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Europe's regional research systems:
current trends and structures

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I Introduction

It is now commonly accepted that a science-based, regional development strategy is an important precondition for European growth. In many countries of the EU, the regional level has become the starting point for policy measures to better exploit research and technology potentials. According to Koschatzky (2005)[1], regions have become the object of multi-actor and multi-level governance structures and hierarchies. Their policy arena is populated by a variety of political, corporate, social and scientific actors. The move towards the region brought a stronger emphasis on the sub-national, mainly regional level of intervention as a driver of public-private processes regarding technology and knowledge transfer, interactive and mainly incremental learning, new modes of the division of labour in technological development, and overall regional institutional building. Within this context, the "network idea" or the "network paradigm" and the possibilities for making use of spatial and cultural proximity between firms and supporting institutions is considered crucial. This becomes an important analytical perspective in the framework of the construction of the European Research Area.

This booklet is divided into three main parts: in the first part, the analytical concept of the booklet is presented. Accordingly, a definition of regional research systems as well as key characteristics and constituent features (actors and structures) is given. In the following chapter, the most recent trends and structures of European regional research systems are described based on the most current data available on the NUTS 2 level.[2] The report will give an overview of a series of research and technology "input" as well as "output" indicators, in terms of R&D expenditure, R&D personnel, patents and publications. In the third part of the booklet, a typology of European NUTS 2 regions based on the framework of reference of the theoretical concept of regional research systems is introduced. It takes into account indicators which reflect the relative socio-economic relevance of the regional research system, the nature of the activities performed and the relative importance of the actors involved. Empirical results with relevance for the European Research Area are presented on the basis of this typology. Finally, chapter 4 gives a summary of the results and formulates the most relevant policy questions.

1 Koschatzky, K. (2005): The regionalization of innovation policy: New options for regional change? In: G. Fuchs/P. Shapira (eds.) Rethinking Regional Innovation and Change Path Dependency or Regional Breakthrough?, pp. 291-312.

2 It is important to note that, due to the availability of data on the NUTS 2 level, all calculations and rankings conducted for this booklet could only take the regions into account for which data are available.

II Europe's regional research systems: analytical concept: actors and structures

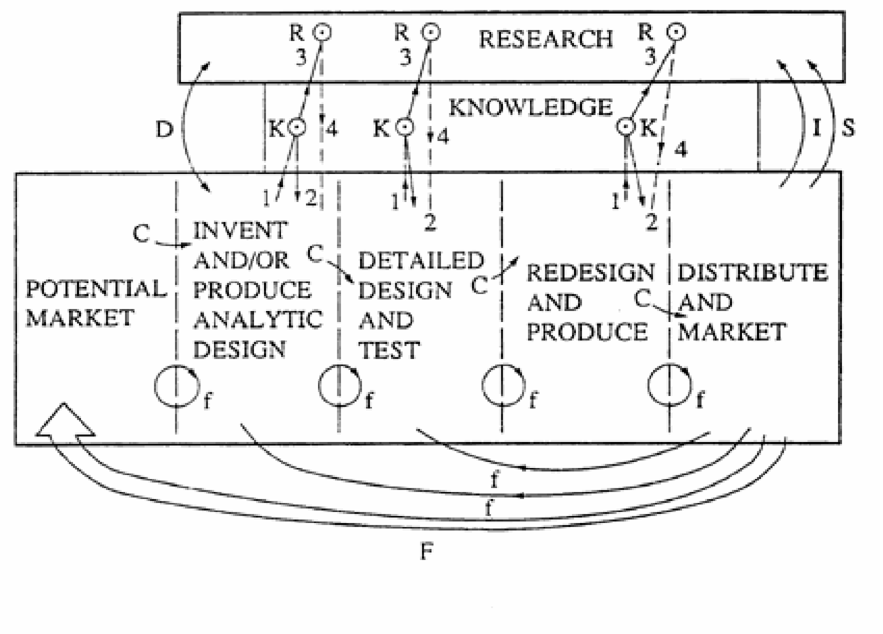
II.1 Definition of the concept of "research systems"

Research and innovation are intricately and systemically linked processes in the framework of a larger, knowledge-driven socio-economic system. In the literature, therefore, no clear distinction is made between the innovation system approach as outlined in the concepts of national or regional systems of innovation and a research system approach. In practice, however, different measures of RTDI policy are decided upon in different and organisationally distinct arenas of policy-making. For this reason, it is useful to develop a distinct concept of research systems – as socio-economic sub-systems with certain key interfaces, which can be addressed by research policy in the interests of overall socio-economic development.

The key element of the systemic model of the innovation process (COM (2003) 112) is the understanding that research and innovation are connected in a non-linear and interactive manner. The first important step towards a systemic understanding of the innovation process was taken by Kline and Rosenberg in 1986. Their chain-linked innovation model (see figure 1) encompasses the notion of systemic interaction and clarifies both inter-linkages and differentiating characteristics of innovation and research systems. According to Kline and Rosenberg, innovation is based on the accumulation and transformation of knowledge. This knowledge base, in different and interactive ways, is fuelled by knowledge created by research (defined by the OECD as "creative work undertaken on a systematic basis"). Hence, research provides an important and indispensable input for innovation activities.

However, innovation encompasses more than the successful application of research results. New knowledge is also created by experiences made during the process (learning-by-doing, learning-by-interacting etc.) and in a number of other non-systematic ways. It is thus important to note that innovation-relevant knowledge is only to some degree identical with knowledge derived from research activities intentionally performed. On the other hand, examples from basic research demonstrate that not all knowledge derived from research is an immediately relevant input to innovation processes. It does, however, add to the knowledge base and may become relevant in the long term.

Figure 1: Chain linked innovation model



Source: Kline and Rosenberg 1986, adapted

Nevertheless, new knowledge is created in a number of non-systematic ways during the innovation process. It is thus important to note that innovation-relevant knowledge is only to some degree identical with knowledge derived from research activities intentionally performed. Many examples from basic research and applied technical development demonstrate that neither is all knowledge derived from research an immediately relevant input to innovation processes, nor is all knowledge relevant for innovation being generated by research activity.

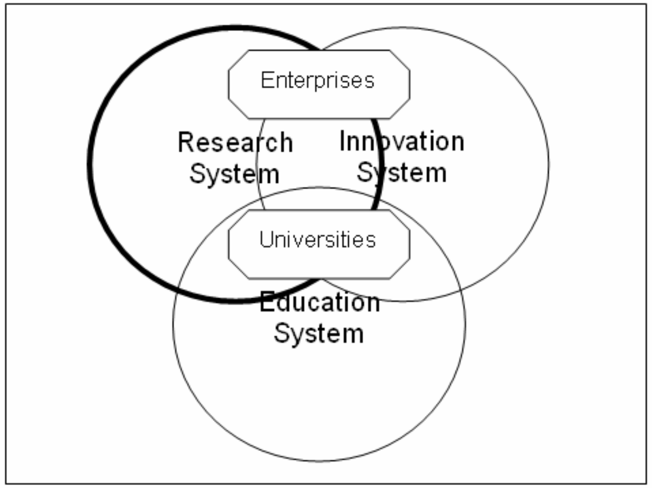
While the research system provides necessary input into the innovation system, it is not limited to this function. It is of key importance to note that the research system is also relevant and connected to a number of other regional socio-economic sub-systems, such as the education system, which may or may not overlap with the innovation system on their own accounts. Additionally, much of the knowledge generated stays within the research system and is fed into internal feedback loops. Due to the uncertainty inherent in learning, it is never entirely foreseeable how knowledge will be transferred. What is distinct about the research system is thus its focus on the creation rather than the transformation and commercialisation of knowledge.

On the one hand, therefore, the research system can be regarded as an important part of the innovation system which overlaps with it to a certain extent, but also includes a number of aspects which do not have direct impacts on innovation activities. As elaborated above, knowledge is generated and exchanged during both research and innovation activities and both systems possess a certain stock of knowledge (and the knowledge of applying it) that remains specific.

Secondly, however, the research system is just as intimately linked with the education system. Besides creativity, education is an indispensable prerequisite for the ability to successfully perform quality research. Major tasks of education thus are to pass on the codes of interpreting information, the combination and re-combination of information into new knowledge, and the upgrading of the existing knowledge base. Additionally, education is an important means to transfer knowledge derived from research and innovation to society.

On an actor level, however, research systems cannot be limited by organisations restricted to conducting research only. Due to the above mentioned close links between research, education and innovation, few such organisations exist. In practice, research will very often be conducted by organisations that also educate and/or innovate. In this sense, universities function as the organisational bridge between education and research, whereas enterprises serve as bridging organisations between research and innovation.

Figure 2: Definition of the concept of "research systems"



Source: own figure

From a policy point of view it is therefore worthwhile to identify the role and relative importance of the different sectors that contribute to the research system, since these actors provide the above mentioned interfaces which can be targeted by research policy action.

In this perspective, a research system generally rests on three pillars: research in higher education institutions, private-enterprise research connected to industrial development, and non-university public research carried out in governmental research or private non-profit organisations. The relevant actors in a regional research system can therefore be listed as follows.

- higher education institutions (e.g. research universities, universities of applied sciences, technical colleges),
- enterprises,
- government research organisations, and
- private non-profit organisations.

Consequently, research policy has to address private enterprises and the higher education sector to the same degree as research institutes.

Additionally, beyond organisational attribution, research comprises a broad spectrum of activities from pure basic research to highly application-oriented research connected to industrial development. Research systems can thus be differentiated by the nature of activities which prevail within the system.

Basic research is characterised by an academic approach focusing on novelty rather than immediate utility. Its central aim is the creation, and usually publication, of conceptually new knowledge.

Industrial development, on the contrary, is characterised by a utility-driven approach focusing on knowledge generation as a means to ensure future economic returns, even if in a long-term perspective.

Whereas academic knowledge generation is geared towards knowledge sharing and debate, industrial development is characterised by secrecy and the protection of intellectual property rights.

While there is undoubtedly a certain correlation between enterprises performing applied research aimed at technological development and universities focusing on basic, academic research – there is also ample evidence of public research institutions performing applied and large enterprises performing rather basic research.

II.2 Regional research systems as an important constitutive element of the ERA

The available literature in economics and regional science unanimously shows that regional research systems cannot be conceived of or defined in isolation. Research, just like innovation, is an undertaking and a process that depends on the exchange of information, on co-operation as much as on regulation. In an increasingly integrated Europe, naturally, none of these interactions and framework conditions can be sensibly conceived of as locked within the boundaries of a NUTS 2 region. On the contrary, regional research systems in the ERA have to be conceptualised as regionalised nodes in an inter-regional, international and increasingly European network.

Most regional research systems at NUTS 2 level are very strongly defined by framework conditions set on the NUTS 1, the national, and increasingly the EU level. While an exchange of knowledge between regional actors is desirable and often present, it cannot a priori be expected to be the dominant factor. Regional research systems therefore do not stand for themselves, but perform different functions in the larger context set by the ERA, the most defining of which will be elaborated in the following paragraph.

