authorities to the importance of scientific education at these basic levels –an area in which there are currently serious shortfalls. This support would also help to eliminate the difficulties affecting teachers in such areas. The Spanish scientific community has a rich variety of opportunities to contribute, in an effective, structured, and systematic way, to updating and disseminating scientific knowledge and technological advances to primary and secondary school teachers. These opportunities have not been fully exploited to date. In addition, the department responsible for education should stimulate interaction of teaching staff with research professionals through participation in joint research projects. facilitating the inclusion of teaching staff in scientific societies, etc. Direct contact between students and scientists should also be promoted through a variety of methods, such as opportunities for young researchers to offer seminars in secondary education centres. Presenting the history of science and technology at these educational levels could also contribute to transmitting a view of science as a fascinating adventure in search of knowledge. The consequences of science in terms of increasing opportunities for individuals would also be communicated through such presentations.

## The researcher as advisor in public matters

Traditionally, only limited resources have been allocated to scientific research in Spain. This is a symptom of the political and governing classes' lack of interest in this essential component of the country's development and culture. Paradoxically, in an industrially advanced state like Spain, an increasing number of political decisions affecting the country's development are closely linked to scientific and technological issues. On a daily basis, the governing classes are confronted (at the national and European levels) by problems in allocating resources, creating normative frameworks, and devising public policies that directly or indirectly have a strong scientific component. Unlike the majority of European countries, Spain has no official and transparent channels for offering scientific and technological advice to either the government or parliamentary representatives. Examples of such channels are: scientific advisory offices for the presidency, permanent scientific commissions in Parliament and the Senate, and scientific advisors in embassies and international organisations. Spanish political representatives rarely resort to scientific advice, despite the fact that a large community of scientists with a wide range of competencies are accountable to the administration. In an advanced country like Spain such an anomaly must be corrected. The number of channels for managing and applying scientific knowledge should be increased. Channels should be formalised and made transparent (or "institutionalised"). They should not only be available in crisis situations, but also for the daily management of the public's interests.

# Science and society: the role of the media

## Introduction

"For most people, the reality of science is what they read in the press", wrote Dorothy Nelkin. This statement is accurate, particularly if we substitute the media for the press. Once individuals leave school, the media are their main channels for remaining informed about scientific advances and their consequences, particularly in the current context of rapid scientific change. As a result, public decision-makers and the scientific community itself have frequently focussed on the role of the media in communicating science activities and news and, consequently, its role in creating the image society has of science and scientists.

This attitude has led to efforts to promote public communication of science through the media. On occasion, scientists have been encouraged to communicate their work directly or through intermediary journalists. However, these initiatives have tended to ignore the essential characteristics of journalism, leading to results that fall short of the effort undertaken. In particular, an attempt has been made to give, *de facto*, the informative media the role of actors in the science and technology system, whereas their function can be none other than transmitting what occurs in the scientific domain. An extreme example illustrates the requirements of the media's information task: if there is an absence or low level of scientific activity, then there is no information to transmit, or only articles of little content can be written.

Another deception can be found in initiatives and proposals on the media's role in communicating science to society, in which the press, radio, and television have been assigned a direct educational role. Thus, confusion arises between the public media's official communication role– a remnant of their function several decades ago, when they were obliged to broadcast and publish whatever those controlling their funds wanted– and the current situation, in which most of the media is privately owned and competes in the market economy. The media need to attract recipients, i.e. audiences, for their business to work. And since they are not subsidised, they cannot ignore the rule of the market: "your worth is equal to the number of times you reach the public". Furthermore, since their core activity must be compatible with making profits to be distributed among shareholders, they resemble, despite their specific characteristics, any other company. Some publicly owned media (notably in television) can and should have greater liberty, even though they cannot completely ignore the above rule. In other words, the regular presence of some contents, such as science, can be required of them, even when this does not result in gaining television audience share.

In general, regardless of whether media are public or private, one of their roles should be to report on science as they do on any other activity. The information should be put into its social or economic context, and according to the target audience's estimated level of knowledge, it should be popularised and made more accessible.

Two types of news items can be distinguished in Spanish science journalism: current science news from any country (including Spain); and news about the science world, the science and technology system, and science policy in Spain and other countries. Information about the science world varies greatly from one country to another and is a result of each country's social image of science, among other factors.

In recent years, a new area of specialisation has emerged in journalism. It focuses on the environment and ecology, has its own space in some media, and is covered by specialised professionals. Nevertheless, it is closely linked to science journalism.

Current science news comes from many sources, including scientific conferences, scientific journals, and researchers themselves. Such news is treated like information about current affairs, which entails certain conditions, such as immediacy. However, science news also needs to be treated with rigour, which makes it difficult to compile news items with the speed journalistic work requires. The origin of information (in Spain or anywhere else in the world) does not affect the way it is communicated, although recipients are more interested in news that has greater proximity.

Science journalism in Spain has recently been roused from a long period of lethargy, in parallel with events in scientific research. Above all, in Spain, it is now –at the beginning of the twenty-first century– also taking into account other people's advances, creations. and research. Both fields i.e. research and journalism, have to communicate with each other for the benefit of all involved, including recipients of the information. The efforts of researchers and spokespeople in this area should be emphasised. Researchers have created communications offices, and journalists are trying to specialise and to be as rigorous in their coverage as possible. The main printed media have special pages; for example, *El País* dedicates one day a week to publishing scientific information; *El Mundo* has a daily section on science; *ABC* has daily coverage of science news; *Heraldo de Aragón* is a pioneer in this area and recently received an award; *La Vanguardia*, etc. In contrast, despite its importance, television is the medium in which scientific information occupies the most precarious position.

## Problems in scientific communication

The position of scientific information in the Spanish media is on a par with its situation in the country, in terms of effort and scientific level. It lies somewhere between that of the most advanced countries and the least developed. The small size of the Spanish science and technology system, the lack of prominent scientists and authorised spokespeople (resulting from a lack of organisation), the limited social and political influence of scientists, and the absence of a scientific tradition in Spain negatively effect social appreciation of science. Thus, there is little sense, on the public's part, of current scientific research and what it means for society.

However, all existing studies concur in indicating medium to high levels of interest in scientific subjects, far from the existing level of information on such topics. In Spain, as in other countries, there is notable interest in biotechnical and health topics. *Interest in science policy and technology seems to be significantly lower than in other European countries, which is parallel to the limi-*

*ted interest shown by the political class and (with some exceptions) the business world*. As indicated earlier, the low level of scientific knowledge in Spain is accompanied by a favourable evaluation of science and a high level of confidence in the scientific community. There are no strong barriers of beliefs or morals that could slow down scientific research. Nonetheless, knowledge about Spanish scientists and their institutions is extremely low, and most Spaniards cannot even cite the name of a single living Spanish scientist.

