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Human resources in research

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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 techno-

logical 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

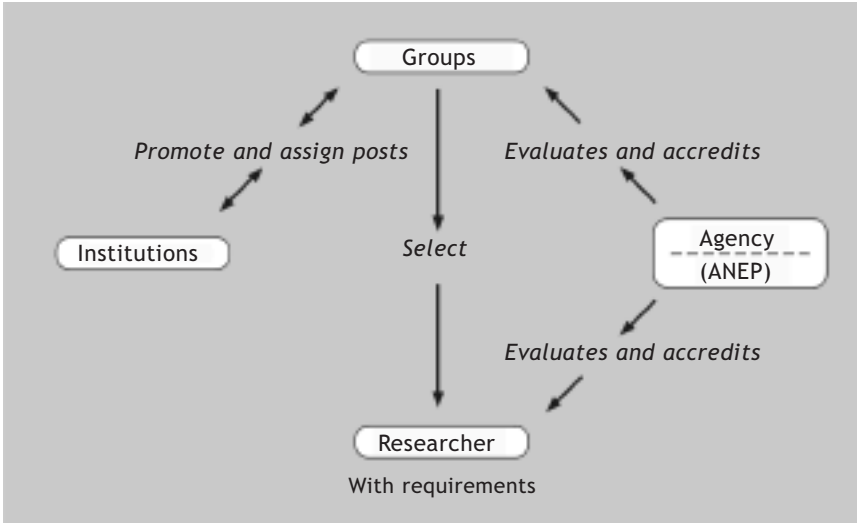

Figure 1 A diagram representing the mechanisms for promoting and evaluating centres and (permanent or associate) researchers

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.

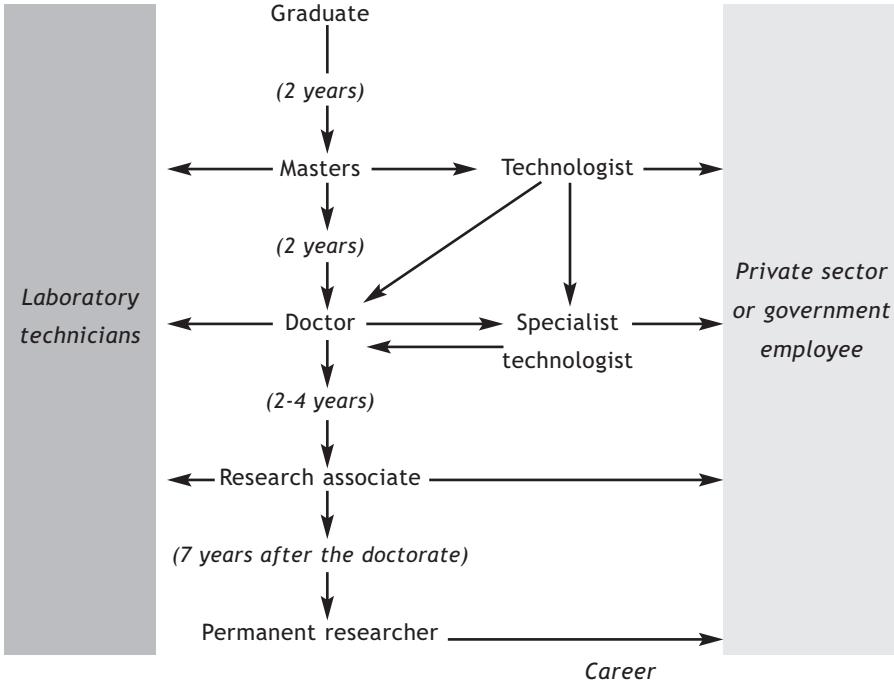

Figure 2. A diagram representing the proposed career structure in research, and the way this is linked to the technological research career in the private sector

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.

Bibliography

"Increasing Human Resources for Science and Technology in Europe". April 2004. EC Conference: Europe Needs More Scientists, Brussels, April 2.

C. Martín, F. J. Velázquez, I Sanz, J Crespo, F.J. Perales y J Turrión: "Capital humano y bienestar económico. La necesaria apuesta de España por la educación de calidad", *Revista del Ministerio de Trabajo y Asuntos Sociales* 2000; 36: 190-192.

V. Demonte: "Trayectoria profesional en investigación biomédica", *Boletín SEBBM* 2004; 142: 14-18. (Extract from the closing ceremony of the Encuentro Trayectoria profesional en investigación biomédica, organised by FECYT. Madrid, November 23, 2004.)

A. Lafuente: "Nuevas orientaciones de la política científica y Tecnológica", Fundación Alternativas. Working paper 5/2003.

V.E. Larraga de Vera: "La pérdida de talentos científicos en España", Fundación Alternativas. Working paper 22/2003.

"Carrera investigadora en España: Deficiencias y propuestas", Comisión carrera investigadora. Federación de Jóvenes Investigadores-FJI/Precarios. March 2004.

"La situación de los Investigadores en Fase Inicial: un estudio comparativo con respecto a Europa", Federación de Jóvenes Investigadores. Comisión de Documentación. June 2003.

J. Zamora Bonilla: *¿Hay una "crisis de vocaciones" científicotécnicas? El tránsito de la enseñanza secundaria a la universidad,* Statistical study, FECYT, October 2004.