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Frontier Research: The European Challenge

High-Level Expert Group Report

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Frontier Research: The European Challenge

High-Level Expert Group Report

This report has been produced thanks to the efforts of the High-Level Expert Group on 'Maximising the wider benefits of competitive basic research funding at European level'.

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Preface

Over the past two years, the idea of a European Research Council, widely regarded within the scientific community as a necessary component of the European Research Area, has become a serious political prospect. The European Commission has strongly supported this initiative and is committed to making it a reality. I am pleased that there is a strong and growing commitment to this exciting project on the part of the public authorities as well as the research community, throughout the European Union.

The ERC provides a means to further improve the quality and impact of European research, with long-term benefits for the competitiveness of our economies and our well-being. It will reinforce the contribution of science and engineering to the achievement of the Lisbon objectives and will make a vital contribution to Europe's quest to master the research and technologies on which our future will depend. Complementing the existing EU research framework programmes, the ERC will provide a distinctive funding mechanism devoted to scientific excellence: it is anticipated that most of the proposals received by ERC will be put forward by researchers on their own initiative, focusing on scientific opportunities they themselves have identified.

This report gives us the opportunity to understand more clearly how European competitive funding of investigator-driven frontier research will generate scientific and economic added value, and how the benefits of such a scheme can best be achieved. As such, it provides a valuable contribution to the debate on European research policy in the lead-up to the Seventh Framework Programme, and I commend it to all those with an interest in these important matters across the EU and beyond.

Janez Potočnik

European Commissioner for Science and Research

Foreword

In 2004 the European Commission proposed that future EU research funding programmes should include a mechanism to stimulate excellence in basic research through competition between individual researchers, and between research teams, at a European scale.

In mid-2004 the Commission set up a high-level expert group (HLEG) with the brief to carry out an assessment of the potential benefits that could accrue to Europe if such a pan-European 'basic research'[2] funding scheme were to become a reality. More specifically, the group's task was "to provide, by collecting and analysing existing data, a clear indication of the types of effects and benefits that may be expected, and their scientific and economic significance"[3].

The HLEG has taken as its starting point the essential concept of a free-standing European Research Council (ERC) that governs and administers funds as part of the overall budget for Framework Programme 7 (FP7), along the lines proposed in the Mayor report (ERCEG, 2003). The HLEG has assumed the existence of such a basic research fund and institution, and concentrated on assessing the potential effects and benefits that are likely to arise from creating an ERC of the form proposed.

Further development of the ERC concept, as well as exploration of options regarding its design and functions, were, however, beyond the remit of the HLEG.

The HLEG met four times in Brussels between September and December 2004 as well as communicating extensively by phone and electronically. Our report is based on intensive group discussions at these meetings, which were facilitated by targeted written individual contributions provided by HLEG members.

The HLEG has produced a substantial report, attempting to provide a detailed and authoritative analysis of the issues involved. This is likely to be of interest to advisors of policy-makers and those preparing political decisions as well as the wider research community. The report also contains an executive summary for key decision-makers and others who, while interested in the subject, have only time to digest a short summary of the main issues and conclusions.

The HLEG would like to express its thanks to the many people who assisted its deliberations and discussions, in particular Pete Mackey for his very substantial editorial contribution. The group is also grateful to European Commission DG RTD staff and a number of independent reviewers for comments received on a draft version of this report.

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2) In the main report, we explain why the term 'frontier research' is more appropriate than the conventional 'basic research', but we use the latter here until we have defined exactly what we mean by 'frontier research'.

3) Hence, it was not the task of the group to set out the basic parameters of an ERC (this has, in any case, already been done by others), nor to consider the details of how an ERC should be structured and how it should operate.

Executive Summary

'Frontier Research: The European Challenge' presents the conclusions of a high-level expert group (HLEG) convened by the European Commission to examine the benefits of creating a new European-level funding mechanism to support the very best research carried out at the frontiers of knowledge.

The report takes as its starting point the concept of a European Research Council (ERC), which would govern and administer funds for such research as part of the overall budget of the Seventh Framework Programme. The arguments presented in the report are supported by extensive references to published studies and data.

Up to now, the case for establishing an ERC has been couched in terms of the need to create a pan-European competition to support the best 'basic research'. However, classical distinctions between 'basic' and 'applied' research have lost much of their relevance at a time when emerging areas of science and technology often embrace substantial elements of both. The report therefore adopts the term frontier research, rather than basic research, to reflect this new reality. Frontier research, because it is at the forefront of creating new knowledge, is an intrinsically risky endeavour that involves the pursuit of questions without regard for established disciplinary boundaries or national borders.

A unique historic opportunity

Limited progress to date in moving towards the Lisbon and Barcelona targets points to the need for substantial improvements in the way Europe manages its research base. Frontier research of the highest quality has a critical role to play, but research funding in this area has until now been largely the province of initiatives at the national level.

An ERC would provide the pan-European mechanism necessary to selectively encourage and support the truly creative individuals – scientists, engineers and other researchers – who, driven by curiosity and a thirst for knowledge, are most likely to make the unpredictable and spectacular discoveries that can change the course of human understanding, as well as perhaps helping to solve some of mankind's most enduring problems.

The accelerating pace of technological advance, the recent enlargement of the EU, the implementation of the European Research Area and the imminent

definition of the Seventh EU Research Framework Programme (FP7) together create a unique opportunity for decisive action with regard to fostering excellent frontier research in Europe.

Meeting the challenges

A number of challenges now facing Europe make the proposal to create an ERC both timely and necessary.

- ***Reinforcing excellence, especially in new, fast-growing research areas.*** Europe does not perform particularly well in terms of truly outstanding research, nor is it mastering sufficiently quickly the new fast growing fields in which science and technology are often closely interlinked. It needs a new funding mechanism such as the ERC that encourages, facilitates and selects more adventurous research, drawing upon the full continental pool of creative researchers.
- ***Staying ahead in a world of growing scientific and technological competition.*** While Europe wrestles with the task of catching up with its traditional competitors, it may face the danger of being overtaken by fast-developing Asian countries. Special attention must therefore be given in European policy to areas such as frontier research and mechanisms such as the ERC where Europe can exploit some of its potential comparative advantages.
- ***Linking science to technological innovation.*** Europe's relative slowness in entering and exploiting new fields of technology closely linked to scientific knowledge has adverse consequences for its ability to generate innovations. A new organisation like the ERC is needed to fund the best frontier research in emerging, fast-growing areas, and thereby to help strengthen European competitiveness in relation to technological innovation.
- ***Competing for talent.*** Success in frontier research as well as in exploiting new scientific knowledge depends increasingly on the efforts of a relatively small number of truly outstanding research leaders. Europe needs a new institutional mechanism to make it more attractive to such individuals (irrespective of their country of origin), providing them with the resources

needed to develop their full research potential, and helping to retain them within Europe.

- ***Encouraging greater investment.*** Europe lags well behind the USA in funding research. To reach the R&D investment targets set by the Barcelona European Council meeting in 2002, national governments and European institutions must both make additional efforts. A pan-European approach for investing in high-quality frontier research through a new ERC is one response to this need and, with other complementary measures, can make Europe more attractive to companies deciding where, and how much, to invest in R&D.

The European added value of an ERC

The ERC, by funding research through a European-wide competition on the basis of scientific excellence, will provide added value above and beyond what can be achieved at the national level, either individually or in combination. It offers arguably the single most important means to remedy Europe's current weakness in high-quality research and in new, fast-developing areas. The main benefits of the ERC include the following:

- ***Encouraging and supporting the finest talent:*** Open and direct competition and better selection at the pan-European level will heighten the aspirations and achievements of European researchers across the full range of research areas, enabling the best talents and ideas to be reliably recognised from a larger pool, and thus raising the overall level of excellence in frontier research across Europe.
- ***Selectivity, agility and focus:*** An appropriately designed ERC will be able to support the best ideas in frontier research, and focus resources selectively on excellent research. Its highly competitive funding will channel funds into new and highly promising research areas, and will capitalise on the diversity of European research talent with a speed, agility and focus not always possible within some national funding systems.
- ***Status and visibility for research leaders:*** The ERC can confer status and visibility on European frontier research and specifically on the best researchers and their teams, attracting talent and creativity to Europe. Through their links

with higher education and their role in training other researchers working at the frontier of knowledge, they will have a strong multiplier effect across the research system.

- ***Dynamic structural effects on the European research system:*** The ERC can catalyse the adaptation of national research structures to the evolving European Research Area, thereby creating a more coherent and effective European research system capable of matching the best in the world. Higher quality peer review, the establishment of international benchmarks of success, and the provision of reliable, up-to-date information on who is succeeding and why, will help individual countries to maximise their research performance, and enable universities and other research institutions to develop better strategies and to establish themselves as more effective global players.
- ***Economic benefits:*** The availability of new knowledge and the expanded, higher-quality and more visible pool of talented researchers funded by the ERC can help to nurture science-based industry, to attract and retain more R&D-intensive firms in Europe, and to create a greater impetus for the establishment of research-based spin-offs.
- ***Societal benefits:*** Excellent frontier research in all disciplines is a necessity to address the complex societal challenges faced by Europe. The ERC can provide the opportunity to invest quickly in the knowledge base necessary to tackle the new and emerging issues confronting society.

Maximising the benefits

The decision to establish the ERC represents a bold initiative, but it needs to be clearly differentiated from existing national activities. The ERC must be positioned within the European Research Area so that it is both a powerful instrument in itself but also acts as a part of a cohesive well-functioning system. This should then ensure that the ERC and the national research-funding instruments add value to one another. In particular, the national agencies, in their role of supporting the development of national research capabilities, will need to work with their respective research communities to help them in developing high-quality research proposals for submission to the ERC.

The success of the ERC will depend on a clear definition of its strategic mission and on firm political commitment to ensure its autonomy and adequate resources to attain its goals. Member States also need to recognise the complementary nature of European and national research funding, and to reject any short-sighted temptation to regard ERC funding as a reason for cutting back on national research funding. This would deny them the opportunity to develop up-and-coming researchers to the level where they can compete successfully at the European level for ERC funds.

With visible and substantial support at both European and national levels for sustaining its operation over the longer term, the ERC will thus provide Europe with the world-leading capabilities in frontier research that it needs to confront the challenges of the 21st century.

Chapter 1: An Historic Challenge

1.1 The Proposal for an ERC

High-quality research has come to be seen as vital to the realisation of the dynamic and competitive knowledge-based European society envisaged in the Lisbon European Council strategy of March 2000. The accelerating pace of technological advance associated with the transition to a knowledge-based society, the recent enlargement of the EU and the imminent definition of the Seventh RTD Framework Programme have all contributed to an intensification of the political, financial and administrative debates on future research policies in the European Union including action by the Commission.

It is also recognised that in the drive to improve its competitiveness, Europe is confronted not only by increasingly rapid technological change, but also by growing competition on a global scale and by the ageing of the European population. Given that Europe has tended to lag behind the USA in key fast-growing areas of research (as we shall show later), and given the limited progress to date in moving towards the Lisbon targets[4] and the R&D investment targets set by the Barcelona European Council meeting in 2002, policy-makers at national and European levels have become more open to the need for substantial improvements in the way Europe manages its research base in both institutional and financial terms. It is recognised that unless Europe makes a commitment to basic research of the highest-quality standards, it risks

- losing part of its heritage and identity;
- becoming a continent of imitators rather than innovators;
- losing out economically, as well as politically, in a globalising world; and
- giving up on the aspiration of developing its own vision of a desirable future for humanity and maintaining the capacity to shape it.

Consensus has emerged that the most appropriate response to these challenges is to increase the capacity of Europe to create, absorb, diffuse and exploit scientific and technical knowledge, and that, to this end, education, research and innovation should be placed much higher on the European policy agenda. The Lisbon declaration expressed the formal commitment of all EU Member States to move in this direction. The progressive creation of the European Research Area (ERA) represents an important step forward by establishing a shared commitment to this aim.

It has also become increasingly accepted that Europe would benefit tremendously from a new mechanism to fund basic research.[5] This mechanism, which would be run by a new and relatively autonomous European Research Council, would operate an EU-wide competitive procedure in which the sole criterion in determining which research proposals to fund would be scientific excellence.

The Commission's report on *Europe and basic research*[6] highlights the "need to introduce a European level support mechanism for individual teams' research projects". The Spring 2004 European Council of Heads of State, in their annual review of progress in the Lisbon agenda, and later the informal Competition Council, welcomed this suggestion to create a mechanism to support basic research at the European level.[7] Over the last two years, reports from various groups[8] and articles by a number of prominent individuals[9] have all argued the need to create an ERC. A mechanism such as the ERC is seen as an important building block both for the ERA and for an emerging European Innovation System, which Europe needs in order to reinforce its position as a knowledge-based economy.

