Towards a European Research Area

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Key findings

– The European Research Area (ERA), as defined as *an area in which research activities at the national and EU level are well integrated and coordinated*, does not yet exist. The first bias affecting the choice of collaboration partners is geographical proximity. Researchers prefer to work with colleagues who are located nearby rather than with those who are further away. A second bias that we identified is that researchers prefer to work domestically rather than across national borders.
– Researchers in 'excellence regions' – regions that produce a high number of scientific publications – prefer to collaborate with each other rather than with researchers from lagging regions. This hierarchy means that less-advanced regions have difficulty entering 'networks of excellence'.
– There is a second, politically structured hierarchy among European regions: researchers in capital regions prefer to collaborate with each other. This may reflect the fact that most national research institutes are located in capital cities, and tend to be over-represented in multi-lateral programmes that are supported by multi-lateral government funding.
– Networks do matter in regional innovative performance. They allow regions to access knowledge that is available in other regions. This knowledge can subsequently be used in processes of innovation, together with the knowledge that is available locally.
– In biotechnology, countries from Southern and Eastern European regions underperform in generating patents, as do the UK and the Netherlands, while Austria, Germany and Switzerland outperform the rest of Europe. German-speaking countries also perform significantly better than the rest of Europe does in semiconductors, while Greece, Poland and Portugal are the least successful in generating patents.
– The results indicate that the European Union has not yet succeeded in creating an ERA. Its present efforts to do so are thus well justified.
– Although the creation of a European Research Area will remove 'artificial' barriers related to geography and borders, thereby benefiting all European regions, it will give preferential support to excellence regions and their mutual networks, with the goal of creating centres of excellence that are competitive on a global scale. These two effects should be both considered as intended outcomes of ERA policy.
– At the EU level, the further development of ERA policy should pay more attention to possible conflicts with cohesion policy. The two objectives, competition and cohesion, could be incompatible if the establishment of the ERA were to generate disproportionate benefits for richer regions, relative to poorer regions.
– At the national level, policies can be informed by benchmark exercises in order to learn from the best practices of member states.

Introduction

At the European Council meeting in Lisbon in 2000, the member states of the European Union formulated a common agenda, which has become known as the 'Lisbon Agenda' (European Council 2000). With the establishment of the Lisbon Agenda, EU leaders signed on to an ambitious programme that aimed at helping Europe 'to become the most competitive and dynamic knowledge-based economy in the world' by 2010. The cornerstone of the Lisbon Agenda is the creation of a European Research Area (ERA), a concept that was launched at the same Lisbon meeting (European Council 2000). In order to create an ERA, the European Council stated that 'research activities at national and Union level must be better integrated and coordinated to make them as efficient and innovative as possible, and to ensure that Europe offers attractive prospects to its best brains' (European Council 2000).

The idea of an ERA grew out of the realisation that European research suffers from three weaknesses: insufficient funding, lack of industrial exploitation of scientific research and lack of coordination between research activities and resources (Commission 2002: 4). Indeed, R&D expenditures in the EU are currently below two percent, while the United States and Japan spend close to three percent of their GDP on R&D investments. The European Council has recognised this gap in R&D spending, and it has urged the European member states to raise this figure to three percent of their GDP by 2010 (European Council 2002). Europe also lags behind the US and Japan in terms of the industrial exploitation of scientific research. A broad consensus exists among European leaders that Europe should become more innovative if it is to sustain jobs and welfare. Recent research attributes Europe's poor performance in innovation to three factors: ineffective transfer of science to industry, few globally leading companies in emerging technologies and a low share of high-impact scientific papers (Dosi et al. 2006). The third weakness signalled by the European Commission refers to the dominance of national governments in research policy. Indeed, over 80 percent of research funding in Europe is still allocated at the national level (Commission 2000). Policies thus remain fragmented, increasing the risk of unnecessary duplication of research and unexploited economies of scale. For more information on the evolution of EU research policies we refer to the first chapter in the in-depth discussion.

Objectives of ERA policy

The European Commission specified the precise objectives of the ERA initiative in 2002 (Commission 2002: 4). These objectives are as follows:

- The creation of an 'internal market' in research, an area of free movement of knowledge, researchers and technology, with the aim of increasing cooperation[1], stimulating competition and achieving a better allocation of resources;
- A restructuring of the European research fabric, in particular by improved coordination of national research activities and policies, which account for most of the research carried out and financed in Europe;
- The development of a European research policy which not only addresses the funding of research activities, but also takes account of all relevant aspects of other EU and national policies.

From the recent assessment of ERA policy (Commission 2007a), it was concluded that policy efforts should be continued and intensified. It was also concluded that the three ERA objectives that were formulated in 2002 are still valid and will continue to guide ERA policy after 2007. For this reason, we use these three objectives (rather than its policies) as the policy background against which to assess the current functioning of the European research system.

From our empirical analysis of the European research system, we derive policy implications and relate them to the further development of ERA policy in light of its three objectives. Because ERA policy consists of a long and still expanding list of policies, however, we will not provide a full and comprehensive evaluation. We will focus instead on issues that we consider key elements of ERA policy and that can be well defined and tested empirically. We do this for each of the three objectives.

Our approach is based on regional analysis. In contemporary thinking about innovation, regions are considered the engines of innovation, employment and growth (Acs 2002). The spatial concentration of firms, research laboratories and training institutes provides opportunities for innovation (Cooke et al. 1998). At the same time, regions use networks at both national and international levels to draw on knowledge created elsewhere (Bathelt et al. 2004). The ERA concept can thus be defined as a European system of integrated regions that compete for markets while simultaneously collaborating within networks. The regional perspective also allows us to address the compatibility of ERA policy with cohesion policy. Following the third ERA objective mentioned above, an ERA should be designed such that possible conflicts between competitiveness and cohesion are avoided. See further the chapter on the evolution of EU research policies in the in-depth discussion.

Research questions

Regarding the first objective, our analysis assesses the validity of implicit assumptions underlying the ERA concept. The first implicit assumption holds that an ERA does not yet exist. Should an ERA already be in place, however, no policy intervention would be necessary. The second implicit assumption holds that ERA will contribute to the overarching Lisbon objective to help Europe become the world's most dynamic and competitive economy. In particular, it is believed that 'research activities at national and Union level must be better integrated and coordinated to make them as efficient and innovative as

1. In the following, we will use of the term collaboration instead of cooperation.

possible, and to ensure that Europe offers attractive prospects to its best brains' (European Council 2000). In other words, with the creation of ERA, the poor industrial exploitation of scientific research is expected to improve such that Europe's innovation output will increase. Although both assumptions are intuitively appealing, they are in need of empirical support. Our first research question is thus as follows:
Are the implicit assumptions underlying European Research Area policy – that such an area does not yet exist and that such an area would contribute to innovation – valid?

The second objective of the ERA is to achieve an 'improved coordination of national research activities and policies'. This objective is important, as it recognises the dominant role of member states in defining research policies and allocating R&D funds. With the adoption of an 'open coordination method', the European Commission will attempt to improve the coordination and coherence of national policies. This method is based on the following principles (Commission 2002: 19):

- setting general objectives and guidelines at the EU level;
- translating these objectives into specific targets and policy measures for each member state;
- establishing quantitative and qualitative indicators;
- benchmarking national and regional performance and policies in the area concerned;
- exchanging information, experience and 'best practices'.

To support the functioning of an open method of coordination, our report includes a benchmark exercise regarding the ability of member states to generate technological innovations from scientific research. The benchmark analyses best practices at the regional level that are specific to each member state. It provides indications about best practices that can be used in future discussions among member states and within the European Union. The second research question is thus as follows:
Which countries exhibit best practices for transforming scientific research into technological innovations?

The third and final objective of the ERA is to develop a research policy that 'takes account of all relevant aspects of other EU and national policies'. In other words, the research policy within the ERA should be coherent with other policy objectives formulated at the national and European levels. The objectives of the ERA and the objectives underlying cohesion policy could be in conflict in this respect (Commission 2001). The creation of the ERA is intended to improve the competitiveness of Europe as a whole by strengthening its capacity for research and innovation, while the cohesion policy aims to reduce income disparities between Europe's poorest regions and the rest of Europe. This leads us to our third research question, which is as follows:
Which potential conflicts and synergies exist between ERA policy and cohesion policy?

Implicit assumptions underlying the European Research Area concept

The first research question addresses the implicit assumptions underlying the ERA policy. It examines whether an ERA already exists and whether an ERA can be expected to contribute to the innovative performance of Europe. In our empirical study, we analyse the first implicit assumption (regarding the existence of an ERA) by examining possible barriers that are currently hampering the formation of the European Research Area. Answering this question requires a working definition of ERA. From the original document of the European Council meeting in Lisbon in 2000, we can derive the original intent of the ERA. The document stated that 'research activities at national and Union level must be better integrated and coordinated' (European Council 2000). The following can thus serve as a preliminary definition of ERA: *an area in which research activities at the national and* EU *levels are well integrated and coordinated.*

In the following section, we analyse the extent to which research activities at the national and EU levels are already *integrated*. We analyse this question in terms of research collaboration between scholars engaged in scientific and technological knowledge production. We consider a system integrated if the scholars within the system are unbiased and choose their collaboration partners solely on scholarly grounds. More specifically, we define the ERA as an area in which scholars do not bias their choice of collaborators according to geographical proximity or national borders. Although this definition of ERA is rather rigid, it captures both the exact idea of integration and the current emphasis on collaborative networks in the Framework Programmes of the European Commission.

Data

To analyse possible biases in the formation of collaborative networks in Europe, we draw upon information concerning co-publications and co-patents. Co-publications (co-patents) are publications (patents) that are associated with two different regions reflecting a collaborative relationship between two regions. Co-publications and co-patents are useful indicators in this context for two reasons. First, collaboration has become a widespread phenomenon in the modern research system, and the majority of publications and patents are currently produced jointly. Second, the Commission's main objective is to stimulate collaboration through subsidies allocated under the Framework Programmes (FPs), which is the main instrument for realising the first objective of ERA. Out of a total budget of EUR 50.5 billion, the most recent Seventh Framework Programme announced that more than EUR 32 billion will be allocated to subsidies for collaborative networks (European Parliament 2007).

Our data on publications were retrieved from the *Web of Science*[2] (WOS), which is a product of Thomson Scientific. Web of Science is an electronic archive of scientific publications in most academic journals. Although WOS does not contain all journals and tends to be biased towards English-language journals, it is widely considered the most comprehensive and reliable source, and it covers all of the major journals in the world. Our analysis focuses on biotechnology and semiconductor technology, which are two key sectors in Europe's research system. We retrieved the information on all scientific articles published in these fields between 1988 and 2004.

Data on patents were obtained from the *European Patent Office* (EPO) database. Our focus on the European Research Area provides a clear rationale for using this European database. Moreover, the choice to use patent data from the European Patent Office instead of from national patent offices ensures that the analysis addresses patents that are likely to be of relatively high commercial value, given that the EPO application procedure is more expensive and time-consuming than are those of national patent offices. As with the publications, we retrieved patent information for biotechnology and semiconductor technology. The information we retrieved concerns patents that were obtained since 1988. We did not extend the patent data beyond 2001, however, because, at the time we retrieved the data, there was a sudden drop in the total number of patents after 2001. This drop reflects a backlog in the review of patents.

To construct the data on the collaborative networks in Europe, we use the address information contained in publications and patents. With this information, we can aggregate the number of publications and patents to the regional level in order to indicate both the science base and innovative output of individual regions. Research collaborations are derived from publications and patents with multiple addresses. The association of a particular region with each address that occurs on a joint publication or patent reveals inter-regional networks of collaboration. The inter-regional networks for biotechnology and semiconductors are shown in Figure A. We refer to the chapter on data collection in the in-depth discussion for more information

Does an ERA already exist?

Although the maps provide preliminary evidence that most of the strong links are between regions that are in close proximity to each other and are often from the same country, statistical analysis is required to obtain empirical proof that such biases actually exist.[3] Our statistical analysis shows that biases do exist among European regions. This means that we cannot (yet) speak of an integrated European research system. The first bias affecting the choice of collaboration partner is geographical proximity. Researchers prefer to work with colleagues who are located nearby rather than with those who are further away. Analogous to economic activity, this means that there are

2. This resource was previously known as the *Science Citation Index*.

3. We use a statistical technique known as the gravity equation (Ponds & Van Oort 2006; Ponds et al. 2007) to determine whether the network structure shows any form of bias.

(still) costs associated with overcoming geographical distance, making long-distance relationships less likely to occur than are short-distance relationships. A second bias that we identified is that researchers prefer to work domestically rather than across national borders. More collaboration exists between regions within the same country than exist between regions from different countries, even after controlling for geographical distance. The national bias reflects the continued dominance of national institutions and policies, including national funding schemes, labour markets, intellectual property right regimes and – in most countries – a common language and culture.

As stated above, we understand an ERA as an area in which scholars do not bias the choice of collaborators according to geographical proximity or national borders. Our analysis shows that the concept of the European Research Area (ERA), as defined as *an area in which research activities at the national and* EU *level are well integrated and coordinated,* does not yet exist. This shows that the European Union has not yet succeeded in creating a European Research Area and that its present efforts to do so are apparently well justified.

A further analysis of European collaboration networks shows that the network exhibits hierarchical structures (see the third chapter in the in-depth discussion). Researchers in 'excellence regions' – regions that are characterised by both high quantity and high quality of research – prefer to collaborate with each other rather than with researchers from lagging regions. Because advanced scholars can learn only from other advanced scholars, this bias is understandable. The existence of a hierarchy with strong ties between excellence regions means that less-advanced regions have difficulty entering the 'network of excellence'. Over time, this exclusion logic is likely to increase existing regional disparities in the production of scientific and technological knowledge (Clarysse & Muldur 2001). We also observed a second politically structured hierarchy among European regions: capital regions prefer to collaborate with each other. This may reflect the fact that most national research institutes are located in capital cities, and tend to be over-represented in multi-lateral programmes that are supported by multi-lateral government funding. Importantly, following our understanding of the ERA (i.e. *an area in which scholars do not bias the choice of collaborators on grounds of geographical proximity or national borders)*, the existence of hierarchical structures is compatible with the concept of ERA, as it refers to structures other than geography.

In light of the discussion above, policymakers should be aware that there are two sides to the ERA concept. Although the creation of an ERA will remove 'artificial' barriers related to geography and borders, thereby benefiting all European regions, it will give preferential support to excellence regions and their mutual networks, with the goal of creating centres of excellence that are competitive on a global scale (Commission 2007b). These two effects should be treated as intended outcomes of ERA policy. Increases in the free movement of people will drive talent towards fewer places and will strengthen networks among them, thus transforming the geography of the European research system from one that is based on geography and national borders into one that is based on the clustering of talent and inclusion in networks of excellence. See further the chapter on 'The geography of research collaboration' in the in-depth discussion.

Does an ERA contribute to innovation?

The second implicit assumption of the European Commission holds that ERA will not simply lead to more collaboration, but that it will also improve the industrial exploitation of research. The ERA concept is based on the idea that Europe must integrate its research activities 'to make them as efficient and innovative as possible, and to ensure that Europe offers attractive prospects to its best brains' (European Council 2000). We assess this claim by analysing the contribution of scientific collaboration networks to regional innovative performance. The analysis (see the chapter on 'Regional innovativeness' in the in-depth discussion) considers whether networks have a significant effect on the innovative performance of regions, as networks could provide access to knowledge outside the region.

An appropriate empirical test for such an effect is to explain the number of patents in a particular region (knowledge output) according to the number of publications in a particular region (knowledge input) and the number of publications in regions to which the particular region is connected (access to external knowledge through networks). We thus assume that the extent to which regions profit from other regions depends on both the number of ties that it has with other regions and the number of publications in the partnering regions.

The results show that networks do matter. Networks allow regions to access knowledge that is available in other regions. This knowledge can subsequently be used in processes of innovation, together with the knowledge that is available locally. This result is important, as it confirms the implicit assumption that European integration – as defined in terms of collaboration networks at the national and EU levels – can indeed contribute to Europe's innovative performance viz. the Lisbon Agenda. For more details we refer to the chapter on 'Regional innovativeness' in the in-depth discussion.

Best practices

In addition to the objective of integrating the research activities of member states, the ERA concept aims to improve coordination between national research policies. By adopting this perspective, the European Commission acknowledges that the national systems are still dominant, as evidenced by the simple fact that member states still control over eighty percent of all research budgets (Commission 2000: 7). During the European Council meeting in Lisbon in 2000, an 'open coordination method' was introduced to improve the coordination and coherence of national policies (European Council 2000). This open coordination method is based on European guidelines, but without sanctions. Instead, national reform programmes are expected to emerge through continuous benchmarking, information exchange and mutual consultation between member states. The exact institutional reforms that particular countries will undertake are thus not dictated by the European Commission but, instead, proceed from a bottom-up process.

To support the open method of coordination, member states need benchmarks that provide information on the relative performance of the various national systems of innovation. From our analysis (cf. chapter 'Best practices of EU member states' in the in-depth discussion), we derive two indicators of the relative performance of EU member states. First, we determine which countries are more efficient in the regional transformation of scientific research into technological innovations. Second, we apply a statistical methodology to assess the contribution of national systems to regional patenting, with regard to factors other than publications.

Our results reveal significant national differences. In biotechnology, countries from Southern and Eastern European regions underperform, as do the UK and the Netherlands, while Austria, Germany and Switzerland outperform the rest of Europe. German-speaking countries also perform significantly better than the rest of Europe does in semiconductors, while Greece, Poland and Portugal are the least successful in generating patents. The resulting grouping of underperforming and overperforming countries is meaningful, as it also reflects institutional features. Notably, Mediterranean countries are characterised by centralised research systems with strong ties to national governments, which may hamper the emergence of science-based innovation processes. In contrast, the innovation systems in the German-speaking world are known for their strong university-industry interaction, particularly in the engineering sectors.

The results of our analysis (cf. 'Best practices of EU member states' in the in-depth discussion) reveal a number of best practices that can guide further discussions among member states. Similar analyses can be conducted with other data regarding input and output. Nonetheless, the results of best practices should be approached with caution. It can be noted that countries that follow the best practices in one technology (e.g. biotechnology) do not necessarily follow the best practices in another technology (e.g. semiconductor technology). Benchmark exercises should therefore be performed at the sector level, and subsequent institutional analysis and policy reform discussions should consider sector specificity.

Competitiveness and cohesion: Can they be combined?

From the outset, the Lisbon Agenda has raised concerns regarding possible conflicts between its objectives and the objectives of cohesion policy. Particularly with the creation of the European Research Area (ERA), the Lisbon Agenda aims to improve the 'competitiveness' of Europe as a whole by strengthening its collective research and innovation capacities. In contrast, the Structural Funds programmes aim to reduce income disparities between Europe's poorest regions and the rest of Europe, as otherwise indicated by the term 'cohesion'. As the main instruments of cohesion policy, the Structural Funds (SFs) are specifically devoted to regions with per capita incomes that are less than 75 percent of the EU average. The two objectives could be incompatible if the establishment of the ERA were to generate disproportionate benefits for richer regions, relative to poorer regions. Such a situation is to be expected, given the tendency of R&D funds to be concentrated in advanced regions simply because they host more researchers as a share of total employment. In addition, because such funds subsequently increase the number of researchers in advanced regions, the advantages of these regions are likely to be cumulative, further increasing the R&D gap between Europe's most and least advanced regions.