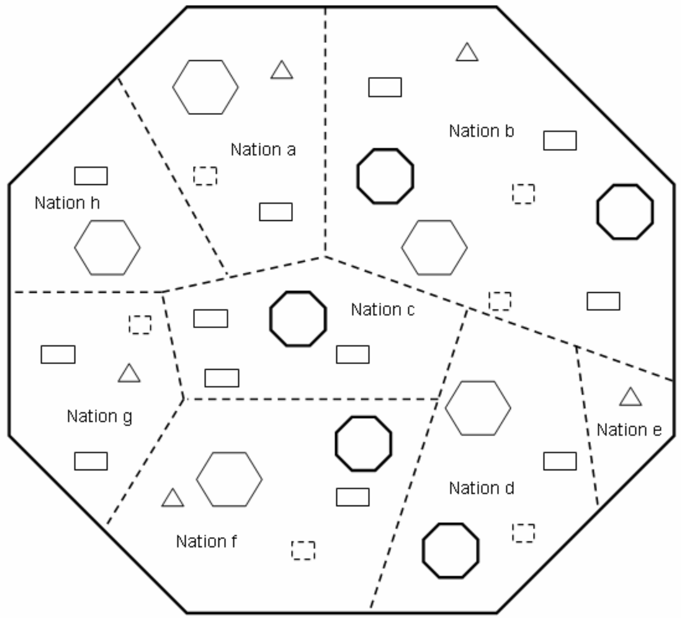
The data presented in the following sections suggest that, while some regional research systems are central loci of knowledge creation with a central role as the ERA's main sources of academic knowledge, others have a role as centres of application that receive and re-combine existing knowledge and excel in the field of applied research. Additionally, there are a number of regions for which R&D efforts do not play a defining role and which could better be defined as recipients of technological knowledge, which conduct a limited amount of targeted complementary research enabling them to better adapt the available information to their regional needs.

Nonetheless, it is important to realise that the place where activities are performed does not necessarily coincide with the place where decisions about them are taken. Regions are "open systems" in the double sense that, on the one hand, national and European level actors decide about activities within them while, on the other hand, regional actors may decide about activities elsewhere. In this sense, it is important to take into account that national framework conditions have an impact on the structure and development potential of regional research systems which are contingent on national level regulation, standardisation and the provision of public services.

This booklet, however, will focus on the characteristics of regional research systems based on their properties relative to the ERA as a whole. We believe that here lies the added value of a NUTS 2 level regional analysis, as national level analyses are available in other (National) Key Figures publications[3].

Against this background, the term "regional research system" is to be seen as an analytical concept (or even tool) which does not imply that in every single region within the EU 27 a dynamic and systemic local research system currently exists, which is endowed with all possible regional actors (higher education, public research, business) and in which significant research, as well as networking activity is conducted by all of them. Irrespective of the individual significance of regional research efforts, however, any regional research system in Europe can and should be seen as part of the larger systemic network of the ERA in which it plays a certain distinct role (Figure 3). Notably, even the strongest regional research systems cooperate in the context of ERA and beyond. While this may appear evident in the case of academic research, empirical evidence strongly indicates that it also applies to applied research activities conducted by firms and public research institutes.

Figure 3: Regional research systems in the European Research Area



Source: own figure

3 http://ec.europa.eu/invest-in-research/monitoring/statistical01_en.htm

Symbols in Figure 3 suggest the basic notion that differences exist between regions with regard to relevance (size) as well as specialisation and function (form). At this point, on a theoretical basis, it is not yet possible to suggest very specific attributes of such regions.

The underlying assumption for this approach is that, in the context of policy design which is to affect the European Research Area as a whole European policy-makers can profit from being aware of the internal composition and structure of the ERA beyond the common national divisions. The following section III will therefore provide information about the EU 27's regional research systems to create the basis for an ERA-wide assessment of the relative frequency of certain, defined types of regional research system in section IV.

However, it is quite clear that the interconnected system of the ERA is evolving as a whole and any typology can only be valid for a certain point in time. Finally, therefore, this booklet will look at the average development of regions of a certain kind, to identify possible indications of convergence, divergence and internal reorganisation.

III Overview of current trends and structures in regions located within the ERA

What are the structures of recent trends among European regions regarding R&D, technological and scientific potentials? Many studies in regional innovation economics document that sub-national research systems with their specific characteristics are more than just parts of the respective national research systems. Depending on their degree of autonomy, the socio-economic path or the political system of the country as a whole (centralised vs. decentralised structures), regional research systems often differ significantly regarding the technological capability or innovative output. In many countries, a few regional "growth engines" exist alongside weaker regions that face the danger of falling behind.

This booklet will describe and analyse recent trends and structures of European regional research systems, based on the most current data available. This chapter will give an overview of a series of "input" as well as "output" indicators, in terms of R&D expenditure, R&D personnel, patents and publications. The analysis will focus on dynamic as well as current aspects in order to assess which of the European regions show the most significant changes and trends in recent years. The selection of indicators is based on the list and structure of indicators designed for the "Regional Knowledge Profiles" of the Regional Key Figures (RKF) database.[4]

[4] The RKF database was built for comprehensive analyses of the structure and development of the national and regional distribution of research and technological activities in the countries and regions of the European Union. The RKF database is a compilation of different sources with the main source being Eurostat. The database is constructed as part of the RKF project funded by the European Commission under the FP6 contract no. PP-CT-M2-2005-002.

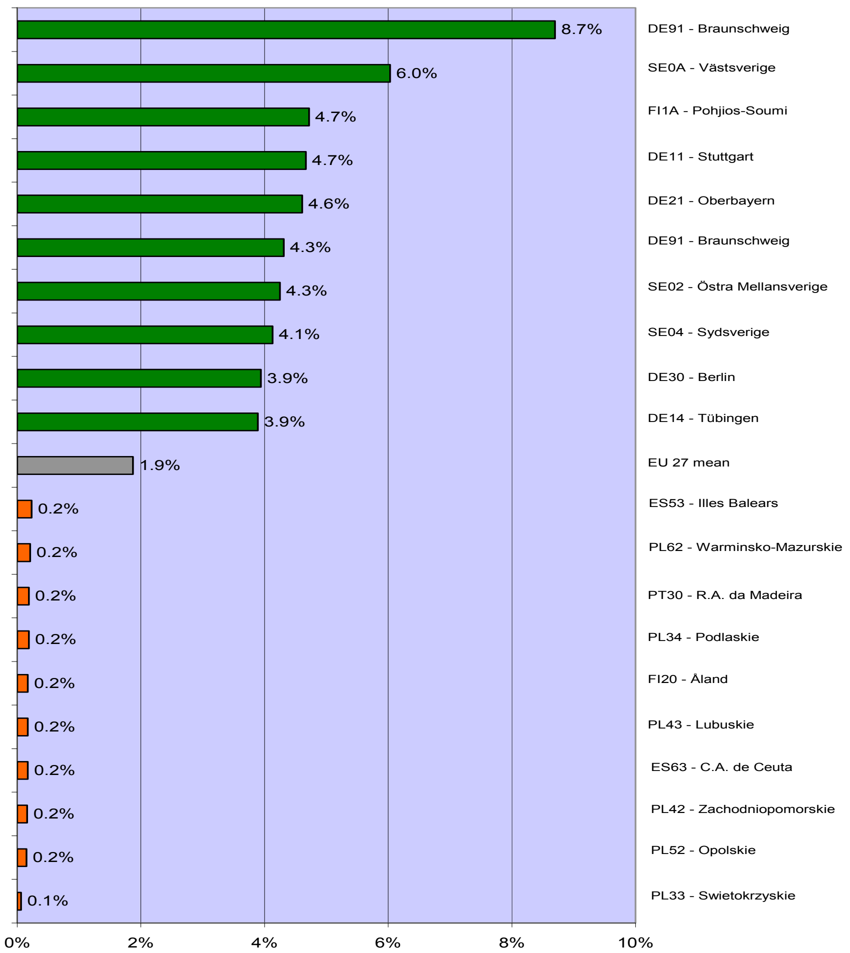
III.1 Overall investment in R&D

R&D intensity, measured as GERD (Gross Expenditure on Research & Development) as % of GDP, is one of the core indicators to assess the research or technological potential of a country or region. It can be used to make international or inter-regional comparisons. Looking at the regions with the highest and lowest R&D intensity, significant differences within the European Union become apparent. As Figure 4 shows, intensities vary from 8.7% in the region of Braunschweig in Germany to 0.1% in the region of Swietokrzyskie in Poland. Unlike the regions with the lowest R&D intensity, which are primarily rural areas without any larger cities, the top performing regions are often urban regions with one major city (like Munich in Oberbayern, the cities of Stuttgart, Stockholm, Gothenburg, Berlin). Some regions which perform well like Braunschweig, Tübingen, Oulu in Finland or Uppsala in Sweden, however, cannot be regarded as metropolitan, but are nevertheless characterised by strong research activities, either in the business sector (Braunschweig with Volkswagen) or the public sector (Tübingen with various semi-public research institutes).

The development of the weakest regions, however, will probably not have any immediate impact on the realisation of the 3% target on the EU27 level. Within the regional division of labour, these regions perform other functions than conducting R&D activities, so that weak R&D intensity often comes with weak absolute spending. In 2003, the 50 weakest regions in terms of R&D-intensity[5] contributed scarcely more than 1% of overall EU27 GERD (PPS2000). The top-50 regions[6], in contrast, contributed more than 50%.

[5] for which R&D intensities are known

Figure 4: European regions with highest and lowest R&D intensities (GERD as % of GDP), 2003



Note: data missing for BG and RO; data partially missing for ES, FR; DE: data partially for 1997, 2001; GR: data for 1999; AT: data for 2002; BE, UK data at NUTS 1 level for 1999.

Source: Regional Key Figures database, own compilation; 196 regions included

Due to the sheer economic size of some leading regions, the leading regions in terms of absolute R&D investment are different from those in terms of R&D intensity. Île de France, Oberbayern and Stuttgart have remained among the top three from 1995 to 2003 while the regions on ranks 4 to 12 have changed quite significantly. The most remarkable change in R&D expenditure from 1995 to 2003 is to be found in the case of Braunschweig, where expenditure increased from € 1,482.7 m to € 3,110.7 m in PPS 2000. From 1995 to 2003 many of the leading regions increased their share of total EU 27 expenditure. The relative contribution of Île de France, Oberbayern, Köln and Lombardia, however, declined, pointing to a shift in relative importance among the key regions.