This report presents the conclusions of a high-level expert group (HLEG) convened by the European Commission to consider the benefits that would arise from establishing an ERC that would support the best investigator-driven basic research on a pan-European scale.

4) As recently emphasised by the High Level Group chaired by Wim Kok ("Kok report", European Commission, 2004e).

5) As we stress later, a range of other initiatives is also needed if Europe is to succeed in becoming more creative and innovative – the ERC provides only part of the solution.

6) European Commission, 2004a.

7) http://europa.eu.int/european_council/websites/index_en.htm

8) e.g. ERCEG, 2003; ESF, 2003a; ELSF, 2003; EUROHORCs, 2004.

9) e.g. One of the first to call for the creation of an ERC was Keith Pavitt (2000). More recent examples include Nedeva et al. (2003) and May (2004).

In the following chapters, this report presents the main underlying reasons for the importance of the research the ERC would support, analyses the potential benefits of an ERC, identifies the challenges faced by the EU in achieving a much stronger position in relation to basic (or frontier) research, and suggests how an ERC can help overcome at least some of those challenges. (Where the creation of an ERC may also bring about certain 'risks' in the form of possible adverse consequences, the report discusses the likely magnitude of those risks compared with the potential benefits from an ERC as well as suggesting ways in which those risks may be minimised.)

1.2 Frontier Research

In framing its recommendations, the HLEG notes that classical distinctions between basic and applied research have lost much of their relevance at a time when many emerging areas of science and technology (e.g. biotechnology, ICT, materials and nanotechnology, and cognitive sciences) often embrace substantial elements of both. We therefore prefer to use the term *frontier research to* basic research to reflect the following characteristics:

- Frontier research stands at the forefront of creating new knowledge and developing new understanding. Those involved are responsible for fundamental discoveries and advances in theoretical and empirical understanding, and even achieving the occasional revolutionary breakthrough that completely changes our knowledge of the world.
- Frontier research is an intrinsically risky endeavour. In the new and most exciting research areas, the approach or trajectory that may prove most fruitful for developing the field is often not clear. Researchers must be bold and take risks. Indeed, only researchers[10] are generally in a position to identify the opportunities of greatest promise. The task of funding agencies is confined to supporting the best researchers with the most exciting ideas, rather than trying to identify priorities.
- The traditional distinction between 'basic' and 'applied' research implies that research can be either one or the other but not both. With frontier research[11] researchers may well be concerned with *both* new knowledge about the world *and* with generating potentially useful knowledge at the same time.[12] Therefore, there is a much closer and more intimate connection between the resulting science and technology, with few of the barriers that arise when basic research and applied research are carried out separately.
- Frontier research pursues questions irrespective of established disciplinary boundaries. It may well involve multi-, inter- or trans-disciplinary research[13] that brings together researchers from different disciplinary backgrounds, with different theoretical and conceptual approaches, techniques, methodologies and instrumentation, perhaps even different goals and motivations.

Because a range of knowledge and skills is required for frontier research, it often cannot be found within single nations, especially smaller ones. Member States of the EU may have well-established national funding mechanisms for supporting basic researchers within their own countries. But Europe lacks a pan-European mechanism for encouraging and funding the best researchers in whichever country they may be found.

As we argue below, by providing such a mechanism, the ERC will generate benefits that cannot be achieved through other means. This action at European level will add value beyond and in combination with national and EU actions, including generating or contributing to the following benefits:

10) This includes (frontier) researchers working in industry as well as those in universities and public research organisations. (There have been several examples of Nobel Prizes awarded to researchers employed in company research laboratories.)

11) As with the concept of 'Pasteur's quadrant' developed by Donald Stokes (Stokes, 1997).

12) This is not, however, to imply that the ERC should fund large volumes of (solely) applied research; only research that meets the other criteria for 'frontier research' (in particular, research that promises a fundamental advance in knowledge or understanding) would be eligible for ERC support.

13) In what follows, we normally use the single term 'multidisciplinary research' rather than the cumbersome (but more precise) 'multi-, inter- or trans-disciplinary research'.

- The ERC can cover the full extent of research not only in science but also the social and human sciences[14].
- As a completely new funding agency, it can, in principle at least, be designed to offer a speed of response not always possible with existing funding agencies.
- Once it develops a reputation for attracting and funding outstanding research proposals, it will confer status and visibility on European frontier research and specifically on the best individuals and their teams, which in turn will help to draw talent to Europe (and to retain it), thereby enhancing creativity.
- With its international visibility, it can better leverage the interest that companies (often the leading ones in their respective industrial sectors) have in accessing frontier research as a means of renewing their products and processes proactively, as well as developing entirely new industries for the future.
- It can help to identify emerging priorities and to channel resources into new research areas (on a larger scale than is possible in most Member States), at the same time capitalising to a far greater extent than previously on the tremendous diversity to be found in European research (something that only a pan-EU institution can do) as well as overcoming some of the limits faced by national funding systems.

In short, the ERC will directly support the aims of the European Research Area, complementing the traditional goals of the Framework Programme while operating in a completely different manner. It will help enable Europe to make the best of its considerable potential for frontier research, adding a crucial missing piece in the construction of the ERA and in turn contributing to the development of a stronger and more effective European Innovation System.

14) Here and elsewhere in the report, the term 'science' is normally used in the broader continental sense of (all) organised knowledge including that in social sciences and humanities, rather than the narrower Anglo-Saxon conception of science (i.e. restricted to mathematical, physical, chemical, biological, environmental and medical science). Likewise, the term 'science' should also be taken to include 'engineering'.

Chapter 2: The European Research System

2.1 Strengths

As we noted in Chapter 1, a number of factors currently combine to offer Europe an unprecedented historical opportunity to take decisive action to support frontier research and to reap the resulting benefits. These factors include the accelerating pace of technological advance, the recent enlargement of the EU, and the imminent definition of the Seventh RTD Framework. In addition, successive EU Framework Programmes and other initiatives such as EUREKA and COST provide an invaluable foundation in terms of support for international research collaboration in areas judged to be of strategic importance and potential market relevance to the EU as a whole.

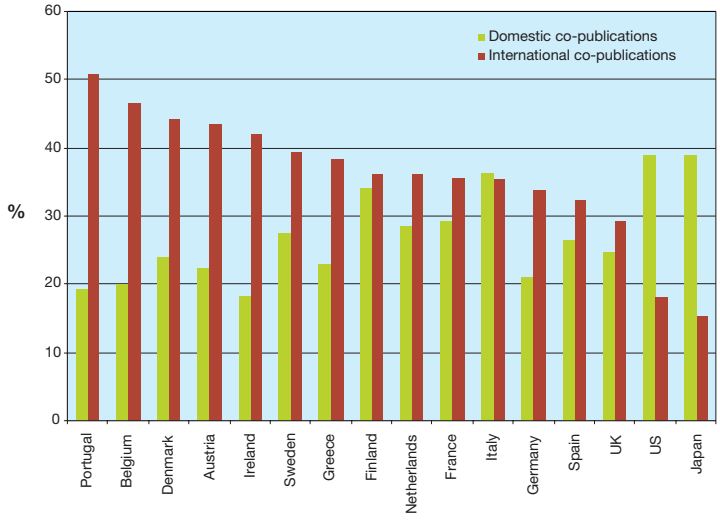
The Framework Programme in particular provides the EU with the opportunity to develop a strategically balanced package of funding for research at the European level: It also contains funding instruments concerned with research capacity-building (such as mobility programmes). In the current Sixth Framework Programme, the Marie Curie award scheme, the FET (Future Emerging Technologies) and the NEST (New and Emerging Science and Technologies) programmes, along with the 'Networks of Excellence' and 'Integrated Projects', offer evidence that the Member States and the Commission are making significant efforts at a European level to improve capabilities in terms of scientific knowledge creation.

Certain other initiatives aim at responding to the challenges that have resulted from a lack of critical mass and the limited scope of what are still relatively distinct national research markets in Europe. For example, the European Science Foundation runs the EUROCORES programme, a research scheme combining national and European financial resources to support European scientists in addressing major research challenges.

Many excellent national and regional schemes fund a wide range of research activities, again primarily within a national context. Other formal and informal alliances promote cross-border cooperation.

Also important is the fact that European countries are significantly stronger than the USA and Japan in terms of international collaboration. This can be seen by looking at data on the relative numbers of nationally and internationally co-authored scientific publications. While Figure 1 undoubtedly reflects to some extent the relative size of the countries (on average, smaller countries engage in a higher proportion of international collaboration), the more extensive practice of international partnerships among European scientific institutions would seem to give Europe a specific

Figure 1: International and domestic co-publications as shares of total publications, 1995-1999, by country



Source: Third European Report on Science & Technology Indicators, European Commission (2003).

asset.[15] It represents another excellent building block for strengthening Europe's position in relation to frontier research.

Benefiting from this context, an ERC will provide the pan-European mechanism required to direct funding at the relatively small number of truly creative individuals that can change the course of humans understanding and perhaps help to solve enduring problems. It offers a unique possibility to exploit and combine what is best in 25 national research traditions that together offer a unique range of diversity in a relatively compact region.

Indeed, the ERC must take advantage of that diversity of research cultures and traditions and the contributions they can make to establishing a more creative research environment. Its research grants can offer support to individual research teams from one European country or from several countries – or, equally, to a single outstanding individual from any European country.

Such a new component of research funding would provide a healthy complement to established funding mechanisms at the national (and regional) level. Within a multi-component system, one is more likely to select the highest-quality research and to encourage talented researchers to submit exciting proposals. As a completely new institution, the ERC would also offer an opportunity to overcome any procedural or cultural impediments within existing funding organisations (e.g. internal barriers due to the dominant positions held by senior researchers in a particular national scientific community; difficulties encountered by young researchers in trying to gain access to funds; inappropriate culture and traditions holding back creative research), as well as providing another competitive source of funding to advance European research.[16]

By stimulating competition for frontier research funding, the ERC can help to drive up the levels of excellence and provide opportunities for the best projects, the best researchers and the best teams across the entire European research sector (including the social sciences and humanities)[17]. In this way, the ERC can exploit the wide-ranging diversity of research approaches present in Europe, in particular responding to the needs of new sciences nurtured by this diversity. It can thus act as a powerful source of what might be termed 'intellectual venture capital' for Europe.

2.2 Frontier Research in the European Research System

Although there is an established tradition of international cooperation at the European level, many of the current schemes (e.g. EUREKA and the Framework Programmes) favour more application-oriented research activities or at least research falling within identified thematic areas linked to existing societal or industrial demands. Most of the existing pan-European research-funding mechanisms are not designed for supporting creative basic or frontier research. Moreover, even where EU support is available for more basic research (as in COST as well as in parts of the current Framework Programme), a requirement prevails for international collaboration between several institutions in several countries regardless of whether this is appropriate for generating the highest-quality research.

Furthermore, research-funding mechanisms at the national level mainly have formal, statutory obligations to focus funding on national teams, and they often cannot fund research across borders. Even though there has been a growing recognition of the importance of networking, reflected in mechanisms such as ERA-

15) However, a certain amount of caution is needed in comparing European countries with the whole of the USA. If one were instead to compare the level of scientific collaboration between Member States in Europe with that between states in the USA, the latter may well be considerably higher.

16) It should be stressed that these are **potential** *benefits of a new organisation. Some cynics may doubt whether an ERC funded from the Framework Programme can escape the problems (such as political pressures for* 'juste retour' *or bureaucratic financial rules) that have bedevilled EU research initiatives up to now. These potential benefits are only likely to be achieved if the ERC has institutional autonomy, and is therefore able to operate in a completely new way on the basis of competitive peer review alone and using the sole criterion of scientific excellence.*

17) See footnote 14 on page 19.

NET, such an approach can only be piecemeal at the moment. National funding agencies generally have different (or additional) functions than an ERC, in particular with regard to building research capacity in identified areas and responding to specific national policy challenges.

The existing European research system, as presently configured, does not always provide an appropriate level of funding for research areas that may well have a high importance at the European (or global) level, but which, for one reason or another, have lower priority at the national level. In many cases, this situation may reflect a lack of critical mass to run major projects of high quality in such research areas, since the number of centres of excellence within given fields in a single country is inevitably limited. (Projects involving the coordination of research partners from two countries each with support from their respective funding agencies tend to be the exception rather than the rule, at least in the larger Member States.) An ERC, involving competition for funds at the European level, will help to bring together the critical mass of researchers needed for outstanding frontier research projects, even in areas accorded lower priority by national funding agencies in countries that lack the necessary critical mass.