In the "Spanish case" a series of specific factors have a negative effect on the relation between science and society. Some of most notable of these include:

- *The Spanish scientific community is small and lacks cohesion. Apart from some exceptions (such as that of young researchers), it is poorly organised and lacks a united voice*. Scientists rarely become involved in public debates. When they do, it is in the context of catastrophic crises (such as the *Prestige* or Doñana disasters) (Nombela, 2004).

- *It is difficult to find researchers willing to make statements about issues that are not entirely scientific but affect society;* i.e. questions that combine science with other issues related to the economy or politics.

- *Debates and controversies rarely arise between scientists; instead they develop between scientists and groups outside of research defending religious beliefs, morals, or social interests.*

- *The principle of excellence is not well-recognised or encouraged.*

- *Scientific information in Spain is not subject to differences in opinion, or to debates or conflicts. These are all essential components of information. The lack of critique is reflected by the observation that the scientific community often provides a sweetened version of information, in which only the successes (real or assumed –a distinction that it is very difficult for non-specialised journalists to make) and assumed positive consequences for society are communicated. There are very few established information channels, pressure groups, or scientists who are well-known outside of their specialised milieu.*

- A very important determining factor in communication is that *most Spanish scientists work in the public system, and have very little influence in companies carrying out research.* Thus, sources of information are distorted and are not countered by sources of information, as is the case in those societies with a greater scientific tradition and higher scientific level. Sources should also be more varied and more open to communication.

- *Another factor that distorts scientific communication in Spain is the fact that a lengthy tradition of science journalism exists only in the Anglo-Saxon world.* This is, in part, a reflection of the US's global scientific leadership. Much of the information about space or biotechnology, to mention just two areas, comes from the US. The Spanish media sometimes take greater notice of a news item because editors have seen it in the Anglo-Saxon media. It has a good headline, excellent photos, and editors know in advance that it will most likely be interesting to readers. The consequence is that a news item previously published in *The New York Times* is communicated more readily than a news item from a Spanish scientific journal.

In addition to these issues, scientific information in Spain has the same problems as in other developed countries. These are reflected in various reports on the subject produced by different countries. The greatest obstacle everywhere is the difficulty the scientific world and journalists have in communicating with each other. However, this is a problem that has diminished considerably in the last few decades. Both scientists and journalists are convinced that the situation could further improve, if a clear framework of collaboration is established in which both sides benefit. The dialogue must be constant and honest. The scientific world has to recognise that the media have their own way of working –which is not going to change– and also that the science cannot be treated any differently than any other field that generates information. This should be accompanied by a media effort to publish or broadcast information that is as rigorous as possible.

The interests behind science news are a growing problem. Any possible conflict in this area is the same as in other informative areas, such as the economy or culture. Identifying these interests and taking the necessary action is a journalistic problem, and does not involve scientists.

The objective should not be to improve the image of science and scientists, but to give people information about topics that directly concern them, increasing their ability to make or influence decisions in the public (with greater knowledge, and therefore greater liberty) and private arenas. Such information enables people to approach the domain of science as they do culture. The final objective of providing more information through the media can be expressed by the following classification, proposed by the astronomer Shen (1975). The first type of *literacy* or scientific information is of a *practical* nature and include scientific knowledge related to health, the environment, work, and consumption. The second type is *civic* and deals with the knowledge needed for public participation in science and technology public policies, in particular those that could causing alarm or lead to controversies. The last is *cultural* and refers to the symbolic nature of humans, who seek knowledge regardless of its short-term practical usefulness. This type of literacy responds to the curiosity that most individuals have. Half way between types 1 and 2 is the communication of *risk,* in which the media exercise an extremely important role, influencing the type and levels of risk perceived by society. For example, issues such as mad cow disease, pollution, and even driving cars have a scientific basis that should be correctly communicated so that society has an adequate perception of the risks.

*The freedom to carry out research in areas susceptible to controversy, such as biomedicine, depends, at least in part, on the existence of an appropriate social and cultural climate.* This is true today in the case of embryonic stem cell research or the use of a preimplantation genetic diagnosis. This diagnostic method is used to select embryos that are free from defective genes that increase the risk of suffering from neurodegenerative diseases. Scientific and technological advances are putting pressure on the ethical criteria, values, and beliefs from the very recent past. The opportunities opened up by genetic manipulation or manipulating matter's atomic structure (nanotechnology) give rise to challenges of great magnitude and importance for all of society, including the scientific community itself. In such matters, a higher level of scientific information is essential, as are ethical criteria and the rational, moral debates of a pluralistic society.

There is another area of interest in the science–society relation: the influence and regulations of governments over the research activities they fund. Governments, in turn, are pressured by groups of people fighting for the inclusion of their concerns or interests in the publicly funded science agenda. Another matter of social relevance, at least for some population segments, is the effect that biomedical research's economic interests could have –and are having– on orienting research towards fields that are not priorities from a scientific perspective, nor are they relevant to improving public health.

There is no simple solution to these problems. They require constant guidance. The effectiveness of any measures should be assessed periodically, as should any undesired effects. In any case, what seems clear is the need to encourage and facilitate an open dialogue between the population, political representatives, business, and the scientific community. This dialogue could take a number of different forms, and address themes central to the science –society relationship:. The net result would be a considerable increase in the amount of scientific information targeted to the general population, and an appreciation of the scientific aspects of many public policies (energy, water, environmental policies, nutrition, communications, etc.).

## Proposals

All agents in the science and technology system should be aware of the importance of keeping society well-informed of their activities through many channels, with a special emphasis on the media. The heads of public institutions should adopt appropriate measures to achieve this aim.

Scientists' main task has been, and will continue to be, to advance the frontiers of knowledge. However, this priority can be made compatible with the task of communicating directly with the public and, more frequently, the media. In any case, it should be the role of specialised professionals or scientific communicators, journalists with scientific training, or scientists with journalistic training who work in communication to communicate scientific information to society. Accordingly, the public system should support training for these communicators.

Bridges need to be laid down, and connections improved, between the scientific community and the media in order to bring about this flow of information, and both groups must play their part in this process.