Following this reasoning, many have argued the existence of trade-offs between competitiveness policy and cohesion policy (Sharp 1998; Clarysse & Muldur 2001; Musyck & Reid 2007). The European Commission, however, does not share this view. Instead, it regards the SFs as a way of enabling lagging regions to strengthen their knowledge bases. Indeed, an increasing share of SFs is allocated to research, innovation and training activities in lagging regions. These improvements should subsequently allow lagging regions to participate more frequently in the collaboration projects funded under the SF programmes. This strategy could make the SFs compatible with the ERA concept.

The Commission's reasoning, however, neglects the hierarchical effects that we identified in the collaboration networks. We observed that researchers in 'excellence regions' prefer to collaborate with each other rather than with researchers from lagging regions. This concentration of talent in a few 'excellence regions' in Europe may actually increase further with the recent policy emphasis on excellent research. This suggests that a lagging region must pass a threshold of quality and size before it can become an important player in the European research network. Bringing about incremental improvements in the research bases of all lagging regions may not be very effective. Member states could stand to profit more by concentrating research subsidies from SFs in a few promising examples chosen from among the lagging regions helping them to become serious candidates in European research networks, while other regions may have more potential as high-end production sites. By providing conditions and facilities for the production of innovative products, these regions may profit from innovative activity carried out in advanced regions. For these latter regions, SFs could realise higher returns if spent on improving production activities, including improving accessibility, training the workforce and modernising business sites.

The free movement of people is another important pillar of the concept of ERA. This objective consists primarily of two parts. First, the budget for mobility of researchers was increased in the last Framework Programme. Second, attempts are being made to remove institutional obstacles that currently hinder labour mobility across national borders, including the diversity of diploma systems and differences in pension schemes. Increases in the mobility of researchers across national borders, however, are likely to reinforce the concentration of talent in a few excellence regions. The most talented researchers are likely to compete for positions at the most prestigious research institutes, thus rendering it more difficult for lagging regions to retain talent within their borders. The best strategy for lagging regions would be to send talent to advanced regions only on a temporary basis. Upon their return, these scholars would bring back state-of-the-art knowledge, as well as social networks that could serve as channels for future collaboration (Agrawal et al. 2006). In this way, lagging regions could start to position themselves within European networks. Special EU schemes that would require researchers who move from less-advanced to core regions to return in order to exploit their knowledge in their regions of origin are not desirable, however, as they would undermine '(t)he creation of an 'internal market' in research, an area of free movement of knowledge, researchers and technology' that underlies the ERA concept. This suggests that lagging regions, or the member states to which they belong, should develop regional schemes on their own to promote labour mobility on a temporary basis in order to profit from knowledge spillovers from advanced regions, as well as from the network connections that they generate.

A final remark concerning the expected increase of concentration of R&D relates to sectoral structure. The sectoral structures of poorer regions in Europe are quite different from those in the richer regions. Low-tech and medium-tech activities tend to predominate in poorer regions. Although some extent of innovation does occur in these sectors, the thematic priorities formulated under the Framework Programmes almost exclusively concern high-tech sectors (with the possible exception of food technology). For this reason, R&D subsidies are likely to become concentrated in richer areas, not only because of differences in the quality of researchers, but also because poorer regions are simply not specialised in high-tech disciplines. General perceptions currently hold that SFs are compatible with the creation of an ERA, as they are intended to improve the knowledge base of lagging regions such that they can effectively enter into European collaborative networks. Nonetheless, the improvements that are expected to emerge from the SFs primarily involve the knowledge base of existing specialisations, while the networks funded under the Framework Programmes focus on high-tech activities. The innovation opportunities for lagging regions thus lie in developing niche areas while drawing on their existing sectoral knowledge bases. The European Commission could therefore consider broadening its notion of innovation from its current bias towards high-tech industries by including niche areas that are relevant to lagging regions. This would allow innovation projects involving both high-tech and low-tech components to be eligible for financing, thereby increasing opportunities for excellence regions and lagging regions to collaborate in such projects. See 'Competitiveness and cohesion: Can they be combined?' in the in-depth discussion for more details.

Conclusion

Our analysis assessed the validity of two key assumptions that are implicit in the concept of the European Research Area (ERA). The first assumption holds that an ERA does not yet exist. The second assumption holds that an ERA will contribute to improving the industrial exploitation of scientific research. From the analysis of collaboration networks across EU regions and their contribution to technological innovation, we can conclude that both implicit assumptions underlying ERA policy are warranted. Because an integrated research system does not yet exist in Europe, there is indeed a need for ERA policy. In addition, if regions were to be better integrated within European collaboration networks, Europe would indeed be better able to exploit scientific research in technological innovation.

To achieve a European Research Area, a number of policy measures should be taken at the national and EU levels. At the national level, policies can be informed by benchmark exercises in order to learn from the best practices of member states. In the fields of biotechnology and semiconductor technology, we found that Germany, Austria and Switzerland performed much better than did other member states. At the EU level, the further development of ERA policy should pay more attention to possible conflicts with cohesion policy. One potential conflict involves the Directorate General for Regional Policy (DG Region), which is responsible for cohesion policy and the Directorate General for Research (DG Research), which is responsible for research and innovation policy. The increased involvement of DG Region in innovation policy through the allocation of SFS creates a potential source of interdepartmental competition with DG Research.

In-depth discussion

The evolution of EU research policies

Early period

The construction of science and technology policy in Europe began at the national rather than at the European level. The founding of the European Atomic Energy Community (EURATOM) in 1957 provided a legal basis for community-based Research and Technological Development (RTD), but its success was hampered by prevailing national nuclear energy programmes in Germany, France and the United Kingdom. In other disciplines, intergovernmental organisations (e.g. CERN and ESA) were established instead of research structures organised under the European Commission (Banchoff 2002).

The first genuine European initiative dates back to the early 1980s with investments in pre-competitive Research and Development. These programmes are typically legitimised by referring to market failures induced by the uncertainty of research activities. The European Commission initiated major collaborative technology projects in information technologies (ESPRIT) and communication technologies (RACE).[1] The emergence of a systematic research policy at the EU level, however, began with the launch of the first 'Framework Programme' in 1984. As the name suggests the framework programme structure was conceived as a common *framework* under which EU research polices should be organised and as a *programme* that lasted several years to make possible long-term investment in specific strategic areas.[2]

Framework Programmes

Europe's RTD policies became institutionalised as multi-annual framework programmes that provided funds for transnational networks of researchers in firms, universities and public laboratories. The cooperative approach of the Framework Programmes (FPS) aimed to overcome impediments to international collaboration and to induce economies of scale. The three main areas of industrial technology (i.e. information, communications and biotechnology) became the thematic pillars of the programme.

The Single European Act of 1987 provided the legal basis for the FPS as the core of Europe's RTD policies. In particular, Article 130f-130p of the Maastricht Treaty is worth considering. Articles 130f and 130g formulate the following two objectives: (1) '*to strengthen the scientific and technological basis of European industry*' AND (2) '*to become more competitive at international level*'. Article 130h subsequently gives the commission power to '*coordinate* RTD

1. The legacy of European funding in Information and Communication Technologies is still visible in current policy, where it remains the most important thematic pillar. Interestingly, Information and Communication Sciences is the only one of the 37 scientific fields in which European researchers generate a higher citation impact than their U.S. colleagues (Commission 2007a: 85). This may suggest that the strong investments of the past have indeed contributed to Europe's leadership in this domain.

2. See the interview with the historian of European integration Michel André: http://ec.europa.eu/research/rtdinfo/special_fp7/fp7/01/article_fp709_en.html *activities so as to ensure that national policies and community policies are mutually consistent'*. Finally, Articles 130i-p introduces the multi-annual FPs as the umbrella of all types of European research activities in the future.

The first three FPs co-funded international collaborations between research actors. In FP1 (1984-1987), 3283 projects were granted. This number was nearly doubled in FP3 (1990-1994), which involved 5529 projects (Schluga & Barber 2006). Although total expenditure levels increased with each FP, they remained modest in comparison with SF expenditures for cohesion policy (Sharp 1998) and with the R&D expenditures of the member states (Banchoff 2002). The nature of the programmes resembled the ideas of the traditional technology-push models, which assume that R&D funding inevitably leads to technological innovation and economic growth.

Several years later, the notion that innovation processes are collective and interactive (Lundvall 1988; Von Hippel 1988) sparked an increase in the contextualisation of RTD policies in FP4, which ran from 1994 to 1998, and FP5, which ran from 1998 to 2002. Emphasis shifted from knowledge production alone towards knowledge transfer and technology diffusion. This can be observed in the integration of SMEs in the programmes, the increased emphasis on training and mobility and the improved synchronisation with the major socio-economic challenges facing Europe. The objectives of RTD policy thus became more diverse, reducing unemployment, ensuring cohesion and accelerating structural change, in addition to stimulating innovation, although the exact contribution to these objectives is hard to prove.

The five successive FPs provided a solid foundation for a community-wide RTD policy. According to Banchoff (2002), however, the institutionalisation of EU research policies also caused a certain level of rigidity. Banchoff observes that institutional inertia appeared at three levels during this period. At the European level, complex and burdensome rules truly hampered the formulation and implementation of new RTD policies. The fixation on the FPs as the only way of organising European RTD policy impeded flexible change. At the same time, member states continued to insist on receiving their fair share of funding (juste retour) without considering European-wide benefits. Finally, programme beneficiaries that had developed powerful policy networks over the successive programmes supported the status quo in order to ensure a continuous flow of funding. It was found that networks that had won subsidies in one programme typically won subsidies in the following programme as well. This claim has been supported by empirical research using data on participation in successive Framework Programmes (Breschi & Cusmano 2004).

'Lisbon' and the European Research Area

The year 2000 saw a dramatic shift in the organisation of RTD policies in Europe. At the European Council meeting in Lisbon 2000, the member states of the European Union formulated what has become known as the Lisbon Agenda. With the establishment of the Lisbon Agenda, EU leaders signed on to an ambitious reform programme that aimed to 'become the most dynamic and competitive knowledge-based economy in the world' by 2010.

No precise actions were specified during the European Council meeting in Lisbon in 2000. Instead, the agenda set forth themes and objectives to be further elaborated at the national and European levels. This bottom-up approach (i.e. 'open method of coordination') allowed different countries to use different implementation strategies at the national level. At the same time, a continuous discussion was started at the European level regarding possible actions to be taken by the European Council. For example, during the European Council meeting in Barcelona, member states decided to strive to increase R&D spending from 1.9 to 3 percent of the GDP by 2010 (European Council 2002). The way in which each member state will try to achieve this goal, and the extent to which they will succeed through public or private funding, remains to be seen.

The cornerstone of the Lisbon Agenda is the creation of a European Research Area (ERA). The ERA concept was launched at the same Lisbon European council meeting (European Council 2000), following an earlier communication of the European Commission (Commission 2000). The general idea underlying ERA is that *'research activities at national and Union level must be better integrated and coordinated to make them as efficient and innovative as possible and to ensure that Europe offers attractive prospects to its best brains'* (European Council 2000). This idea grew out of the realisation that research in Europe suffers from three weaknesses: insufficient funding, a lack of industrial exploitation of scientific research and a lack of coordination between research activities and resources (Commission 2002: 4).

The R&D figures provide clear evidence of the weakness caused by insufficient funding. During the period 1995-2005, R&D expenditures in the EU remained below 2 percent of the GDP, while the United States and Japan spent close to 3 percent of their GDP on R&D. Remarkably, China is catching up quickly, having increased its R&D expenditures from less than 1 percent in 2000 to 1.3 percent in 2005. If the current stagnating trend in the EU and the increasing trend in China continue, China will have caught up with EU levels by 2009 (Commission 2007a: 76).

Europe's lack of commercial exploitation of scientific research is considered a second weakness. This is evident from the lower number of patents per capita in the EU to the US and Japan (Commission 2007a: 88-89). The relatively high level of public R&D expenditures is not matched by similar private expenditures. European firms apparently expect fewer returns on R&D investments than American or Japanese firms (Commission 2007a: 80). In particular, the EU is weak in emerging technologies (e.g. biotechnology and ICT), while it remains strong in many traditional industries (Dosi et al. 2006).

The lack of coordination of national research policies has been observed as a third weakness in Europe. The fragmented nature of research policy in Europe results from the dominance of member states in R&D funding. Approximately 17 percent of public research expenditures are allocated through community programmes and multi-lateral cooperation (Commission 2000: 7). National funding programmes have typically focused on the same themes, thereby duplicating research efforts and missing opportunities for realising economies of scale.[3]

Objectives of the European Research Area

The precise objective of the ERA initiative was formulated in 2002. It combines three related and complementary concepts (Commission 2002: 4):

– *The creation of an 'internal market' in research, an area of free movement of knowledge, researchers and technology, with the aim of increasing cooperation, stimulating competition and achieving a better allocation of resources*
The main instrument for the first target involves multi-year FPs that provide the funds for transnational networks of researchers in firms, universities and public laboratories. The budgets of FP6 (EUR 16.270 billion 2003-2006) and FP7 (EUR 50.521 billion, 2007-2013) are substantial. In particular, FP7 marks an increase over previous programmes (see Figure 1), and FP6 marks a shift in selection procedures, placing more emphasis on excellence (favouring established regions) and less on cohesion (favouring poorer regions). For example, the introduction of Networks of Excellence was specifically designed to pool European talent, regardless of the region of origin. In addition, a debate has started concerning the establishment of a European Institute of Technology (EIT) to concentrate talented researchers and promote the effective industrial exploitation of scientific research (Commission 2005: 23).The breakdown of the FP7 expenditures is shown in Figure 2. The current FP7 promotes excellent frontier research ('Ideas') by spending 14.9 per cent of its budget on such initiatives. This new programme is managed by the newly established and independent European Research Council, in order to assure the highest quality control. The majority (64.1%) of the funding, however, is still reserved for 'Cooperation', thus continuing the core instrument of the previous FPs. The continued emphasis on ICT and biotechnology provides evidence of thematic continuation from previous programmes (see Figure 3). Other important elements of the budget include the labour mobility of researchers, which is shown under the heading of 'People' (9.4%) and the enhancement of research and innovation infrastructures, shown under the heading of 'Capacities' (8.1%).

Another important action that is currently being undertaken is to harmonise the European patent system and to simplify procedures, thereby accelerating the patent-granting process and reducing the costs of filing a patent. Although this objective had already been stated during the European Council meeting in Lisbon (European Council 2000), the process has yet to be finalised.

3. To some extent, the European Commission and the European Parliament can be held responsible for the fragmentation of research policies. Most of the Commission's expenditures are devoted to thematic priorities, as the Commission and Parliament want to promote research in specific areas. As a result, much of the research that is financed is of an applied nature, while economies of scale are more readily achieved in fundamental research, due to its 'universalistic' nature (Banchoff 2000). There are several arguments for increasing the role of the European Commission in fundamental research (Pavitt 2000). A shift towards fundamental research can be seen in the latest funding scheme under the Seventh Framework.

– *A restructuring of the European research fabric, in particular by improved coordination of national research activities and policies, which account for most of the research carried out and financed in Europe*
This second aim is achieved through voluntary cooperation between member states based on the open method of coordination. This method is characterised by the following principles (Commission 2002: 19): setting general objectives and guidelines at EU level; translating these objectives into specific targets and policy measures for each member state; establishing quantitative and qualitative indicators; benchmarking national and regional performance and policies in the area concerned; and exchanging information, experience and best practices. The open method rests on such soft laws as guidelines, indicators, benchmarking and learning through best practice. There are thus no official sanctions, as it is believed that the method's effectiveness is ensured through a form of peer pressure and a process of 'naming and shaming'. It is assumed that no member state would want to be ranked worst in a given policy area. As such, this instrument functioned as a catalyst for national policy reform. Recent examples of this instrument include the ERA-NET,[4] which tries to counteract the fragmentation of national research policies and funding schemes between separate member states, the ERA-WATCH,[5] which provides information on the research policies and systems of member states, and the ESFRI, which coordinates investments in pan-European research infrastructures.
– *The development of a European research policy which not only addresses the funding of research activities, but also takes account of all relevant aspects of other EU and national policies*
The third objective contributes to coherence between the ERA and other policies at the European and national levels. The most important interface – and a potential source of incompatible objectives – exists between ERA policy and cohesion policy. Structural Funds (SFs), which are allocated to regions whose per capita income is less than 75 percent of the EU average, constitute the main instrument of cohesion policy. With a total budget of EUR 307.6 billion for the period from 2007 to 2013, the SFs have the potential to bear a strong impact on Europe's knowledge economy. Initially, SF activities in less favoured regions concentrated on physical infrastructure to improve accessibility and on capital to boost investment. Under the influence of the Lisbon Agenda, an increasing share of SF funding is currently devoted to intangible investments in education, training, research and innovation priorities. This raises the question of whether investments from the FPs are complementary to investments from the SFs.Possible tensions between the two programmes were recognised at an early stage (Commission 2001). Recent consensus holds that synergies are being created between SFs and ERA, as the SFs enable less-advanced regions to strengthen their knowledge base, thereby making them more attractive as collaboration partners for projects funded under the FP (European Parliament 2007:16). Another synergy involves the fact that the ERA

4. http://ec.europa.eu/research/fp6/index_en.cfm?p=9_eranet
5. http://cordis.europa.eu/erawatch/

provides regions with a European platform upon which to coordinate their respective regional policies that are being developed within the context of the SF. One such coordinating device, 'Regions of Knowledge', is institutionalised in FP7 under the heading of 'Capacities', with a budget of EUR 126 million (European Parliament 2007: 10). A similar concern can be expressed regarding the established Competitiveness and Innovation Programme (CIP), which runs from 2007 to 2013. With a budget of EUR 3.6 billion, this programme is much smaller than those of the ERA and SF are. The main objective of the CIP programme is similar to that of the ERA, in that it aims to strengthen innovativeness. In contrast to ERA policy, however, it is targeted primarily at SMEs, and it focuses on the adoption rather than the development of new technology (especially ICT and clean energy technology). Contrary to SF and ERA, CIP is designed as a formal complement to the ERA (European Parliament 2007: 15); synergy problems are therefore unlikely. Given that CIP is a new and small programme, we limit the discussion in the remainder of this report to the interface between the Framework Programmes (FPs) and the Structural Funds (SFs).

ERA policy assessment

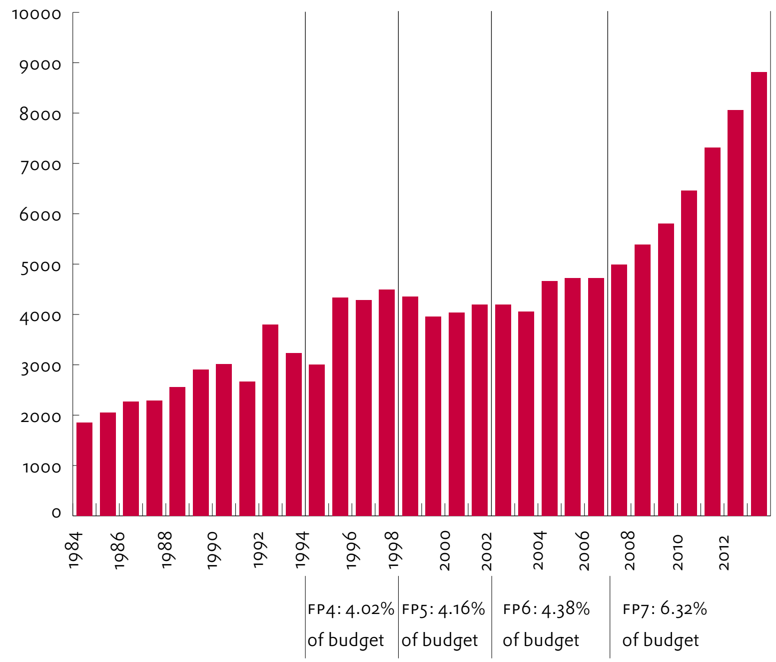
Since the launching of the ERA concept at the Lisbon council meeting in March 2000, many initiatives have been undertaken at the European level, as well as at the level of member states. Notably, the budget for the FPs has been increased substantially, and these programmes have placed more emphasis on excellence in research. In addition, several organisational bodies have been established, including the ERA-NET scheme, which coordinates national and regional research policies, and the ESFRI, which coordinates investments in pan-European research infrastructures. The establishment of the independent European Research Council to allocate funds for excellent research is also widely considered a major institutional breakthrough.