Table 1: Gross domestic expenditure on R&D (GERD) of top performing regions, 1995-2003

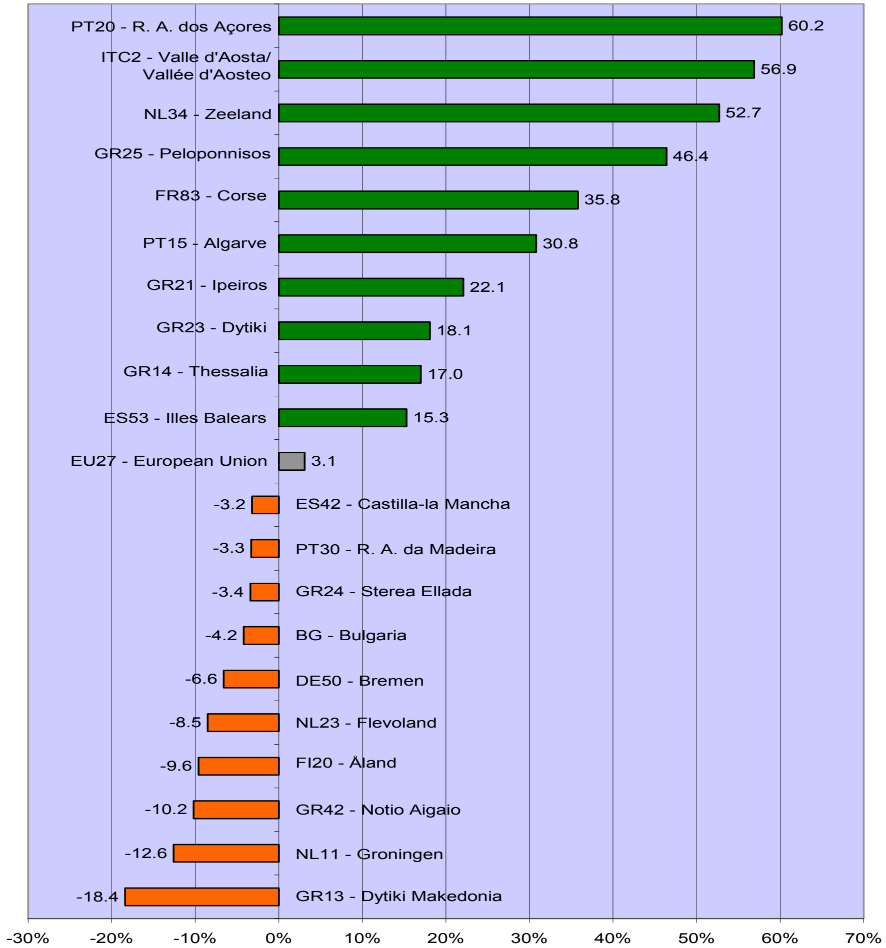
	2003			1995		
	Rank	€ m (PPS2000)	% of EU27	Rank	€ m (PPS2000)	% of EU27
FR10 Île de France	1	12,499.2	7.0	1	11,060.3	7.7
DE21 Oberbayern	2	6,362.0	3.6	2	5,315.2	3.7
DE11 Stuttgart	3	5,189.1	2.9	3	4,218.4	2.9
DE71 Darmstadt	4	3,763.7	2.1	5	2,750.5	1.9
DK00 Danmark	5	3,498.8	2.0	10	2,113.7	1.5
FR71 Rhône-Alpes	6	3,390.4	1.9	7	2,285.4	1.6
DEA2 Köln	7	3,214.9	1.8	4	3,149.8	2.2
ITC4 Lombardia	8	3,164.7	1.8	6	2,733.1	1.9
DE91 Braunschweig	9	3,110.7	1.7	15	1,482.7	1.0
BE2 Vlaams Gewest	10	3,024.8	1.7		no data	
DE12 Karlsruhe	11	2,739.6	1.5	11	2,003.3	1.4
SE01 Stockholm	12	2,688.7	1.5		no data	
EU27 European Union		178,850.1	100		143,991.8	100

Note: BG, RO, IE covered at NUTS 0 level; BE covered at NUTS 1 level; UK not covered as most current data available are from 1999; FR10 is identical to NUTS 1 FR1; DK00 is identical to NUTS 0 DK.

Source: Regional Key Figures database, own compilation; 196 regions included

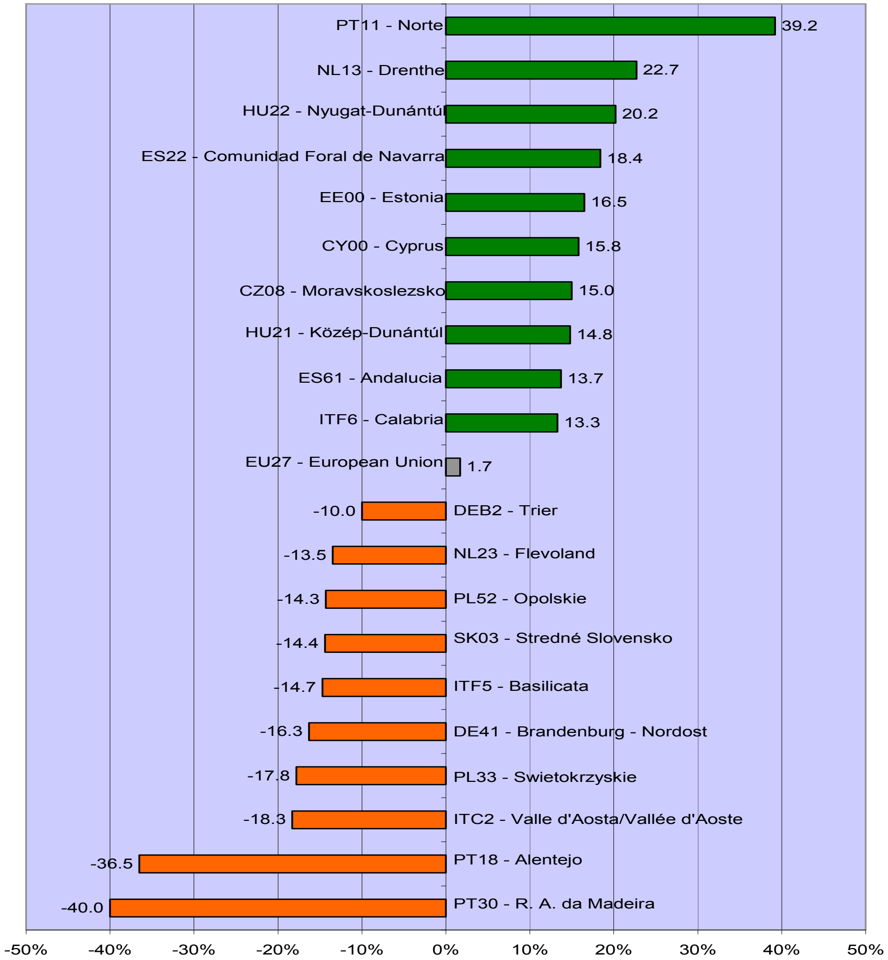
Which are the most dynamic regions in terms of growth of gross domestic expenditure on R&D? The data have been calculated separately for two time periods in order to measure whether there are different regional dynamics. For the period from 1995 to 1999, dynamic developments were particularly evident in small to medium-sized regions rather than in leading metropolitan areas. Many of these regions, however, increased expenditures from very low levels (see Figure 7). In 1999, the most dynamic region, the Região Autonoma dos Acores spent only € 61.3 m in PPS 2000, compared to € 12,607 m in PPS 2000 of the leading region Île de France. On the other hand – considering the absolute values – a few of the least dynamic regions, like Groningen, Flevoland or Bremen spent more on R&D in 1999 than the most dynamic regions. With a view to the most recent time period, from 2000 to 2003 it can be observed that both the group of the "most dynamic" and the group of the "least dynamic" is now largely constituted by different regions. Additionally, the positive growth rates are less distinct compared to the period 1995-1999. Obviously, no clear picture can be drawn from the analysis of the growth rates, except for the fact that quite a few southern European regions (in Portugal and Greece) as well as eastern European regions (in Hungary, Estonia, Czech Republic) are obviously catching up in development – or quite possibly are also still recovering from the deep restructuring of the research sector they had to face during transition.

Figure 5: Gross domestic expenditure on R&D (GERD) average annual real growth rates, 1995-1999



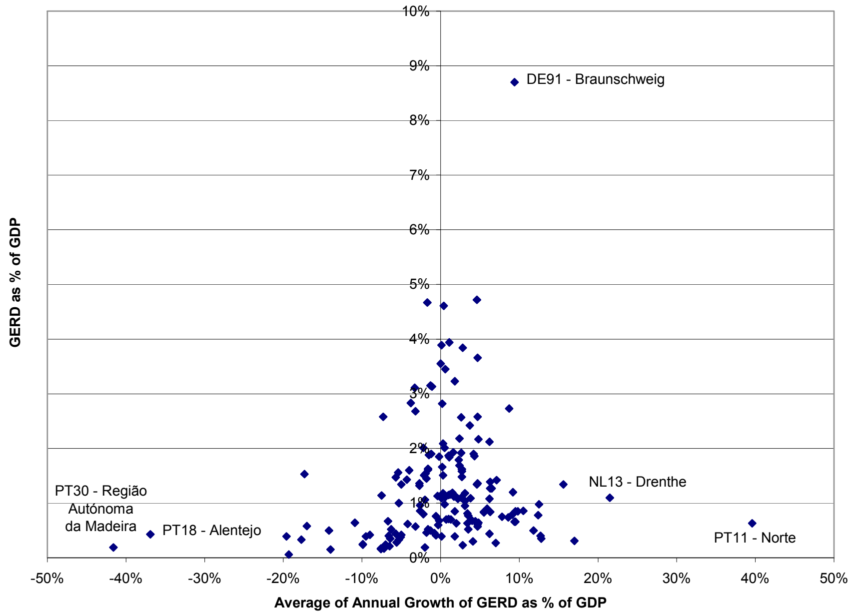
Notes: NUTS 2 data do not include BE, BG, CZ, DE41-42, DEC0-DED3, EE, IE, ES63-64, FR91-94, ITD1-2, CY00, LU, HU, MT, NL12-13, AT, PL, PT16-18, RO, SK, FI18-1A, SE, UK; NUTS 0 data used for BE, BG, IE; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 130 regions included

Figure 6: Gross domestic expenditure on R&D (GERD) average annual real growth rates, 2000-2003



Notes: NUTS 2 data do not include BE, BG, DE22-23, DE27, IE, GR, ES63-64, FR91-94, ITD1-2, MT, AT, RO, SE, UK; NUTS0 data used for BE, BG, IE, RO; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 167 regions included