Ideally, given the current position of scientific information in the mass media, and particularly on television, the scientific community should use contacts, press releases, basic documentation, availability of sources, images, etc., to do at least half the groundwork. Internet tools are now essential to modern means of communication. However, even if a Web page is well-designed and has a rich content, it should be complemented by other channels, all of which would then constitute a communication policy of scientific institutions and organisations targeted at the media.

A corollary of the above is that all scientific institutions need to have scientific communicators, as these professionals are in the best position to transmit scientific results and to explain to non-specialised journalists how scientists work.

The scientific communicators' tasks should also extend to communicating with specialised journalists, and scientific, pharmaceutical, technological, or innovative companies in general. They would also provide information on science policy.

Although scientific information quotas cannot be imposed on the private media, a more receptive attitude to science than the present one could be requested. Authorities could begin a dialogue on this topic with the media. Similarly, the public media should considerably increase the amount of attention paid to science and technology, even if this does not lead, in the short-term, to increases in readers, listeners, or television viewers.

With the universities' agreement, the administration should introduce improvements in scientific education at each stage of university education.

It is important to remember that in the current context, science will have to continue to earn its presence in the media by generating interesting news, being open and transparent to the media, and offering quality up-to-date information.

One way to obtain greater media coverage would undoubtedly be to increase the influence of science in the political arena. Top public officials frequently rely on scientific advisors. However, in general, these advisors are totally unknown to both the scientific community itself and to society. Such experts have the capacity to influence decision-making as well as the transparency of guidelines and advice given to public decision-makers. If they were more visible, the interest of the media and the general population in science policy would increase.

# Science on TV, in publications, and on the internet

## Textual dissemination of knowledge

Advanced societies are currently moving from an information culture to a knowledge culture, with vast and ever-increasing amounts of available information. Channels of communication are sought to enable this information to reach its final destination: the population. These pathways to knowledge are increasingly rapid, which makes any incipient process of cultural adaptation difficult, and hinders the generation of "ordered" access routes to the prospects of information.

As a result of the enormous development that science has undergone in recent decades, a considerable proportion of this information is scientific. Therefore, increasing efforts have to be undertaken to disseminate scientific information, if it is to reach large population segments. However, once this objective is achieved, the problem no longer lies in an excess information supply, and the resulting differences in individual and group preferences. Instead, the main issue becomes the growing difficulty the population has in accessing the information. This is due to the increasingly high threshold of knowledge needed to access introductory, informative, and even educational scientific texts. This extreme situation is well-documented in the first part of this section.

Each society has approached this problem according to its own resources and characteristics. In Spain, shortcomings have accumulated. As a result, levels of knowledge transfer between the science world and society continue to be particularly low, even though Spanish society adopts the different communication channels quite rapidly as they emerge. *However, there are notable shortfalls in the depth and intensity of use of the new communication channels by both recipients and disseminators.*

Regarding the characteristics of dissemination channels, once a cluster of scientific information has obtained the form of contents that can be published or broadcast. its base and organisation are *textual* and it can be expressed in different formats (print, sound, and image) that can be quickly communicated through technological media, from the printed word to TV and the internet.

Communication "products" that are able to transmit scientific and any other information could be organised into the following categories:

*a*) Printed texts: books and publications that are updated with very limited or no periodicity; periodical publications and magazines.
*b*) Digital text: internet portals containing information and documentation; some are updated with periodicity, some not. Web pages can be developed by the system or consist of a replica of the printed edition, in which case it is only a change in format.
c) Oral communication: broadcasting and stage productions based on pre-established scripts.
*d*) Audiovisual communication: audiovisual programmes, TV (news programmes, series, and

dramas) and cinema, in which the script also forms the basis and structure of the contents.

## The relation of science to different communication channels

### *Books and publications*

Science has maintained a clichéd, almost mythical and historical relation with the printed word. Libraries have been science's reservoir for centuries. From its enlightened beginnings to the present, science has essentially been *written science.* The major classic scientific theories have been forged in the written word, expressed on printed paper, and bound. In turn, such theories have been deeply conditioned by this format. If books had had a different form, the major classic scientific theories (Newton and Darwin are paradigms of these) would have had different formulations to those that we now consider to be standards.

Therefore the book is a mature format; it is both highly developed and "tailor made" for science. It is also tailor made for society –or at least for those that have been at the receiving end of scientific advances over the last two centuries.

While the prominence of the book in the current scientific arena is limited in comparison to the volume of science in circulation, it does not lack importance. Books detailing scientific theories continue to be published, and many such books have been written, particularly during the last two decades of the twentieth century –for example by Lovelock, Margulis, Dawkins, Gould, and Kauffman). More recently, there seems to have been a certain resurgence of this genre by unconventional scientists such as Hawkins (*On Intelligence*) and Luca Turin (*The Emperor of Scent*). In these books, the authors provide first-hand accounts of scientific theories in order to spread information and to present it in a way that can be accessed by a wider public. A slight resurgence of popular science books is also taking place. These books are written by authors (scientists and specialised communicators) who are not the creators of the theories they describe. Such books have attained a certain degree of success with the public.

The different kinds of science books described above have at least one characteristic in common: they have all been profoundly influenced by literary norms, both in their form and formulation. The science book has therefore become a crossover of cultural expressions, and a graphic illustration of the existence of a connection between these two forms of expression.

Due to its own cultural nature, the book is usually much longer-lasting than the formats created by new technologies. Thus, the book has become "science to keep", allowing readers to return to it again and again.

### *Magazines*

The magazine is a contemporary format for communication compared to the thousand-year-old tradition of the book. Magazines have brought to published science its well-known characteristics: access, brevity, and the development of a non-literary language, culminating in the "technical report" style of scientific journals. Magazines are, almost by definition, also introduced "multi-authored, but in a very different way than found in encyclopaedias.

Scientific magazines are, to the same extent as books, essentially written science. However, "illustration" (a double-edged word in publishing) acquires a relevance in magazines that it does not have in books. It is the seed of the "viewed science" that has developed in association with advances in representation technologies.

For many reasons, as magazines have flourished and their influence expanded, scientists have largely abandoned directing their writings at society and instead focused them at their colleagues. As a result, many scientific magazines stopped trying to keep the general public among their readers. Scientific journals were founded that have become increasingly prestigious and inaccessible to most of the population –and to some scientists themselves. Such journals have constructed a wall from which science is imparted and thus frequently control what is newsworthy by rationing out advances to the main media organisations. In response to the exclusivity of journals, other magazines have taken over the task of informing wide segments of society about science, with notable success. These have developed from a strictly textual format with simple illustrations (*Scientific American*) to the visually oriented magazine dominated by photographs, computer graphics, and 2D/3D (e.g. *Muy Interesante* in Spain). However, the origin and splendour (both past and present) of both types of magazines resides in the Anglo-Saxon world.