Despite these developments, a recent overall assessment concluded that 'actions undertaken at EU level since 2000 in support of ERA have delivered modest and varied progress' (Commission 2007a).[6] The lack of progress is most visible and troublesome in at least three main areas (Kok et al. 2004; Commission 2005, 2007a, 2007b). First, despite widespread consensus regarding the need for more innovation in Europe, and despite the increased policy efforts at the national and European levels, R&D expenditures have grown little during the past seven years and are still below two percent of the Gross Domestic Product (GDP) in Europe. Second, the modernisation of the European patent system has proven problematic. Although European leaders had already decided during the Lisbon council meeting in 2000 to harmonise and improve the European patent system, the process has yet to be finalised. Third, despite a number of initiatives, national research policies have not been changed in any fundamental manner. Policy continues to be driven by national considerations rather than by a vision of how national and European efforts can be made coherent and complementary.

6. This observation is in line with a more general concern that the Lisbon Agenda, even though it is widely shared, has been poorly implemented during its first five years (Kok et al. 2004; Commission 2005).

From the recent assessment of ERA policy, it was concluded that the policy efforts should be continued and intensified. It was also concluded that the three ERA objectives that were formulated in 2002 are still valid and will continue to guide ERA policy even after 2007. For this reason, we use the three objectives of the ERA (rather than its policies) as the policy background against which to assess the current functioning of the European research system in the following chapters.

Figure 1. Budget of the European Union for RTD programmes 1984-2013 (constant 2006 prices*). *Source:* Commission (2004) and Commission (2006)



* We applied an inflation factor of 0.02 for the period 2007-2013.

Figure 2. Budget breakdown of the Seventh Framework Programme. *Source:* Commission (2006)

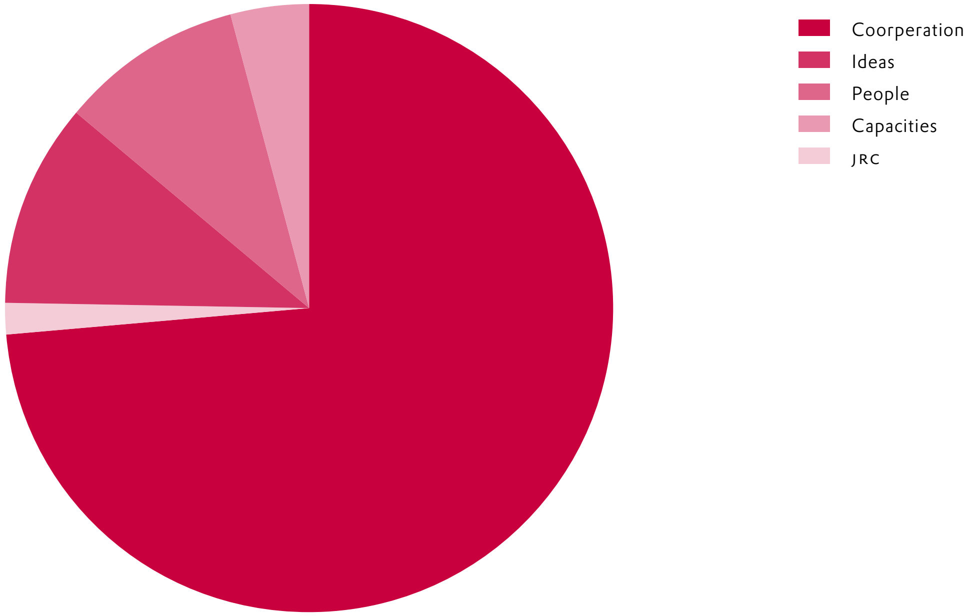
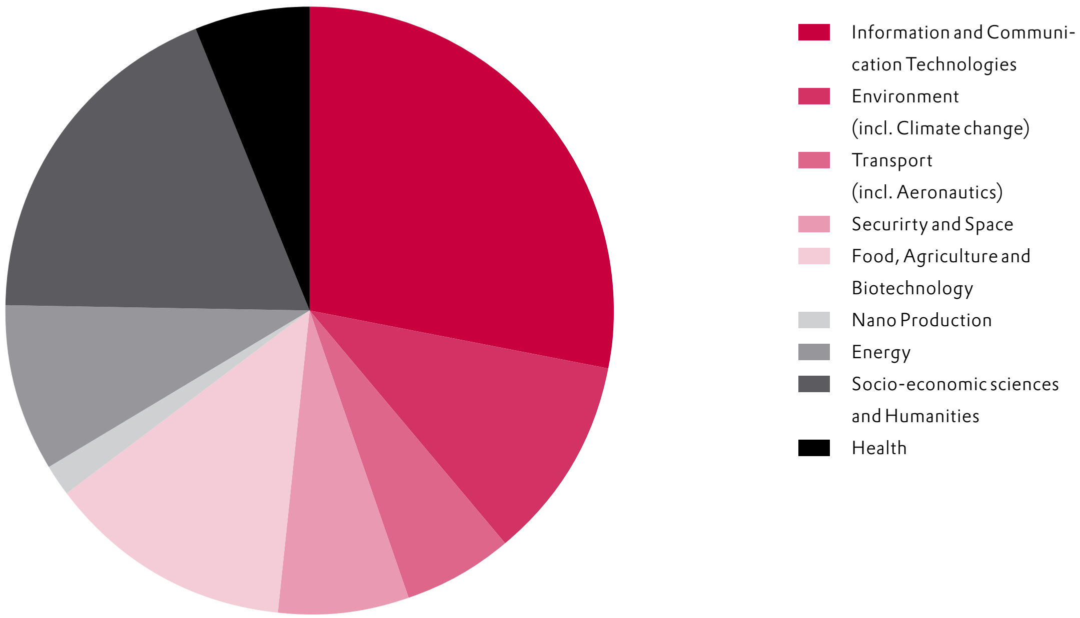


Figure 3. Budget breakdown of the Cooperation heading in the Seventh Framework Programme. *Source:* Commission (2006)



Data collection

DATA COLLECTION

Research on knowledge production has always relied on partial indicators. Because knowledge is intangible by definition, it can be neither measured nor counted directly and unequivocally. Nonetheless, many knowledge production processes, particularly those in the areas of scientific research and technological innovation, do have tangible output: texts. Many of these texts reach the general domain in the form of publications in scientific journals or in the form of patents awarded by patent offices. Both publications and patents indicate research activity of proven value. Publications in scientific journals have been subjected to peer review, assuring a minimum level of quality and originality. Patent examiners review and grant patents according to the originality of inventions.

Scholars who study science and technology make extensive use of publications and patent data, due to a number of advantages (Griliches 1990). The following are among these advantages:

1. Each publication and patent contains highly detailed information on content (title words and abstract), previous art (citations), researchers (names), organisations involved (institutional affiliations), and geographical location (addresses).
2. Systematic data collection on patents and publication goes back a long time.
3. The current 'stock' of patents and publications is extensive and continues to expand.

Despite these advantages, we should bear in mind that their use is also subject to limitations (Griliches 1990). More specifically, we can identify three major drawbacks:

1. Research does not necessarily lead to publications or patents. Rejection by reviewers is one of the main reasons. Other reasons include the time/cost constraints of researchers with regard to the submission of reports for publications or patenting, and the non-disclosure strategies of firms who value secrecy more highly than they value property rights.
2. Publications and patents do not necessarily contribute to our knowledge. Most publications and patents are rarely cited, if at all, suggesting that they add little value to the knowledge system. The commercial value of patents also varies widely.
3. Publication and patenting rates differ systematically across scientific disciplines and technological fields, respectively. Differences in technological specialisation can therefore render inter-regional comparisons misleading.

Despite these shortcomings, we make use of both publications and patents, as we consider these data appropriate to our purposes. With regard to the first limitation, our research topic (the European Research Area) renders the use of quantitative information almost indispensable. Alternative research methodologies (e.g. expert interviews), would be too limited in scope. We address the second limitation by aggregating publications and patents to the regional level in order to minimize differences in quality. With regard to the third limitation, the separate analysis of various scientific disciplines and technology classes (i.e. 'science-based sectors') allows us to avoid making conclusions that are biased by regional differences in scientific or technological specialisation.

Data on publications were retrieved from the *Web of Science*[1] (WOS), which is a product of Thomson Scientific. The WOS is an electronic archive of scientific publications in most scientific journals. Although the WOS does not contain all journals and tends to be biased towards English-language journals, it is widely considered the most comprehensive and reliable source covering all the major journals in the world. We retrieved the information on all scientific articles published between 1988 and 2004.

Data on patents were obtained from the *European Patent Office* (EPO) database. Our focus on the European Research Area provides a clear rationale for the use of this database. Moreover, the choice to use patent data from the European Patent Office instead of from national patent offices ensures that the analysis addresses patents are likely to be of relatively high commercial value, given that the EPO application procedure is more expensive and time-consuming than are those of national patent offices.

We retrieved information on scientific articles that were published between 1988 and 2004, as access to the WOS is restricted before 1988. We therefore obtained information on patents that have been granted since 1988. We did not extend the patent data beyond 2001, however, because there was a sudden drop in the total number of patents after 2001 at the time we retrieved the data. This drop reflects a backlog in the administration of patents awarded.

We did not retrieve all publications and patents, due to the excessive amount of time that would have been necessary. We limited our analysis to two science-based technologies (defined as technologies that often cite scientific literature) in order to make our comparison between scientific publications and technological patents empirically relevant. To this end, we use an existing study that assesses the science base of technologies by analysing the share of citations of scientific publications that are made in patents (Verbeek et al. 2002). In this way, the study uses the existing classification of scientific disciplines in the WOS and the existing classification of technologies used by the EPO.

From this list, we selected the IPC classes of biotechnology and semiconductors as the focus of our analysis, as these two patent classes belong to the

1. This resource was previously known as the *Science Citation Index*.

2. The funding for semiconductors falls largely under the heading of Information and Communication Technologies (ICT).

3. Although publications from the field of applied physics are cited even more frequently than are publications from electrical and electronic engineering, applied physics is considered too broad to treat as a single discipline.

group of patents that make the most frequent reference to scientific fields. Moreover, these two technologies had a revolutionary global impact during the last two decades. From a policy perspective, biotechnology and semiconductors have also been thematic priorities of Europe's RTD policy for more than two decades, and the successive Framework Programmes have therefore devoted substantial resources devoted to these fields.[2] We subsequently chose the scientific disciplines that are most often cited by the two technological classes. For biotechnology, the relevant scientific disciplines were biochemistry and molecular biology; for semiconductors, we chose electrical and electronic engineering as the relevant scientific disciplines.[3]

One major advantage of using publications and patents is that the addresses of researchers are systematically recorded in these texts. We make use of this information to aggregate the number of publications and patents to the regional level in order to indicate the scientific base and innovative output of particular regions.[4] The assignment of publications and patents to regions is based on the method of 'full counting'. This means that all addresses on publications and patents are counted as a unit. For example, if a publication or patent contains three addresses within one NUTS3 region, this region receives a total number of three publications. If the three addresses are in different regions, however, each of the three regions receives a count of one. An alternative method is fractional counting, in which any occurrence of three regions ona single publication or patent is divided by the total number of address occurrences. For example, if a publication contains three addresses in three different regions, each region receives a count of 1/3. Logically, if all addresses are in the same region, the region receives a count of one. The final dataset of publications and patents by region based on full counting is very similar to the dataset obtained by fractional counting.[5]

With regard to the territorial breakdown, we constructed our dataset at the NUTS3 level covering the 27 countries of the European Union, plus Norway and Switzerland. We consider the NUTS3 level of spatial aggregation relevant, as it corresponds most closely to regional labour markets *in casu* 'regional innovation systems' (Cooke et al. 1998). All addresses occurring in publications and in patents have therefore been assigned to one of the 1316[7] NUTS3 regions in the aforementioned 29 countries in Europe. A more detailed overview of the NUTS classification and our choice for the NUTS3 level is shown in the Box 'NUTS Classification'.

In addition to our dataset of publications and patents, we constructed a dataset of inter-regional research collaborations. More than half of all publications and patents contain multiple addresses that are located in more than one NUTS3 regions. In our dataset, this phenomenon represents an inter-regional collaboration link. The intensity of collaboration between two regions is then defined by the number of times addresses from these two regions co-occur in a publication or a patent. This process yields four matrices of inter-regional

4. The address information contained in publication data refers to the address of the organisation where the researcher works. In contrast, the address information in the patent data we used refers to the home addresses of the researchers involved. This difference should always be kept in mind, as it impedes and limits any comparison between the collaboration patterns that are reflected in publications and those that are reflected in patents.

5. Correlations are as follows: biotechnology publications (0.994), semiconductor technology publications (0.995), biotechnology patents (0.993), semiconductor technology patents (0.995). All results are significant at the .01 level.

7. Because we were not able to locate the addresses within the greater urban areas of London and Manchester, we consolidated them into two new areas. We also excluded a number of islands because of their remote location and disproportionate geographical distance from other regions. The following islands were excluded: Guadeloupe Las Palmas (ES), Santa Cruz de Tenerife (ES), Guadeloupe (FR), Martinique (FR), Guyane (FR), Réunion (FR), Região Autónoma dos Acores (PT) and Região Autónoma da Madeira (PT). These exclusions yield a total of 1316 NUTS3 regions instead of 1329.

NUTS Classification[1]

We used the NUTS classification of the European Union to aggregate patents and publications to the regional level. The statistical office of the European Union (EUROSTAT) provides the Nomenclature of Territorial Units for Statistics[2] (NUTS) as a uniform breakdown of territorial units for the production and analysis of regional statistics. The NUTS classification is a three-level hierarchy that ranges from NUTS0 to NUTS3. The NUTS0 level corresponds to the territory of individual member states, and each NUTS0 region can be subdivided into at least one NUTS1 region, which in turn can be subdivided into at least one NUTS2 region and so on.

At the regional level (NUTS1, NUTS2, NUTS3), the NUTS classification largely follows existing administrative boundaries. If municipalities are not taken into account, however, only two administrative layers are usually present at the regional level (e.g. *région* AND *departement* in France, *Länder* and *Kreise* in Germany, *regioni* and *provincie* in Italy). For this reason, a third 'artificial' level is added for each member state. Whether the administrative regions are classified as NUTS1, NUTS2 or NUTS3 depends entirely on the minimum and maximum population thresholds for the size of regions. For example, the administrative regions in some countries may correspond to NUTS1 and NUTS2 with an artificial NUTS3 layer (as in Belgium); in other, they correspond to NUTS2 and NUTS3 with an artificial NUTS1 layer (as in Italy and France). Moreover, at a more detailed level, EUROSTAT distinguishes between Local Administrative Units (e.g. municipalities and districts), although these units are not subject to the NUTS regulation.

To date, all studies analysing the European Research Area have used NUTS2-level data, as most empirical data are not available at lower levels of spatial aggregation. In theory, however, NUTS3 regions are more relevant as units of analysis, as they correspond more closely to labour market areas.[3] In the context of knowledge production and innovation, labour market areas are relevant

systems of reference, given that most people change jobs within the same area, thus contributing to the circulation of knowledge (Breschi & Lissoni 2003). 'Regional innovation systems' (Cooke et al. 1998; Asheim & Isaksen 2002) are thus conceptually more likely to be present at the NUTS3 level than at NUTS2 level. Furthermore, most NUTS3 regions harbour only one major city, implying that the impact of population concentraTions can best be addressed at the NUTS3 level. Our analyses are therefore performed for NUTS3 regions rather than for NUTS2 regions.

1. See also http://ec.europa.eu/eurostat/ramon/nuts/basic-nuts_regions_en.html for a more detailed overview of the NUTS classification.

2. Officially, NUTS is a French abbreviation for *Nomenclature des Unités Territorial Statistiques*.

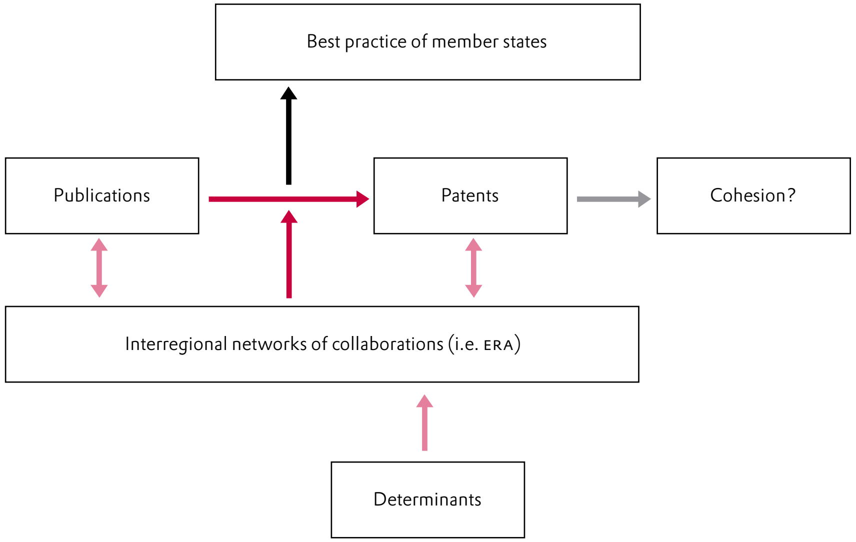
3. For Germany, however, labour market areas are known to be a combination of the NUTS2 and NUTS3 levels.

collaboration patterns. In this dataset as well, we use the 'full counting' method to derive the interaction strength between two regions. This means that regions that are overrepresented in networks will have more publications or patents, because any publication or patent counts as one, regardless of the number of collaborators.

At this point, it is important to note that the occurrence of publications and patents with multiple addresses may refer to several underlying mechanisms. In most cases, an inter-regional link represents collaboration between two or more inventors or institutions. In some cases, however, a single researcher may appear on a publication or patent with two or more addresses. This phenomenon also counts as collaboration and could indicate that the researcher worked for two or more organisations or conducted a study for one organisation and subsequently moved to another organisation. The inter-regional collaboration networks thus refer primarily to the main pillar of the Framework Programmes (i.e. cooperation); to some extent, however, they also reflect labour-mobility mechanisms, which are another pillar of Europe's RTD policies, under the heading of 'People'.

The data we collected allows the examination of several aspects of the European research system. Our analysis focuses on three phenomena in particular. In the third chapter, we analyse factors that determine the structures of these collaboration networks. In the fourth chapter, we use the networks to determine whether they contribute to the industrial exploitation of scientific research. In the fifth chapter we identify the countries that exhibit best practices for transforming scientific knowledge into technological innovation. Finally, we draw upon our findings to discuss potential conflicts and synergies between ERA policy and cohesion policy. The framework represented in Figure 4 summarises our approach.

Figure 4. Analytical framework



- Chapter 'The geography of research collaboration'
- Chapter 'Regional innovativeness'
- Chapter 'Best practices of EU member states'
- Chapter 'Competitiveness and cohesion: Can they be combined?'