Figure 7: R&D intensity, 2003 vs. average annual growth, 2000-2003



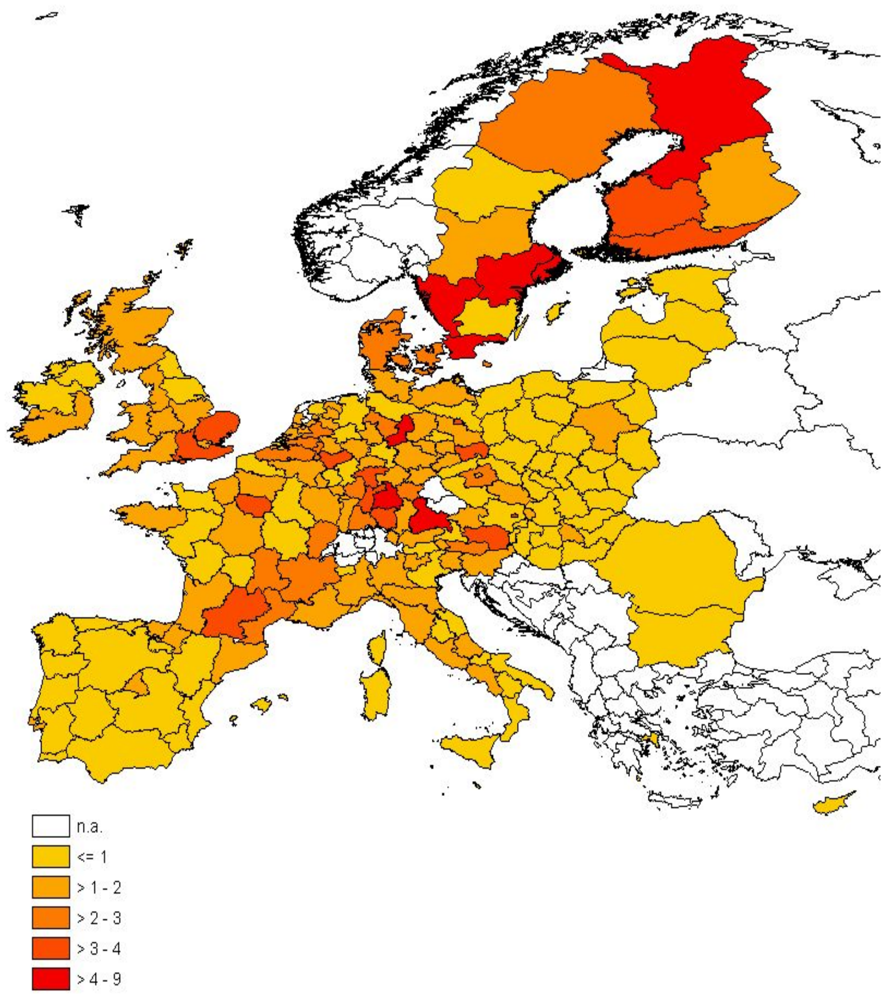
Notes: NUTS 2 data do not include BE, BG, DE22-23, DE27, IE, GR, ES63-64, FR91-94, ITD1-2, MT, AT, RO, SE, UK; NUTS 0 data used for BE, BG, IE, RO; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 166 regions included

In 2003, overall R&D intensity in the EU 27 was 1.87% (Figure 4), only a slight increase since 2000 (1.85%) as the average annual growth of R&D intensity in the period 2000-2003 was a mere 0.2%. As regards the European regions, one may distinguish between those with an average annual growth in the period 2000-2003 and those with a decline. While the R&D intensity of most of the regions (for which data are available) grew or shrank up to 10% in the period 2000-2003, there are some regions in which R&D intensity grew by a remarkable annual average in the range of 10-20% (like Nyugat-Dunántúl in Hungary and Comunidad Foral de Navarra in Spain). This figure clearly suggests that high growth rates of R&D intensities (both positive and negative) do in fact occur much more often in regions where R&D intensities are low than they do in regions where R&D intensities are already high.

A stable development of its R&D intensity at a quite high level can be observed in Oberbayern and Stuttgart. The most remarkable performances in terms of a significant growth from an already quite high level can be identified in Braunschweig (DE91) and Pohjois-Suomi (FI1A).

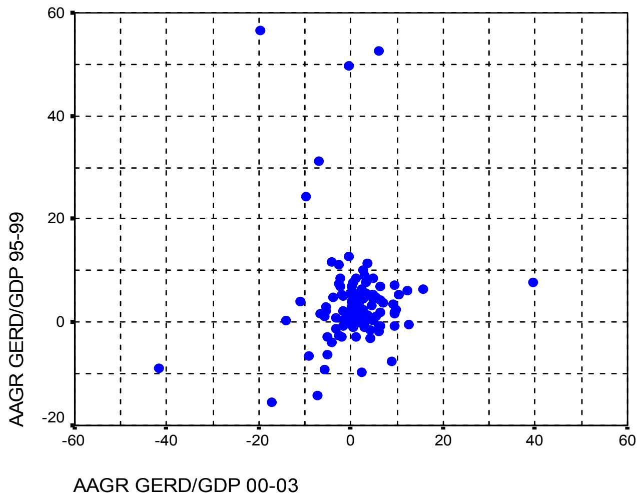
Figure 9 illustrates the performance of the regions using the same indicator and comparing the two periods 1995-1999 and 2000-2003. Again, the bulk of the regions record an average annual growth of the R&D intensity between 0 and 10% in both time periods. While this is not remarkable as such, Figure 9 thus illustrates that there is only a small number of noteworthy outliers for each time period, which can be identified by the looking at the respective top-10 regions in Figure 5 and Figure 6. This underlines that the scope of the two figures is sufficient to highlight those regions where a substantial change in R&D intensity, from whatever level, has taken place.

Figure 8: R&D intensity (GERD as % of GDP), 2003



Note: NUTS 2 data do not include BE, BG, RO, UK and GR other than Athens; NUTS 1 data used for BE and UK; NUTS 0 data used for BG, RO; UK data for 1999 (last available).
Source: Regional Key Figures database, own compilation; 196 regions included

Figure 9: Average annual growth of GERD as % of GDP 1995-1999 vs. 2000-2003 R&D intensity (GERD as % of GDP)

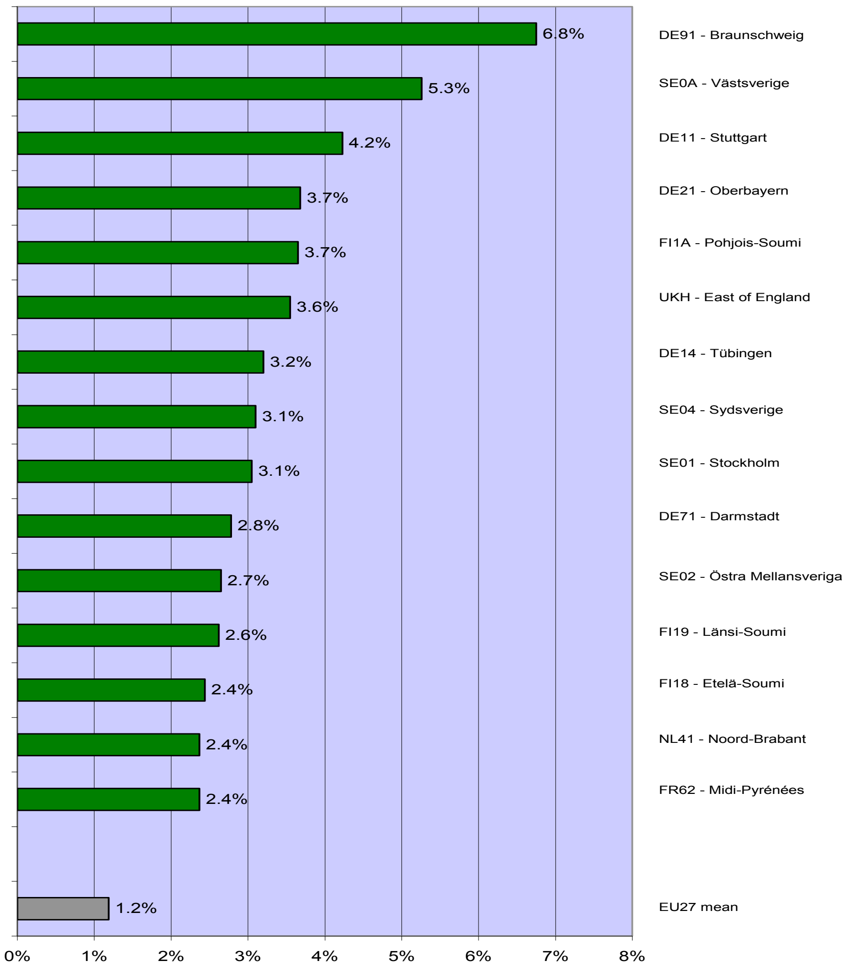


Note: Data missing for: BE; BG; CZ; DE 22-23, 27, 41-42, C0-D3; EE; GR; ES 63-64; FR 91-94; ITD1-ITD2; CY; LU; HU; MT; NL13; AT; PL 33-43, 42-63; PT 16-18; RO; SK 01-04; FI18-1A; SE; UK. Coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 111 regions included

III.2 Private sector expenditures on R&D

The level and intensity of expenditure on R&D in the business sector are key determinants of the future competitiveness of an economy. Business R&D expenditures are in most cases intricately connected to R&D activities regarding the development of new products, processes or technologies, in the manufacturing as well as the service sector. These research activities with a close connection to applied development are very relevant for overall socio-economic development and therefore of particular interest for policy-makers at all levels. Private sector investment R&D indicators mirroring trends in the performance of business sector R&D are therefore a constitutive element of any analysis concerning R&D trends and structures.

Figure 10: European regions with highest business R&D intensity (BERD as % of GDP), 2003



Note: data missing for BG and RO; data partially missing for BE, PL and FR; BE: data at NUTS1 level; UK: data at NUTS 1 level for 1999; GR: data for 1999; data for the 10 regions with lowest values not included as they are 0.0%
Source: Regional Key Figures database, own compilation; 206 regions included

Figure 10 shows the European regions with the highest business R&D intensity (BERD as % of GDP). It is noteworthy that the regions with the highest business sector R&D intensity are almost the same as the regions with the highest overall R&D intensity.

Braunschweig and Västsverige are the top performers with business R&D expenditures of 6.75% and 5.26%. The other leading regions (e.g. Stuttgart, Oberbayern) are likewise among the regions with the highest overall R&D intensity, indicating that in these cases the business sector clearly dominates the regional R&D activities. For the five leading regions the share of business expenditure on R&D in gross expenditure on R&D ranges between 77.3% and 90.6%.

Table 2: Business enterprise expenditure on R&D (BERD) of top performing regions, 1995-2003

	2003			1995		
	Rank	€ m (PPS2000)	% of EU27	Rank	€ m (PPS2000)	% of EU27
FR10 Île de France	1	8,533.4	7.5	1	8,256.8	9.2
DE21 Oberbayern	2	5,082.6	4.5	2	4,158.9	4.6
DE11 Stuttgart	3	4,700.4	4.1	3	3,737.7	4.2
UKJ - South East	4	4,360.3	3.8	4	3,455.5	3.0
UKH - Eastern	5	4,346.5	3.8	5	3,133.4	2.7
DE71 Darmstadt	6	3,241.2	2.8	6	2,294.0	2.5
DK00 Danmark	7	2,417.8	2.1	13	1,213.0	1.4
DE91 Braunschweig	8	2,413.3	2.1	22	873.0	1.0
FR71 Rhône-Alpes	9	2,310.0	2.0	10	1,646.0	1.8
SE0A Västsverige	10	2,246.1	2.0		no data	
BE2 Vlaams Gewest	11	2,195.5	1.9	11	1,510.3	1.7
ITC4 Lombardia	12	2,093.9	1.8	7	2,087.6	2.3
EU27 European Union		114,039.1	100		90,146.7	100

Note: BG, RO, IE covered at NUTS 0 level; BE, UK covered at NUTS 1 level; FR10 is identical to NUTS 1 FR1; DK00 is identical to NUTS 0 DK.