Magazines in the category of "scientific culture", such as those published by some scientific societies and universities, deserve special attention. Their content looks at society from a scientific perspective (either generally or in part). Good examples are: *Revista de Física,* published by the Real Sociedad Española de Física (Spanish Royal Society of Physics); *SEBBM,* published by the Sociedad Española de Bioquímica y Biología Molecular (Spanish Society of Biochemistry and Molecular Biology); and *Quark,* published by the Universidad Pompeu Fabra. By allowing scientists to disseminate science information in the first person, these magazines provide a fertile breeding ground for science professionals' to become science communicators.

Magazines have therefore become a powerful format to which science has adapted perfectly and have in the process become science's "official version".

In Spain, hardly any scientific journals stand out as capable of competing with major international publications. To do so, their content has to be published entirely in English, which contributes to distancing them from a position of cultural proximity to Spanish society. Apart from the notable exceptions mentioned above, popular science magazines have become short-term projects (they arise, shine, and then either disappear or survive), incapable of finding the tone and the accent required by Spanish society.

Due to their periodic nature, magazines are culturally "perishable" and their contents are not normally re-read. Popular science publications use an increasingly journalistic style of writing, while specialised scientific journals have developed a form resembling technical reports, which their bleak lack of literary style.

### ***Internet Portals***

The information structures on the internet, particularly those that have arisen due to the popularisation of the World Wide Web, represent a significant change in format. However, this change is not as radical as it may at first appear. It is true that some of the main characteristics of the internet, such as the interactivity between issuer and recipient and the ease with which anybody can send a message, have made this new medium a revolutionary form of communication. However, this radicalism has not yet been paralleled by a dramatic change in content or format. The page, i.e. a surface area that confines a determined amount of text, continues to be the conceptual unit of the Web. In fact, the main characteristic, in terms of content, is that such digital pages impose functional brevity. Moreover, there is a social factor that acts as a preliminary barrier: the extent of widespread access to the internet.

Since the early days of the internet, science has sought and found its place in the resources of the Web. This has raised its prospects of moving closer to society. Nevertheless, these prospects seen to be taking a long time to be completely fulfilled. Internet portals have a unique, attractive form, and open up interactive opportunities. However, their structure and presentation continue to be too similar to that of printed publications (books, magazines, newspapers), and the discourse and origin of their texts are too closely based on those of publications with traditional formats. As the creators and editors working on the internet become capable of adding new formats to the novelty of contents, and abandon the continuous direct and indirect reference to the printed page, the potential of this new medium will be released and inevitably pervade science.

Considering the immediacy and the interactivity of the internet, it is plausible that we are not far from the day when a scientific theory will initially be expressed on an internet portal, with a formulation that is essentially different from those used to date. Certain structural parallels can be drawn between new formats found on the internet, such as blogs and tags, and the (laboratory and field) notebooks and notes that scientists have used to express their theories first-hand. These new structures could be the source of the first steps in this long-awaited revolution. The prospects of scientific theories constructed in real time on the internet, with the attentive observation and interaction of an infinite number of spectators-followers-collaborators, could bring about a resurgence of the interaction between the scientific community and society. (This would be a new and powerful version of Benjamin Franklin's practice of hanging the proofs of his books in the window of the printer's shop so that passers-by could correct them according to their criteria).

There are many examples of internet portals for science. All large scientific institutions have developed and maintain their own spaces on the internet. However, the most well-known and frequently visited sites tend to be those created by the major scientific journals and popular science magazines. Scientific organisations, hospitals, universities, science academies and societies, companies carrying out research, government departments, foundations, museums, libraries and databases, the media, associations of science enthusiasts in any field, and an increasing number of organisations and individuals are creating –in most cases independently though sometimes in collaboration– a vast space for learning and communicating about science. As stated at the beginning of this section, an emerging problem, multiplied by the development of the internet, is how to move from the previous chronic lack of scientific information to *the overabundance of information and resulting cognitive overload* for individuals. In addition, it is relatively difficult to find a system that can qualify knowledge as valid (that is, validated by peer review, according to the strict formal protocols of printed journals) on the public space of the internet. It is increasingly difficult for the end user to distinguish between *authentic* and spurious, or at least non-validated, knowledge. This is particularly true when information does not come from a publicly and scientifically prestigious and verified source. Thus, it is difficult to ascribe appropriate relevance to the information about specific scientific fields that is available on the internet. (This can have direct, undesired consequences on the end user of the information, particularly in cases such as biomedicine and health care). In Spain, it is essential and urgent to provide *training for society on how to filter scientific information and recognise its validity.* This should be done within the frame of plans for promoting the information society. Such measures would prevent a large population segment from assuming that relevant and verified knowledge means those pages that are presented at the top of a search engine's list. The internet is, without doubt, a space and a group of tools that have unknown potential. Both creators and users of scientific information need to have a good command of it (acquiring a new kind of "*literacy*" or capacity) and use it intensively. Without losing the spontaneity and the degree of freedom that creators and users have had on the Web to date, giving it its shape, it is clear that the education system, government departments, and the scientific community itself should contribute to teach the public how to surf this ocean of information with minimum risk and the greatest benefits.

### *Television*

Television is by far the most widely disseminated media form, with the largest audiences. TV's visual component has generated its own language, which prevails over its textual references (the almost indispensable script). Despite the fact that the content is often far from spectacular or interesting, it is clear that TV is an excellent medium for science communication (not science in its strictest sense, which has not found its place in this medium). Broadcasts classified as "science" programmes often have a report or magazine format. There are a certain number of broadcasts on Spanish television channels that could be labelled as "science" programmes in some way. However, their audience is small and they are usually broadcast at inconvenient times; this feeds back into their lack of viewers. The number of documentary series about the natural world stands out. Many of these are about animal ethology, and most have been made outside of Spain. Clearly, the barriers to entering TV are high, due to the substantial financial resources required.