The geography of research collaboration

Introduction

From a policy evaluation perspective, it is legitimate to assess the need for policies that aim to create the European Research Area (ERA). After all, the desire to create the ERA assumes that such an area does not yet exist. If it does already exist, the rationale for policies that are thought to be instrumental in the creation of the ERA can be questioned.

Before we can assess the need for ERA policy and derive conclusions in this regard, we need a working definition of the European Research Area. Unfortunately, no such definition is provided in any document of the European Council or the European Commission. It is possible, however, to derive the original meaning of the ERA from the original document of the European Council meeting in Lisbon in 2000. This document stated that 'research activities at national and Union level must be better integrated and coordinated to make them as efficient and innovative as possible, and to ensure that Europe offers attractive prospects to its best brains' (European Council 2000). From this, we can derive the following preliminary definition of the ERA: *an area in which research activities at the national and* EU *levels are well integrated and coordinated*.

In the following section, we analyse the extent to which research activities at the national and EU levels are already *integrated*. The *coordination* of research activities at the national and EU levels is the focus of the analysis in the fifth Chapter. We analyse integration in terms of research collaboration between scholars engaged in scientific and technological knowledge production. We consider a system integrated if the scholars within the system are unbiased and choose their collaboration partners solely on scholarly grounds. More specifically, we understand the ERA as an area in which scholars do not bias the choice of collaborators according to geographical proximity or national borders. Although this understanding of the ERA is rather rigid, it captures both the exact idea of integration and the current emphasis on collaborative networks in the Framework Programmes of the European Commission.

Collaborative knowledge production

The most striking characteristic of knowledge production in science and technology during the twentieth century was its increasingly collaborative nature. At the beginning of the twentieth century, co-authorships accounted for less than 10 percent of all scientific publications. At the end of the twentieth century, co-authorships accounted for more than half of all scientific publications (Wagner-Doebler 2001). Natural scientists are particularly likely to collaborate in their research projects, while collaborations are less frequent in the social sciences and even less so in humanities (Guimera et al. 2005). These differences can be explained by the extent to which particular types of research can benefit from division of labour. In natural sciences, many competences must be brought together to produce a new piece of knowledge in the laboratory, while a smaller range of competences are required in the social sciences and humanities.

The average number of inventors that contribute to a given patent has also increased during the past 20 years (Fleming & Frenken 2007). A similar tendency towards increasing division of labour can be observed. With the universe of knowledge ever expanding, researchers must specialise in order to continue contributing to the production of state-of-the-art knowledge.

Research collaboration generates benefits in several ways (Katz & Martin 1997). Economically, it provides opportunities to realise savings in the costs of training and research infrastructures, and it helps to avoid the duplication of research efforts. Collaboration is also expected to generate intellectual benefits through the cross-fertilisation of ideas that were previously unconnected, and it is expected to enhance quality control through internal peer review. Indeed, scientific articles stemming from international collaborative projects are cited more frequently, on average, than publications from national collaborative projects (Narin et al. 1991; Katz & Martin 1997; Frenken et al. 2005). The European Commission's objective to create an ERA by stimulating research collaboration is therefore legitimate as long as barriers exist that impede European researchers from engaging in research collaborations.

A number of previous studies have analysed the extent of European integration in networks of research collaboration. These studies, however, have been limited to the international level, addressing collaborations between countries (e.g. Narin et al. 1991; Moed et al. 1991; Glänzel 2001; Frenken 2002; Wagner & Leydesdorff 2005; Ponds 2007). These studies focus on the pattern of inter-country collaboration in terms of the frequency of collaboration between countries as compared to the frequency of collaboration within countries. When considering all scientific fields, the results showed that the EU15 was not well integrated during the period 1992-2000, due to a strong and persistent bias towards national collaboration (Frenken 2002). It is important to note, however, that the disappointing results of such aggregated analysis leaves open the possibility that the scientific fields that the EU specifically targets in its policies (e.g., biotechnology, ICT, clean energy) are already well integrated.

Although studies of research collaboration have traditionally focussed on the national level, a number of studies have analysed research collaboration between regions. These studies, however, have been limited to regions belonging to a single country. The first study on co-publications between regions concerns the United Kingdom, where it was found that the geographical distance between two regions significantly decreased the number of research collaborations between two regions (Katz 1994). This result was also found for co-publications among Swedish regions (Danell & Persson 2003), Chinese regions (Liang & Zhu 2004) and Dutch regions (Ponds et al. 2007). Similar analyses using address information appearing on co-patents have been conducted for Swedish regions (Ejermo & Karlsson 2006) and for regions of six EU countries (Maggioni et al. 2006). Similar to the patterns revealed by data on co-publications, co-patent data show that geographical distance significantly reduces the likelihood that researchers from two regions will collaborate. This research suggests that 'distance still matters', despite the Internet, inexpensive air travel and the use of English as a common language in the global knowledge economy.[1]

1. In other words, these studies refute the 'death of distance' hypothesis put forward by Cairncross (1997).

Theoretical framework

The rationales for collaborative knowledge production are straightforward: scholars engage in collaborations in order to learn and benefit from each other and to make a stronger impact on the field than could be achieved individually. At the same time, the pursuit of quality is subject to several constraints. The time and money required to engage in collaboration are substantial, thus forcing researchers to be selective when choosing collaboration partners. The strength of interaction between any two scholars and any two regions is therefore dependent on both the learning opportunities involved in collaboration and the amount of time and money that is required to participate.

Starting with the costs involved, we can distinguish between two forms of distance that are expected to raise costs and, thus, to decrease the probability of interaction (Boschma 2005). First, the costs of collaboration increase as a function of geographical distance. Research collaboration over longer distances involves more travel time and higher travel costs. As a result, geographically proximate research collaborations are more likely to occur. Second, the costs of collaboration increase with institutional distance (Gertler 1995). This form of distance is more abstract than geographical distance is. By institutional distance, we mean the extent to which scholars work under different sets of institutions. The greater the difference is between the institutions involved in a collaboration, the more likely that collaboration is to fail and the more difficult it will be to collaborate, given that the two partners apply different 'sets of habits, routines, rules and laws' (Edquist & Johnson 1997). This type of collaboration is thus less likely to occur and more likely to fail. In the case of knowledge production in the fields of science and technology in Europe, the various institutional arrangements have strong national components. Although by no means exclusively, funding, labour markets regulations, intellectual property right regimes, language, culture and similar institutions are predominantly present at the level of nation states. Our hypothesis therefore holds that scholars in regions belonging to the same country are institutionally proximate and thus more likely to collaborate, while partners in regions belonging to different countries are institutionally distant and less inclined to collaborate.[1]

The benefits of research collaboration are more specific to the background of the scholars involved. In this regard, asymmetry is to be expected between scholars who differ in quality. In general, scholars who know less stand to profit more from collaboration than scholars who know more, as the former can learn more than the latter. The knowledge asymmetry between scholars implies differences between scholars with regard to the incentive to collaborate. High-quality researchers are likely to prefer to work with other high-quality researchers, because they can learn much more from people who are working at the same level than they can from people who are less knowledgeable.

It is known that high-quality research is concentrated in certain regions (Tijssen 2007). Given that scholars in these regions have particular incentives to form networks, regional hierarchies are likely to emerge, with well-connected regions hosting the scientific elite and poorly connected regions hosting the other scholars. Following the nomenclature of the European Commission, we use the term 'excellence regions' to refer to high-quality regions. The hierarchical structure resulting from research collaboration is expected to be such that, with all else being equal, pairs of excellence regions will have stronger ties than will pairs of any other type of regions.

In our analysis, excellence regions are defined as those belonging to the top 25 most publishing regions and the top 25 most patenting regions. Size is treated here as a proxy for quality. Regions that host top institutes will typically grow and attract the best talent, while regions with poor institutes will have trouble growing and retaining their talent. The assumption that size and quality are closely correlated is also supported by the empirical finding that the mean citation rate for scientific articles in a region increases with the number of articles produced in that region (Tijssen 2007). This is also evident in our data, as represented in Figures 5 and 6.[3]

A second hierarchical structure can be expected to follow from political elites. Collaboration requires resources, and differential access to resources will affect the propensity of scholars to collaborate. Resources are concentrated in large cities – predominantly capital cities – in which governmental agencies and private investors tend to be concentrated. Scholars located in capital regions may thus have better access to resources than other scholars do, because they are better able to influence agenda-setting processes and lobby for public funding. Furthermore, most national research institutes are located in capital cities, and these institutes are typically over-represented in multi-lateral programmes supported by multi-lateral government funding. Following this reasoning, we expect that, all else being equal, pairs of capital regions are likely to have stronger ties than pairs of any other type of region.[4]

2. This should not be confused with the alternative notion of institutional proximity, which refers to organisations that operate within the same societal subsystem (e.g. inter-university, inter-firm or inter-governmental relationships). For more information on this point, see Ponds et al. (2007).

3. Also note that the European Commission also associates size with quality, stating that 'some concentration and specialisation is necessary to permit the emergence of (...) European centres of excellence competitive on the global scale' (Commission 2007b: 14).

In summary, we define integration as the absence of any geographical barriers to collaboration. This means that an integrated system at the national and EU level is one in which research collaboration between regions is no longer affected by either geographical distance or national institutions. In addition to geographical distance and national institutions, we analyse hierarchies in research collaboration, as these hierarchies can be expected to form between excellent regions and between capital regions.

Methodology

The dataset of inter-regional collaborations on co-publications and co-patents that is introduced in the previous chapter is used to indicate the collaboration networks between European regions. Maps showing the inter-regional collaboration networks are presented in Figures 7 and 8 for biotechnology and semiconductor co-publications. Maps for biotechnology and semiconductor patents are shown in Figures 9 and 10. These maps clearly show that networks are concentrated in Western Europe and that most of the strong links are within countries. At first glance, therefore, the formation of collaborative networks does appear to be affected by geographical distance and national borders.

Table 1 shows descriptive statistics for inter-regional collaborations in Europe. Because our analysis addresses all possible pairs of regions, and not individual regions, the total number of observations amounts to $\frac{1}{2} \cdot 1316 \cdot 1315 = 865270$ observations. This implies that the mean number of collaborations is very low, as the large majority of pairs do not collaborate at all. When broken down to domestic and international collaboration, it becomes apparent that domestic collaborations are much more frequent than are international collaborations.

We use a gravity model to analyse the determinants of the inter-regional networks. This model, derived from Tinbergen (1962), is used extensively in the economic trade literature to estimate trade flows between two countries according to the size of the two countries and the geographical distance between them. In a gravity model, the gravitational force between two objects is dependent on the mass of the objects and inversely dependent on the distance between them (as in Newton's law). The explained variable in a basic gravity equation is the intensity of interaction between each pair of objects or entities. In our case, this refers to the number of collaborations between each pair of regions. The explanatory variables are the 'masses' of the two regions *i* and *j* and the geographical distance between two regions. MASS is measured by counting all publications or patents that have at least one address stemming from a given region.[5] The more active two regions are in research,

4. Moreover, the main airports of almost all countries are located in their capital regions, providing an advantage in accessibility through air travel.

the stronger the interaction between the two regions is expected to be. The variable DISTANCE is measured 'as the crow flies'. In this regard, we expect greater distances between two regions to be associated with lower numbers of collaborations between two regions. The basic gravity equation is therefore as follows:

$$I_{ij} = \alpha_1 \cdot \frac{\text{MASS}_i^{\alpha 2} \cdot \text{MASS}_j^{\alpha 3}}{\text{DISTANCE}^{\alpha 4}}$$

As previously explained, we expect the interaction intensity between two regions to depend not only on size and distance, but also on other characteristics of the interregional pairs. For example, when two regions belong to the same country, we expect the collaboration intensity to be stronger. To account for this hypothesis, we add a dummy variable (COUNTRY) to the gravity equation; this variable is coded as 1 for regions that belong to the same country and as 0 otherwise. The variable is a proxy for homogeneity in culture, language and institutions (even though we recognise that some countries are less homogeneous than others).

Finally, we analyse the extent to which hierarchical structures play a role in the formation of collaboration networks between regions. As mentioned, we expect two such structures to exist. First, ties between pairs of excellence regions may be significantly stronger than are the ties between pairs of other regions. Excellence regions are defined as those that belong to the top 25 regions in terms of publications and those that belong to the top 25 regions in terms of patents within a particular field. The 25 excellence regions for biotechnology and semiconductors are listed in Tables 2 and 3. Second, the ties between two capital regions may be significantly stronger than are those existing between other pairs of regions. We thus constructed a dummy variable (EXCELLENCE), which takes the value of 1 when both regions in a pair are excellence regions and 0 otherwise, and a dummy variable (CAPITAL), which takes the value of 1 when both regions in a pair are capital regions and 0 otherwise.[6]

The extended gravity equation to be estimated is thus as follows (see Box 'Model specification of the gravity equation' for more details):

$$\ln I_{ij} = \ln\alpha_1 + \alpha_2 \ln \text{MASS}_i + \alpha_3 \ln \text{MASS}_j + \alpha_4 \ln \text{DISTANCE}_{ij} + \alpha_5 \ln \text{COUNTRY}_{ij}$$

$$+ \alpha_6 \text{EXCELLENCE}_{ij} + \alpha_6 \text{CAPITAL}_{ij} + \varepsilon$$

Results

Before discussing the results of the regression analysis, we present correlation matrices in Table 4 to determine whether any explanatory variables are influencing each other because of high correlation. All correlations are within the allowed range. This means that all variables, as specified in the extended gravity equation, can be included in the regression analysis.

5. Because collaborations are undirected by definition, we include an interaction between a particular pair of regions only once. The value of the coefficient of the two masses may therefore differ slightly. Note also that we added 1 to all masses in order to allow for logarithmic transformation of observations without any publications or patents.

6. All capital regions correspond to a single NUTS3 region, with the exception of Paris (which contains five NUTS3 regions) and Copenhagen (which contains two NUTS3 regions). For the case of London, we refer to Footnote 7, p.37.

Tables 4 through 8 show the results of our statistical analysis for the publications and patents in the two technologies under consideration. In all four of the tables, the results of Model A show that mass and geographical distance are indeed powerful predictors of research collaboration in terms of co-publications and co-patents. Mass obviously contributes positively to interaction, indicating an increase in the intensity of collaboration between two regions that accommodate larger numbers of knowledge-producing actors. Distance has a significant negative effect on the intensity of collaboration between two regions. Regions that are farther apart collaborate less than regions that are in closer proximity. This shows that geographical distance continues to be a structuring force in the European research system, thereby favouring central regions and punishing peripheral regions.

Institutional proximity, as captured by the dummy variable COUNTRY, is added in Model B. It is significant in three of the four tables, and it has the expected positive sign, thus indicating that two regions belonging to the same country collaborate more frequently than two regions from different countries. It clearly shows that national borders still hamper research collaboration in Europe, although belonging to the same country has no significant effect in the case of co-patenting in semiconductors. Comparison of the results of Model A and Model B reveals that the inclusion of the COUNTRY variable diminishes the estimate of DISTANCE, simply because regions from the same country are generally less distant from each other than are regions from different countries. More importantly, geographical distance remains significant in Model B. This shows that geographical distance and national borders have independent effects on collaboration.

In the final model (Model C), we add the two dummy variables to denote the possible hierarchical structures in research collaboration. In this model, the results for publications differ from those for patents. In the scientific system, we observe a significant and positive bias towards collaboration between excellence regions for both biotechnology and semiconductor publications.[7] No such effect is found for patents, however, indicating that excellence regions have no particular incentive to collaborate in patenting with other excellence regions.[8] The strength of the networks that exist among excellent researchers in science is rather strong. The coefficient of the EXCELLENCE variable is close to the value of the COUNTRY variable, indicating that the tendency of excellent researchers to collaborate in networks is almost as strong as the tendency of researchers to collaborate in national networks.

The dummy variable CAPITAL (which refers to pairs of capital regions) is positive and significant in three of the four models. It suggests that location in a capital region is indeed an advantage in the likelihood of collaboration.

7. This finding is in line with a recent study by Tijssen (2007) who found that regions with higher quality of research (indicated by the mean citation rate) have a higher propensity to collaborate internationally.

8. A possible explanation for the absence of an elite structure in collaborative patenting in patenting can be based on the differences between science system and the innovation system. In science, knowledge production is a more of a collective endeavour, while in patenting the major actors are compete for markets. This could explain why technology researchers in excellence regions show no particular bias to collaborate with.

Discussion

We understand an ERA as an area in which scholars do not bias their choice of collaborators according to geographical proximity or national borders. Our analysis clearly shows that the concept of the European Research Area (ERA), as defined as an area in which research activities at the national and EU levels are well integrated, does not yet exist. We found that geographical distance continues to hamper collaboration between scholars who are located in different regions. We also found that scholars working in different countries tend to collaborate less than scholars who work in the same country. The latter result is associated with the advantages associated with the presence of national institutional frameworks and (in most countries) a common language and culture.

The main conclusion that can be drawn from the results reported in this chapter is that the European Union is still far from having created a European Research Area. More specifically, there is a need to harmonise the national research systems, including the alignment of labour market regulations, diploma systems and property rights. The current heterogeneity of national institutions explains why most researchers are still heavily biased towards domestic collaborations, even though European collaboration could offer more opportunities in many cases. The present efforts towards the creation of such an area thus seem well justified. The focus of EU policy is primarily on removing the national border effect in research, as most subsidies are allocated to international research projects under the 'Cooperation' instrument of the Seventh Framework Programme. Because there is evidence that the effect of geographical proximity exists independently of national borders, the process of integration within countries is also incomplete.[9] This means that member states should also play an active role in further integrating their own national research systems.

A different, more subtle finding of our analysis has to do with hierarchical structures. First, excellence regions have a bias towards collaborating with each other rather than with regions whose performance is less outstanding. This can be explained by the incentive structure for top scholars who engage in state-of-the-art research. Because they can learn only from other top scholars, they tend to form cliques in 'networks of excellence'. This finding, however, was observed only for networks derived from co-publications (the science system); no evidence of this effect was found for the networks that were derived from co-patents (the economic system). Second, we found that capital regions have a bias towards collaborating with each other rather than with other regions. This shows that the national political structures that are concentrated in capital cities and traditionally underlie multi-lateral cooperation programmes, continue to function as a specific network for carrying out many international collaborative projects. These structures are likely to reflect the simple fact that most national research are located in capital cities and the fact that they are over-represented in multi-lateral programmes supported by direct government funding.

9. The observation that integration at the national level is incomplete is also in line with studies on research collaboration within single countries, including studies on the UK (Katz 1994), Sweden (Danell & Persson 2003; Ejermo & Karlsson 2006) and Dutch regions (Ponds & Van Oort 2006; Ponds et al. 2007).

Importantly, following our definition of the ERA (i.e. *an area in which scholars do not bias the choice of collaborators on grounds of geographical proximity or national borders*), the existence of hierarchical structures is compatible with the concept of an ERA, as it refers to structures other than geography. Such hierarchical structures seem to emerge 'naturally' from the sheer concentration of talent in excellence regions and the concentration of political power and national research institutions in capital regions. These regions create elite structures that provide significant support to the formation of collaboration networks. Extending this reasoning towards the future, we can expect the gap between excellence regions and other regions to increase even further under the influence of ERA policy. With the recent emphasis on frontier research under the 'Ideas' instrument of the Seventh Framework Programme, excellence regions will have even greater access to funding. Excellence regions will also continue to profit most from subsidies for collaborative projects, as such funds are allocated partially according to excellence. In addition to funding opportunities, the removal of obstacles that currently hinder the mobility of labour across national borders is also expected to reinforce the concentration of talent in a few excellence regions. All of these tendencies will further strengthen the scientific elite structure among European regions.