Nevertheless, it would be a serious mistake to regard the ERC as merely a means of filling certain gaps in which national and European research funding schemes do not currently operate. Such a limited approach would not allow the full benefits of the ERC to be realised for at least two reasons:

- First, the actions of national organisations are themselves diverse in terms of types of funding and instruments, and it is this diversity on which an ERC will build and from which it can offer its benefits.
- Second, policy makers are alert to developments elsewhere and quickly learn from their counterparts around the world. Consequently, it would be difficult if not impossible to identify a niche for the ERC that does not in some way overlap with some other existing activity. (Indeed, if this were possible, it might well indicate that the niche in question was unlikely to prove especially productive.)

The key point to stress, however, is that national research funding systems inevitably focus their attention primarily on their own domestic research communities. The continued national segmentation of the great bulk of funding for frontier research sustains institutional fragmentation, and is holding back the development of an open European labour market for leading researchers. This segmentation may also considerably lessen the global impact of the frontier research carried out at present within European countries, certainly as such research might compare with that generated by EU-wide competition for funding of the best research. More than that, it is frequently almost impossible to support the appropriate balance between existing research fields (and researchers) and newly emerging ones at the national level. Virtually no country can claim that it is able to fund all its excellent researchers and their ideas, particularly those who, in order to achieve their full potential, need to collaborate with one or more leading researchers in another country.

A pan-European organisation such as the ERC will be able to fund research that some national governments at least find it difficult to support – either because it is too risky or too intrinsically international in nature, or it is not seen as a priority at the national level, or alternatively because of the need to adopt several complementary approaches. Likewise, because it can draw upon the resources to be found in what might be called a much larger 'research market', the ERC should be able to channel funds more quickly into new fast-moving research areas.[18] In this way, it will provide a new component of funding based purely on competition between leading researchers and their teams, thereby forming a good complement to efforts of national research councils (NRCs) and regional research funding institutions.

Lastly, and very importantly, the ERC, as a model and through the impact it will have on such a research market, will offer a powerful positive stimulus for change among other research funding agencies. It is true that there are also potential drawbacks to creating an ERC. For example, an individual Member State might see it as an excuse to cut back on national

18) This assumes that the ERC is provided with resources on the scale necessary to achieve this.

funding of research. However, to do so would be short-sighted in the extreme since this would deny that country the opportunity to develop up-and-coming researchers to the level where they could compete successfully at the European level for ERC funds. The assessment of the expert group, however, is that the benefits of creating an ERC are likely to be much greater than the potential negative consequences.

For the longer term, the ERC should help national and European actors collectively to generate dynamic and beneficial structural effects across the entire research funding system of Europe. By providing information on the research market, new benchmarks for selection at the national level, and – thanks to the visibility of ERC-funded researchers – creating a virtuous circle concentrating funding on distinctly excellent research, the ERC is likely to accelerate the reforms already underway in several Member States. Indeed, this may prove to be one of the largest benefits that will flow from establishing the ERC.

2.3 Potential Alternatives to an ERC

Why can the effects described above not be achieved in some other way? Is it really necessary to create a new organisation for funding European research, with all the related institutional implications?

In principle, one could envisage an arrangement that built on existing collaboration between national research agencies – a development of the ERA-NET scheme, for example. While worthwhile in itself, this is nevertheless likely to fall far short in bringing the benefits expected from the ERC, in particular in terms of obtaining a full European dimension to projects. The diversity of actors, the need to combine different statutory arrangements and objectives, and the differences in governance and instruments, not to mention the complication of possible demands for *juste retour*, would make this extended collaboration far more time-consuming and cumbersome to implement than an ERC. However, such an option can certainly be combined with the creation of the ERC. Indeed, the ERC and the ERA-NET would jointly make a powerful combination – one focusing on excellence at the pan-European level, the other on progressively overcoming the national fragmentation of research funding in the emerging ERA.

Another possible alternative to the ERC would be to dramatically increase the budget for the current NEST (New and Emerging Science and Technology) activity within the Framework Programme. However, although NEST provides a number of the elements necessary for a responsive and excellence-driven funding mechanism open to multidisciplinary research, and can provide useful lessons for operating such a scheme in the EU context, it does not have some crucial characteristics of the ERC. In particular, under NEST there is the requirement for collaborative proposals, as well as the absence of an independent governance structure.

The ERC will also help to create a highly visible community of leading scientists in frontier research. This result will enhance Europe's ability to play its role as an important global player, primarily with respect to international research, but also contribute to sustainable development and the solution of global problems.

Chapter 3: The European Challenge

Any examination of the proposed ERC requires an appreciation of the current condition of research in Europe, as well as the wider context in which an ERC will be implemented. An ERC will have a strong foundation on which to build, albeit with certain challenges to be faced, as we shall summarise. But the context for this mechanism is a Europe that is, on the whole, strongly positioned compared with other continents, notably due to its wealthy, healthy living conditions and to the quality of education of its citizens. (The EU-15 countries have the highest Human Development Index[19] in the world.)

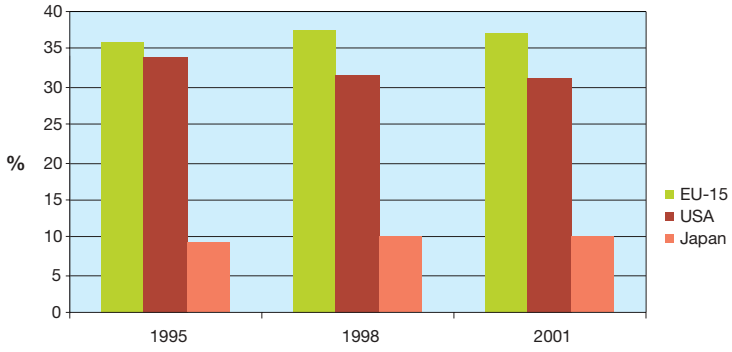
Indeed, one of the immediate advantages of the enlargement of the EU is that the already highly educated workforce in the EU-15 has seen a further dramatic increase with the accession of the new Member States. This now makes the EU-25 the world's largest pool of well-educated people. Meanwhile, with an embedded tradition in scientific research, the EU-15 has been the world's leading region in terms of the authorship of scientific papers since 1995 (see Figure 2)[20].

A deeper analysis of available data indicates, however, that in coming decades the European research system will face several challenges, which we summarise below.

3.1 Research Challenge One: Reinforcing Excellence, Especially in New, Fast-Growing Sciences

Analysis of the available data on research activity (based on the number of publications in leading international learned journals) and its impact (as reflected in the number of citations earned by those publications in subsequent research papers) suggests that the EU-15[21] performs at around the world average level if we take all scientific fields together. However, it is important to note that two thirds of all EU publications come from just three countries: the UK, Germany and France.

Figure 2: Share of global scientific publications from EU-15, USA and Japan



Source: Third European Report on Science & Technology Indicators, European Commission (2003).

19) The Human Development Index (HDI) is a complex indicator combining three dimensions of human development: health, education, and access to resources conferring a decent living standard. All of these factors are given equal weight, and the figures are population-weighted averages. In 1999, the HDI value was 0.92 for the EU-15, 0.91 for the Dynamic Asian Countries, 0.82 for North-America, and 0.48 for Africa (European Commission, 2003).

20) From 1995 to 1999, the scientific publications authored by researchers in the EU-15 as a share of the world total grew from 35.8% to 37.4%, while NAFTA's share dropped from 38.3% to 35.2% (European Commission, 2003).

21) It should also be noted that many of the new Member States have particular strengths in basic or frontier research that will be an asset to the emerging ERA and not least to the ERC. However, for the analysis here, data for the new members is not always as readily available as for the EU-15.

Meanwhile, the USA, although producing a broadly similar number of scientific publications to Europe, leads both in terms of total numbers of citations (reflecting the total impact of research) and in terms of the average number of citations per paper (reflecting the average impact per paper)[22]. It performs significantly above the world average in the fields of physics, clinical medicine, biomedicine, chemistry, and basic life sciences[23]. Moreover, if one looked in detail at the US publication data, one would find that, while a subset of the 50 states carry out the majority of the highly cited research, the US system is open and fluid so that researchers collaborate or move across state boundaries effortlessly.

Another way to consider competitiveness is to look at the small number of truly outstanding publications that have an extraordinary impact on the international research community. Analysis of the top 1% of publications in terms of citations reveals even more discouraging evidence for Europe. In almost all fields, the USA dominates in terms of high-impact papers. Its share of highly cited publications is disproportionately much larger than its share of total publications. While this indicator may be influenced to a certain extent by a bias in favour of the USA and other English-language countries in the original data source (the Thomson ISI database), this is by no means sufficient to explain away the difference between the USA and Europe, as can be seen from the distribution of Nobel and other international prizes for outstanding scientific research over recent years.

In short, if we consider the impact, rather than simply the volume, of scientific publications, the position of the USA is extremely strong. US researchers publish approximately one-third of world scientific papers; but they receive half of world citations, and account for no less than two-thirds of the world's most highly cited papers and scientists.[24]

European science and technology, and its related research policies, have in recent decades tended to be more successful in fields that exhibit slower growth (e.g. organic and inorganic chemistry), convergent

Box 1: Fast-emerging research areas

In the field of **information and communication technologies (ICT)**, the available set of data on scientific publication shows a clear US dominance in both the activity (the number of publications) and the impact (citation rate). However, a number of small European countries can be found in the top ten as measured by the citation impact.

In **biotechnology** the EU-15 is the most active region (350 000 papers between 1994 and 1999), but the data on relative citation impact again reveal the US dominance (the EU-15 figure is only two-thirds that of the US). The European innovation performance in this field as reflected in patent data highlights one of the obstacles that the European biotechnology industry faces: the lack of critical mass for industry-academia research linkages and collaborations at national level.

In the fast-emerging area of **nano-science**, Europe (EU-15 + EFTA) is in a leading position in terms of the total number of publications (a 33-35% share of the world total in the 1990s). Not surprisingly, the patenting statistics show US-Canada dominance, but their 45% share in total is only slightly higher than Europe's (39% between 1991 and 1999).

(Source: European Commission, 2003).

22) Although the Thompson ISI database that provides the basis for the publication and citation indicators used in this section is biased to a certain extent in favour of the USA and other English-language countries, as we note in the argument below, this is not sufficient to explain all the difference between the USA and Europe with regard to high-impact research.

23) European Commission, 2003

24) 'Top 1%' of scientific publications in the world ranked in terms of their citation scores (source: Thompson ISI – see http://www.isinet.com).

dynamics (i.e. with an established standard theory or paradigm, such as particle physics or aerospace), or have low equipment or infrastructure needs (e.g. mathematics, humanities).

If we disaggregate the data on scientific production in different disciplines, we see that the particular challenge facing Europe is even starker. Although Europe demonstrates reasonable strength in chemistry, physics, mathematics and clinical medicine, it is heavily under-performing in new, fast-growing fields, such as biotechnology, information and communication technologies (ICT) and nano-science (see Box 1).

In recent years, some commentators have puzzled over what has been termed 'the European paradox'– why is it that Europe is apparently strong in basic science but performs poorly relative to the competition in innovation-oriented research linked to those sciences? The above analysis suggests a different explanation of what is occurring. While institutional, social and economic constraints certainly contribute to Europe's relatively poor performance in innovation, one of the key factors seems to be Europe's weaker research performance in fast-growing fields in which science and technology are closely interconnected. Linked to this situation is the longer time-lag that typifies Europe's entry into new areas of research with high promise.

If Europe wants to play a more prominent role in new leading sciences, where many possible research directions must be pursued in parallel, it must draw upon a large number of potentially productive researchers, fostering diversity of approaches. This goal cannot be achieved by national research councils drawing solely on the domestic pool of scientists. Europe also needs a new funding mechanism that encourages creative researchers to take risks and provides them with the necessary resources to pursue more adventurous research than at present.

Europe must be able to draw upon the full continental pool of creative researchers to decide which ones to back. It also needs a new funding mechanism that encourages and facilitates more adventurous research. This combination of a selection mechanism operating at the European level with a premium on high-risk research is essential to promote world-class scientific production in fast-growing research areas.

3.2 Research Challenge Two: Staying Ahead

What is often not emphasised when examining academic and innovation rankings is that it is not just a question of Europe catching up the USA; there is also the challenge of staying ahead of other parts of the world.[25] In particular, Asia is not only a fast growing manufacturing and economic power, but also rapidly developing its scientific strength.

China and India both have a strong commitment to personal savings and to education, in particular to science and engineering education, despite comparatively low public expenditure on welfare. In 2003, China awarded 337 000 science and engineering degrees, while India awarded 316 000. (In the USA the figure was around 400 000.) China and India are producing growing numbers of highly skilled scientists and engineers trained at fine universities, thereby creating a huge resource for future knowledge-based activities.[26]

Furthermore, by sending their brightest students to the USA, these and other Asian countries aim to position themselves at the forefront of scientific research. Further increasing the competitive dynamic is the fact that US universities and research institutions subsequently recruit some of the best of these students, who then establish collaborations with home-country institutions; others return home, but with a rich web of personal

25) This is not to imply some sort of 'battlefield' between Europe and the rest of the world. While reinforcing the European knowledge system, we also have to search for partnerships with North America, Asia and other emerging economies. However, that goes beyond the primary mission of the ERC and certainly beyond the scope of the expert group.