There are very few landmark science communication TV programmes (two emblematic ones would be the Carl Sagan series and the work of the singular Rodríguez de la Fuente). In its process of specialisation, TV has generated channels whose content is focused on providing quality information (Discovery, NatGeo). Although these channels provide many examples of how science can be communicated on TV, the dissemination of such programmes continues to be limited. One internationally broadcast TV series, *CSI*, should be highlighted. Its plot is based on applying scientific techniques, and the traditional image of a researcher is replaced by an unusual kind of policeman. The series' success in the US has given rise to various franchises, but is producing the disturbing effect of identifying scientists with detectives and scientific activity with the plot of a detective novel. We should stress that the series' internet portal contains abundant scientific material at a level that goes beyond strictly popular science.

After reports, dramas (and hybrids between the two) are the best option TV has found for disseminating scientific information. It is clear that the nature documentaries rely heavily on simulation and preparation. This is probably the key to their success. TV as a vehicle for scientific knowledge has strengths and weaknesses. The written text (the book) is ideal for transmitting/creating abstract thought, whereas television is best at transmitting/creating emotion. It is a poor transmitter of data, due to the fact that an accumulation of data saturates viewers' receptive capacities. As a result, they will either change channel or simply switch off their TVs. In both cases, the attempt at communication is aborted by errors in the approach to and execution of the message (this does not only occur in science programmes, but also in some television treatments of history). Nonetheless, some televised works have managed to transmit highly complex concepts using appropriate language.

An analysis of the most reliable data on the presence of science on television (audience data compiled by Sofres) reveals a relative lack of science content in Spanish TV programming. For example, data for the period 2000–2004 confirmed science's marginal presence in TV programming. In 2004, TVE 1 broadcast 19 hours of science programmes, and a few hours were also broadcast on TVE 2. Together, this represents 0.001% of the total annual broadcast time of each channel (both broadcast 24 hours a day, i.e. 8784 hours/year). These data are far from being complete, and were drawn up using a specific classification of what does and does not constitute science content (e.g. the TVE magazine *Redes* does not appear in the list of science programmes). Therefore, the actual science content may be higher. But even if this leads to a correction factor of 10, the annual percentage would still only be 0.01%, which is modest, and far from the desired level.

If the presence and influence of scientists in "page" formats is limited, in the audiovisual media it is negligible. This has helped to contribute to the "invisibility" in many social sectors of not only science but also scientists.

## Proposals

### *General proposals*

*Actions should be created and supported to maintain interest not only in newsworthy science but also in scientists.*

Periodically focus attention on a scientist and his/her work. This could contribute to "humanising" science and to perceiving the diversity of its contents through the diversity of its protagonists.

Propose a *"scientist of the month (or quarter)"* to the media. Continuously highlighting the importance of the profession through its most distinguished members and their current projects could contribute to increasing society's interest. COSCE should assume the lead in this initiative.

From an institutional perspective, there is a lack of reference bodies (institutes, agencies) with enough prestige and communicational capacity to stimulate the appearance of scientific topics with multimedia material that can be used in the media. These bodies are indispensable during times of crisis (such as the recent case of "ice meteorites"), when society needs a voice that is capable of giving satisfactory responses.

*Scientific institutions that undertake science communication should be strengthened.*

Although there are professionals of unquestionable value on both sides of the science–communication interface, it appears to be necessary to strengthen professionalism in the "transactional space". *To this end, the profile of a profession-*

*al scientific communicator, someone who is integrated in both worlds* and is equipped with more effective tools to avoid scientific reticence and the population's incomprehension, should be increased.

An agency assigned with disseminating science news and capable of providing an overall view of science current affairs in Spain should be created. This agency would integrate and coordinate information from the many university offices, public and private research centres, companies engaged in biomedical research, etc.

*Provide a science news agency that brings together and organises Spanish scientific-technical current affairs.*

Finally, the greatest problem found along the path that leads scientific information from its origins to society does not lie in the creation of products (whether they are printed or in visual or digital formats) but in their dissemination and distribution. Therefore, *the dissemination of scientific information should be taken into account when it comes to appraising, encouraging, or attending to any project or scientific proposal.* Experience shows that wonderful science-communication projects have not reached their destination due to a lack of an appropriate distribution plan (and funding).

## Specific proposals

### *Books*

Intellectual access to science and other information has been seriously jeopardised due to the fact that reading habits and comprehension have seriously deteriorated, particularly among schoolchildren. Recovering and strengthening these capacities should be compatible with the emergence of new media and formats.

An increase in science education is essential if science is to become more important to society and involve greater activity on behalf of the population. Such education should be promoted and structured with the rigour that a conceptual structure like that of science requires. One of the steps to promoting science education is to increase the availability and quality of published products.

The publishing industry in Spain is suffering the same crisis of identity as in the rest of the world. It deserves the attention and resources needed to overcome this situation. There are very few science publishers in Spain. Thus, considering the level of scientific activity, the production of science books is less than desired, and that by Spanish science authors is particularly rare.

Joint-publication agreements concerning science communication and dissemination of works of clear social interest should be drawn up with those institutions that have a direct or indirect interest in science.

*Specifically promote scientific publications through joint-publication agreements.*

In their capacity as social (and also cultural and commercial) objects, books should be made readily available to the public through libraries. However, the presence of science books in libraries is negligible, and those books that are available are often out of date.

*Increase the presence of science books, in particular new titles, in public libraries.*

Commercial access to science books is restricted by the lack of facilities the retail book system offers. Competitiveness for space in bookshops and the rapid stock rotation imposed by distributors of popular books place science books at a serious disadvantage, as they are usually not impulsive purchases and thus require a longer shelf-life.

*There should be a dialogue between the publishing world and bookshops so that science books are treated in a different and favourable way, enabling readers to have better access to them.*

Finally, the culture of science books is linked to the culture of reading, and reading is not sufficiently encouraged in the education system. At present, books are undervalued in schools and rarely take the leading role in the education process. This situation is even worse in the case of science books.

*Fully incorporate science books into the learning experience.*

An undesired consequence of the limited presence of books in schools is that the population's reading comprehension is decreasing. As a result, people lose access to one of the most powerful channels for acquiring information about science. It is important to stop the idea that the computer is a "natural substitute" for books.

#### *Magazines*

The seemingly unstoppable plunge in the status of popular science magazines and the rapidly growing interest in new formulations should be analysed to identify the changes that are occurring in society's perception of science. Such analyses would also indicate whether new forms of popular science magazines are replacing older forms in the public's preferences, or reaching sectors of society that have previously shown no interest in science.

There has been a spectacular increase in the number and quality of illustrations in the new popular science magazines. This seems to indicate that these publications are emphasising visual communication and minimising textual information. While the objective of this approach is to satisfy the population's preferences, it is not clear whether scientific information presented in this way retains the accuracy and completeness obtained from a "textual" format.