Policy makers should thus be aware of the dual effects of the concept of an ERA. Although the creation of an ERA will remove 'artificial' barriers related to geography and borders, thereby fostering integration and benefiting all regions, it will provide preferential support for excellence regions and their mutual networks. The two effects should be considered as intended outcomes of ERA policy (Commission 2007b). Increased funding for collaborative networks will favour excellent scholars. In addition, increases in the free movement of people will drive talent towards fewer places and will strengthen networks among them. The European research system of the future is thus expected to transform from a system that is based on geography and national borders into a system that is based on the clustering of talented scholars and their inclusion in networks of excellence.

Model specification of the gravity equation

Data derived from publications and patents are often treated as if they are continuous, and therefore appropriate for estimation using linear regression techniques. Nonetheless, application of the Ordinary Least Squares Method (OLS) in this case can produce 'inefficient, inconsistent and biased estimates' (Long 1997), as the data fail to satisfy many of the underlying assumptions of OLS (e.g. normal distribution, homoskedasticity). For this reason, the use of alternative regression techniques is more appropriate (Burger et al. 2007).

Because our data count the frequency of inter-regional collaborations between each pair of regions, they should be treated as 'count data'. The regression model that is most commonly applied in this respect is probably the Poisson regression model, which is estimated using maximum likelihood estimation techniques. In this log-linear model, the observed interaction intensity between regions i and j has a Poisson distribution with a conditional mean (μ) that is a function of the independent variables.

$$\Pr[lij \mid \mu] = \frac{\exp^{-\mu_{ij}} \mu_{ij}^{\,l_{ij}}}{l_{ij}!},$$

where, in our model,

$$\mu_{ij} = \exp(\alpha_1 + \alpha_2 \ln(\text{MASS}_i) + \alpha_3 \ln(\text{MASS}_j)$$

$$+ \alpha_4 \ln \text{DISTANCE}_{ij})$$

In practice, however, the Poisson regression model is rarely appropriate due to overdispersion (i.e. the conditional variance among inter-regional pairs is assumed to be equal to the conditional mean). This problem is best addressed by estimating negative binomial regression models instead, which add a parameter to the model, thus capturing unobserved heterogeneity and correcting for overdispersion in the data.

In addition to the problem of overdispersion, our dataset also suffers from an excessive number of zeros relative to the amount of actual observed inter-regional collaborations. Although the negative binomial regression model would be an improvement over the under-prediction of zeros, Vuong tests indicate that we should use a zero-inflated variant of the negative binomial regression model.

The zero-inflated negative binomial model considers the existence of two (latent) groups within the population: a group having strictly zero counts and a group having a non-zero probability of counts other than zero. Correspondingly, its estimation process consists of two parts. The first part contains a logit regression of the predictor variables on the probability that there is no interaction between two regions. In this case, the coefficients indicate change in the odds of belonging to the strictly zero group in response to a one-percent increase in one of the independent variables, holding all other variables constant. The second part contains a negative binomial regression on the probability of each count for the group that has a non-zero probability of having a count other than zero. When the covariates are log transformed, as they are in this study, the coefficients in this part can be interpreted as elasticities. Because we are merely interested in the intensity of collaboration, using the zero-inflated model only to correct for the excessive number of zero counts, we report only the negative binomial part of our analyses. Nonetheless, the outcomes for the zero-inflated part resemble those of the negative binomial part and are available on request.

Figure 5. Mean number of citations per biotechnology publication (y-axis), by size of region (x-axis)

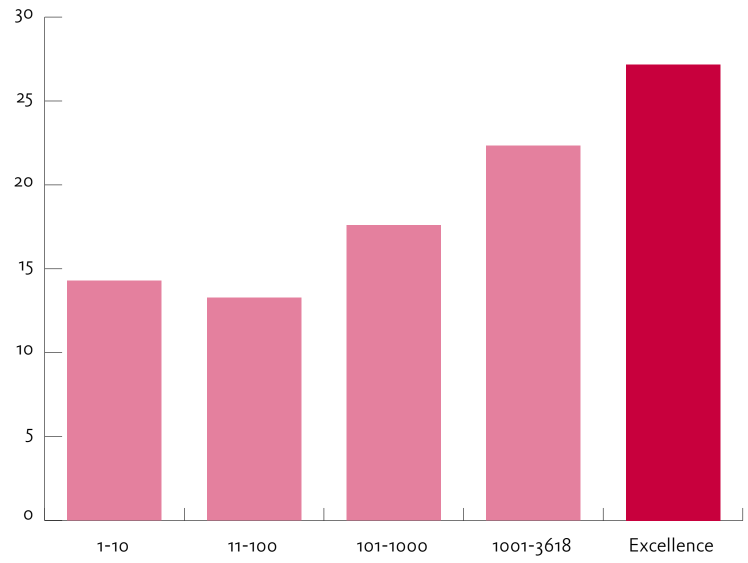


Figure 6. Mean number of citations per semiconductor publication (y-axis), by size of region (x-axis)

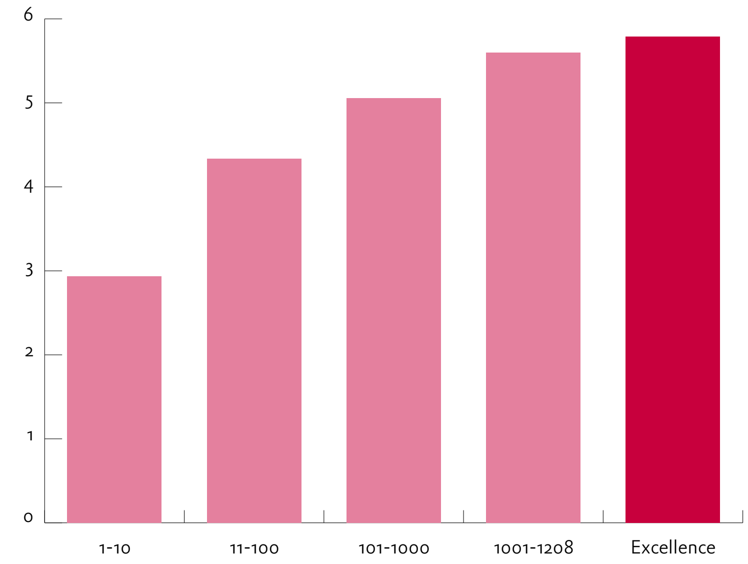
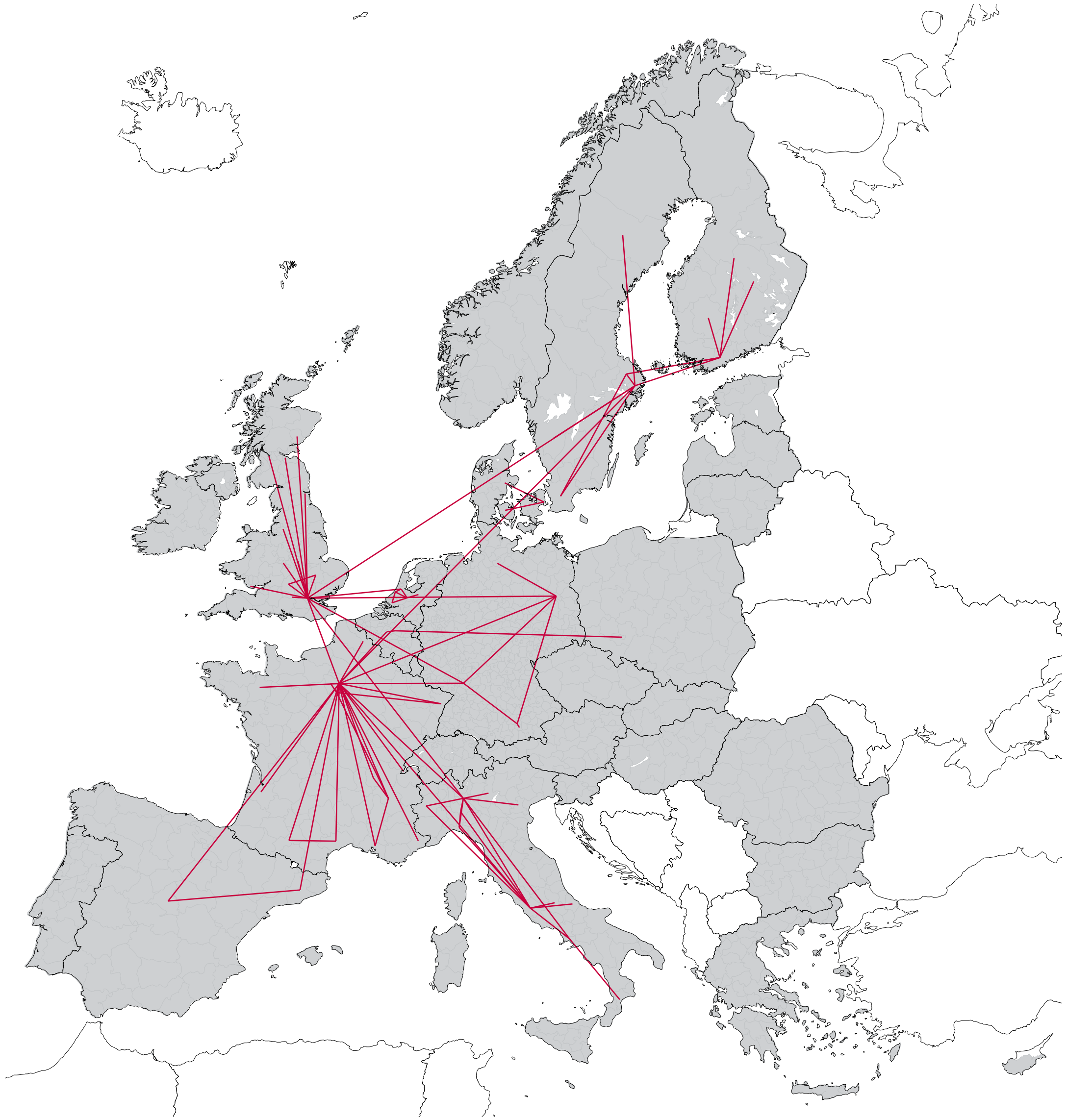


Figure 7. Collaborations in biotechnology publications (1988-2004)



> 175 collaborations

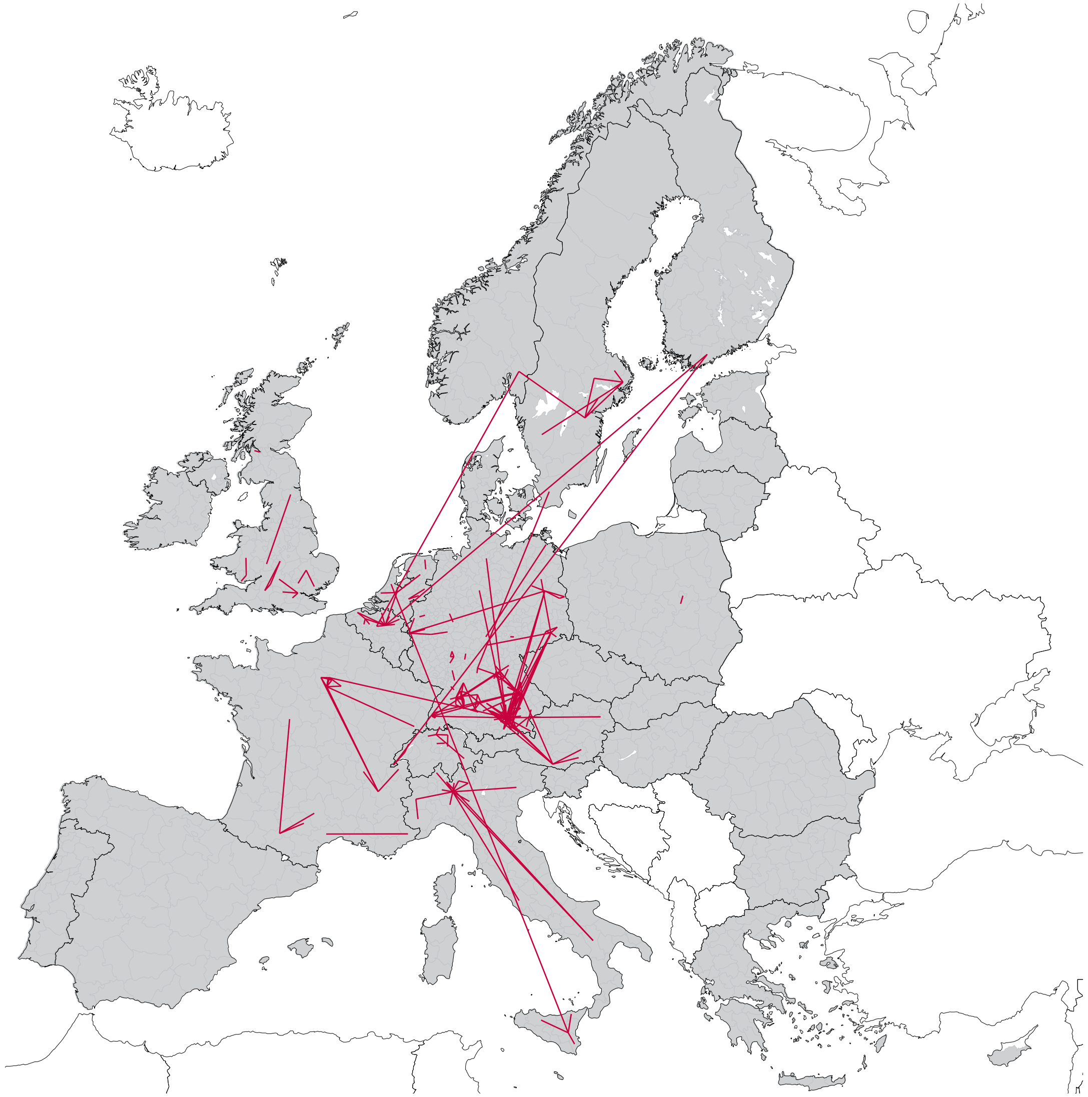
Figure 8. Collaborations in semiconductor technology publications (1988-2004)

> 45 collaborations

Figure 9. Collaborations in biotechnology patents (1988-2001)

> 20 collaborations

Figure 10. Collaborations in semiconductor patents (1988-2001)



> 8 collaborations

Table 1. Descriptive statistics for inter-regional collaborations

	N	Mean	SD	Min.	Max
Biotechnology					
Publications					
Inter-regional collaborations	865,270	0.251	5.058	0	1671
National collaborations	122,942	0.808	12.116	0	1671
International collaborations	742,328	0.158	2.336	0	510
Patents					
Inter-regional collaborations	865,270	0.039	1.595	0	338
National collaborations	122,942	0.217	4.162	0	338
International collaborations	742,328	0.009	0.298	0	275
Semiconductors					
Publications					
Inter-regional collaborations	865,270	0.060	1.118	0	296
National collaborations	122,942	0.192	2.683	0	296
International collaborations	742,328	0.038	0.644	0	107
Patents					
Inter-regional collaborations	865,270	0.011	0.814	0	81
National collaborations	122,942	0.073	2.152	0	81
International collaborations	742,328	0.001	0.073	0	38

Table 2. Excellence regions in biotechnology

Code*	Name**	Code*	Name**
Publications		**Patents**	
AT130	Wien	AT130	Wien
DE125	Heidelberg, Stadtkreis	BE234	Arr. Gent
DE212	München, Kreisfreie Stadt	CH011	Vaud (Lausanne)
DE300	Berlin	DE125	Heidelberg, Stadtkreis
DK001	København og Frederiksberg amt kommuner	DE212	München, Kreisfreie Stadt
ES300	Madrid	DE21N	Weilheim-Shongau
ES511	Barcelona	DE300	Berlin
FI181	Uusimaa (Helsinki)	DE724	Marburg-Biedenkopf
FR101	Paris	DEA23	Köln, Kreisfreie stadt
FR104	Essonne (Paris)	DK001	København og Frederiksberg amt kommuner
FR421	Bas-Rhin (Strasbourg)	DK002	Københavns amt
FR714	Isère (Grenoble)	FR101	Paris
FR716	Rhône (Lyon)	FR104	Essonne (Paris)
FR813	Hérault (Montpellier)	FR105	Hauts de Seine (Paris)
FR824	Bouches-du-Rhône (Marseille)	FR107	Val-de-Marne (Paris)
ITC45	Milano	FR421	Bas-Rhin (Strasbourg)
ITE43	Roma	FR716	Rhône (Lyon)
ITF33	Napoli	FI181	Uusimaa (Helsinki)
NL310	Utrecht	ITC45	Milano
NL326	Groot Amsterdam	NL331	Agglomeratie Leiden en Bollenstreek
SE010	Stockholms län	UKH12	Cambridgeshire CC
SE021	Uppsala län	UKH33	Essex CC
UKI11	Greater London	UKI11	Greater London
UKH12	Cambridgeshire CC	UKJ11	Berkshire
UKJ14	Oxfordshire	UKJ14	Oxfordshire

* First two characters of NUTS3-code refer to the region's country.
** In case the central city of the NUTS3-region is not clear from the name, it is indicated between brackets. Yet, some regions do not have one central city and as a result are only mentioned by their region name.

Table 3. Excellence regions in semiconductors

Code*	Name**	Code*	Name**
Publications		**Patents**	
BE242	Arr. Leuven	BE242	Arr. Leuven
DE212	München, Kreisfreie Stadt	CH033	Aargau
DE300	Berlin	CH04	Zürich
ES300	Madrid	DE111	Stuttgart, Stadtkreis
ES511	Barcelona	DE141	Reutlingen
FR101	Paris	DE212	München, Kreisfreie Stadt
FR104	Essonne (Paris)	DE218	Ebersberg
FR623	Haute-Garonne (Toulouse)	DE21H	München, Landkreis
FR714	Isère (Grenoble)	DE232	Regensburg, Kreisfreie stadt
FI181	Uusimaa (Helsinki)	DE238	Regensburg, Landkreis
GR300	Attiki (Athens)	DE257	Erlangen-Höchstadt
ITC11	Torino	DE300	Berlin
ITC45	Milano	DEA21	Aachen, Kreisfreie Stadt
ITE43	Roma	DED21	Dresden, Kreisfreie stadt
NL333	Delft en Westland	FR101	Paris
NL414	Zuidoost-Noord-Brabant (Eindhoven)	FR104	Essonne (Paris)
SE010	Stockholms län	FR105	Hauts-de-Seine (Paris)
SEOA2	Västra Götalands län (Gothenburg)	FR107	Val-de-Marne (Paris)
UKD32	Greater Manchester	FR714	Isére (Grenoble)
UKE32	Sheffield	ITC45	Milano
UKH12	Cambridgeshire CC	ITG17	Catania
UKI11	Greater London	NL414	Zuidoost-Noord-Brabant (Eindhoven)
UKJ14	Oxfordshire	SE010	Stockhholms län
UKJ32	Southampton	UKH12	Cambridgeshire CC
UKM34	Glasgow city	UKJ33	Hampshire CC

* First two characters of NUTS3-code refer to the region's country.

** In case the central city of the NUTS3-region is not clear from the name, it is indicated between brackets. Yet, some regions do not have one central city and as a result are only mentioned by their region name.