26) Source: OCSE, National Science Foundation, CHI Research, in Business Week, October 11, 2004.

Box 2: Evaluating the benefits of publicly funded research

One approach for evaluating the benefits of publicly funded research is based on analysing the scientific publications cited in patents (Narin et al., 1997). An examination of the front pages of 400 000 US patents issued in 1987-88 and 1993-94 traced the 430 000 non-patent citations contained in these patents. 175 000 were to scientific papers published in the 4 000 journals covered by the Science Citation Index. The study determined the sources of US and foreign research support acknowledged in the 45 000 papers with at least one US author. The findings on the increasing number of scientific references cited in patents suggest that over a period of six years, knowledge flow from US science to US industry increased very substantially. US government agencies were frequently listed as sources of funding for the research cited in the patents. This fact indicates a strong and growing reliance by industry on the results from publicly funded research, a conclusion that has had a significant impact on government research policy in the United States.

contacts of the highest quality. In the USA, seven nations from Asia are among the top ten sources of foreign students. Indeed, four countries – India, China, Taiwan, and Korea – supply approximately 67% of all foreign PhDs in the USA, another sign of the growing research competitiveness of Asia.

These facts shed light on one of the most interesting recent phenomena related to the emergence of new countries in advanced areas of science and technology. In several leading-edge research areas such as biology and biochemistry, growing numbers of Chinese or Chinese-origin scientists rank among the most-cited researchers in the world.

At a time when Europe is focusing its attention on the most developed economic competitors, and in particular the USA, Europeans must take serious note of what the emerging economies of Asia are accomplishing in higher education, research and technology. It has become a gross over-simplification to persist in seeing Asia primarily as a manufacturer, with only Europe and the USA at the heart of knowledge creation.

One response to the emerging competition from Asia is for Europe to create a more effective means of developing higher-quality research leaders than those of the emerging nations. Strong research leaders can embody the knowledge, know-how and sense of purpose necessary to ensure the competitiveness of European academia and industry. One of the tasks of the ERC would be to identify at an early stage potential research leaders from all around Europe and provide them with the necessary resources to develop their full potential.

In a world of growing scientific and technological competition, Asia is fast emerging as a key player. While Europe wrestles to catch up with its traditional competitors, it may itself face the danger of being overtaken by Asian countries. Special attention must therefore be given in European policy to areas where Europe has certain comparative advantages. One such area is frontier research. The creation of an ERC dedicated to supporting excellent frontier research offers a means to help achieve this.

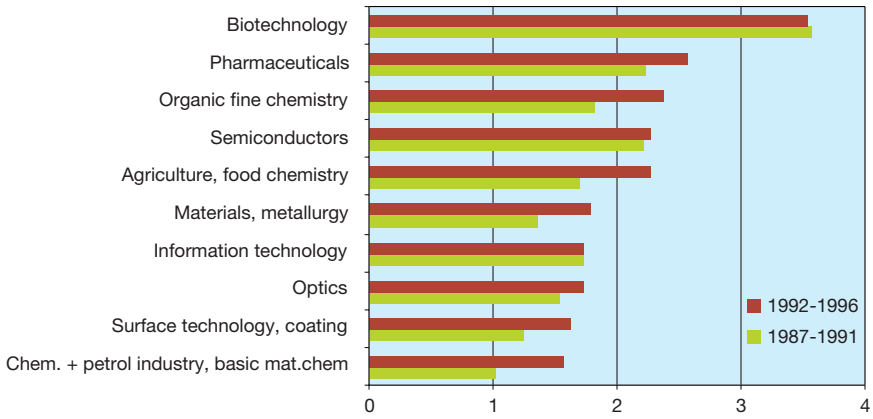
3.3 Research Challenge Three: Linking Science to Technological Innovation

Box 2 describes the results of one approach to evaluating the benefits of publicly funded research. These facts are based on the scientific publications cited in newly registered patents[27]. The findings point to a strong reliance by industry on results from publicly funded research in developing technological innovations. This finding has already had a significant impact on government research policy in the USA and deserves to have a similar impact on research policy in Europe.

Research and development (R&D) have become key functions of companies in many traditional sectors as well as in most emerging industries. To be effective in R&D, industrial enterprises require a supply of highly skilled scientists and engineers. They must also have

27) The approach has been pioneered by Narin and colleagues at CHI Research, a US consultancy (Narin et al. 1997).

Figure 3: Average number of scientific articles in patents (application at the EPO), 10 most science-intensive technology fields, all countries



Source: Third European Report on Science & Technology Indicators, European Commission (2003).

the ability to provide these personnel continuously with new knowledge and skills and state-of-the-art equipment. Besides hiring new recruits from university, these companies may also have to build research collaborations with universities and other research institutions so that they can keep up to date with the latest research.

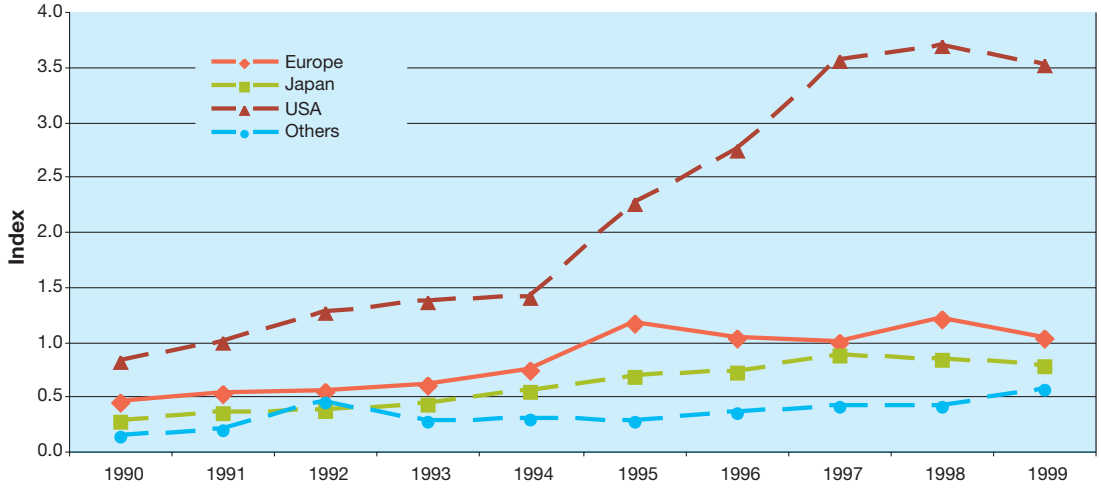
Frontier research, it must be noted, can and often does take place in industry. Industry not only absorbs and exploits new knowledge but also creates knowledge. This work occurs in industry because the technological development involved in creating new products or processes often requires further scientific advances. In many areas, science and technology are becoming ever more closely interlinked. If the EU does not address its current weakness in frontier research, European firms will be at a serious comparative disadvantage in global markets.

In recent years, the evidence strongly suggests that science has in fact become even more central to the creation of knowledge useful in innovation. This trend is clear from the number of patents citing scientific publications, which grew substantially in the 1990s at both the European Patent Office (EPO) and the US Patent and Trademark Office.[28]

Significantly, this trend is apparent across most of the technology fields with a high propensity to cite previous scientific research in applications to the European Patent Office. As can be seen from Figure 3 above, patents in all but two areas – biotechnology and information technology – showed substantial growth during the mid 1990s in the average number of scientific articles cited. In terms of scientific publications cited in patents, biotechnology currently has the most intense science-technology linkage.

28) The number of scientific publications cited in patents may certainly be influenced by a number of other factors as well the 'science intensity' of the technology. In particular, the access to electronic databases and on-line search facilities has undoubtedly made it easier for patent applicants and examiners to identify more scientific publications to cite in patents. However, it is difficult to see how those 'other factors' can explain entirely the different patterns across fields (and their various trends), which leads to the conclusion that the number of scientific publications cited in patents is at least a **partial** *indicator of 'science intensity' of the technology concerned. Moreover, it should be noted that EPO data reveal broadly similar patterns and trends to the US patent data.*

Figure 4: Scientific links of patents by economic region, 1990-1999



Source: Data by TECHLINE, elaboration by A. Bonaccorsi (HLEG member).

Analyses of the co-authorships between academic and industrial researchers in patent applications likewise point to a steady increase in the scientific content of technology over the 1990s. Yet even as the evidence grows for stronger links between research and its application, Europe continues to perform relatively poorly in this respect. In fact, the gap is growing. Between 1990 and 1999 the scientific research link to patenting grew fastest in the USA (at an annual average growth rate of 17.7%), almost twice the rate for Europe where the annual average was 9.7% (see Figure 4[29]).

The evidence shows that Europe is better at producing knowledge than at accessing and applying knowledge wherever it is created, including that originating in Europe itself. This weakness reflects the fact that existing research funding mechanisms seem to favour support for more established disciplines and specialities where the traditional division between basic and applied research (and between science and technology) is more pronounced. Europe has been relatively slow to move resources into new fast-growing areas where science and technology are much more closely intermingled, and where what is needed is not basic research (carried out in one set of institutions – primarily academic ones) followed by applied research (carried out in another set of institutions – primarily in industry) but frontier research. The situation therefore calls for a new institution to fund the best frontier research in Europe. From this initiative are then likely to flow significant improvements to European competitiveness.

Europe is notably less successful than its competitors in developing new technologies closely linked to scientific knowledge. It is slower to enter these fields, and its links between technology and science have been growing less rapidly than in the USA, with adverse consequence for Europe's ability to generate innovations. A new organisation like the ERC is needed to fund the best frontier research in emerging, fast-growing areas of science and thereby to help strengthen European competitiveness in relation to technological innovation.

29) Source of data: the index is calculated on the basis of TECHLINE data aggregated across companies. TECHLINE data are based on the normalised number of references to scientific publications out of the total number of references cited in patents (see Bonaccorsi, 2000).

Box 3: ERC favours intra-European researcher mobility

Dr P is a brilliant up-and-coming scientist based in Dublin, where she has already won several major grants for her groundbreaking research. She knows that the best laboratory for the next phase in her career is in Vienna and that the faculty is willing to offer her a post. However, she recognises that she knows nothing about how the research council system of funding works in Austria and that she will have to invest considerable time and effort before being in a position to win major research grants in that country. She therefore decides to remain in Dublin, and her subsequent career progress slows significantly.

Contrast this with Dr Q, another fast-rising scientist in the US. Currently based at Columbia, where she has already won several major grants from NSF, she decides that the best laboratory for her next career advance is thousands of kilometres away in Caltech. They, too, offer her a post, and she immediately accepts, knowing that she can continue to submit proposals to NSF to finance her leading-edge research. Her subsequent career benefits hugely from moving to this better environment. (She may also be able to take the current grant with her.)

If an ERC were in existence, then Dr P, having already gained experience with winning ERC grants while in Ireland, would have no problem in applying from a new base in Austria.

3.4 Research Challenge Four: Competing for Talent

The transformation towards a knowledge-based society has resulted in a fast-growing demand for highly skilled scientific labour, accompanied by major changes in the skills most valued by the employment market. Success in the worldwide competition for truly outstanding talent, however, has become an even more decisive factor in the transition to more knowledge-intensive economies.

Historians and sociologists of science have demonstrated that, although the numbers of individuals involved in research around the world is large, a relatively small number produce a disproportionately large number of scientific publications.[30] Scientific contributions of the highest quality even more disproportionately originate from a comparatively few elite scientists. Furthermore, as the origins of the biotechnology sector in the USA show, leading researchers often then play a major role in exploiting the new scientific knowledge, establishing new companies and developing new products.[31] The competition for these outstanding research leaders, wherever they originate, will become much more pronounced in the knowledge-based society.

Researchers not only create new knowledge; they also play a vital part in knowledge transfer and constructing networks that often serve as platforms for technological development and commercialisation. Indeed, as technologies become more and more research-intensive, creating and developing networks of researchers from enterprises and academic institutions are likely to contribute even more to the technological development and innovation that are vital to improved competitiveness. Low barriers to mobility – whether between institutions, sectors or countries – promote the flow of ideas between the frontiers of research and rapid, successful exploitation of those ideas. (The example in Box 3 suggests further benefits from such mobility.)[32]

In absolute terms, the challenge is substantial since the EU-25 lags behind the USA in terms of the total number

30) This was first demonstrated in the 1920s by Lotka and the resulting distribution of publications is known as 'Lotka's Law' (Lotka, 1926).