As a consequence of trying to mimic "television language", popular science magazines are becoming expensive projects that cannot be financed by the publishing sector alone.

There is a lack of major science magazines in Spain (for both popular science and scientific reflection), whilst they are common in other European countries. It is hard to overcome this shortfall without an enormous increase in the efforts of both private bodies and public institutions.

*Multiple collaborations need to be coordinated to provide Spain with major popular science and scientific culture magazines.*

A careful approach, in which, for example, financial backing is made available to popular science and scientific culture magazines, will help serious projects to be created and to last. This would put an end to the socio-economic and cultural shortfalls caused by the limited presence or complete absence of such magazines in Spain.

#### *Internet portals*

The first and most urgent measure should be to foster and increase internet use by the general population. To achieve this goal, decisive actions need to be taken by all interested parties. There is no need to be creative or original in this task;

Spain can simply adopt measures similar to those implemented in other countries.

As mentioned above, the internet is a medium with enormous potential for communicating science. However, such prospects are affected by the fact that, apart from sites concerning health, science communication portals –in the strict sense of the term– are almost nonexistent and have only marginal influence. If a lack of professionalism can be seen in the traditional means of science communication, it is even more noticeable on the internet. In response, all scientific institutions should engage in social communication initiatives, using both consolidated and emerging formats. The contents of those initiatives should include explanations of research activity carried out in the institutes, presented in a form that is intelligible to the population.

***TV***

Due to the lack of science content in TV programming, it is essential to ensure that each new broadcasting opportunity exploits this medium's potential to the maximum. There is little point in investing resources (public or private) in series or popular science campaigns if the transmitted messages make poor or mistaken use of TV.

"Ghetto" strategy ,infiltration, or both? The following need to be increased to raise the presence of science on TV:

*a)* Communication: already-acquired knowledge; biographies
*b)* Debate: on scientific and moral opinions, such as stem cells
*c)* Information: new scientific ideas, science policy
*d) T*he influence of science in the public imagination: real or fictitious characters
*e)* Science in children's programming

The first three items are related to the treatment or reflection of "reality", as presented in news programmes, reports, magazines, documentaries. TV stations (whose programmes are, by definition, aimed at large audiences) tend to consider that such contents interest only a minority of viewers, and should therefore be relegated to secondary channels and broadcast at times other than prime time. This situation should be improved by aiming to increase the quantity and quality of this kind of science programme. This is the "ghetto" strategy: increase the amount of products for the small audience that already consumes them.

The infiltration strategy involves introducing science contents into non-science genres and formats. Examples of this can be seen in characters from several fictitious series, such as *Siete Vidas, Aquí no hay quien viva, El Comisario,* etc.

The advantage of infiltration is that it helps science to reach a much wider public, as the "carrier" genre has a large audience. The disadvantage is that a greater degree of compromise has to be accepted. In fact, the plots of these series are usually centred on relationships between characters rather than on the professional aspects of their lives. But stressing the latter also entails a compromise, as the activity is made more glamorous than it is in reality.

Including science content in children's' programmes or offering science-oriented programmes during children's viewing times is a clear investment in the future. The practical aspect of science (experiments) enables programmes to be created that, using appropriate language, aim to stimulate children's' interest in the fascination of discovery (e.g. *Beakman's World*, broadcast on some regional channels in Spain). Private channels should be encouraged to broadcast these kinds of programmes, and they should be obligatory for publicly owned channels.

*Promote the strong presence of science programmes during children's' and young peoples' viewing times, particularly on public channels.*

In considering science programmes, the issue of language arises. In any format, it is difficult to adapt scientific language to the language of the media. This is particularly true when the medium is television. However, (more or less pure) fiction seems to be the road to success. The first conclusion is that writers for television should receive enough information to stimulate the inclusion of science in their scripts. A clichéd view is that TV recreates real society. However, "only" police, medics, journalists, and lawyers exist in this TV world. There are no signs of scientists, and scriptwriters do not know how to incorporate them.

To rectify this situation, *a common platform should be created (forums, meetings) where scriptwriters and scientists can work together to improve the science content of* TV *programmes.* This type of platform can also be exploited by scientists and TV news editors.

*Generate fixed platforms where scientists, scriptwriters, and TV news editors can work together.*

Positive examples of this improving the relationship between science and television includes: the recruitment of science editors by officials responsible for those news programmes with the largest TV audience; a report on the science topic of the month, based on a science debate moderated by the science editor.

A negative aspect is the low profile of events in which major science prizes are awarded. News programmes do not seem to have found the tone or the way to make either the award winners or the research that led to the award accessible to the public.

It is clear that the success of audiovisual scientific productions has wide-ranging political and social repercussions, as demonstrated by the aforementioned programme *CSI* and the recent film *The Day After Tomorrow.* This film aroused debate over climate change (despite its being a dramatisation, the film was sufficiently rigorous and well-documented) and contributed to establishing a more sensitive context for climate research.

Public TV should make a decisive, medium-term commitment to increase popular science programmes, even if they are not initially as successful as a programme needs to be to continue being aired. There are many cases in which a programme's culture keeps it on the TV screen.

The advice of consumer motivators should be sought in choosing the science content of programmes. These kinds of actions need to be taken to bring science closer to popular modes of communication.

# Science museums and their role in the relationship between science and society

The number of centres devoted to science communication in Spain is now substantial and currently includes: interactive science museums and centres as well as specialised museums, such as planetariums, aquariums, botanical gardens, and zoos. The definition of a science-communication centre remains controversial; for example, should an institution containing a dolphinarium be included? There are also various examples of joint centres, such as an aquarium/museum (Casa de los Peces) and a planetarium/Imax cinema (Hemisfèric).

The most important development in recent years has been the appearance of new museums and planetariums, including about twenty distributed around Spain. The initiative to create these centres, their funding, and their active maintenance have come from foundations linked to financial institutions (CosmoCaixa, Kutxaespacio de la Ciencia); town councils (Museos Científicos Coruñeses, Planetario de Madrid); regional governments (Planetario de Pamplona, Museo de las Ciencias de Castilla-La Mancha); and consortiums bringing different bodies together (Parque de las Ciencias de Granada). Society's recognition of the financial contribution of these institutions to popularising science is richly deserved. Currently, the number of visitors and people involved in the activities of these museums is over 10 million per year. The number of visitors to the Museo de las Ciencias Príncipe Felipe in Valencia stands out in particular.