Table 4. Correlation matrix of covariates for gravity equation

	1	2	3	4	5	6
Biotechnology publications						
Mass origin (ln)	1.000					
Mass destination (ln)	0.011*	1.000				
Distance (ln)	0.036*	0.067*	1.000			
Country	- 0.025*	- 0.128*	- 0.616*	1.000		
Excellence	0.048*	0.043*	- 0.000	-0.002	1.000	
Capital	0.050*	0.042*	0.009*	-0.009*	0.113*	1.000
Semiconductor technology publications						
Mass origin (ln)	1.000					
Mass destination (ln)	0.011*	1.000				
Distance (ln)	0.016*	0.058*	1.000			
Country	0.007*	-0.125*	-0.616*	1.000		
Excellence	0.052*	0.043*	- 0.000	-0.002	1.000	
Capital	0.049*	0.040*	0.009*	-0.009*	0.070*	1.000
Biotechnology patents						
Mass origin (ln)	1.000					
Mass destination (ln)	0.005	1.000				
Distance (ln)	- 0.121*	- 0.121*	1.000			
Country	0.051*	- 0.003*	- 0.616*	1.000		
Excellence	0.050*	0.053*	- 0.011*	0.000*	1.000	
Capital	0.040*	0.035*	0.009*	-0.009*	-0.090*	1.000
Semiconductors patents						
Mass origin (ln)	1.000					
Mass destination (ln)	0.011*	1.000				
Distance (ln)	-0.161*	-0.165*	1.000			
Country	0.144*	0.039*	-0.616*	1.000		
Excellence	0.057*	0.071*	-0.014*	0.005*	1.000	
Capital	0.025*	0.027*	0.009*	-0.009*	-0.009*	1.000

Table 5. Determinants of co-publications in biotechnology (1988-2004)

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	- 2.363 (0.067)*	- 5.401 (0.086)*	- 5.034 (0.087)*
Mass origin (ln)	0.640 (0.006)*	0.649 (0.005)*	0.621 (0.006)*
Mass destination (ln)	0.591 (0.005)*	0.636 (0.005)*	0.609 (0.005)*
Distance (ln)	- 0.734 (0.009)*	- 0.368 (0.010)*	- 0.367 (0.010)*
Country		1.160 (0.022)*	1.146 (0.022)*
Excellence			0.832 (0.056)*
Capital			0.475 (0.052)*
	Fit statistics		
Overdispersion (α)	1.098 (0.017)*	0.881 (0.014)*	0.848 (0.013)*
Vuong-statistic	27.43*	27.25*	27.58*
Log Likelihood	-102711.865	-99774.550	-99545.800
Mc Fadden's Adj. R2	0.442	0.458	0.459
AIC	0.237	0.231	0.230
N	865270	865270	865270
Nonzero observations	25589	25589	25589

Table 6. Determinants of co-publications in semiconductors (1988-2004)

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	- 2.091 (0.013)*	- 4.064 (0.133)*	- 3.763 (0.135)*
Mass origin (ln)	0.550 (0.010)*	0.533 (0.009)*	0.504 (0.010)*
Mass destination (ln)	0.526 (0.010)*	0.552 (0.010)*	0.525 (0.010)*
Distance (ln)	- 0.565 (0.013)*	- 0.301 (0.016)*	- 0.299 (0.016)*
Country		0.824 (0.036)*	0.836 (0.035)*
Excellence			0.626 (0.073)*
Capital			0.450 (0.076)*
	Fit statistics		
Overdispersion (α)	1.502 (0.038)*	1.333 (0.034)*	1.302 (0.034)*
Vuong-statistic	20.30*	20.41*	20.46*
Log Likelihood	-52191.683	-51301.529	-51202.390
Mc Fadden's Adj. R2	0.429	0.439	0.440
AIC	0.121	0.119	0.118
N	865270	865270	865270
Nonzero observations	12531	12531	12531

* indicates significance at 1 percent level. Estimates for the zero-inflated part (see 'Model specification of the gravity equation') are not reported, but are significant and of the expected sign.

Table 7. Determinants of co-patenting in biotechnology (1988-2001)

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	0.417 (0.105)*	- 0.187 (0.147)	- 0.180 (0.148)
Mass origin (ln)	0.411 (0.013)*	0.419 (0.013)*	0.414 (0.013)*
Mass destination (ln)	0.376 (0.013)*	0.387 (0.013)*	0.381 (0.013)*
Distance (ln)	- 0.572 (0.015)*	- 0.503 (0.018)*	- 0.499 (0.018)*
Country		0.275 (0.053)*	0.296 (0.053)*
Excellence			0.046 (0.115)
Capital			0.453 (0.153)*
	Fit statistics		
Overdispersion (α)	2.022 (0.082)*	1.880 (0.072)*	1.865 (0.071)*
Vuong-statistic	22.22*	19.08*	19.04*
Log Likelihood	-31659.830	-30738.290	- 30702.77
Mc Fadden's Adj. R2	0.369	0.387	0.388
AIC	0.073	0.071	0.071
N	865270	865270	865270
Nonzero observations	6078	6078	6078

Table 8. Determinants of co-patenting in semiconductors (1988-2001)

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	0.206 (0.163)*	0.567 (0.224)*	0.596 (0.228)*
Mass origin (ln)	0.424 (0.020)*	0.427 (0.020)*	0.421 (0.021)*
Mass destination (ln)	0.452 (0.023)*	0.448 (0.022)*	0.443 (0.023)*
Distance (ln)	- 0.585 (0.027)*	- 0.614 (0.030)*	- 0.612 (0.031)*
Country		- 0.233 (0.113)	- 0.239 (0.114)
Excellence			0.131 (0.166)
Capital			- 0.627 (0.734)
	Fit statistics		
Overdispersion (α)	1.690 (0.125)*	1.647 (0.120)*	1.653 (0.120)*
Vuong-statistic	13.52*	12.24	12.12*
Log Likelihood	-11996.461	-11757.489	-11751.202
Mc Fadden's Adj. R2	0.396	0.408	0.408
AIC	0.028	0.027	0.027
N	865270	865270	865270
Nonzero observations	2196	2196	2196

* indicates significance at 1 percent level. Estimates for the zero-inflated part (see 'Model specification of the gravity equation') are not reported, but are significant and of the expected sign.

Regional innovativeness

Introduction

The creation of a European Research Area (ERA) is not an end in itself. Rather, that the presence of an integrated and coordinated research system in Europe is expected to contribute to the overarching Lisbon objective of helping Europe to become the world's most dynamic and competitive economy. In particular, the European Council stated that 'research activities at national and Union level must be better integrated and coordinated *to make them as efficient and innovative as possible*' (European Council 2000, our emphasis).

An implicit assumption of the European Commission holds that the ERA will not merely increase collaboration, but that it will also contribute to improving the exploitation of research by industry. As such, the ERA is intended as a remedy for the perceived underperformance of the European research system with regard to the industrial exploitation of scientific research (Commission 2002: 4). In the following section, we use a *knowledge production function* approach to assess this claim according to an analysis of the contributions made by scientific collaboration networks to regional innovative performance. We analyse whether these networks have a significant and independent effect on the innovation performance of regions by providing access to knowledge outside the region.

In this sense, we are not analysing whether the proposed ERA would contribute directly to improving the industrial exploitation of scientific research. As shown in the third chapter, the ERA does not yet exist; it is therefore impossible to measure its effect on the industrial exploitation of research. We can, however, analyse the effect of the current state of the ERA and assess whether research collaboration contributes to innovation. In this way, we can test the European Commission's claim that an increase in collaboration across Europe would indeed generate more technological innovations.

Knowledge Production Function approach

Statistical studies analysing the determinants of innovation view innovation as an outcome of a knowledge-production process (Jaffe 1989; Autant-Bernard 2001; Acs 2002; Fritsch & Slavtchev 2007). In this process, knowledge inputs are transformed into knowledge outputs. Investment in R&D is one obvious example of a knowledge input. Other examples include the human capital of researchers, laboratory equipment, software tools and scientific publications. As the output of the knowledge-production process, innovation is typically associated with patents (even though, strictly speaking, patents indicate inventions more than innovations).

This input-output approach has become known as the *Knowledge Production Function* (KPF) approach. The standard setup for this approach is to collect R&D data as input and patents as output for a specific population of entities (e.g. firms, cities, regions, countries). Following our regional approach, we limit our discussion to the regional KPF. Examples of such regional applications of the KPF approach include Jaffe (1989), Feldman & Audretsch (1999) and Acs (2002) for regions in the United States and Bottazzi & Peri (2003), Greunz (2003), Moreno et al. (2005) and Maggioni et al. (2006) for regions in the European Union. Results of these studies have clearly shown that there is indeed a very strong association between regional investment in R&D and regional innovative performance, as captured by patents.

Regional applications of the KPF approach have also found that regional innovation is not only dependent on regional knowledge inputs, but also on spillovers from neighbouring regions. This neighbourhood effect is understandable, as investment in R&D cannot be fully appropriated by the investor. Some part of the investment in any innovation project will 'spill over' to other innovation projects. One example would be a situation in which a researcher changes jobs or exchanges information informally with a fellow researcher (Almeida & Kogut 1999; Breschi & Lissoni 2001; Weterings & Ponds 2007). These processes of labour mobility or informal knowledge exchange are very sensitive to geographical proximity (Breschi & Lissoni 2003, 2004, 2006). As is the case in other professions, most researchers find new jobs within the same or a neighbouring region. In addition, most informal contacts between researchers take place nearby, because these contacts generally rely on face-to-face communication.

In addition to processes of labour mobility and informal knowledge exchange (which usually occurs locally), knowledge spillovers can stem from global networks of collaboration between researchers. Such long-distance collaborations often take the form of formal collaborations in that some type of contract has been signed (as with personnel interchange, publicly funded projects or joint ventures) or in that objectives and schedules (at the very least) have been decided upon beforehand. The more formal nature of long-distance collaboration is understandable, given the investments and uncertainties that are involved in such collaborations. Yet, formal collaborations also lead to knowledge spillovers during the project as well as after its completion. It is precisely these types of collaboration that the European Commission seeks to promote through the creation of a European Research Area (ERA) and, more specifically, with the Framework Programmes.

The importance of collaborative networks (whether long-distance or not) suggests that the KPF approach, which includes spillovers from neighbouring regions, should be supplemented by data on 'relational' proximity, which captures the strength of network relationships between two regions.[1] In the following section, we analyse regional patenting at the NUTS3 level using a KPF approach that includes both the spillover effects of neighbouring regions and the spillover effects of regions that are inter-linked through collaboration networks. The first type of dependency between regions is based on geographical proximity, while the latter type of dependency between regions is based on 'relational proximity'. The more relations that two regions have in the form of collaborations, the more they are expected to realise mutual benefits from their knowledge through the spillovers that occur during and after these collaborations.

Methodology

The usual method of estimating a KPF is to apply R&D investments as knowledge inputs. No such data are available for the EU at the NUTS3 level, however, let alone for the two selected technologies of biotechnology and semiconductor technology separately. As an alternative, we use the total number of scientific articles produced in a region as knowledge input. We use patents as outputs of the knowledge production process.

The use of scientific publications (as a knowledge input) to explain patents (as knowledge output) can be criticised. In many research projects, both publications and patents are produced as outputs of a single process (Price 1984). The use of publications can be justified nonetheless, as we are dealing with biotechnology and semiconductor technology, which are two science-based sectors. Scientific research in these areas, as published in scientific articles, is indeed a major source of inputs for technological innovations. We also know that the stock of scientific publications correlates strongly with R&D investments, thereby increasing our confidence in using scientific articles as a knowledge-input variable.[2] In this context, the number of scientific publications can be considered a proxy for R&D expenditures in this context.

To understand the benefits that regions stand to gain from the knowledge that is being produced in other regions, we construct two matrices that define interdependencies between regions. The first matrix WSPATIAL, here called the spatial weight matrix, contains weights for each pair of regions, which define the strength of the spillovers between two regions. The larger the geographical distance between two regions is, the smaller the effect of spillovers between the two regions will be. More precisely, we compute the weight between two regions as the inverse of the quadratic distance, normalised for the sum of all these values. The second matrix WRELATIONAL defines the strength of spillovers between each pair of regions resulting from formal scientific collaborations, as expressed in co-publications. Using the collaboration data from the previous chapter, we define the weight between

1. A first attempt in this direction was made in a recent study by Maggioni et al. (2006), who investigated patenting at the NUTS2 level in Germany, France, Italy, Spain and the UK. Their pioneering study addresses the role of collaboration networks in explaining regional innovation. Their research (which involves only five countries at the NUTS2 level) was subject to a number of data limitations that could be avoided in our study, which addresses 27 countries at the NUTS3 level. A further limitation of the Maggioni study is that the network data includes only the network relationships taken from the Fifth Framework programme. The present study considers any network relationship that is visible in co-publication data. Peri (2005) also addresses long-distance inter-regional dependencies in a KPF framework. His approach differs from ours, however, as he considers flows of patent citations rather than collaboration networks between regions.

2. Using data on Dutch regions collected by Roderik Ponds (Netherlands Institute for Spatial Research, RPB), we were able to estimate the correlation between scientific articles and public and private investment. Correlation with public R&D is 0.925 for biotechnology and 0.846 for semiconductors, while correlation with private R&D is 0.595 for biotechnology and 0.658 for semiconductors. All correlations are significant at the .01 level.

each two regions as the number of co-publications between two regions I_{ij} divided by the sum of all these values. The precise procedure is explained in more detail in Box 'Model specification of the Knowledge Production Function'.

Following this procedure, with the abbreviation 'PUB' representing the number of publications, our basic KPF equation is as follows:

$$\text{PATENTS}_i = \alpha_1 \cdot \text{PUB}_i^{\alpha 2} \cdot (\text{W}_{\text{SPATIAL}} \cdot \text{PUB}_j)^{\alpha 3} \cdot (\text{W}_{\text{RELATIONAL}} \cdot \text{PUB}_j)^{\alpha 4}$$

This equation states that the number of patents generated in region i depends on the number of publications in region i and the number of publications in other regions, weighted for the geographical and relational proximity of region i to other regions.

In addition to considering publications as knowledge inputs, we include population, as measured by the total number of inhabitants, in the analysis. This variable is added in order to assess urbanisation economies that may occur due to the sheer concentration of population. Large urban areas may provide better opportunities for technological innovation, as they harbour more supporting services and a greater variety of related research activities and local demand.

Finally, we include dummy variables to capture spatial differences at the regional and national levels. At the regional level, excellence regions and capital regions (as introduced in Chapter 'The geography of research collaboration') are included in order to assess whether these regions, in addition to being better collaborators, are also more able to transform scientific research into technological innovations. Note that 'excellence' refers in this context to excellence in terms of publications. At the national level, country dummies are included to control for any national effects that may influence our results. The equation to be estimated is thus as follows:

$$\ln\text{PATENTS}_i = \ln \alpha_1 + \alpha_2 \ln \text{PUB}_i + \alpha_3 \ln(\text{W}_{\text{SPATIAL}} \cdot \text{PUB}_j) + \alpha_4 \ln(\text{W}_{\text{RELATIONAL}} \cdot \text{PUB}_j) + \alpha_5 \ln\text{POP}_i + \alpha_6 \text{EXCELLENCE}_i + \alpha_7 \text{CAPITAL}_i + \text{COUNTRY DUMMIES} + \varepsilon$$

where:
PATENTS = number of patents in a NUTS3 region (*ln*), 1997-2001
PUB = number of publications in a NUTS3 region (*ln*), 1995-1999
WSPATIAL = spatial weight matrix based on the inverse of quadratic kilometre distance[3]
WRELATIONAL = relation weight matrix based on the number of interregional co-publications in the period 1988-1994[4]
POP = number of inhabitants in a NUTS3 region (*ln*), 1995-1999
EXCELLENCE = dummy excellence region (*as in previous chapter*)
CAPITAL = dummy capital region (*as in previous chapter*)
COUNTRY-LEVEL DUMMY VARIABLES

3. We did not row-standardise the weights in the weight matrix, as we believe that the capacity of a region to absorb spillovers from other regions is not bounded.
4. See previous footnote.

Note that we use different time periods for different variables. Because a time lag is to be expected between the occurrence of publications and their subsequent use as inputs in the innovation processes, we applied a lag of two years. Furthermore, to construct the relational weight matrix, we used data from the early period 1988-1994 to avoid a dependency between the matrix data and the publication data. For a more technical discussion of the constructed explanatory variables and the estimation procedure, we refer to the Box 'Model specification of the Knowledge Production Function'.

Descriptive statistics are presented in Table 9. The number of observations differs between the two technologies and is less than the total of 1316 regions. This is because we limited the analysis to those regions that have at least one collaborative relationship to assure a positive value for the relational weight matrix. In Figures 11 and 12, we mapped the dependent variable patents for biotechnology and semiconductors, respectively.

Results

Table 10 shows the correlation matrix for the explanatory variables of both technologies. The high correlation between publications and (WRELATIONAL X PUB) indicates that, in the estimation process, these two variables may interfere with each other, especially in case of biotechnology. Because we lack data on R&D, we are not able to correct this problem in further detail. In the following, however, the estimates for publications and (WRELATIONAL X PUB) are stable in the various regressions in terms of size and significance.

The results of the regression analysis are presented in Table 11 for biotechnology and in Table 12 for semiconductors. In both tables, Model A shows that publications indeed provide a valuable input for patents at the regional level. Having a double-log specification, the coefficients can be interpreted as elasticity. The coefficient is quite high and lies in a range similar to that of the coefficients that were found for private R&D data (Fritsch & Slatchev 2007). This result suggests that publications are indeed an important source of technological innovation.

In Model B, we added the spatial and relational weight matrices to account for the benefits a region stands to gain from using the knowledge that is available in other regions. The positive and significant coefficients in the case of biotechnology provide evidence of both spatial and relational effects. The semiconductor data reveal only a spatial effect. As in Model A, the contribution of the publications generated within the own region remains positive and significant. This means that, in the innovative processes, regions draw upon knowledge bases that are available though formal networks, in addition to their own knowledge bases. The coefficients differ in that the spatial effect seems to be more important than the relational effect. This suggests that the mechanisms underlying local knowledge spillovers are more important than

Model specification of the Knowledge Production Function

The knowledge production function to be estimated includes interdependencies between regions according to 'weight matrices'. This procedure allows the estimation of a separate effect for the learning benefits that regions stand to gain from the knowledge produced in other regions. More precisely, in the knowledge production function we add the stock of accessible publications in other regions as two separate variables, in addition to the region's own stock of publications. As specified in our theoretical framework, learning benefits are expected to occur when regions are geographically proximate (in terms of distance, as the crow flies) and when regions are relationally proximate (in terms of the number of research collaborations).

We account for accessibility to geographically proximate publications by creating a squared* inverse distance-weight matrix that is standardised over the total sum of distances. This reflects the tendency of accessibility to decline with increasing distance. More precisely, the weight attributed to the publications of region j when estimating the innovativeness of region i is calculated as follows:

$$W_{SPATIAL\_ij} = \frac{d_{ij}^{-2}}{\sum_i \sum_j d_{ij}^{-2}}$$

In this formula, dij stands for the geographical distance in kilometres 'as the crow flies' between two regions.

For some variable of interest (in this case, PUB), each element of the spatially lagged variable is the average of the publications of other regions weighted by their geographical proximity. Note that intra-regional distances are not taken into account, since accessibility to the own stock of publications is already accounted for in the publication variable PUB.

Concerning access to publications through collaboration networks, we use the data on inter-regional collaboration networks. Each time two addresses from different NUTS3 regions occur on a publication, we count it as a relationship between two regions.