31) See Zucker and Darby (1997) on the role of 'star scientists'.

32) As elsewhere, it should be stressed that the ERC on its own cannot solve all the problems. There are a number of barriers in Europe holding back the exploitation of potentially useful knowledge that will require measures other than the creation of an ERC if they are to be fully overcome. Europe needs complementary mechanisms to the ERC if it is to significantly improve its competitiveness, mechanisms addressing barriers to mobility, barriers to innovation in industry itself, a shortage of venture capital, difficulties with IPR and spin-off creation, and so on.

Box 4: First ten universities awarding a degree to the top 1 000 researchers in computer science

A recent analysis of the educational background of scientists in the field of computer science highlights the extent to which US universities are dominant in terms of attracting and training the very best researchers. The analysis was based on the CVs of the top 1 000 scientists by number of citations (source: the home-page of CiteSeer – www.citeseer.com and Bonaccorsi, 2004b) and focused on the universities at which they obtained their bachelors, master's and doctoral degrees.

All the top 10 universities from which leading researchers in computer science most frequently received a doctoral or master's degree are based in the US. At the bachelor level, four universities among the top ten are not located in the US, but only one of them is European (Cambridge). The others are from Asia (India, Taiwan, Korea).

With the establishment of an ERC, those universities that were successful in the pan-European competition for research funds would be more visible and attractive to the best graduate students from around the world.

of researchers[33]. Likewise, the share of researchers in the total labour force is still much lower in Europe than in the USA and Japan[34].

There is another important trend to consider. Historically, the bulk of the scientific base of a country has been, in most cases, built on the efforts of each country's own researchers. Increasingly, however, national scientific and technological communities can compete at the frontier by attracting the best researchers from around the world. Here, the record of Europe is rather weak. Although Europe produces more scientists and engineers than either the USA or Japan[35], Europe is a net exporter of talented researchers, especially to the USA.

In some respects, Europe is relatively open with regard to the nationality of its students and researchers. For example, in 2001, there were 795 436 foreign students pursuing their education in the EU-15[36]. Most of these, however, came from other EU-15 states, and many of the others from new Member States (in particular Poland). Likewise, in 2000, about half of all the S&T employees of foreign-country origin working in the EU-15 belonged to another EU-15 nation, and a further 20% to other European countries[37]. These figures suggest that Europe draws most its research talent from within the European continent.

The USA has also been especially successful attracting students and researchers from other countries.[38] Indeed, in some fields more PhD students come from outside than from within the country. And US universities, research institutions or companies then recruit many of the best of those foreign PhD students. One crucial difference, however, distinguishes the USA from Europe. The USA recruits from a truly global pool of students and researchers, rather than primarily from other countries within the same continent. This fact is surely one reason why the USA has successfully attracted a disproportionate share of outstanding scientists to its shores over recent decades. This USA

33) In 2000, the EU-25 had 1 084 726 researchers, the US 1 261 227 and Japan 675 898 (European Commission, 2003).

34) In 2001, in the EU-15 there were 5.7 researchers per 1000 labour force, in Japan 9.1 and in the USA 8.1 (European Commission, 2003).

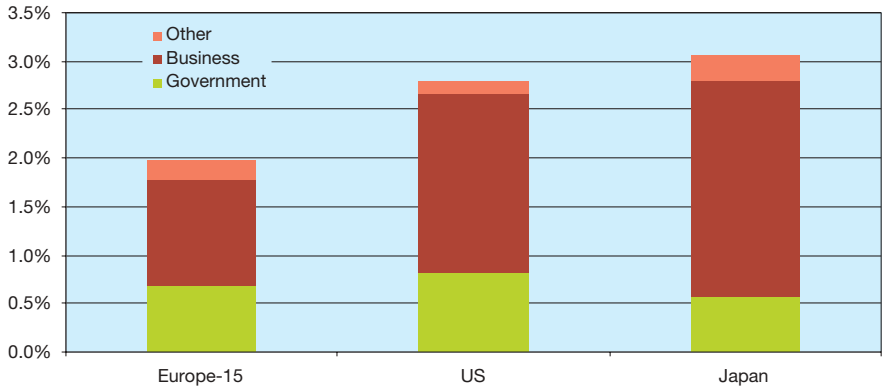
35) In 2001, about one quarter of all European students graduated in the fields of science and engineering (for the EU-15, the total was around 600 000, while for the EU-25 –it was some 675 000). This compares with a total of 370 000 S&E graduates in the USA and 230 000 in Japan (European Commission, 2004c).

36) In the US this number was somewhat lower at 582 996 and in Japan the figure was 63 637. (European Commission, 2004c)

37) European Commission, 2003.

38) It is true that there has been a fall-off in overseas recruitment to the USA in the last year or so but it remains to be seen whether this is the start of a long-term trend or merely a short-term 'blip' linked perhaps to the Iraqi war and the 'war on terror' with all the associated restrictions on visas and immigration. Moreover, some European countries such as the UK have also experienced a similar decline in the number of overseas (non-EU) graduate students over the last year.

Figure 5: R&D expenditure as a proportion of GDP, 2001, by sources



Source: Towards a European Research Area, Science, Technology and Innovation - Key Figures 2003-2004; European Commission (2004).

success is well illustrated by data on the most successful researchers in the field of computer science. The story detailed in Box 4 indicates the extent of the current US dominance in the global competition for scientific talent at the highest level.

Europe, by contrast, has been recruiting primarily from a much narrower pool of talent. It has then suffered from the further effect of losing many of its brightest researchers to the USA. Evidently, some new institutional mechanism is needed to assist in attracting, developing and retaining the best scientists in Europe. This includes providing greater incentives to European researchers who have moved abroad (e.g. for their PhDs or as postdoctoral fellows) to return to Europe.

Success in frontier research as well as in exploiting new scientific knowledge depends increasingly on the efforts of a relatively small number of truly outstanding research leaders. Europe needs a new institutional mechanism to make it more attractive to such individuals (irrespective of their country of origin), providing them with the resources needed to develop their full research potential, and helping to retain them within Europe.

3.5 Research Challenge Five: Encouraging Greater Investment

In 2001, the EU-15 countries spent €175 billion on R&D. Including all the accession and EFTA countries, the total investment was about €190 billion. This figure is significantly less than the USA spent (€315 billion) and somewhat greater than Japan spent (€143 billion).[39]

Gross expenditure on R&D expressed as a share of GDP (GERD/GDP) in 2001 was highest in Japan, followed by the USA, with Europe lagging significantly behind (see Figure 5). The largest component of the gap between the USA and the EU-15 can be attributed to business funding, but public financing is also significantly less in Europe than in the USA. Industrial investment in R&D is unlikely to grow significantly while the EU investment in high-quality frontier research lags behind in fast-growing areas where science and technology are closely intermingled.[40]

39) If one adjusts for relative purchasing power and deflates to 1995 prices, the corresponding figures are €147 billion for the EU-15, €234 billion for the USA and €87 billion for Japan (European Commission, 2004c).

40) Other complementary mechanisms to the ERC will, of course, be needed to overcome this problem fully.

Expressed as a percentage of GDP, the US government allocates much more funding to R&D than governments in the EU-15[41]. Moreover, in the period between 1997 and 2003, the EU-15 had by far the lowest annual growth in government budget for R&D.[42] The R&D spending in large countries such as India and China, meanwhile, continues to grow rapidly to its current rate of 1-1.2% of the GDP, while smaller, more developed countries such as South Korea, Singapore and Taiwan already spend more than the EU average (between 2.2% and 2.9% of their GDP). Since government funds traditionally play the most significant part in supporting frontier research, these facts – in addition to those detailed under Research Challenges One and Two above – indicate that Europe almost certainly under-invests in frontier research.

To reach the R&D investment targets set by the Barcelona European Council meeting in 2002, national governments and European institutions must both make additional efforts. Europe lags well behind the USA in funding knowledge creation. A pan-European approach for investing in high-quality frontier research through a new ERC can fulfil a crucial need in the ERA concept, one that, with other complementary measures, might well make Europe more attractive to companies deciding where, and how much, to invest in R&D.

41) In 2003, the government research budget allocation was equivalent to 1.05% of GDP in the USA and 0.77% of GDP in the EU-15 (European Commission, 2004c). Ideally, the international comparisons made here should be based on the relative funding of research aimed at the creation of knowledge (i.e. excluding applied research). However, it is virtually impossible to get comparable data on 'basic research' funding from all countries because of definition and data coding issues.

42) For the EU-15 the annual growth rate was 3.2% compared with 5.5% for the USA and 4.7% for Japan (European Commission, 2004c).

Chapter 4: Benefits of an ERC

4.1 Serving Society

Addressing the research challenges summarised above requires a mechanism for funding frontier research of truly international excellence. Yet it would be a mistake to consider that meeting such challenges would be the sole benefit of an ERC. On the contrary, and to begin with the wider picture, it is likely that a strong and creative research base will provide societal contributions that ultimately represent one of the most important benefits of investment in frontier research. In particular, new knowledge is required to meet the needs of this and future generations of European citizens. Health, a sustainable high-quality environment, education, culture, democracy, justice, effective governance, responsible citizenship – these and other aspects of social life are all likely to be affected by the new knowledge developed as the result of ERC-funded frontier research.

In this connection, it is clear that human and social sciences have a significant role to play. Hence, the proposed ERC will need to provide funding for leading researchers in these areas, both on a stand-alone basis and in conjunction with other sciences, as well as in science more narrowly defined. An ERC operating on a Europe-wide basis will provide an invaluable resource in terms of the latest knowledge and ideas for politicians, administrators, policy-makers, industrialists and others needing a solid evidence base to develop policies, programmes and institutions capable of meeting the challenges facing the world in the 21st century.

At the same time, the ERC will provide a platform to extend further one of the most significant roles of the European Union – contributing to over 50 years of peace in a region previously riven by wars and strife. Building on the collaborative schemes that have already created a spirit of cooperation across borders, the ERC should add to this harmony by developing a confident and integrated system of frontier research not only across old and new Member States, but also among disciplines and between science and society, thereby improving the dialogue among people of different backgrounds, experience and values.

As a completely new institution, the ERC can give particular emphasis in its funding policy to research activities that transcend national borders and cross disciplinary boundaries. Indeed, as a pan-European organisation devoted to frontier research, it should. While research is a highly specialised undertaking, complex contemporary problems now often need to be tackled with multidisciplinary[43] approaches. The capacity of the research community to undertake multidisciplinary research projects (and the ability of the ERC to cope fairly and promptly with such proposals) will therefore be vital in maximising the benefits of the new instrument. By providing grants to individual researchers selected from the full pool of European research talent, the ERC will give research leaders an incentive to assemble groups based on new combinations and configurations, driven only by the requirement for excellent science. They will be free to choose their collaborators within or beyond their own teams, just as they are free to choose the topic of their studies.[44]

4.2 Building Excellence and Prestige

Excellence in research is driven primarily by competition – between individuals, institutions, even countries. The desire to be first to make a major new discovery or a significant advance in theoretical understanding drives researchers to devote themselves single-mindedly and for long hours. Researchers compete with one another all the time – for funds, for new equipment, for the best technicians, to get their publications accepted in the leading journals, and for prizes (especially the Nobel Prize) and other recognition-based measures of esteem.

In the USA, virtually all of this competition takes place not at the level of the state but at the federal level. In Europe, in contrast, much of the competition is still at the national level. This may well be one of the main reasons why Europe has a weaker record than the US for truly excellent frontier research. The creation of the ERC (provided it is appropriately designed and funded) and the subsequent development of pan-European competition among the best researchers for funds

43) Or interdisciplinary or transdisciplinary – see footnote 13 on page 18.

44) Inter-institutional or international collaboration may well be needed for some frontier research, but it will not be a formal requirement for ERC funding. It will be up to the researchers who put forward proposals to the ERC to decide what is best suited in their case.

offers arguably the single, most important means to remedy Europe's current weakness in quality research and in research in new, fast-developing areas.

The competition for ERC funding will be broader and more intense than can be achieved at the national level, even in the larger European countries. More than that, by allocating grants solely on the basis of strict quality criteria, the ERC will confer status and visibility on European researchers and teams both within Europe and across the entire world stage. At the individual level, the ERC mechanism will encourage scientists to be more productive by providing a highly regarded additional form of recognition. Sociologists and philosophers of science have demonstrated that the desire for recognition is one of the main factors leading scientists to work at the research frontiers. They have emphasised how the socialisation process of graduate students and postdoctoral fellows nurtures this desire. Peer-reviewed awards from ERC, especially if the process includes efforts to identify young and up-and-coming researchers who have the potential to become the research leaders of tomorrow (see the following section), could provide an important form of recognition, the meaning of which the research community readily understands.