In general, the new museums and planetaria present exhibitions and undertake activities that are related to aspects of contemporary science and the social impact of science and technology. Such exhibitions do not necessarily use collection items; instead, they often use exhibition components of a different nature (interactive, audiovisual, computer-based, models, etc.) that are specially designed to demonstrate a phenomenon, explain a concept, or provoke ideas and responses in general.

One of the most notable characteristics of the new museums is the opportunity they offer for interaction. This arises from a concept of exhibition items as educational elements (regardless of whether they are part of the collection or not). The importance of interaction has been emphasised by the popular statement that contains four invitations: "Forbidden not to touch, forbidden not to think, forbidden not to feel, forbidden not to dream".

Traditional science and technology museums have also undergone a transformation, incorporating some interactive elements into their exhibitions. However, it has to be said that both the Museo Nacional de Ciencias Naturales and the Museo Nacional de Ciencia y Tecnología lack the resources required to carry out their educational tasks at the level one would expect from such important institutions, and from the research activity they undertake. The Museo Nacional de

Ciencia y Tecnología de Cataluña is a unique model of an integrated and coordinated network of interesting installations in the field of industrial archaeology.

The new science museums have an extensive social task. They play a key role in improving the public perception of science, contributing to a positive evaluation of science and its technological developments. In addition, they stimulate the population's education about the characteristic activities and abilities of science. They also help people to understand scientific concepts linked to the present day and propose steps for integrating them into culture.

Science museums also play a role in supporting and complementing formal education. They are therefore visited by numerous schoolchildren every year and present aspects of science that differ in content and form from those of educational centres. Such aspects are more closely related to current affairs and interdisciplinarity and are linked to situations involving play, happiness, and freedom of initiative. Other activities, such as science workshops, have a more didactic focus, or are oriented towards specifically teaching certain topics specified in the school curriculum.

Annual meetings of the managers of science centres and planetarium have been held since 1997, to exchange experiences and establish guidelines for collaboration. In the first of these meetings, held in La Coruña, a manifesto was signed (see Bibliography) linking the activity of these centres to the cultural needs of the population that arise from scientific and technical developments.

The atmosphere among Spanish museums is one of a community with common objectives. This has led to the joint production of exhibitions (one that stands out is "Madera del Ayre", which travelled all over Spain and was brought about by collaboration between the Museo Nacional de Ciencias Naturales and the Casa de las Ciencias). It has also resulted in audiovisual planetarium programmes (such as *Vía Láctea* -the Milky Way- that premiered simultaneously in planetariums in Madrid, Pamplona, and La Coruña). There are many other shared projects, including publications, conferences, and general activities.

Science museums not only carry out activities within their facilities, they also frequently present their exhibitions in other non-specialised locations, or even move around in the form of "travelling museums", as did the Fundación La Caixa's *Carpa de la Ciencia* (Science Marquee). Another notable example of this is the portable planetarium, which was a private initiative.

Science museums have taken the lead in carrying out actions such as producing publications with a wide circulation, and holding conferences, debates or exhibitions to inform the public about alarming or worrying social situations related to science and technology (mad cow disease, mobile phone antenna, black tides, human cloning, etc.).

Since 1988, the Museos Científicos Coruñeses have held annual awards for the best science communication work (audiovisuals, books, unpublished texts, journalistic articles). These awards are currently linked to the European Commission's Descartes Prize for Science Communication. Likewise, there are prizes to encourage scientific research among young people, including those directed at secondary education students, such as the "Luis Freire" prize, held annually since 1998.
Science museums have particular importance, as organisers or major participants, in a wide range of initiatives, including science fairs, science days, and similar events. Those held in Madrid (*Madrid por la Ciencia*, Madrid for Science), La Coruña (*Día de la Ciencia en la calle*, Day of science in the

street), Seville, and the Balearic Islands are particularly noteworthy.

We should also highlight museums' concern for the task of public communication of science and technology. Their involvement in this task is demonstrated by the three *Comunicación Social de la Ciencia* congresses that have been held by the Parque de las Ciencias de Granada (1999), the Museo de las Ciencias Príncipe Felipe de Valencia (2001), and the Museos Científicos Coruñeses (2005).

In addition, science museums participate in organising (alone or in collaboration with universities, CSIC institutes, and other bodies) days, courses, and conference cycles. Museum conference halls have become the most appropriate place for meetings between scientists and the general population.

Planetaria are an exceptional tools for teaching concepts related to astronomy and geography. Above all, they make it possible for people of all ages to become enthusiastic about the marvellous spectacle of the night sky, through the learning process. The trend of creating public planetaria should be supported, until there is at least one per regional government.

The development of zoos and aquariums must enable them to combine, in an increasingly effective way, the task of environmental education with a philosophy of respect for living beings and biodiversity conservation.

# A central aspect of the relationship between science and society: women and science

This section outlines some of the issues comprising the complex problem of the professional development of women within the scientific community. European data show that, despite numerous European Commission initiatives to promote gender equality in the area of research and teaching, progress has been very slow. This was also recognised in a recent document (*Women and Science: Excellence and innovation-Gender Equality in Science. European Commission,* SEC 2005: 370). In Spain, the progress of women in education in the last two decades has been spectacular. According to data provided by the *Conferencia de Rectores de Universidades Españolas* (the Conference of Spanish University Rectors) from 71 universities (www.ujaen.es/serv/gerencia/images/webestudio-crue04/index.htm), women make up 53% of enrolled students and 59% of graduates; Seventy-five percent of the students enrolled in health sciences are women, compared with 65% in the humanities, 63% in social sciences and law, 59% in experimental sciences, and 28% in engineering and technical careers. For the first time in Spain, 51% of doctoral theses were defended by women. However, as women move higher up the teacher-researcher career ladder, they become a minority. Only 35% of permanent teaching staff are women, and they only occupy 13% of professorships or 15% of the equivalent rank in the CSIC.

The gender differences seen today are partly due to clearly discriminatory trends that belong to a Spain from earlier times. They are also the result of the interaction of an extensive series of variables from different domains: from "private" life and the distribution of roles and expectations in the family, to the influence of intangible cultural aspects that still exist in Spanish society and institutions. These aspects converge to give priority to men when high levels of responsibility are assigned (in this case, in research and/or teaching).

In addition to the absence of equal opportunities in past decades, one of the main reasons for the near absence of women at high levels of the R+D system is that they have not been given incentives to be group leaders. This socio-cultural condition is not, of course, specific to scientists – it affects all professions. In research, another significant factor applies: there are many more men than women on panels and evaluation committees. The *Asociación de Mujeres Investigadoras y Tecnólogas*, AMIT (Association of Women Researchers and Technologists) has been fighting for measures to be taken to redress this imbalance. Such measures should be carefully considered by the different agents in the Spanish science and technology system.