The full matrix is then derived by counting, for each pair of regions, how often two regions occurred jointly within a publication in a given period. The weight attributed to publications of region j can therefore be specified as follows:

$$W_{RELATIONAL\_ij} = \frac{n_{ij}}{\sum_i \sum_j n_{ij}}$$

In this formula, *nij* stands for the number of co-occurrences of addresses from region *i* and region *j*.

As before, for some variable of interest (in this case, PUB), each element of the relationally lagged variable is the average of the publications of other regions weighted by their relational proximity. As in the distance matrix, intra-regional networks are not taken into account in the matrix.

A restriction in the use of weight matrices holds that no dependency is allowed to exist between the relational matrix data and the publication data. After all, a collaboration between region *i* and *j* also indicates a publication for both region *i* and *j*. We neutralise this problem by taking the relational matrix for a period preceding the publications. This solution allows for the occurrence of regions with publications but no networks, and vice versa.

We subsequently standardised both weight matrices over the sum of the counts of all pairs of regions to make the effects of the two created weights mutual comparable. Therefore, in contrast to other KPF studies (e.g. Anselin et al. 2000), we did not row-standardise the weights in the weight matrix, as we believe that the capacity of a region to learn from other regions is not bounded. The final variable was created by multiplying both weights by the number of publications in region *j*.

As in the gravity equation, the dependent variable in this chapter (i.e. number of patents in region *i*) has the character of count data, which typically implies a skewed distribution with many observations with low values and a long tail. Once again, however, our patent data suffers from overdispersion. We therefore use the negative binomial regression model instead of the Poisson regression model.

are the mechanisms underlying knowledge spillovers that occur through formal collaborations.

A comparison between Models A and B indicates that the correlation between the stock of publications and the relational weight matrix is not problematic. Although the coefficients of the publication variable decrease when including the relational weight matrix, it remains significant and within the range of elasticities found in other studies.

The final model (Model C) includes all explanatory variables. Note that we also included dummy variables for country, in order to control for unobserved differences between national systems (which are further analysed in the next chapter). Model C clearly shows that relational networks become even more important in the field of biotechnology. Importantly, in the case of semiconductors the relational weight matrix becomes significant as well, thereby diminishing the influence of the spatial weight matrix.

In addition, excellence regions perform much better in Model C than do other regions. This suggests that concentration of talent contributes significantly to innovativeness. This finding supports the European Commission's strategy of stimulating the concentration of talent. In contrast, no such effect is found for capital regions.

Discussion

The analysis showed that scientific publications are indeed a major input for technological innovations for the two fields considered. The diagnosis of insufficient funding of research in the EU compared to the US and Japan (Commission 2002: 4) seems warranted, in that an increase in such funding would indeed strengthen Europe's innovative performance.[5]

The empirical analysis also suggests that regional innovative performance is dependent on more than simply a region's own science base; it also depends on geographical and relational proximity to the science bases of other regions. Geographical proximity captures spillovers that are associated with local mechanisms of learning, while relational proximity captures spillovers that stem from formal collaborations, at least to the extent that such effects are visible in the results concerning scientific publications.

Reasoning from a policy perspective, the spatial weight matrix is determined by geography and beyond the control of policy (because distance is a given). Considering travel time instead of geographical distance, however, policy can influence spatial weight matrices through infrastructure projects. Nonetheless, the return on infrastructure investment is likely to be determined primarily by productive activities and only slightly by the resulting increase

5. This conclusion is in line with Dosi et al. (2006), who argued that Europe has a greater lack of knowledge inputs than it does of institutions that support the transformation of inputs into output. The latter claim has been the subject of dispute.

* The choice of the distance-decay parameter is somewhat arbitrary. A larger decay parameter would yield stronger distance decay and more restricted access to publications through space. Conversely, a smaller decay parameter would yield weaker distance decay and wider access to publications through space. We repeated our analysis by using a distance decay of one. We obtained the same results in terms of signs and significance that were obtained in the reported analysis, with one exception: the estimate of the spatial weight matrix was no longer significant for semiconductor technology.

in knowledge spillovers between neighbouring regions.[6] Knowledge spillovers alone could never justify the allocation of large sums to infrastructure projects.[7]

In contrast, subsidising collaborative research projects between regions could influence relational proximity more directly. Indeed, the main pillar of the seventh Framework Programme involves funding for collaborative research projects. The results presented here show that such subsidies are indeed likely to contribute to improving the industrial exploitation of scientific research. Access to the science bases of other regions through collaboration networks does help regions to become more innovative.

The policy implication that can be derived from the other explanatory variables included in the Knowledge Production Function seems straightforward. The concentration of talented researchers in excellence regions leads to more innovations. This outcome indicates that strategies that aim to concentrate high-quality research at the national and EU levels are likely to generate more innovation than would the dispersion of investments in research and development. However, the precise effect of spatial concentration of research requires more research.

Finally, we conclude that the implicit assumption of the ERA policy – that an ERA will contribute to improving the exploitation of scientific research in the form of technological innovations – is apparently justified, as regions with more extensive collaboration networks are more innovative than are regions with few network relations. Although this result held both for biotechnology and for semiconductor technology, further studies in other fields are needed to assess the generality of these results.

6. Note that this reasoning does not hold for airport infrastructure, which would be provide more support for relational proximity between regions in terms of formal collaboration projects.
7. The results, however, suggest that the effect of infrastructure on knowledge spillovers could be taken into account in future cost-benefit analyses on infrastructure.

Table 9. Descriptive statistics

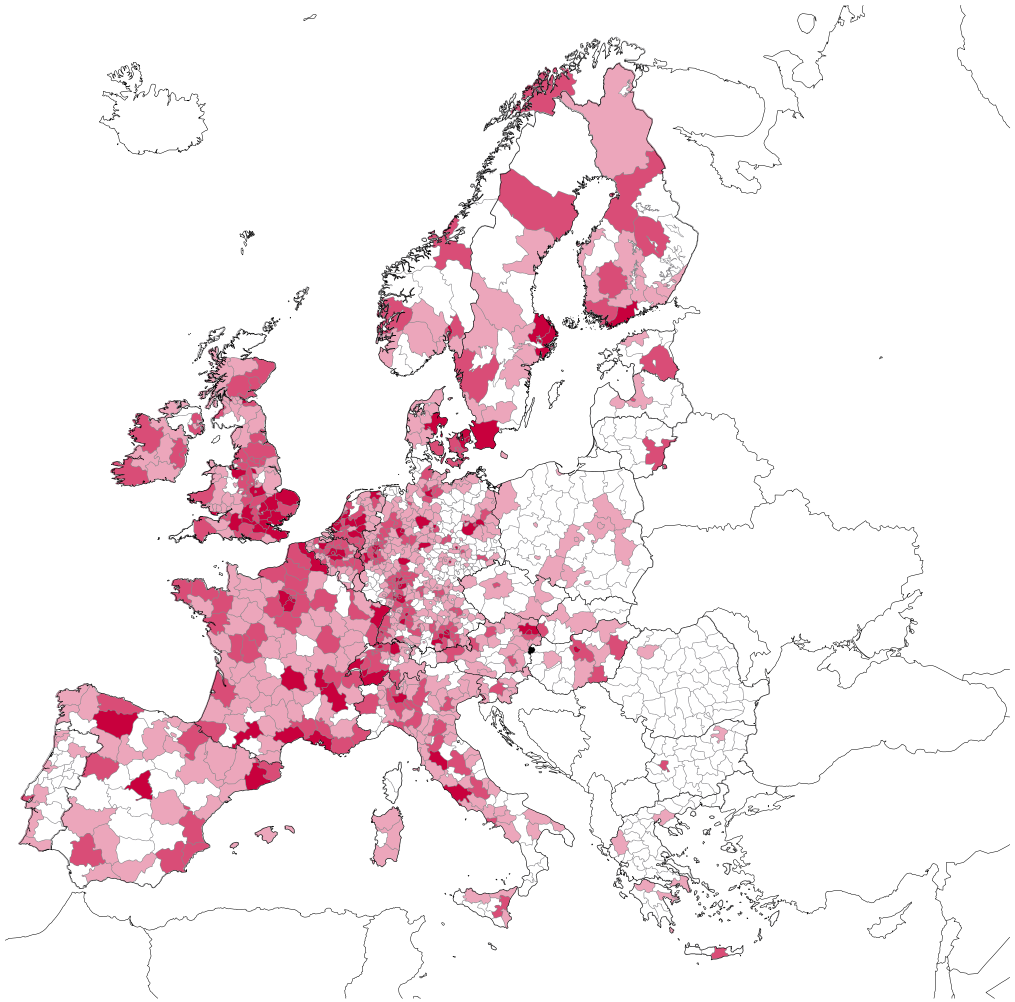
	N	Mean	SD	Min.	Max
Biotechnology					
Patents	476	39.313	78.769	0.000	618.000
Publications	476	289.082	637.182	1.000	8027.000
$W_{SPATIAL}$	476	3.290	7.226	0.002	68.042
$W_{RELATIONAL}$	476	0.113	0.330	0.002	5.783
Population	476	616.435	664.634	43.080	7147.860
Semiconductors					
Patents	351	21.558	79.254	0.000	829.000
Publications	351	111.313	172.846	1.000	1546.000
$W_{SPATIAL}$	351	1.006	1.816	0.000	13.798
$W_{RELATIONAL}$	351	0.301	0.056	0.001	0.596
Population	351	456.888	595.900	19.760	7147.860

Table 10. Correlation matrix for Knowledge Production Function

	1	2	3	4	5	6
Biotechnology publications						
Publications	1.000					
$W_{SPATIAL}$	0.019	1.000				
$W_{RELATIONAL}$	0.879*	0.158*	1.000			
Population	0.424*	-0.114	0.362*	1.000		
Excellence	0.397*	0.041	0.387*	0.353*	1.000	
Capital	0.272*	-0.032	0.217*	0.361*	0.313*	1.000
Semiconductor technology publications						
Publications	1.000					
$W_{SPATIAL}$	0.060	1.000				
$W_{RELATIONAL}$	0.679*	0.216*	1.000			
Population	0.008	-0.120	-0.024	1.000		
Excellence	0.459*	0.023	0.340	-0.071	1.000	
Capital	0.260*	-0.056	0.253	-0.026	0.239*	1.000

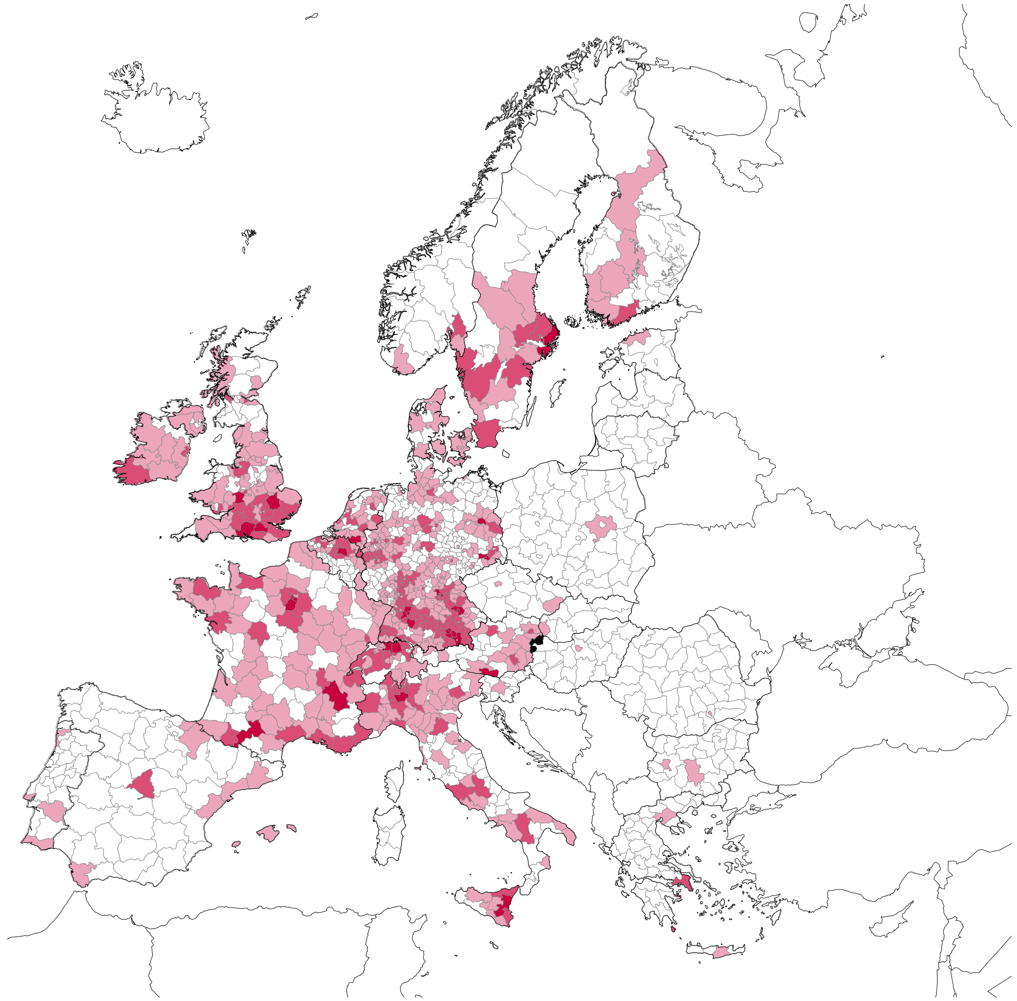
* Indicates significance at 1 percent level

Figure 11. Number of patents in biotechnology



☐	0
■	1-10
■	11-100
■	> 100

Figure 12. Number of patents in semiconductors



☐	0
■	1-10
■	11-100
■	> 100

Table 11. Determinants of patenting in biotechnology

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	1.256 (0.141)**	3.316 (0.284)**	0.894 (0.742)
Publications	0.465 (0.030)**	0.375 (0.062)**	0.262 (0.062)**
$W_{SPATIAL}$		0.625 (0.050)**	0.414 (0.068)**
$W_{RELATIONAL}$		0.171 (0.059)**	0.202 (0.058)**
Excellence			0.715 (0.255)**
Capital			-0.128 (0.248)
Population			0.344 (0.094)**
Country dummies	No	No	Yes
	Fit statistics		
Overdispersion (α)	2.102 (0.137)**	1.481 (0.103)**	1.071 (0.080)**
Log Likelihood	-1922.844	-1839.889	-1770.004
Cragg & Uhler R2	0.324	0.523	0.645
AIC	8092	7752	7538
N	476	476	476

Table 12. Determinants of patenting in semiconductors

	Model A	Model B	Model C
	Estimate (SD)	Estimate (SD)	Estimate (SD)
Constant	0.626 (0.236)**	3.121 (0.540)**	1.618 (1.000)
Publications	0.537 (0.056)**	0.438 (0.092)**	0.401 (0.092)**
$W_{SPATIAL}$		0.485 (0.100)**	0.252 (0.113)**
$W_{RELATIONAL}$		0.153 (0.084)	0.199 (0.084)*
Excellence			1.443 (0.406)**
Capital			0.047 (0.401)
Population			-0.168 (0.100)
Country dummies	No	No	Yes
	Fit statistics		
Overdispersion (α)	3.671 (0.291)**	3.342 (0.269)**	2.198 (0.189)**
Log Likelihood	-1115.495	-1099.674	-1031.039
Cragg & Uhler R2	0.191	0.261	0.501
AIC	6373	6294	6012
N	351	351	351

* and ** indicate significance at 1 and 5 percent level, respectively

Best practices of EU member states

Introduction

As discussed in the introductory chapter, the second objective of the ERA is to improve the coordination between member states' national research activities and between member states' national research policies. Improved coordination can reduce unnecessary duplication of research efforts, increase the opportunities to realise economies of scale and make national institutions mutually more compatible (e.g. with regard to labour markets and property rights). Only by reforming the national systems in a mutually consistent manner can the European Union expect to profit from its scale in ways similar to United States, Japan and China.

The coordination objective recognises the continued dominant role of member states in defining research policies and allocating R&D funds. In 2000, the European Commission accounted for only five percent of public funding for research in Europe (Banchoff 2002). If the multi-lateral agreement on intergovernmental programmes is included, this figure increases to 17 percent (Commission 2000: 7). Given the strong institutions at the national level, the European Council decided in 2000 to adopt an 'open coordination method' in order to improve the coordination and cohesion of national policies (European Council 2000). Rather than imposing a uniform set of institutions and policies from the top down, member states are expected to reform their national institutions in a mutually consistent manner. This method of open coordination is based on the following principles (Commission 2002: 19):

- The setting of general objectives and guidelines at EU level
- The translation of these objectives into specific targets and policy measures for each member state
- The establishment of quantitative and qualitative indicators
- The benchmarking of national and regional performance and policies in the area concerned
- The exchanges of information, experience and 'best practices'.

The success of such a process is by no means guaranteed. The main risk underlying the open coordination method is the lack of sanctions against member states that fail to deliver. The method's effectiveness depends on peer pressure and a process of 'naming and shaming'. It is assumed that member states will reform, as no member state wants to be ranked worst in a given policy area. To support such a process, it is crucial that peer review be based on a solid empirical foundation, such that benchmarking exercises will indeed act as catalyst for national policy reform.[1]

1. In this context, one important initiative that has been launched by the European Commission is the ERA-WATCH, a platform that provides information on the research policies and research systems of member states. See http://cordis.europa.eu/erawatch/

At this point, we present an analysis of the best practices of EU member states according to a statistical methodology that follows from the analysis presented in the previous chapter. This procedure allows us to compare member states in terms of their ability to exploit scientific research. This exercise provides information that can be used to support the open method of coordination regarding the reform of national innovation systems.

Methodological remarks on benchmarking

Benchmarking has become a popular tool for assessing the performance of a particular entity in comparison to a given 'best practice'. For example, firms benchmark various aspects within the organisation with industry leaders in order to identify the parts of the organisation that require improvement. Similarly, cities, regions and countries are increasingly participating in benchmark exercises to assess their performance (however defined) in comparison to their counterpart cities, regions or countries.

Benchmarking analyses should be used with great care, however, as most benchmark exercises involve a number of methodological shortcomings that should be avoided. First, many benchmark exercises compare entities in terms of their absolute performance (e.g. the total number of patents in a country). This can be relevant in some contexts. For example, given the concrete objective that all EU member states should allocate three percent of their GDP to R&D, it would be possible to benchmark each country according to the percentage of its GDP that is allocated to R&D in the EU. Such indicators do not indicate the actual performance of a system, however, but the state of a system. A more interesting approach, and one that is more relevant to policy, would be to consider the efficiency of a national system, as efficiency reveals the performance of national institutions in transforming inputs into a given form of output. In the context of the current study, we can analyse the best practices of countries by considering how successful countries are in transforming their R&D investments in true innovations. An alternative indicator of efficiency, which we will examine, involves determining how many patents are 'generated' from a given stock of publications.

Best practices in the industrial exploitation of scientific research

To analyse the ability of countries to utilise scientific research in industrial innovation, we computed the patent-publication ratio at the national level by dividing the number of patents by the number of publications for each country. At this point, we show the ratio for the entire period rather than for each year, as the latter results are highly irregular. Figures 13 and 14 present this ratio for each country. Even this simple indicator reveals marked differences between countries. First, Germany and Switzerland are the most successful in patenting, relatives to their publication base. The innovation systems of these countries are apparently successful in transforming scientific research into commercial patents. In biotechnology, Denmark is also successful, even though it is quite unsuccessful in semiconductor technology. Scores from the Netherlands are particularly high for semiconductor technology. A number of countries (e.g. Belgium, France and Austria) show moderate performance in both technology fields, while the scores of the United Kingdom, Scandinavian countries and southern countries are relatively low.