By making European science more visible, the ERC will help individual European institutions and nations attract and retain the brightest researchers. As these prominent researchers build their necessary linkages with higher education activities and train other researchers working at the frontier of knowledge, they will have strong multiplier effects across the research system.

To return to the societal value of such an initiative, role-model researchers created by a highly visible ERC grants system should contribute to making science more attractive to the general public as well as to students deciding whether to study science or engineering or pursue careers in research. Enhanced visibility will thus raise the status of research itself among policy-makers, politicians and the public.

4.3 Fostering Leadership Qualities

Another function of both societal and competitive importance is that the ERC will help with the early recognition of new talent by funding young researchers who in some countries may encounter difficulties in obtaining financing at the national level. The ERC will make a dedicated investment in the brightest young researchers and enable a new cadre of talented researchers to develop careers and to pursue research at the frontier of knowledge in a way not previously possible (or not otherwise possible until later in their careers). Boundaries (whether disciplinary or institutional) and barriers to achievement (those associated with conservative, inward-looking or complacent peer-review as found in some national research systems) will be reduced as funding decisions in the new ERC become based solely on scientific excellence and the potential of young researchers to become the best in their field. This focus on excellence

Box 5: Giving early chance to exceptional contributors

Science is often perceived as a young person's endeavour. There are various reasons why the young may be especially adept at discovery. Many of these have been discussed in work by Stephan and Levin (1992). Research suggests that, while the importance of age may well have been over-stressed, there is nevertheless evidence that age matters, especially with regard to exceptional contributions.

Career trajectories of exceptional scientists tend to differ from those of their colleagues (Simonton, 1991; Stephan and Levin, 1992). Exceptional scientists often demonstrate high creativity/productivity relatively early in their careers; they generally maintain a high level of productivity, even after adjusting for quality, and then show a slowly falling rate of productivity while remaining productive well into their later years. On the other hand, 'average' or 'journeymen' researchers tend to produce at a slower rate early in their careers and find their productivity slows even further by mid-career or thereafter.

The concept of cumulative advantage in science, discussed first by Merton (1968), and then by Cole (1979), demonstrates the important role that early success can play in contribution to a successful career.

should spill over to the economic system and society more generally, enhancing the levels of enthusiasm, energy and creativity across the whole of Europe.

As is clear from Box 5, the risk is that, in the absence of an ERC, some of these young researchers from certain countries will not manage to establish their independence in due time, and Europe will consequently lose the research that exceptional individuals often make early in their careers. Moreover, without the challenge that the ERC will stimulate, a number of these individuals may never be given the opportunity to fully develop their potential. This career-building effect of the ERC should therefore impact substantially on the pool of human resources for future frontier research in Europe.

4.4 Stimulating Greater Selectivity

The peer-review system proposed for the ERC provides an additional method for building excellence. In assessing the proposals submitted to it, the ERC will draw on a much larger pool of reviewers than national review systems currently do, and should ensure a higher quality of review. A wider pool of reviewers will thus encourage the development of higher-quality research in Europe. As the size of the pool and the quality of reviewers both expand, they will reinforce peer pressure to focus on excellence in the selection process. Furthermore, the open composition of peer review committees will better inform researchers around Europe of the latest developments and ideas in frontier research.

In addition, the peer-review system proposed for the ERC will likely have indirect benefits for national research systems. First of all, national research councils (particularly, perhaps, some of those in smaller or newer Member States) will benefit from the overall improvement in the quality of peer review, enabling them to focus their resources more selectively and effectively on higher-quality research. Secondly, the international system of peer review established by the ERC will provide useful benchmarks of success. As researchers and research institutions determine what research problems to tackle and how, they must know how they compare against their peers elsewhere in Europe. The combination of a powerful incentive to excel, along with reliable up-to-date information about who is succeeding and why, should enable national funding authorities to make more informed and better strategic judgements than possible currently. This information will indicate where and how investments can maximise a country's research potential, and assist universities and public research institutions in developing more effective strategies.

Focused as it is on competition between individuals or research teams, the ERC nevertheless does open the prospect that institutions or research teams with larger numbers of world-class scientists, well-equipped laboratories and better infrastructure and visibility will

Box 6: Additional sources of funding help develop talent from any research environment

A benefit to the peer review system such as the one envisaged under the ERC is that lesser-known institutions may be able to recruit talented individuals because the talented individuals know that their funding opportunities (once the ERC is established), and hence their research career prospects, are not tied exclusively to the institution employing them.

Evidence of this comes from the USA where, during the 1960s, there was a considerable expansion in the number of universities and PhD programmes. This expansion came at approximately the same time that a large influx of PhDs left graduate school – a consequence of increased enrolments in graduate school following Sputnik and of the draft-deferred status of graduate students. Many of these PhDs ended up being hired by new universities. They knew that they would still be able to apply for investigator-initiated grants from the federal government. Many of them have subsequently had very successful research careers (source: Stephan and Levin, 1992).

enjoy more immediate success from an ERC. But at the same time, the ERC will provide opportunities for researchers throughout Europe to access unique research facilities and contribute significantly to the development of special local knowledge. As such, the ERC could prove extremely important for regions in a catching-up phase. Indeed, as elaborated upon in one respect in Box 6, the smaller countries and new Member States may well in some respects experience a proportionately greater impact on their research quality and performance because the ERC's size-of-market effect is likely to be more significant for them than for the larger countries.

4.5 Linking Talents and Disciplines

Although research is a highly specialised undertaking, complex contemporary problems often need to be tackled by drawing on the knowledge and methodological approaches from a range of disciplines. The history of science reveals that some of the most fundamental advances often take place at the interstices of established disciplines (i.e. involving interdisciplinary research), have involved researchers from two or more disciplines combining their efforts (i.e. multidisciplinary research), or follow the migration of established scientists from one discipline into another (i.e. transdisciplinary research). In due course, such advances may come to form the basis of new research fields or even new disciplines. Even somewhat lower-level scientific developments often emerge from a new combination of individual talents, networked resources, and flexible and mobile researchers, along with stable structures to guarantee continuity. The research may require concentrated work within one laboratory or parallel efforts in several. It may involve a combination of expertise drawn from two or more partners in the same country or from several countries, as suggested by the example in Box 7.

Despite the fact that Europe has a high-quality and diversified research base, the growing costs of research means that the resources available to national research councils can rarely cover the entire range of fields, especially in smaller countries. This creates a dual problem: on the one hand, potentially wasteful duplication of funding across European countries in a number of fields deemed to be strategically important by most if not all countries; and, on the other, a lack of funding for areas that are considered to be less strategically important for each individual country (but which may nevertheless be important for Europe or for science as a whole).

As a new institution insulated from political priorities and focused uniquely on frontier research, the ERC will need to be able to react quickly to newly emerging research developments. Likewise, the capacity of leading researchers in the European scientific community to undertake multi-, inter- or trans-disciplinary research projects (and the ability of the ERC to cope with such proposals) will be critical in maximising the benefits of the new institution. The increasing importance of multidisciplinary research adds further urgency to the need for such an approach.

Box 7: ERC makes it possible to fund European research of the highest quality

Take the following example: in a particular field, it is clear that a fundamental breakthrough is imminent and with it is likely to come a Nobel Prize. In the USA the three scientists best able to tackle this happen to work in different institutions separated by thousands of kilometres. However, this presents no problems – either they simply use their existing NSF grants, refocusing the funds and perhaps requesting funding supplements (to which the NSF program officer can respond quickly), or they can submit a joint proposal.

In Europe, there are three equally brilliant scientists from institutions again separated by large distances, but this time in three different countries. At present, each must prepare a proposal to their respective national research council. Each proposal is weaker than if all three researchers were included on the same proposal. The prospects of obtaining funds are therefore reduced, while the risk of delays with one or more of the proposals is increased. By the time all three projects are funded and the project is up and running, the American team has made the crucial discovery. If there had been an ERC to which they could have submitted their single joint proposal, they might have had a better chance of winning the Nobel Prize.

Most national research councils tend to have a structure based at least in part on long-established disciplines (such as physics, chemistry and mathematics) with discipline-based committees to determine the allocation of resources. Such a structure makes it harder for researchers who propose a multidisciplinary project to decide which committee they should aim their proposal at. Whichever committee they choose, they run the risk that those on the committee will see the project as somewhat peripheral to their mainstream activities. The peer reviewers whom they consult are likely to judge the proposal from their own disciplinary perspective and hence find certain aspects of the proposal less convincing. Sending the proposal to researchers in different disciplines merely increases the chances that it will be criticised, thereby reducing its chances of being funded. Likewise, the approach that some councils adopt requiring two committees to deal with multidisciplinary proposals merely raises the prospect of a kind of double jeopardy – i.e. increasing the probability that one or other of the committees with be critical or at best lukewarm in their support, thereby damning the prospects of receiving funding.

The creation of a new organisation, the ERC, offers a unique opportunity to overcome some of the constraints facing researchers who wish to propose a project outside the mainstream of a particular discipline. To reduce the difficulties of establishing evaluation procedures that succeed in embracing potentially disruptive multidisciplinary ideas, the ERC will have to build on current 'best practice' with regard to peer review[45], developing procedures to ensure that the ERC is fully open to innovation, to novel proposals, to new areas of research, and to ideas introduced by new, younger researchers. Some national research councils are constrained to a certain extent by the historical legacy of established peer-review procedures, long-established criteria for judging proposals, and committee structures based largely on traditional scientific disciplines. With a new research council, there is an opportunity to develop new and more transparent evaluation procedures (e.g. taking advantage of the electronic era to encourage more of a interactive 'dialogue' between proposer and reviewer) and new selection criteria (e.g. ones giving much greater emphasis to bold and adventurous research). Moreover, there is no reason why the sub-structure of a 21st century research council should be based on scientific disciplines that emerged in the 19th century. In short, from the beginning, the ERC needs to be characterised by innovativeness and flexibility – necessary and vital complements to its focus on excellence.

Grants based on individuals selected from the pool of European research talent will provide openings to research leaders to assemble groups in virtually any combination and configuration, driven only by the requirements for excellent science. They will have the freedom to choose their collaborators within or beyond their own teams, just as they are free to choose the topic of their studies.

Here, there are important lessons to be learned from experiences in the USA with the National Science Foundation, the National Institutes of Health and other funding agencies. The extremely competitive funding of frontier research in the USA together with high-quality peer review results in a prompt focus on emerging and highly promising areas, because of the competition for funding. The ERC, by increasing the overall level of competition as well as improving the quality of peer review, should yield similar benefits.

Ultimately, an ERC that achieves these purposes will speed up the adaptation of the research base through its direct effect on those researchers who receive funds from it as well as indirectly at the national level as existing national research councils seek to emulate the greater flexibility of ERC and benefit from better-quality peer review. The ERC will thus supplement current efforts already underway to reinforce the efficiency and relevance of the research base to meet the challenges of the knowledge-based economy. Differentiating the ERC from existing research-funding mechanisms in frontier research can also add the greatest value to research across Europe.

45) Some national research councils have excellent peer-review systems from which the ERC can clearly learn. The very positive experiences with EURYI (the European Young Investigator award scheme, co-ordinated by the European Science Foundation) might also be mentioned; by adopting high quality professional review procedures, it proved possible to identify the best talent in Europe. The ERC can learn from success stories such as these.

4.6 Strengthening Research Institutions in a Single European Research Space[46]

Universities, public and private research institutions, hospitals and companies are the main actors when it comes to the development and exploitation of research capacities for frontier research, while universities and public research laboratories are responsible for training the researchers. The ERC will reward strategies to develop excellence by concentrating research resources in areas of real potential and facilitating the formation of strategic partnerships within or across national borders.

At present, Europe consists essentially of a large number of national research communities. The relatively small scale of many of these poses constraints on the strategies that research institutions (and indeed funding agencies) can pursue. As Europe develops into more of a single research space, universities, like industrial firms, will have opportunities to pursue more differentiated strategies, enabling them to make best use of their capabilities. The creation of the ERC will encourage research-intensive universities in this direction, with the expectation that the best will then be in a far stronger position to establish themselves as effective global players. For those universities already taking up this challenge, the ERC would provide much-needed support, acting as an incentive and providing an indicator of success as well as a source of funds.

Again, there are likely to be significant ancillary benefits to the national funding agencies. These bodies, which are charged with the health of the national research systems, need the comparative information the ERC can provide on how national research actors are performing against their counterparts elsewhere. Moreover, just as the creation of the ERC will increase the level of competition between researchers for funds, so it will also increase the competition among research councils to attract the best proposals, with attendant benefits in terms of the quality of research supported as well as the ability to target resources where they will yield the greatest scientific benefits.[47] This, together with the advantages associated with greater diversity in funding sources that the establishment of an ERC will create, provides further examples of the wider systemic benefits that we expect the establishment of the ERC to generate across Europe.[48] The ERC is certainly not a panacea for the problems currently confronting European research. Instead, it should be viewed as one part – albeit a very important one – in developing a more effective European research system.