Source: Regional Key Figures database, own compilation; 206 regions included

Measured in absolute values for 2003, the five regions with the highest business expenditure on R&D (BERD, see Table 1) are the same than those with the highest overall R&D expenditure (GERD, see Table 2). The top performer in 2003 was Île de France where € 8.5 bn (PPS2000) were spent on business R&D. This equals approximately 68% of the total regional R&D expenditure (GERD). In Oberbayern, the share of business expenditure in the overall R&D expenditure amounts to 79%, in the Stuttgart region to 90% and in the Darmstadt region to 86%.

Multinational corporations – regional centres of control for ERA-wide business R&D expenditure

In most of the top performing regions, a significant contribution to the total regional R&D expenditure in the business sector comes from large multinational companies. The increase of BERD between 1995 and 2003 can thus partially be attributed to an increase in R&D expenditure by the top private R&D investors. Furthermore, MNCs in strong regions very often even constitute a nexus of control over business R&D expenditure that reaches far beyond the activities performed in the region where their headquarters are located.

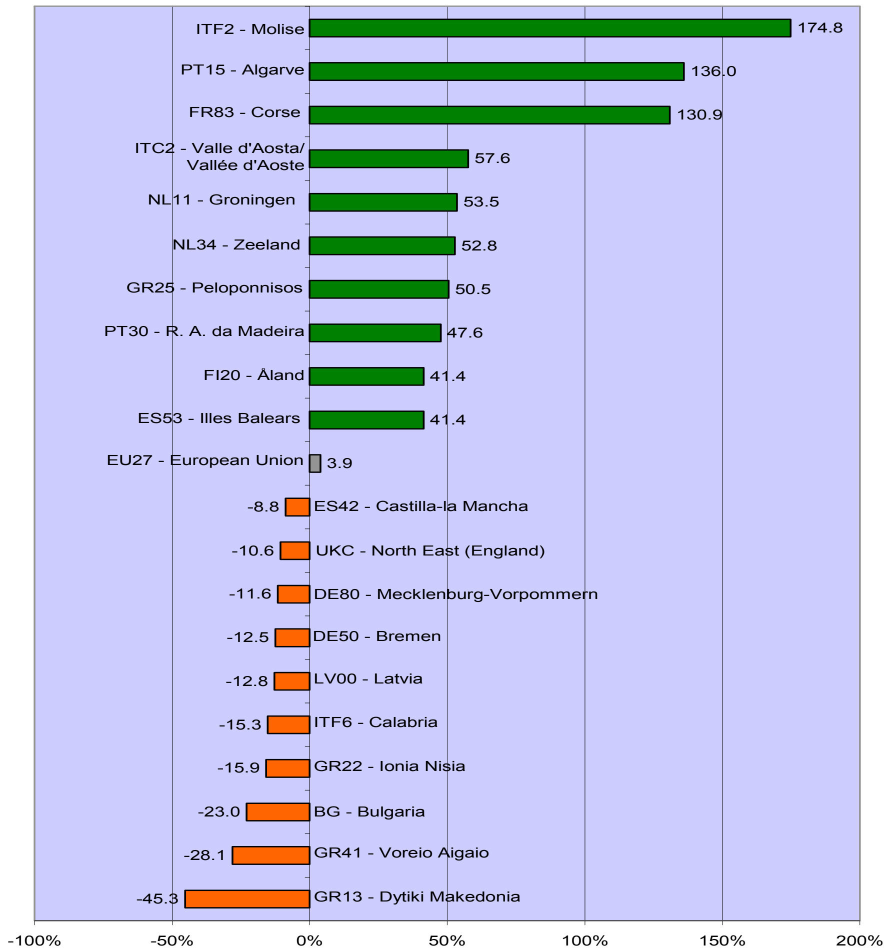
The combined R&D expenditure of Sanofi and Aventis, for example, amounted to € 4.240 bn[6] in 2003, equivalent to 50% of BERD spent in the region of Île de France. Even more starkly, the headquarters of Siemens in Munich alone had control over € 5.511 bn R&D spending in 2003 – a figure that exceeds regional BERD by 10%. Similarly, the 2003 R&D expenditure of the (then) DaimlerChrysler concern was 1.2 times higher than overall BERD spent in the Stuttgart region (€ 5.571 bn) where the headquarters of DaimlerChrysler are located. This finding illustrates that the importance of several regions in the ERA cannot be defined by their regional GERD or BERD alone. Instead, based on regionally located centres of control, several regional research systems appear to have a hub function or, in other words, excess importance so that their impact stretches far beyond their own administrative boundaries.

6 See European Commission (DG JRC, DG Research): Monitoring Industrial Research: The 2004 EU industrial R&D Investment Scoreboard.

For capital regions like Île de France or Stockholm, non-private R&D expenditures are often slightly higher compared to other regions due to the location of various public or non-profit research institutes. As important as the absolute values of R&D expenditures are the shares of the respective regions' BERD on total BERD of the EU 27: five among 13 regions for which data are available for 1995 and 2003 show a decrease of their share in EU 27 total BERD, indicating that their relative importance declined between 1995 and 2003. Quite remarkable in this respect is the significant decrease of Île de France from 9.16% in 1995 to 7.5% in 2003.

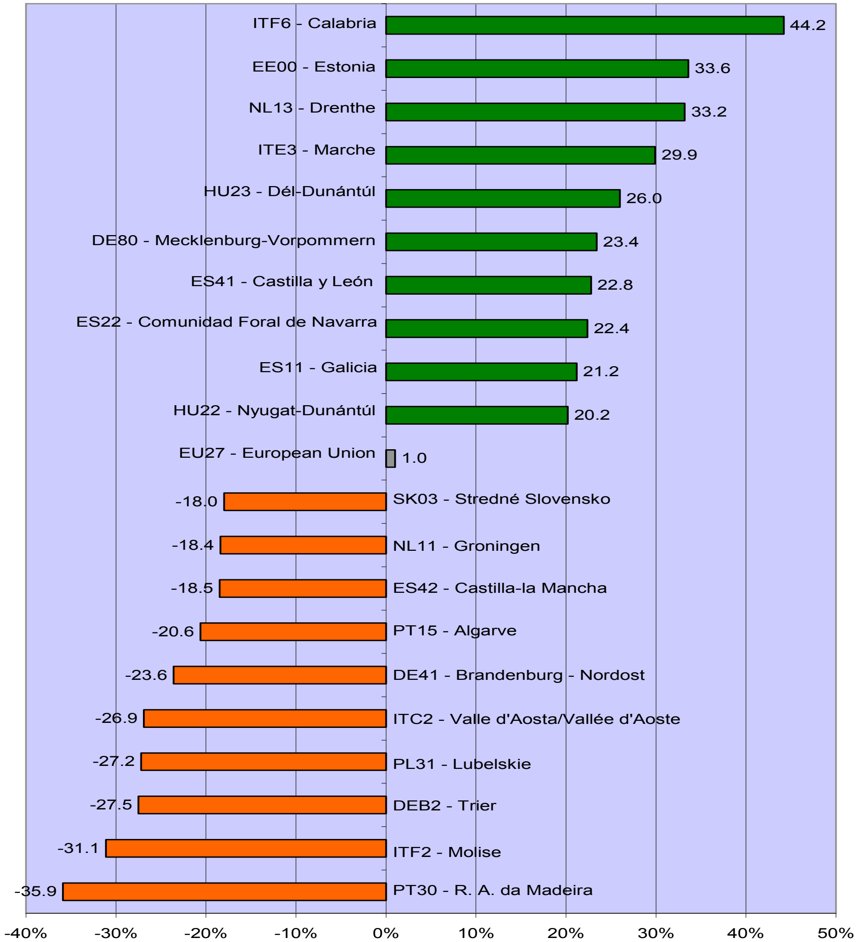
Concerning the average annual growth of business expenditure on R&D, the two different time periods 1995-1999 and 2000-2003 show quite different dynamics. For instance, a few regions (like Algarve and Valle d'Aosta) dropped from the group of regions with the highest average annual growth rates to the group with the lowest respective rates. The opposite is true for other regions like Calabria or Mecklenburg-Vorpommern. As in the case of GERD growth, however, the analysis of BERD growth has to take into account the absolute level of expenditure, which reveals that the seemingly dynamic development of many regions in both time periods is in fact just volatility on a very low absolute level.

Figure 11: Business expenditure on R&D (BERD) average annual real growth rates, 1995-1999



Notes: NUTS2 data do not include BE21-35, BG, CZ, DE41-42, DEC0-DED3, EE, IE, ES63-64, FR91-94, ITD1-2, CY, LU, HU, NL13, AT, PL, PT16-18, RO, SK, FI18-FI1A; NUTS1 data used for BE, IE, UK; NUTS0 data used for BG, RO; Coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 143 regions included

Figure 12: Business enterprise expenditure on R&D (BERD) average annual real growth rates, 2000-2003

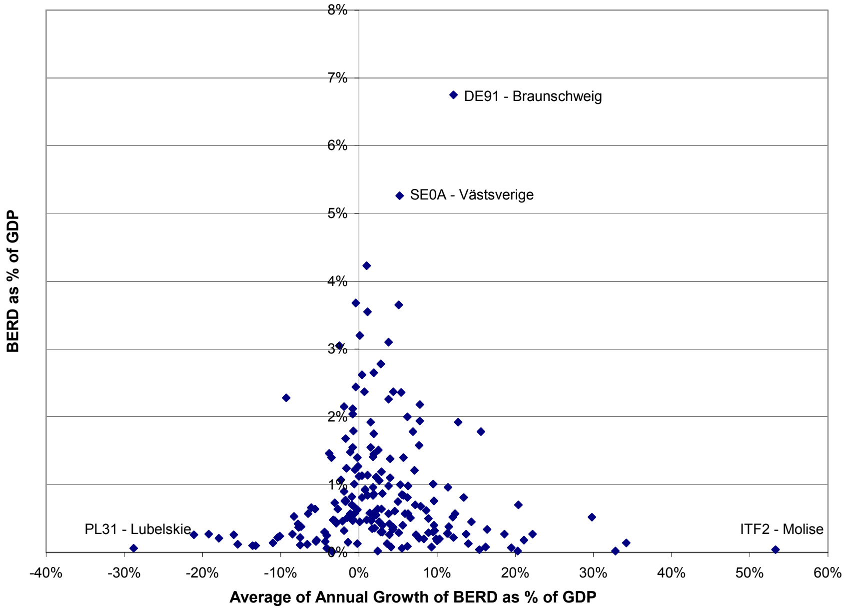


Notes: NUTS 2 data do not include BE21-35, BG, GR, ES63-64, FR83-94, ITD1-2, MT, AT, PL33-34, PL42-62, PT20, RO; NUTS 1 data used for BE, IE, UK; NUTS 0 data used for BG, RO; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 174 regions included

The region of Calabria, for instance, increased its BERD from only € 1.6 m PPS2000 in 2000 to € 4.8 m PPS2000 in 2003. Similarly, some regions like Drenthe, Estonia, Mecklenburg-Vorpommern and Marche realised high relative, but low absolute increases in business R&D expenditures between 2000 and 2003; e.g. Drenthe from € 55.6 m PPS2000 (2001) to € 98.7 m PPS2000; Mecklenburg-Vorpommern from € 37.6 m PPS2000 (2001) to € 70.6 m PPS2000. Unlike the top performing R&D regions in Europe, no major R&D investing company as listed in the 2006 EU industrial R&D investment scoreboard is headquartered in these regions. Nonetheless, at this low level of overall expenditure, these changes could still be attributable to distinct projects in single companies.