A second way of assessing the relative performance of countries in terms of patenting is to use dummy variables in the knowledge production function, as presented in Chapter 4. We derived the dummy values from a knowledge production function in which the number of regional patents is explained solely by the number of regional publications and the number of publications weighted elsewhere by distance and networks. This is a way of benchmarking national innovation systems according to their ability to generate patents while controlling for differences in their publication inputs.

The results are presented in Table 13. We limited our analysis to the 16 most active countries in terms of publishing, in order to avoid outliers resulting from small numbers. The countries are ranked according to their performance, while the value is computed using the countries without dummy variables as the reference group. We can observe a distinction between different types of national systems. In biotechnology, Southern and Eastern European countries generally underperform, as compared to Mid-European countries. Greece, Poland and Portugal are particularly unsuccessful in generating patents, while Germany, Austria and Switzerland perform very well in both technologies in terms of patenting. Somewhat surprisingly, the UK does not rank highly, despite the common knowledge that they have 'modernised' their system of innovation in the past fifteen years.

Interestingly, groups of countries with similar performance levels are also known to share institutional features (Senker et al. 2007). The Mediterranean countries are characterised by strong central research institutions that have close ties to the national government (Hall & Soskice 2001). Their relatively poor performance in biotechnology suggests that this model, although appropriate in some areas, may not function in the more entrepreneurial field of biotechnology, in which universities and start-up companies play an important role. The strong performance of German-speaking countries in semiconductor technology resonates with their long-standing reputation in engineering, which is supported by a corporatist model of university-industry relations and the global competitiveness of their firms (Murmann 2003).

The results also provide evidence of sector specificity. Countries that underperform or over-perform in one field do not necessarily do so in the other field. This means that the sector specificity must always be taken into account in both benchmark analysis and innovation policy.

Figure 13. Best practices of European countries in biotechnology

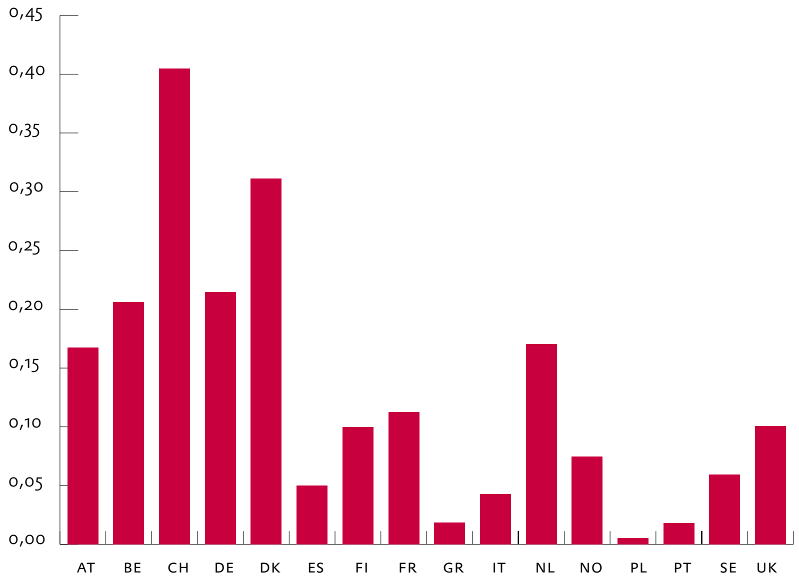


Figure 14. Best practices of European countries in semiconductor technology

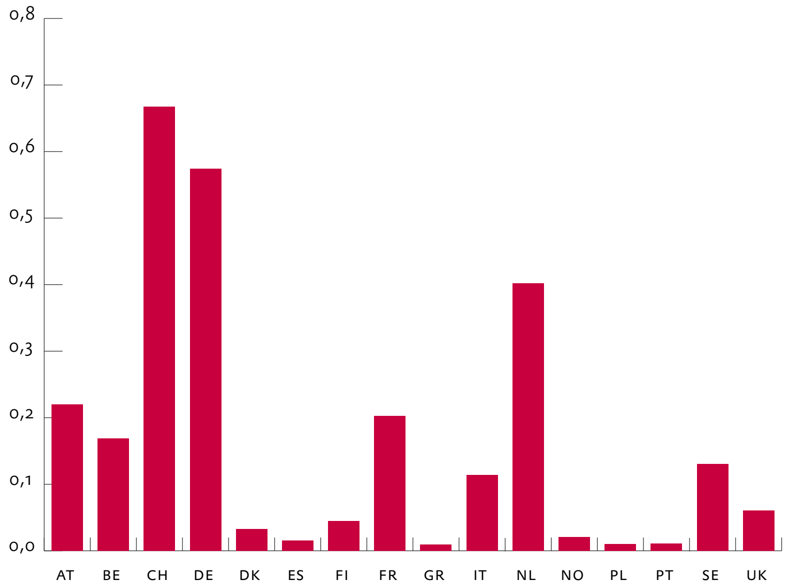


Table 13. Benchmarking EU member states on efficiency of publication-patent relations

Biotechnology		**Semiconductors**	
Country	Estimate (SD)	Country	Estimate (SD)
DK	0.823 (0.399)	AT	3.611 (0.761)
AT	0.800 (0.431)	CH	2.772 (0.733)
CH	0.600 (0.439)	DE	2.579 (0.481)
DE	0.525 (0.289)	NL	1.895 (0.619)
FI	0.352 (0.446)	SE	1.800 (0.636)
NO	0.285 (0.506)	BE	1.673 (0.682)
BE	0.236 (0.395)	FR	1.330 (0.483)
ES	- 0.021 (0.291)	IT	0.958 (0.482)
FR	- 0.044 (0.288)	FI	0.794 (0.784)
SE	- 0.080 (0.454)	NO	0.480 (0.915)
UK	- 0.385 (0.301)	UK	0.345 (0.543)
NL	- 0.458 (0.382)	DK	0.097 (0.827)
PT	- 1.106 (0.497)	PL	- 0.117 (0.182)
IT	- 1.203 (0.276)	GR	- 0.788 (0.829)
PL	- 1.808 (0.458)	ES	- 0.800 (0.588)
GR	- 1.932 (0.657)	PT	- 1.129 (0.900)

Competitiveness and cohesion: Can they be combined?

Introduction

From its inception, the Lisbon Agenda has raised concerns regarding possible conflicts between its objectives and the objectives of cohesion policy. The Lisbon Agenda aims to improve the competitiveness of Europe as a whole by strengthening its collective research and innovation capacities, particularly through the creation of the European Research Area (ERA). In contrast, cohesion policy aims to reduce income disparities between Europe's poorest regions and the rest of Europe, otherwise indicated by the term 'cohesion'. These two objectives can be incompatible, insofar as the establishment of the ERA is likely to generate disproportionate benefits for richer regions. Because more advanced regions host more researchers per capita than lagging regions, even a random distribution of funds to researchers would automatically favour advanced regions. A trade-off exists between competitiveness and cohesion or, more generally, between efficiency and equity (Okun 1975).

Concerns about the incompatibility of 'competitiveness' and 'cohesion' had already been voiced in policy discussions taking place before the establishment of the Lisbon Agenda. In particular, Sharp (1998) shows that the early Framework Programmes (FPs) indeed favoured the richer regions at the expense of poorer ones.[1] This was to be expected, simply because the advanced regions in Europe host many more R&D departments and research institutes than the lagging regions in Europe. The proportional funding of all R&D projects would thus lead to a highly disproportionate funding of European regions. The specialisation of advanced regions in high-tech disciplines would cause a disproportionate allocation of research funding to advanced regions.

The tendency of scientific research and technological innovation to concentrate in a few regions is strong. Figure 15 shows the cumulative distributions of the number of patents and publications for each region, as compared to the cumulative distribution of Gross Regional Product. This figure clearly shows that research is indeed much more concentrated than economic activity is. This means that any increase in investments that are specifically devoted to research activities are likely to increase rather than decrease regional income disparities, as the more advanced regions will receive the most funding, thereby generating more growth than the lagging regions, which receive only a small share of the funds (Clarysse & Muldur 2001; Musyck & Reid 2007).

1. Sharp (1998) shows that richer regions did indeed receive more R&D funding per capita than poorer regions did, but that poorer regions actually received more funding per R&D personnel than did the richer regions. The higher level of funding per R&D personnel for lagging regions probably reflects the special eligibility conditions of that time, which biased funding towards project proposals with participants from poorer regions. Because these special conditions were dropped in FP7, there is no reason to assume that the pattern found by Sharp (1998) will be replicated in the future.

Whether the uneven distribution of research funding is truly contrary to EU cohesion policy oriented towards reducing income disparities remains an open question. It is difficult to assess the spatial effects on R&D policy. Even though funds are allocated to specific organisations in specific regions, knowledge, by its nature, easily spills over to other regions. Another possibility is that the innovations generated from European funding in richer regions are likely to be exploited commercially in poorer regions, albeit with a time lag. In this chapter, we do not attempt to apply explanatory statistical analysis to assess the compatibility of the competitiveness and cohesion objectives. The non-disclosure of data on recipients of R&D funding makes such analysis impossible. Instead, we use the results obtained in the previous chapters to discuss possible conflicts between ERA policy and cohesion policy.

Interfacing ERA policy and cohesion policy

Possible conflicts between the Lisbon Agenda and cohesion policy were recognised by the European Commission at an early stage (Commission 2001). More specifically, the question concerns whether the Framework Programmes (FPS) carried out by DG Research to promote excellent research are compatible with the Structural Funds (SFS) allocated by DG Regions to reduce income disparities. Whereas all EU regions are eligible to receive FP funding, SFS are allocated only to regions with a per capita income less than 75 percent of the EU average.

The need to interface both policy domains has only been strengthened by the increasing attention to regional innovation policy as part of the SFS that are allocated by DG Region. The involvement of DG Region in innovation policy involves a risk of inter-departmental competition with DG Research, which retains primary responsibility for research and innovation policy. A recent report showed that SF budgets between 2000 and 2006 allocated more than EUR 10 billion to innovation activities, amounting to 5.5 percent of the total budget for SFS (Technopolis 2006). For the present budget, which runs from 2007 to 2013, this share is expected to increase to at least 20 percent, which would amount to more than EUR 50 billion. In this (likely) scenario, the budget that would be spent on innovation through the SFS would be approximately equal to the budget that is available for the seventh Framework Programme run by DG Research.

The Commission's intention to allocate a substantial amount to innovation policy under the SF programmes raises the question of how these funds should be allocated. The precise allocations of the SFS are decided during the budgetary period, in close consultation with individual member states. The remaining discussion is specifically meant to provide broader input into the current debate on the role of SFS in relation to EU innovation policies. In doing so, we consider the European policies, their instruments and the budgets as given. We therefore discuss only how these policies could be implemented in a mutually consistent way.

Policy considerations

With the establishment of the Lisbon Agenda, the emerging consensus on the compatibility between the FPS and SFS holds that the SFS can be considered as making it possible for lagging regions to strengthen their knowledge base. Improvements in knowledge should subsequently allow these regions to participate more frequently in collaborative projects that are funded under the Framework Programmes. Following this reasoning, the SFS are compatible with the concept of the ERA (European Parliament 2007: 16). This reasoning, however, neglects possible hierarchical effects in networking. We have observed that researchers in 'excellence regions' (i.e. regions with a high concentration of publications) prefer to collaborate with each other rather than with researchers from lagging regions.

In the Chapter 'The geography of research collaboration', we provided evidence of these hierarchical effects. The concentration of talent in a few 'excellence regions' in Europe may actually increase further, given the recent policy emphasis on excellent research. This suggests that a lagging region must pass a threshold of quality and size before it can become an important player in the European research network. Incremental improvement of the research bases of all lagging regions may not be very effective. Member states may profit more by concentrating research subsidies from SFS into a few promising regions among their numbers, helping them to become serious candidates in European research networks. While some lagging regions are promising as future research sites, other regions may have more potential as high-end production sites. By providing conditions and facilities for the production of innovative products and the adoption of new technologies, these latter regions may still profit from innovative activity (and subsidies) in advanced regions (Musyck & Reid 2007). From this perspective, the SF budgets would have a higher return if they were to be spent on improving production activities, including accessibility improvements, workforce training and the modernisation of business sites rather than on research and innovation, at least, for most of the lagging regions.

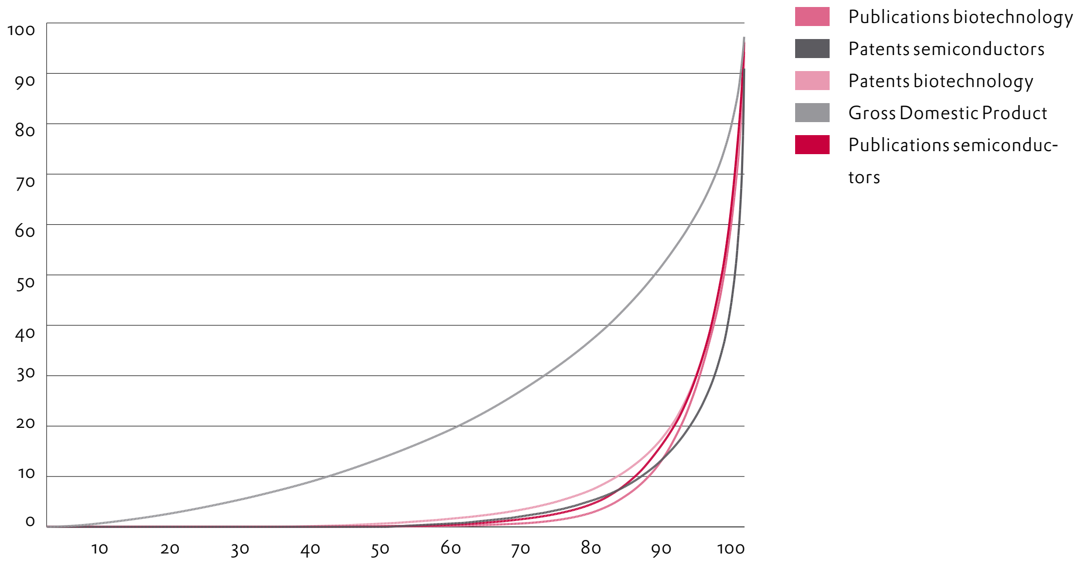
The free movement of people is another important pillar of the ERA concept. This objective consists largely of two parts. First, the budget for mobility of researchers was increased in the most recent Framework Programme. Second, attempts are being made to remove institutional obstacles that currently hinder labour mobility across national borders (e.g. the diversity of diploma systems and differences in pension schemes). Increasing the mobility of researchers across national borders, however, is likely to reinforce the concentration of talent in a few excellence regions. The most talented researchers will compete for positions at the most prestigious research institutes, thus rendering it more difficult for lagging regions to retain talent within their borders. From the perspective of lagging regions, talent should be sent to advanced regions only on a temporary basis. Upon their return, they would bring back not only state-of-the-art knowledge, but also the social networks that serve as channels for knowledge spillovers and future collaborations (Breschi & Lissoni 2003; Agrawal et al. 2006). In this manner, lagging regions could start to position themselves within European networks. Special EU schemes that would obligate people moving from lagging regions to core regions to return in order to exploit their knowledge in their regions of origin are not desirable, as they would oppose 'the creation of an "internal market" in research, an area of free movement of knowledge, researchers and technology' that underlies the ERA concept. This means that lagging regions, or the member states to which they belong, should develop regional schemes on their own to promote labour mobility on a temporary basis in order to profit from knowledge spillovers from advanced regions, as well as from the resulting networks connections.

A final remark concerning the expected increase of concentration of R&D relates to sectoral structure. The sectoral structures of the poorer regions in Europe are quite different from those in richer regions. Low-tech and medium-tech activities tend to predominate in poorer regions. Although some extent of innovation does occur in these sectors, the thematic priorities formulated under the Framework Programmes almost exclusively concern high-tech sectors. Table 3 showed that thematic priorities lie in such advanced sectors as IT, biotechnology and energy (with the possible exception of food technology). For this reason, R&D subsidies are likely to become concentrated in richer areas, not only because of differences in the quality of researchers, but also because poorer regions are simply not specialised in high-tech disciplines. As mentioned earlier, general perceptions in the European Union currently hold that SFs are compatible with the creation of ERA, as they are intended to improve the knowledge base of lagging regions such that they can effectively enter into European collaborative networks. Nonetheless, the improvements that are expected to emerge from the SFs primarily involve the knowledge base of the existing specialisations, while the networks funded under the Framework Programmes focus on high-tech activities. Given that regional specialisations are highly stable and persistent (Rigby & Essletzbichler 1997; Essletzbichler & Rigby 2005), the innovation opportunities that are available to lagging regions thus lie in developing niche areas while drawing upon their existing sectoral knowledge bases (e.g. tourism) and extending them into related areas (e.g. healthcare, conferences, education). The European Commission could therefore consider broadening its notion of innovation from its current bias towards high-tech industries by including niche areas that are relevant to lagging regions. This would allow innovation projects involving both high-tech and low-tech components to be eligible for funding as well, thereby providing opportunities for excellence regions and lagging regions to collaborate in joint projects. It would also open up opportunities for lagging regions to collaborate on common innovation projects in overlapping niche areas (Musyck & Reid 2007).[2]

2. The question of whether such programmes should be set up by DG Research or DG Region is of a more practical nature, and it lies outside the scope of this study.

The suggestions that have been made regarding innovation policy in the European Union, along with the potential for synergy between the instruments of the Framework Programmes and those of the SFs, are intended to serve as inputs for a more differentiated regional policy. Rather than promoting similar strategies based on 'best practice' and a restricted notion of innovation, our argumentation favours a differentiated approach, in which regions develop systematic, long-term development strategies based on their current competencies and realistic goals. The instruments of the European Union allow a bottom-up approach; it is up to the regions themselves to act proactively.

Figure 15. Lorenz curve GDP, total number of patents and total number of publications



Note: Due to a lack of data on GDP, we did not include data for the countries of Bulgaria, Cyprus, Norway, Luxemburg, Switzerland and Romania in the figure.

APPENDIX 1. LIST OF ABBREVIATIONS

CERN	Council Européen pur la Recherche Nucléaire (European Organization for Nuclear Research)
CIP	Competitiveness and Innovation Programme
DG	Directorate General
EIT	European Institute for Technology
EPO	European Patent Office
ERA	European Research Area
ESA	European Space Agency
ESFRI	European Strategy Forum on Research Infrastructure
ESPRIT	European Strategic Programmes of Research and Development
EU	European Union
EU27	27 Member States of the European Union
EURATOM	European Atomic Energy Community
FP	Framework Programme
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IPC	International Patent Classification
KPF	Knowledge Production Function
NUTS	Nomenclature des Unités Territorial Statistiques (Nomenclature of Territorial Units for Statistics)
OLS	Ordinary Least Squares
R&D	Research and Development
RACE	Research and development in Advanced Communication technology, Europe
RPB	Ruimtelijk Planbureau (Netherlands Institute for Spatial Research)
RTD	Research and Technological Development
SF	Structural Funds
SME	Small and Medium-sized Enterprises
US	United States
WOS	Web of Science

APPENDIX 2. LIST OF COUNTRY ABBREVIATIONS

AT	Austria
BE	Belgium
BG	Bulgaria
CH	Switzerland
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FR	France
FI	Finland
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LV	Latvia
LU	Luxemburg
MT	Malta
NL	Netherlands
NO	Norway
PL	Poland
PT	Portugal
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
UK	United Kingdom

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