4.7 Benefiting the Economy

Today, the ability to compete and prosper in the global economy increasingly builds on the capacity of nations to attract, retain, develop and harness the abilities of creative people. ERC-funded activities will assist this process[49] by enhancing attitudes towards creativity and excellence across research throughout Europe.

46) This section draws on the results of the 'Europolis' project (Europolis core-group, 2000).

47) Existing examples of this include the funding of medical research in the UK by the Medical Research Council and the Wellcome Trust, and the funding of physics in US by the Department of Energy, Department of Defense and National Science Foundation; in both cases a balance of cooperation and competition between research funders helps to drive up quality.

48) As noted earlier, there are also potential risks. For example, a particular Member State might decide that, because the research funded by the ERC is much better than what is funded nationally, they should reduce or even abandon national funding. However, as pointed out earlier, this would be counter-productive in the longer term.

49) It is important to re-stress that the ERC will not solve all the problems currently facing Europe in relation to R&D and innovation. In particular, the management and protection of intellectual property needs to be properly addressed. In the case of the ERC, most of the projects funded are likely to result in broad fundamental research results, but in certain sectors some form of IPR protection may be essential if the exploitation potential is not to be lost to countries and regions better than Europe at exploiting research results. Other issues to be addressed if Europe is to improve its innovative capacity include competition policy, regulatory frameworks and attitudes to risk. All these issues are, however, well beyond the remit of the expert group.

Through an ERC, researchers will be able to

- reinforce research productivity in key frontier domains, many of which may then contribute to technological progress and industrial innovation
- help to retain the best scientists in Europe and attract the best from elsewhere
- develop new scientific instrumentation, methodologies and techniques
- contribute to the creation of a highly skilled and motivated workforce
- encourage and expand the problem-solving capabilities in successive generations of researchers
- help stimulate the creation of technology-oriented firms and spin-off companies
- contribute to a better understanding of how to translate knowledge into results and programmes of high social value.

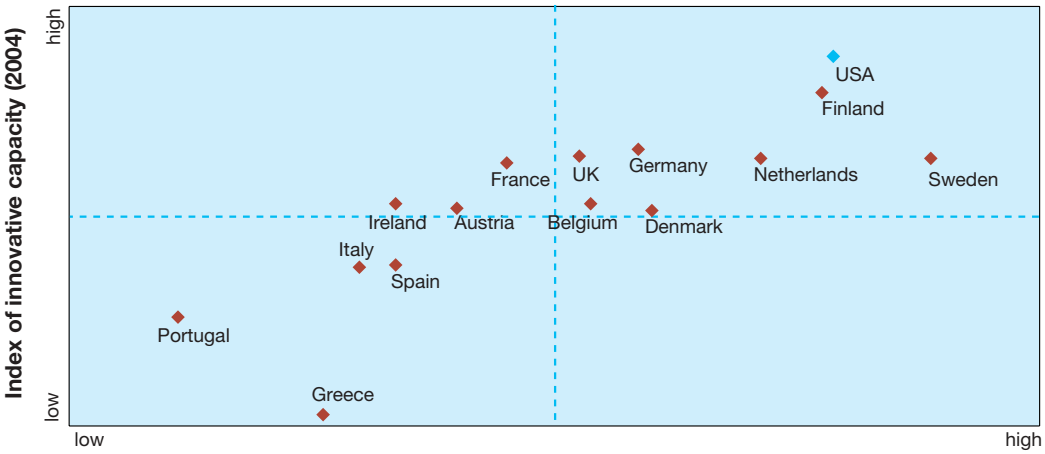
As this list of potential benefits suggests, the ERC can contribute to the growing availability of skilled people for the productive sector, the attraction and retention in Europe of R&D-intensive companies and creative people, and the establishment of economic spin-offs to exploit new knowledge. In particular, ERC-funded frontier research will support the creation of hot spots of excellence, which then attract R&D-intensive businesses in Europe and foster the creation of spin-offs from a flourishing science base.

It is worth considering in more detail each of the main ways in which the establishment of the ERC is likely to benefit the economy.

4.7.1 Providing a Base for Creativity

Advanced research performed by highly motivated and skilled scientists and researchers is a crucial element of creativity. Locations hosting advanced research at the frontiers of knowledge, and housing concentrations of people able to undertake and lead such research, are attractive both to other ambitious individuals (researchers, innovators, entrepreneurs) and to internationally active companies in knowledge-based industries. Analysis based on the Creativity Index developed by Florida and Tinagli[50] and on Michael Porter's Innovation Index[51] demonstrates that the nations able to attract or keep the most creative people also tend to perform best with respect to innovation (see Figure 6).

Figure 6: Creativity and innovation, by country, EU-15 and USA



Source: Florida and Tinagli (2004), and Porter (2001).

50) Florida and Tinagli, 2004.

51) Porter, 2001.

4.7.2 Offering Industry More Talent

Skilled people emerging from ERC-funded research will have the ability to assume positions in industry, where they can improve their employers' competitiveness and efficiency by bringing leadership, knowledge, know-how and access to a large network of researchers. Such mobility between the science sector and industry is important because it brings not only the codified knowledge contained in scientific publications, but also the tacit knowledge possessed by researchers, which is otherwise difficult for companies to access.

ERC-funded frontier research, besides producing new knowledge, will also expand the pool of talent and enhance the levels of excellence. It will create research leaders who are easily identified even from outside the science sector. These developments will help to attract R&D-intensive companies seeking to create interactions with the science base (see the next section), and provide opportunities for academic or other entrepreneurs to exploit new research developments in commercial undertakings. Such benefits will aid Europe in restructuring its productive activities towards promising science-based industries with the potential to sustain its future competitiveness. Individually and collectively, such effects represent additional channels through which the ERC can contribute to the economic health of Europe.

4.7.3 Attracting R&D Intensive Firms

The ERC can increase Europe's attractiveness as a hot-spot for multinational R&D activities. Multinational companies have a growing interest in direct investment in foreign locations with attractive and excellent research environments. During the 1990s, companies intensified their foreign research activities in fields where they needed access to top-level knowledge and centres of excellence.

Surveys of the specific motives of multinational companies (see Figure 7[52]) with regard to R&D investments in countries other than their own home base reveal that the internationalisation of R&D is mainly influenced by three factors:

- early linkage of R&D activity to leading, innovative clients (lead users) or access to lead markets;
- early coordination of an industry's R&D with related projects in the academic (or public sector) research system; and
- close links between production and R&D.

Given the relevance of frontier research for innovation, as discussed elsewhere in this report, these findings underline that the ERC would strengthen Europe's attractiveness to multinational companies, especially with regard to the factors (a) and (b)

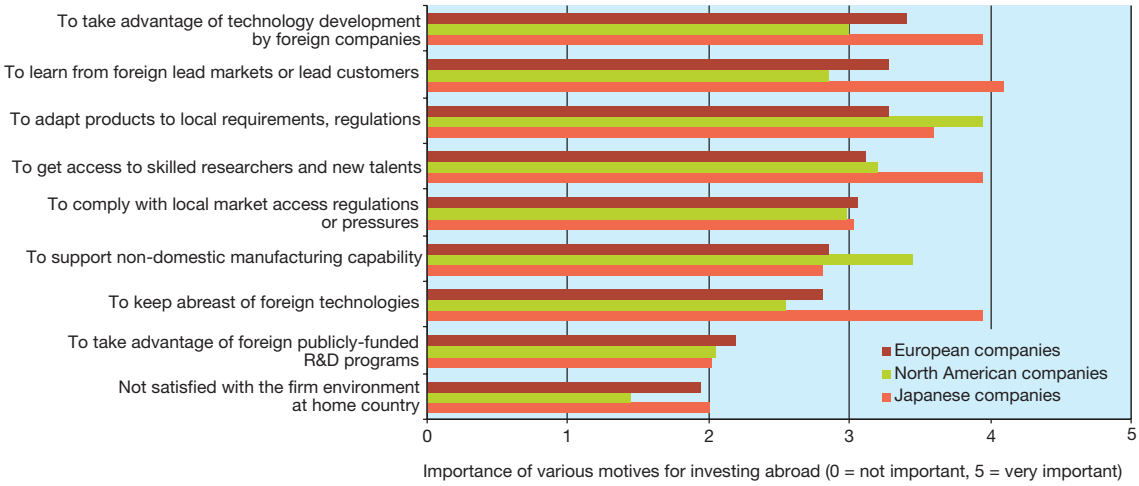
4.7.4 Contributing to Spin-off Creation

Many high technology start-up ventures and spin-off companies from academia result from frontier research (Box 8 provides a particularly striking example of this effect). ERC funding will increase the volume and in particular the quality of the research fuelling this activity. It should also result in greater numbers of top scientists – scientists who are bold, creative and entrepreneurial in their frontier research activities. These same characteristics are also ideally suited to the task of exploiting and commercialising the knowledge generated by research. They will therefore add to the pool of potential entrepreneurs who may be tempted to take the risk involved in creating a start-up or spin-off company. In this way, the ERC can contribute quite directly to economic value creation to the benefit of Europe.[53]

52) *Explanation of legend for Figure 7: North American multinational companies = Canadian and US; European multinational companies = EU 15 and Switzerland*

53) *The new companies created around MIT or other top US universities such as Stanford are undoubtedly the result of many factors including the ready availability of venture capital and the American culture of entrepreneurship. The creation of the ERC will clearly not solve all the problems, but adding to the number and quality of European researchers will undoubtedly help.*

Figure 7: Motivations of multinational companies from Europe, North America and Japan to invest in R&D abroad



Source: Edler et al. (2002)

Box 8: The role of frontier research in knowledge-based business creation

Graduates of the Massachusetts Institute of Technology (MIT) have founded some 4 000 currently active companies, employing 1.1 million people. Worldwide these companies account for annual revenues of almost $232 billion.

In addition, company founders arise within the USA after being attracted into the country to study at MIT. The 1 065 MIT-related firms headquartered in Massachusetts employ 353 000 people worldwide and 125 000 people in the state.

MIT-related firms account for about 25% of sales of all manufacturing firms in its home state of Massachusetts and 33% of all software sales there. More than 42% of the software, biotech and electronics companies founded by MIT graduates are located in the state.

Similar developments have taken place in California's Silicon Valley, the Research Triangle of North Carolina/U.S., Cambridge in the UK – and to a lesser degree in other European countries (source: Moscovitch *et al.*, 1997).

Let us conclude this section by again stressing that the ERC should not be seen as a panacea for overcoming the so-called 'European paradox'. It is just one of a range of initiatives that Europe needs to take if it is to become more innovative and competitive. However, that competitiveness is dependent on the effective functioning of the emerging European innovation *system*, a system requiring dense linkages between knowledge creation, absorption, diffusion and exploitation. Well-developed knowledge flows between academic institutions, public research organisations and private industry are essential to this. The ERC can certainly contribute to achieving this, even if it cannot resolve all the problems on its own.

The table below summarises the main forms of benefit that an ERC could potentially bring to the European research and innovation system, in particular the 'added value' compared with existing funding mechanisms whether national, regional or European. It should be stressed that all of these potential benefits depend crucially on the ERC having the characteristics identified in earlier reports – institutional autonomy, allocating funds in the form of flexible grants not rigidly defined contracts, proposals being judged strictly on the basis of competitive peer-review and with the sole criterion of scientific excellence. Any compromise with respect to these essential characteristics will mean that many of the potential benefits will not be achieved in practice.

The added value of an ERC

- *Encourage and support the finest talent:* Open and direct competition and better selection at the pan-European level will heighten the aspirations and achievements of European researchers across the full range of research areas, enabling the best talents and ideas to be reliably recognised from a larger pool, and thus raising the overall level of excellence in frontier research across Europe.[54]
- *Speed, agility and focus:* An appropriately designed ERC will be able to support the best ideas in frontier research, channel resources into new research areas, and capitalise on the unique diversity of European research talent with a speed, agility and focus not always possible within some national funding systems.
- *Status and visibility for research leaders:* The ERC can confer status and visibility on European frontier research and specifically on the best researchers and their teams, attracting talent and creativity to Europe.
- *Dynamic structural effects on European research system:* The ERC can catalyse the adaptation of national research structures to the evolving European Research Area, thereby creating a more coherent and effective European research system capable of matching the best in the world.
- *Economic benefits:* The availability of new knowledge and the expanded, higher-quality pool of talented researchers funded by ERC can help to nurture industry, to attract and retain more R&D-intensive firms in Europe, and to create a greater impetus for the establishment of research-based spin-offs.
- *Societal benefits:* Excellent frontier research in all disciplines is a necessity to address the complex societal challenges faced by Europe. The ERC can provide the opportunity to invest quickly in the knowledge base necessary to cope with the new and emerging issues confronting society.