Figure 13 plots the high variance of business R&D intensity among the European regions (BERD as % of GDP) in 2003 against the average annual growth rate of BERD in the period 1995-2003. Like the other graphs, this figure has to be interpreted carefully, as average annual growth rates of relative values do not evidence the absolute level from which potential growth has been generated. Most of the regions showed an average annual growth up to 10% in the period 1995-2003. Looking at the outliers, it must be noted that the regions showing a relatively high business R&D intensity in 2003 (like Braunschweig, Västsverige, Stuttgart, Tübingen, Oberbayern, Stockholm, Pohjois-Suoimi), are at the same time regions, which are among the top regions in terms of absolute BERD (almost over the whole time period 1995-2003). As pointed out in the case of overall R&D expenditure, this figure underlines the well-known fact that high growth rates of business sector R&D intensities do in fact occur much more often in regions where intensities are low than in regions where intensities are already high.

Figure 13: BERD as % of GDP in 2003 compared to average annual growth rate of BERD, 1995-2003



Notes: NUTS 2 data do not include BE21-35, BG, GR11-25, GR41-43, ES63-64, FR83-94, ITD1-2, MT, PL33-34, PL42-62, RO, UK; NUTS 1 data used for BE, IE, UK; NUTS 0 data used for RO, BG; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 194 regions included

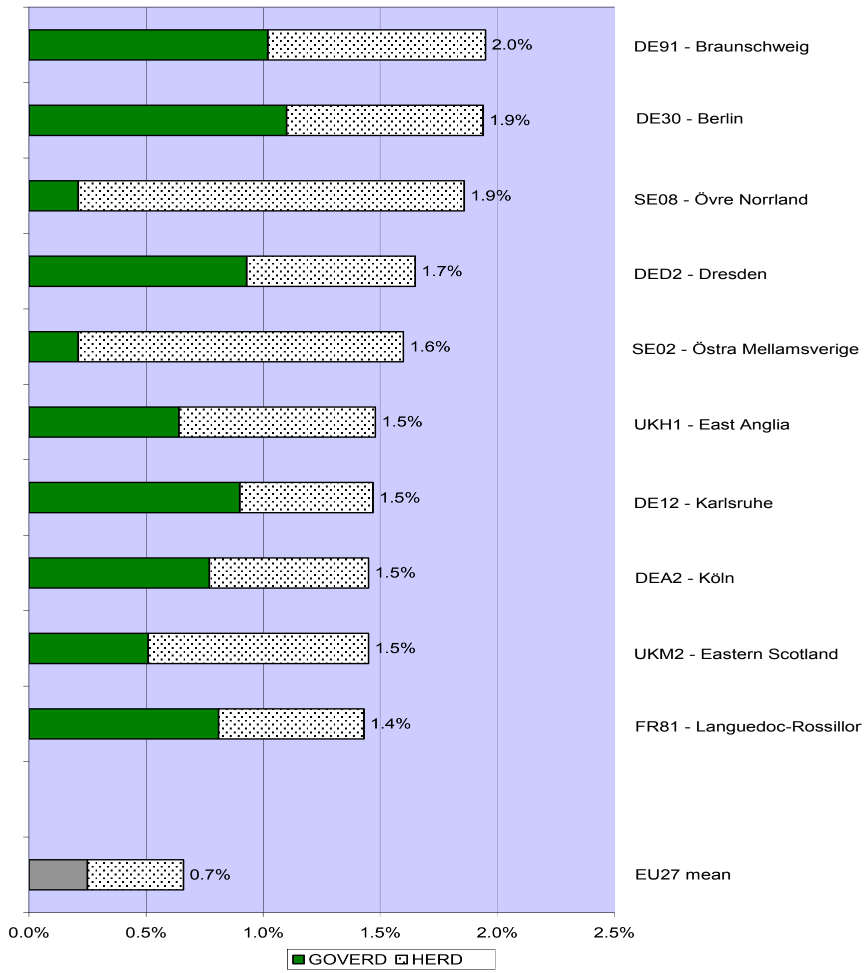
III.3 Public sector expenditures on R&D

The public sector plays an important role within the process forming national and regional research and innovation systems. The public sector usually acts within the context of financing public research institutes, universities and research-oriented polytechnics, and also regarding the support of private sector R&D (e.g. within the framework of special research and innovation initiatives).

Thus, in many research systems, the public sector is a key actor in combination with the private sector. Therefore, many policy initiatives focus on strengthening public research institutes and also on improving technology and knowledge transfer to the private sector (incl. public-private partnerships, start-up initiatives, entrepreneurship education). Depending on the different political and historic development of economic, technological and institutional structures in the respective countries and regions, research and innovation systems can either be public-sector-dominated or business-led, the latter referring to a dominance of business sector R&D expenditures. In any case, the level of public sector R&D expenditures (GOVERD and HERD) gives evidence of the significance of public research institutes, universities, polytechnics, etc. Regarding the spatial level, it has to be noted that in many peripheral NUTS-2 regions, only a few public research institutes are located, often one university only. These are the regions where the public sector expenditure on R&D is pretty much identical with the R&D budget of the respective university (assuming, oftentimes plausibly, that third-party funding does not play a significant role).

Figure 14 shows the public sector expenditures on R&D as % of GDP for the European regions with the highest research intensity. Due to the federal and urban structure, as well as the dense network of public research institutes (see for instance the Fraunhofer and Max Planck Societies with institutes located all over the country), many German regions are among the top 10 European regions. Braunschweig, for example, a region with quite high business R&D expenditures also has the highest public R&D intensity among European regions. Nevertheless, its absolute expenditure (€ 697.5 m PPS2000 in 2003) remains far below that of Île de France, the region with the highest absolute public sector expenditure on R&D (€ 3.816 bn PPS2000 in 2003).

Figure 14: Public sector expenditure on R&D (GOVERD and HERD) as % of GDP, 2003



Note: data missing for BG and RO; data partially missing for DE, ES, PL, NL, FR; UK HERD data for 2001; data for the ten regions with lowest values not included as they are below 0.1%
Source: Regional Key Figures database, own compilation; 190 regions included

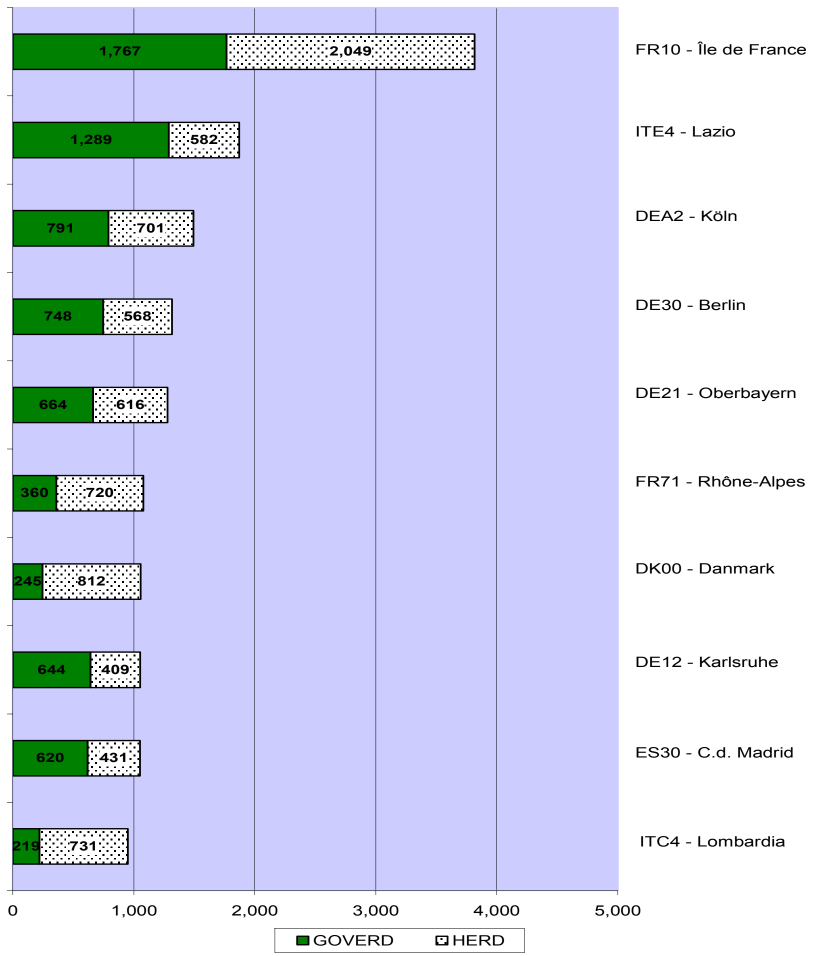
With the exception of the two Swedish regions, where due to the particularities of the Swedish innovation system most of the public sector expenditure on R&D is spent in the higher education sector, all other leading regions show a fairly equal distribution of R&D intensity (i.e. expenditure) between the higher education sector and the remaining public sector.

Remarkably, many European regions spend more than 40% of their total R&D expenditure on R&D activities in the higher education sector. In some of those the share reaches 80% and above (e.g. Calabria, Podlaskie, Ciudad Autónoma de Ceuta, Algarve), pointing to the fact that in those regional systems higher education institutes are the only relevant performers of research (cf. Figure 17).

However, it can be observed that the R&D intensity in the group of regions spending more than 60% of total R&D expenditures for higher education research and development is often below the European average (cf. Figure 16). In contrast, regions with above average total R&D intensities like Braunschweig, Västsverige, Stuttgart, Oberbayern, Stockholm, Sydsverige, Östra Mellansverige and Pohjois-Suomi are often characterised by relatively small higher education R&D intensities (compared to other regions).