To tackle a problem of this complexity, the first and most urgent recommendation is to *encourage more reliable and systematic information to be obtained. This can be used to undertake precise* *statistical analyses of the source of the current situation of inequality in the Spanish science and higher education systems*. The availability of standardised quantitative indicators and rigorous statistical analyses should help to identify the different variables that contribute to generating a combined effect of inequality. Variables may be from the past and/or the present; private or public; easily supported or intangible. This information would provide more effective tools for correcting inequalities in a decisive and sustained way. At the same time, analyses would help to avoid the undesired effects of measures that are not based on evidence obtained in accordance with the protocols used in the social sciences.

Some measures, several of which were recommended by AMIT, can be applied before these analyses are undertaken. . Among them is the recent creation of the *Unidad de Mujer y Ciencia*, UMYC (Women and Science Unit), which is dependent on the Ministry of Education and Science. Other measures do not need further analysis, as it is easy to predict that they will have clearly beneficial effects. These include:

1. Create or strengthen mechanisms to harmonise professional, private, and family life, such as flexitime, public social services to look after dependents; tax incentives that promote these mechanisms.
2. Encourage non-sexist education at all educational levels, and raise the awareness of the entire society regarding this issue.
3. Communicate European policies that promote equal opportunities for the sexes in the science and technology system.
4. Urge the different administrations and public organisations to unify their criteria for drawing up itemised gender indicators.
5. Publish and disseminate statistics and indicators annually.

In the Nordic countries in particular, numerous initiatives have been put into practice that facilitate researcher mobility and a return to a scientific career or part-time work after periods of maternity leave. Many of these can be transferred to Spain. They would contribute to stemming the loss of women from the fragile Spanish R+D system, and prevent their serious demotivation, caused by the additional barriers they encounter in seeking a competitive career in research excellence. This is clearly a problem that has a detrimental effect on progress in Spain.

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# ACCIÓN CRECE

**Comisiones de Reflexión y Estudio de la Ciencia en España**
**(Proposal by the Scientific Community to boost Science in Spain)**

# Appendix

The Confederation of Spanish Scientific Societies
(Confederación de Sociedades Científicas de España, COSCE)

# Confederation of Spanish Scientific Societies (COSCE)

Spain's inclusion in the new international structures has brought about changes to society, in response to a future that is bound to the new social reality. A fundamental element of this reality is undoubtedly the role that scientific knowledge and technological development has to play. It is clear that vigorous European civil society must act in this process. In particular, the contribution of the scientific community is an ingredient of undeniable importance.

Social coordination has long been awaited in Spain. To bring about this coordination, the scientific community has to become a consistent and well-integrated interlocutor both for society and for the authorities. The Spanish scientific community is aware of responsibilities it has in building this new future. As a result, it decided to contribute to this collective company through its most representative scientific societies, some of which are already more than a century old. It has done this by encouraging them to join a ***Confederación de Sociedades Científicas de España*** **(Confederation of Spanish Scientific Societies)**. This confederation was the result of different collective initiatives promoted in 2003. It now includes, after the joining of new members in 2004, more than 50 scientific societies.

**COSCE's** aims, which are written in their articles of association, are the following:

– Contribute to scientific and technological development in Spain.
– Act as a qualified and unified interlocutor with civil society and the authorities on issues affecting science.
– Promote the role of science and contribute to its dissemination as an essential and indispensable aspect of culture.

The creation of **COSCE** clearly indicates the maturity of scientists and their capacity to serve. In addition, it shows their desire to assume the responsibility that society demands of them, without renouncing the collective prominence that the future doubtless holds for science.

## First executive board of COSCE

**President:** Joan Guinovart
**Vice-president:** Alfredo Tiemblo
**General secretary:** Pablo Espinet
**Treasurer:** Juan Luis Vázquez

**Members:**
Emilio Muñoz (arts, humanities and social sciences)
José Miguel Rodríguez Espinosa (mathematics, physics and physics technologies, chemistry and chemistry technologies)
Manuel Mas (life sciences and health)
José López-Ruiz (earth sciences, agriculture and the environment)
Manuel Palomar (materials science and technology and information and communication technologies)

**COSCE members (May 2005)**

Asociación Española de Andrología
Asociación Española de Ciencia Política y de la Administración
Asociación Española de Científicos
Asociación Española de Genética Humana
Asociación Española de Historia Económica
Asociación Española de Leguminosas
Asociación Española para el Estudio del Cuaternario
Real Sociedad Española de Física
Real Sociedad Española de Historia Natural
Real Sociedad Española de Química
Real Sociedad Geográfica
Real Sociedad Matemática Española
Sociedad de Biofísica de España
Sociedad de Espectroscopia Aplicada
Sociedad de Estadística e Investigación Operativa
Sociedad Española de Agroingeniería
Sociedad Española de Astronomía
Sociedad Española de Biología Celular
Sociedad Española de Biometría
Sociedad Española de Bioquímica y Biología Molecular
Sociedad Española de Cerámica y Vidrio
Sociedad Española de Ciencias Fisiológicas
Sociedad Española de Ciencias Hortícolas
Sociedad Española de Cultivo In Vitro de Tejidos Vegetales
Sociedad Española de Diabetes
Sociedad Española de Epidemiología
Sociedad Española de Fertilidad
Sociedad Española de Fijación de Nitrógeno
Sociedad Española de Física Médica
Sociedad Española de Fisiología Vegetal
Sociedad Española de Fitopatología
Sociedad Española de Genética
Sociedad Española de Geomorfología (SEG)
Sociedad Española de Inmunología
Sociedad Española de Inteligencia Artificial
Sociedad Española de Malherbología
Sociedad Española de Matemática Aplicada
Sociedad Española de Materiales
Sociedad Española de Microbiología
Sociedad Española de Mineralogía
Sociedad Española de Neurociencia
Sociedad Española de Óptica
Sociedad Española de Paleontología
Sociedad Española de Protección Radiológica
Sociedad Española de Psicofisiología
Sociedad Española de Psicología Experimental
Sociedad Española de Virología
Sociedad Española para el Fomento de la Investigación en Materiales e Ingeniería de la Fabricación
Sociedad Española para el Procesamiento del Lenguaje Natural
Sociedad Geológica de España