54) Besides investing in European talent on a competitive basis, there is also a need to invest in research infrastructure and in cooperative arrangements (such as ERA-NET or its successor). Europe must strive for a broad portfolio of strategies and initiatives in order to become a world-class knowledge region. The ERC is just one of a range of initiatives needed.

Chapter 5: ERC in the European Research Area

If the benefits that a mechanism for supporting frontier research can offer are to be achieved, careful attention must be given to the context in which it will be established. In the present situation, where the ERA is gradually developing in a more tangible form, any new European instrument for research funding will obviously have a broad impact on research activities and funding mechanisms. The ERA is a dynamic entity, evolving on the basis of interventions at several interacting levels. In this environment, the coherence of policy must be assured by means of collective responsibility, exercised by a range of actors operating in many different arenas.

The ERC will enter an environment in which other bodies already hold strong positions, mostly at the national level. According to the traditional perception in Europe, basic research falls within the responsibility of individual nations. After the Second World War, the Western European countries established national agencies with a large degree of autonomy in funding basic research. In only a few cases has basic or frontier research been successfully institutionalised at the European level, and these mostly focus on specific areas (e.g. CERN, ESO and EMBO).

The European Research Area initiative, launched at the beginning of the 21st century, is designed to encourage the development of a single market in research and to enable researchers in universities, public and industrial laboratories and other entities to be freed progressively from any constraints in national environments that currently inhibit the pursuit of bold, creative, path-finding research of the highest quality. This development opens up the possibility of otherwise unachievable dynamic and entrepreneurial behaviour by those engaged in research and with it the prospect of a more effective European research response to developments in the wider world.

The ERC will be the sole institutional mechanism of the ERA responsible for ensuring open competition in frontier research on a Europe-wide scale. It will thus be in a powerful position to catalyse a process of continual adaptation and evolution towards more creative and effective performance across the European research system. It will respond to scientific opportunities on the basis of excellent ideas and excellent researchers and their teams. It is essential that the ERC has the institutional autonomy to ensure that it is not beholden to any national or politically inspired strategic priorities. Operating independently from existing research traditions, it can be designed so that it will be able to mobilise resources quickly for investing in promising new research areas. It needs to be able to support riskier projects not easily funded at national level, making available new funding sources to any top-level researcher independently of location.

The decision to put into place the ERC must, in short, be seen as a bold intervention clearly differentiated from existing national activities. Its main aim is to generate a new dimension of competition among researchers and institutions, with scientific excellence as the sole criterion for deciding who and what to back.

The EU needs to implement the ERC, and to implement it soon, because of the benefits it is capable of bringing, benefits that a national research council finds it difficult to generate on its own. However, there is a risk of conflict with existing funding mechanisms, both national and European. Hence, the ERC's mission ("supporting excellent frontier research") and scope ("on a pan-European basis") need to be carefully differentiated from those of other funding mechanisms if counterproductive competition is to be avoided. Moreover, because the ERC will have dynamic effects on the operation of the national research councils (and vice versa), there will be a continuing need to consult and collaborate with the other funding agencies to ensure that the difference in missions remains clear and is understood by all.

At the same time, as part of the European Research Area, the ERC will form just one element of the broader European innovation system. It must therefore be positioned so that a complementary relationship among the European, national and regional actors engaged in innovation can be arrived at though an evolutionary process of adjustment. In particular, the actions of the ERC must be configured to avoid unproductively duplicating, or competing with, national or regional agencies.

Ultimately, an ERC set up in the form proposed (i.e. as an autonomous body allocating grants through a competitive peer-review process in which the sole criterion is scientific excellence) will

- facilitate knowledge flows between science and industry, and to society at large;

- enable Europe, regionally, nationally and across the continent, to increase the generation of research skills and its absorptive capacity for foreign research; and
- complement existing mechanisms to promote research capacity-building across the whole European continent.

In summary, the ability to reap such benefits, as with those benefits summarised earlier, rests on the successful functioning of the ERC mechanism. The ERC will enter an arena where other bodies already hold established positions, mostly at the national level. Its success will depend on a clear definition of its strategic mission, a firm political commitment to ensure its autonomy and adequate resources to attain its goals. Member States also need to recognise the short-sightedness of regarding ERC funding as a reason for cutting back on national research funding (for the reason elaborated earlier). The European research system as a whole needs to function more effectively, allowing the various types of knowledge to interact and nurture each other to generate progress, and ultimately contribute to economic, human and societal development. As science policy researchers over the past decade or so have clearly demonstrated, and as we have explained above, the creation of knowledge, its diffusion, and its use need to be seen in terms of a *system* in which frontier research, more applied research and technological development – in both the public and private sectors – interact fruitfully with one another.

A new and evolving distribution of responsibilities in research funding across national and European systems, disciplines and institutions will certainly result from implementation of the ERC. The national and European actors must work collectively to ensure that the emerging division of responsibilities is functionally appropriate and provides the most structurally beneficial role for, on one hand, the ERC and, on the other, the national agencies.

5.1 Funding and Political Commitment

Major determinants of the success of the ERC's role in the European research system will be the scale of the available budget, the impartiality of ERC decision-making, and the motivation of creative, high-quality researchers to take advantage of the funding opportunities.

If it is to provide a real stimulus for such researchers to prepare and submit high-risk/high-return proposals, the ERC needs to offer a reasonable probability that strong projects will be successful in the application process for grants. Besides taking the bold and important step of setting up the ERC, the EU should also have the confidence and foresight to see it as a long-term investment in the creation of a durable institution on the European stage. This implies that, if it is to make a significant impact on the wider system, the ERC should have access to adequate funds right from the start. The pool of funds available to the ERC must be sufficient to maintain a broad range of research and to provide adequate funds to top researchers in all of these. In this connection, it should be noted that the additional benefits noted earlier from creating a more effective European Research Area are likely to be large in comparison to the actual ERC budgets.

But funding is far from the only critical issue. In addition, for the new organisation to work, it needs strong political support at both European and national level. Political commitment entails at least two important elements. First, frontier research funding requires a high degree of freedom from political influences. Policy formulation, decisions on funding schemes and project funding should all be left to the governing body of the ERC, which needs to be representative of the research community. European political institutions must certainly be active in setting up the ERC, in assuring adequate levels of funding, and in maintaining appropriate accountability, including evaluating the outcomes. But they should create the ERC in a form that does not entail the need for continuous engagement with its business at the day-to-day operational level.

Second, there must be visible and solid support, not only for establishing the ERC, but also for sustaining

its operation over the longer term. This factor requires, as we have noted above, particular attention to the interfaces between the ERC and national activities. For example, the fact that some of the very best individuals within a given country come to be supported by the ERC should be seen as an indication of that country's success. National research councils will need to adjust to this change rather than seeing it as a threat.

This political commitment also needs to be fully integrated into current policy actions so as to form a coherent basis for improving Europe's innovation capabilities. Research is only one of the main components contributing to the Lisbon objectives. EU policies, including research and development, should form an effective set of measures, tools and actions. The establishment of the ERC, as part of the effort directed at developing the ERA, clearly has strong links to the European Higher Education Area, and to regional, economic and enterprise policies.

Success will also depend heavily upon the existence of a set of framework conditions. As we noted above, the most important is that this EU instrument should work well and in synergy with other EU instruments, such as existing parts of the Framework Programme, and also with the national research councils.

On the one hand, ERC and the national research-funding instruments should add value to one another. On the other hand, the national agencies, in their role of supporting the development of national research competencies, need to work with their respective research communities to develop and submit high-quality research proposals to the ERC. The ERC must be positioned within the ERA so that it is both a powerful instrument in itself and acts as a part of a cohesive well-functioning system.

In summary, the ERC will require:

- a strong commitment from policy-makers at all levels,
- a clearly defined role as part of the pan-European research funding system,
- a complementary relation to the national research funding bodies, and
- sufficient funding.

To achieve all of these will require considerable effort and deft political skills, and, most of all, a willingness to be bold in creating and investing in an entirely new form of organisation.

5.2 Coordination with Other EU Mechanisms

Clearly, the establishment of an ERC dedicated to concentrating its resources on the best researchers engaged in frontier research in Europe raises issues and potential problems (e.g. with regard to capacity-building and cohesion) for countries and regions currently less well endowed with such researchers. We cannot stress too strongly, however, that the task of addressing and resolving such issues should not be added to the responsibilities of the ERC. To do so would fatally weaken the ability of the ERC to deliver the various benefits outlined in this report. Instead, the task needs to be seen as the responsibility of other institutions and mechanisms – for example in the case of the EU, of those concerned with regional development and cohesion. This is not to say that the ERC is intrinsically 'unfriendly' to cohesion, but that it should be part of a balanced framework programme that retains the existing structure for collaborative research and for addressing issues relating to cohesion. Moreover, there will need to be careful monitoring of the impact of the ERC along with that of other mechanisms for fostering the ERA and cohesion to ensure the widest possible benefits.

National research policies and funding agencies cannot remain neutral in this respect. One of their traditional roles – that of competence building – will be amplified once the ERC is established. They will need to integrate national and EU resources if they are to develop top-flight researchers who can compete successfully for ERC funds and thus benefit their own national knowledge-base as well as Europe as a whole.

A number of EU Member States are already attempting to modernise and reform their research systems, although the process is taking place at an uneven rate. The ERC, as a model and through the impacts it will have on the research market, will represent a powerful and positive stimulus for such changes.

Chapter 6: Conclusion – Looking Forward

The competitive challenges of the 21st century require that researchers not only think imaginatively about the work they want to do, but also have at their disposal an instrument flexible enough to meet their needs under all kinds of circumstances from a European and not just a national perspective.

The ERC offers a mechanism to provide this stimulus to frontier research and ultimately, through the various mechanisms that we have identified, to innovation. To achieve these goals, the ERC must put a clear emphasis, first, on funding research that is novel and of the highest quality, and, second, on covering the full range of sciences with a view to stimulating diversity in the thinking of researchers, including offering researchers from different disciplines the opportunity to work creatively together. Underpinning such potential is a concept at the heart of the ERC – that practising researchers are best placed to identify exciting new frontier research opportunities and directions.

In this way, the ERC will be able to take advantage of the wide diversity of European environments and cultures and the contributions they can make to a more creative research environment. The approach will be truly European as the individual research grants begin to support either teams involving researchers from one or several European countries or outstanding individuals from any European country. By adopting this model, the ERC will strongly complement and reinforce the other mechanisms that support research activities.

If the ERC is created as a new instrument at arms length from political priorities, working in a completely different way from existing EU mechanisms under the Framework Programmes, then it should be able to react quickly to newly emerging developments in frontier research. Provided it is allocated the necessary scale of resources, it should be able to attract to Europe, and to retain, the best researchers, support risk-taking, stimulate novelty and research that has a high impact, give special attention to newly emerging areas, strengthen multidisciplinary approaches, and make the long-term grants that provide world-leading researchers with the freedom and flexibility required to achieve the greatest impact. Building on this model, an ERC will speed up the adaptation of the research base, in particular at the national level, and supplement efforts already underway to reinforce its efficiency and relevance to the challenges of the knowledge-based economy. The ERC will thus provide Europe with the world-leading capabilities in frontier research that it needs to confront the challenges of the 21st century.

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Acronyms and abbreviations

BERD	Business Expenditure on Research and Development
CERN	European Organisation for Nuclear Research
COST	European Co-operation in the field of Scientific and Technological research
EFTA	European Free Trade Area
EMBO	European Molecular Biology Organisation
EPO	European Patent Office
ERA	European Research Area
ERA-NET	European Community scheme for co-ordinating and networking research activities in the European Research Area
ERC	European Research Council
ERCEG	European Research Council Expert Group
ESA	European Space Agency
ESF	European Science Foundation
ESO	European Southern Observatory
EU-15	15 (older) Member States of the European Union
EU-25	The 25 (new and older) Member States of the EU
EUROCORES	European Science Foundation Collaborative Research scheme
EUROHORCs	EU Research Organisations Heads of Research Councils
EURYI	European Young Investigator award scheme
FET	Future and Emerging Technologies
GERD	Gross Expenditure on Research & Development
HLEG	High-level expert group
ICT	Information and communication technologies
IPR	Intellectual property rights
NAFTA	North American Free Trade Area
NEST	New and Emerging Science and Technology
NRC	National research council
R&D	Research and development
RTD	Research, technology and development

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