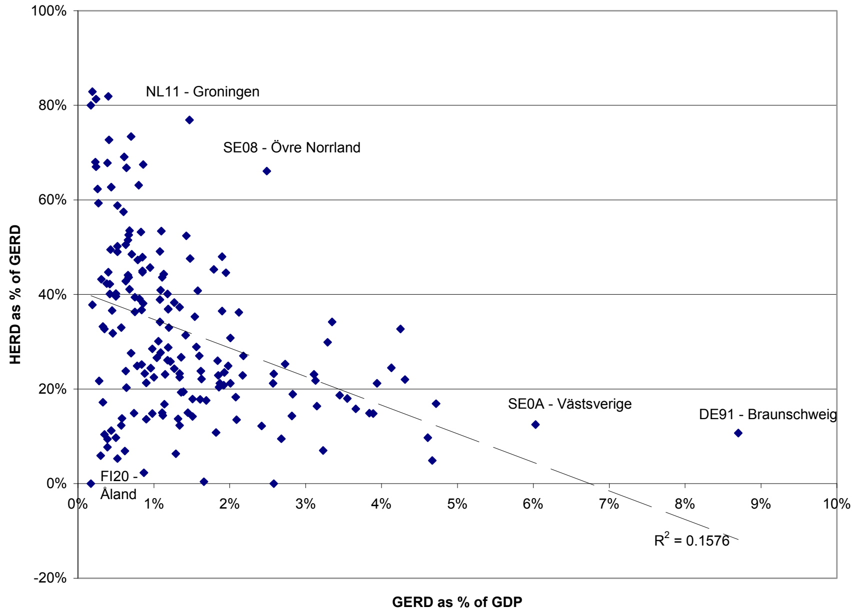
Implicitly, this confirms the findings of III.2 that the main carrier of R&D in the strongest regions of the ERA is without exception the business sector. In a market economy context this is not surprising and does not call the relevance of the contribution of the public research sector (research institutes & research at institutes of higher education) into question. However, it does highlight the important fact that there are quite a number of regional research systems within the ERA in which government-driven R&D activities are not *locally* matched with an equal extent of business R&D activities. It suggests potential benefit of inter-regional integration for these regions.

Figure 15: Public sector expenditure on R&D (GOVERD as well as HERD) in million PPS2000, 2003



Note: data missing for UK; data partially missing for DE, ES, FR, PL; NL: data partially for 2002; SE: data for 1999
Source: Regional Key Figures database, own compilation; 190 regions included

Figure 16: Higher education expenditure on R&D (HERD) as % of GERD compared to R&D intensity (GERD as % of GDP), 2003

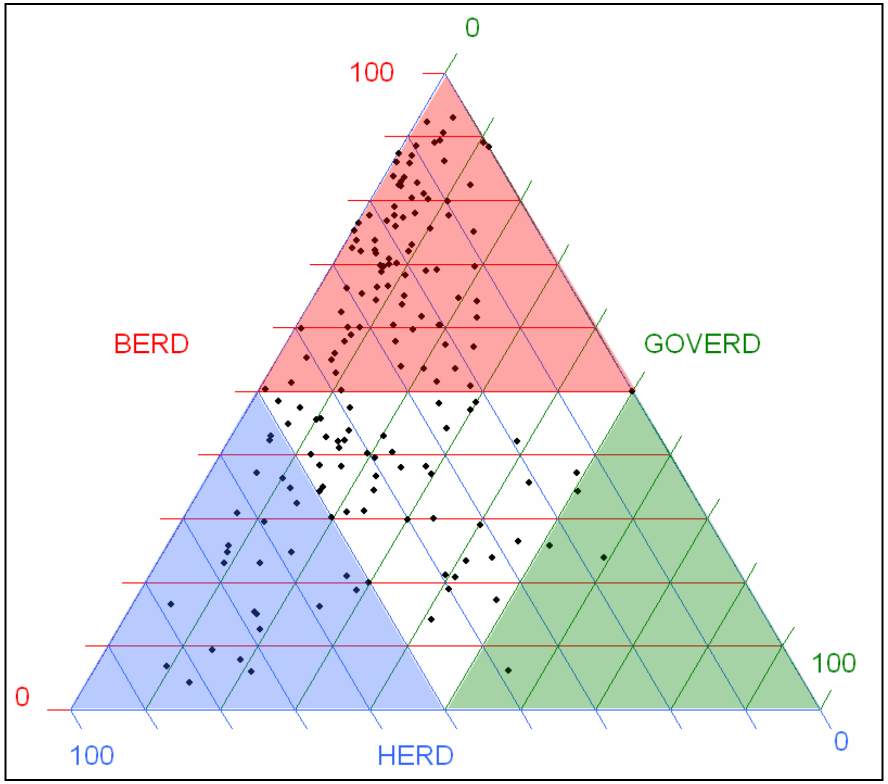


Notes: NUTS 2 data do not include BE21-35, BG, DE22-23, GR11-25, GR41-43, ES64, FR91-94, NL12-13, NL23, NL34, AT11, AT21, AT32, AT34, PL32-33, PL42-62, RO, UK; NUTS 1 data used for BE; NUTS0 data used for RO, BG
Source: Regional Key Figures database, own compilation; 177 regions included

The relation between business, higher education and government sector R&D expenditure for all European NUTS 2 regions is presented in Figure 17. It can be observed that the number of regions merely dominated by either higher education or government sector research is quite small compared to those dominated by the business sector, an observation that changes slightly when both groups related to public expenditure are added up.

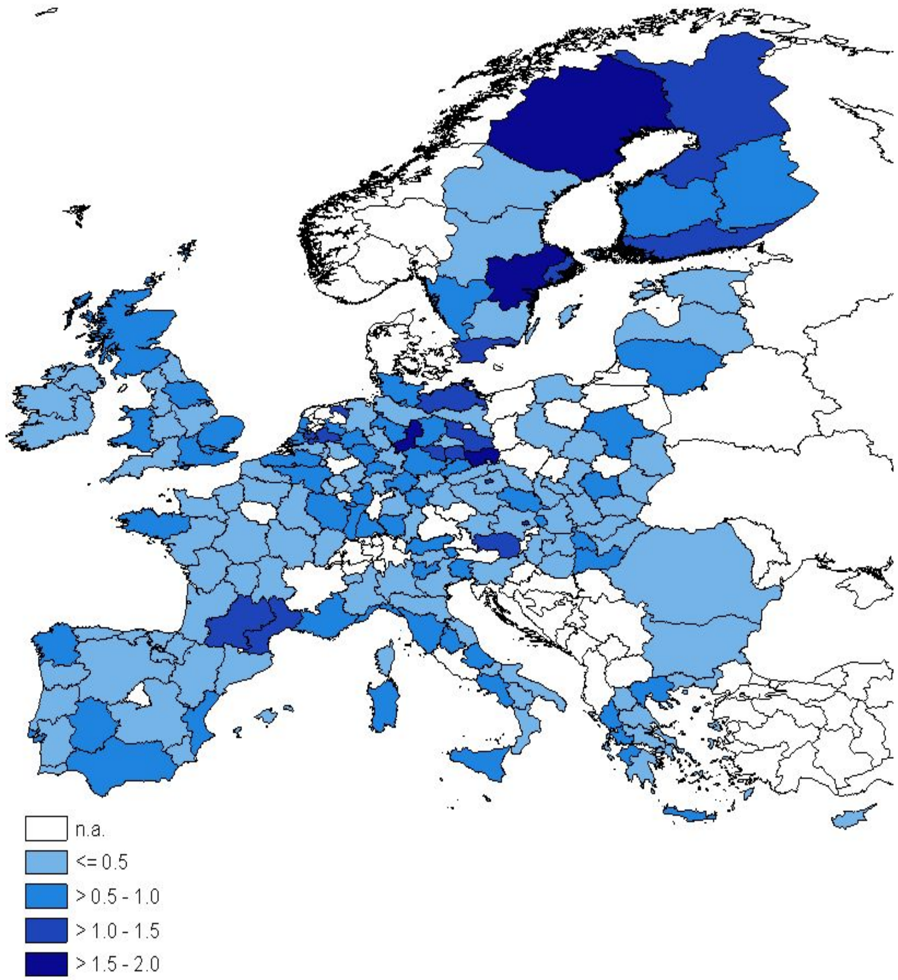
In general, the figure demonstrates that there are quite a number of broadly based innovation systems which are neither completely business-led nor completely public-sector-dominated.

Figure 17: Shares in BERD, GOVERD and HERD in total R&D expenditure, 2003



Notes: NUTS 2 data do not include BE21-35, BG, DE22-23, GR11-25, GR41-43, ES64, FR83-94, NL12-13, NL22-23, NL32, NL34, AT11, AT21, AT32, AT34, PL32-33, PL42-62, RO, UK; NUTS 1 data used for BE; NUTS 0 data used for RO, BG
Source: Regional Key Figures database, own compilation; 173 regions included

Figure 18: Public research intensity (HERD & GOVERD as % of GDP), 2003



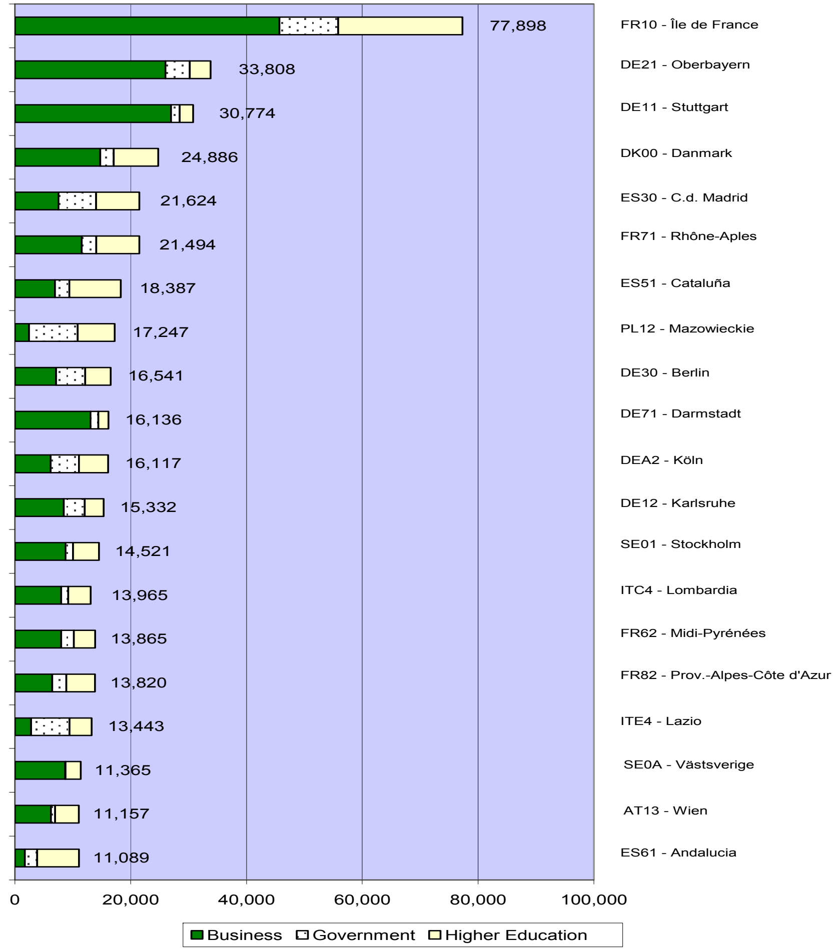
Note: NUTS 2 data do not include BE, BG, DK, RO, UK; NUTS 1 data used for BE, UK; NUTS 0 data used for BG, RO
Source: Regional Key Figures database, own compilation; 194 regions included

III.4 R&D personnel (researchers)

The supply of human resources in science and technology is among the most important factors that determine the competitiveness of countries and regions. Depending on the concrete industry or technology sector, R&D expenditure is often contingent on labour costs, limiting its validity. The indicators "R&D personnel" and "Researchers" thus complement the core indicator "R&D expenditure". Nonetheless, most of the top performing regions in terms of total R&D expenditure are also among the leading regions as regards researchers. In line with R&D expenditure, the region of Île de France has by far the largest number of researchers, nearly twice as many as Oberbayern, the region ranking second. In total, approx. 132,000 persons are engaged in R&D activities in the region of Île de France.

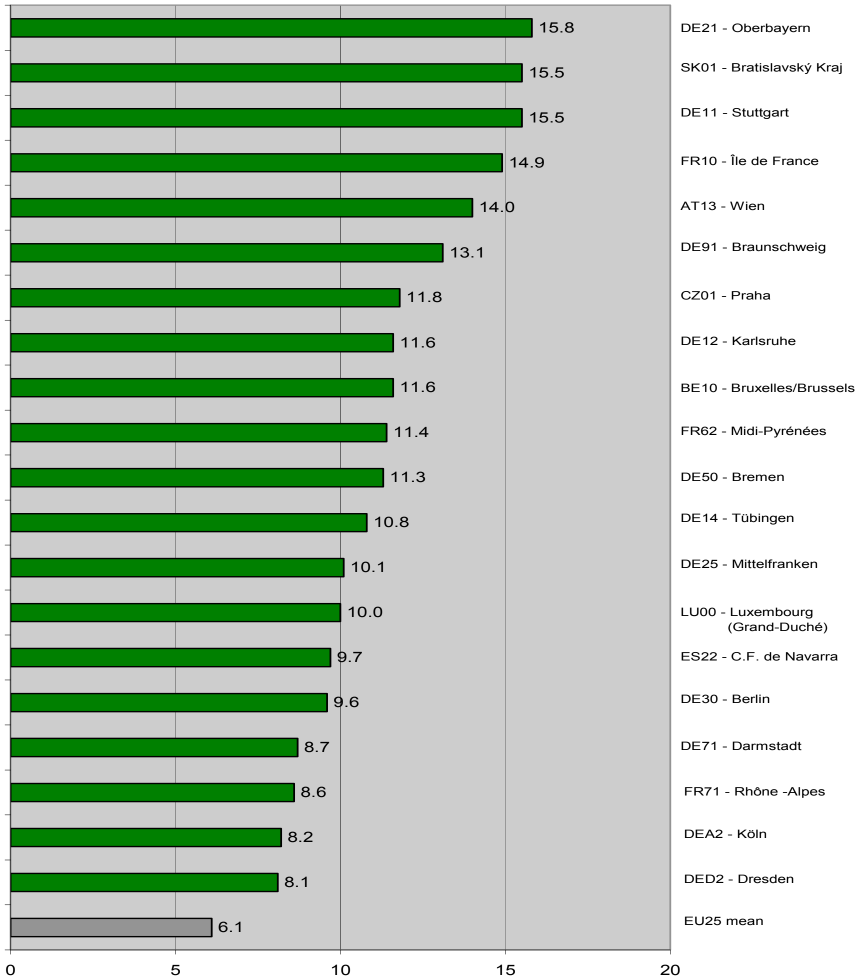
The number of researchers per 1,000 of the labour force in the top 20 regions ranges between 8 and 16 (FTE). As can be seen in figure 20, the highest relative numbers of researchers are found in the regions of Oberbayern, Bratislavsky, Stuttgart and Île de France. With the exception of Bratislavsky, this corroborates the above mentioned finding that these are clearly the most research-intensive regions in Europe. With the exception of Paris (for Île de France) and Munich (for Oberbayern), most of the largest cities in these leading regions are comparatively small: Bratislavsky, Braunschweig, Karlsruhe, Bremen and Tübingen for instance, are far from being large metropolitan regions.

Figure 19: Researchers (FTE) in the business, higher education and government sectors, 2003



Notes: 2003 data do not include AT11, AT21, AT32, AT34, BE, BG, DE22-23, FI, FR83-94, GR11-25, GR41-43, NL12-13, NL22-23, NL32, NL34, PL32-34, PL42-42, RO, UK; 2001 data used for Higher Education Researchers in SE
Source: Regional Key Figures database, own compilation; 164 regions included

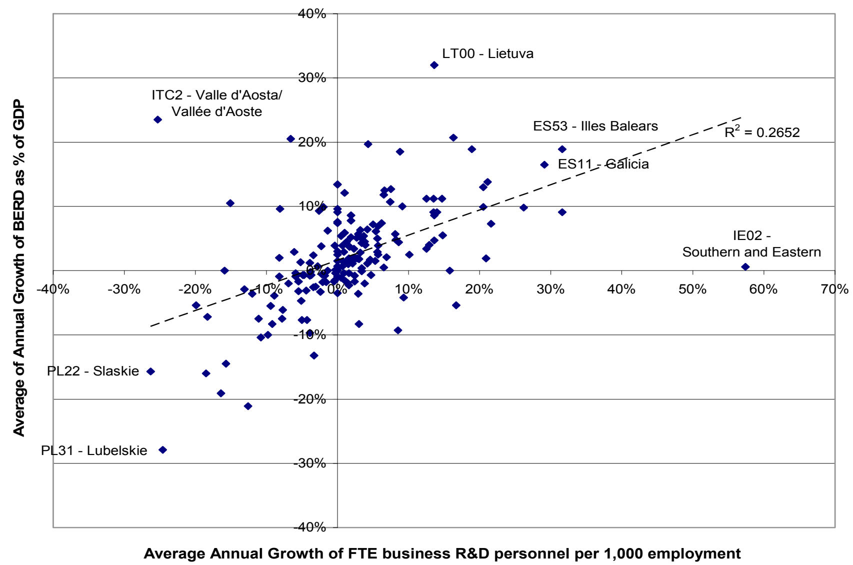
Figure 20: Researchers (in FTE) per 1,000 labour force, 2003



Note: EU 27 average not available; NUTS 2 data do not include BE, BG, DK, DE22-23, DE41-42, DEE1-3, GR11-25, GR41-43, ES64, RO, FI, SE, UK; NUTS 1 data used for BE, IE; data for the 10 regions with lowest values not included as they are below 2 per 1000; abbreviation 'BE1 - Bruxelles/Brussels' used for 'BE1 - Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest'.
Source: Regional Key Figures database, own compilation; 178 regions included

Figure 21 shows that an average annual growth of business R&D intensity (BERD as % of GDP) is not necessarily correlated with an increase in FTE R&D employment. Many regions show a quite remarkable growth of R&D intensity and at the same time a negative growth of FTE R&D personnel. Often, this can be attributed to the following reasons: (1) structural change: rising labour costs result in the reduction of R&D personnel and/or in growing expenditures for R&D personnel, (2) above average capital investment increases BERD, yet leaves employment unaffected, (3) the growth of total employment was more dynamic than the growth of R&D personnel.

Figure 21: Average annual growth of business R&D intensity compared with business R&D personnel per 1,000 employees, 1995-2003



Note: NUTS 2 data do not include BE, BG, DE41-42, GR, ES63-64, FR83-94, ITD1-2, ITF1, ITF6, MT, AT, PL33-34, PL42-62, PT15, RO, UK; NUTS 1 data used for BE, IE, UK; NUTS0 data used for RO, BG; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation; 178 regions included

III.5 Technological and scientific output

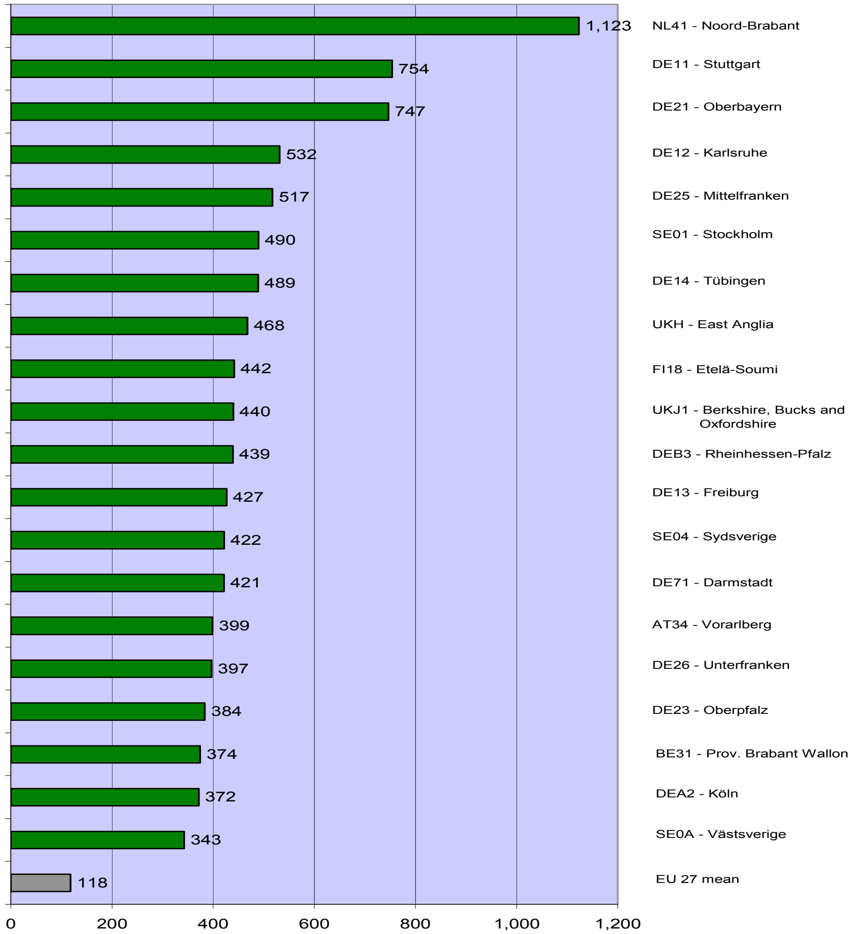
Technological and scientific output indicators are essential to assess the present and future competitiveness of a country or region and its ability to transform R&D-related results into innovative products, processes or services. In this field, technological output (primarily of the business sector) is commonly measured by the number of patents or patent intensity, whereas scientific output (primarily of research institutes and universities) is typically measured by the number of publications or publication intensity.

Regarding the European regions with the highest *patent intensities* (as presented in Figure 22), a certain similarity with the regions ranking high in R&D-intensity can be observed. For instance, the presence of Stuttgart, Oberbayern, Stockholm and Tübingen suggests a connection between the intensity of R&D investment and patent intensity.[7] Additionally, there are some regions with a particular strength in patenting, such as Noord-Brabant, Karlsruhe and Mittelfranken. In terms of *patent productivity* the best performing regions in 2001 were Lüneburg (1.564 patents per € m R&D investment), Noord-Brabant (1.334) and Koblenz (1.331).

The technological output of some regions is extremely high compared to their R&D expenditures (is should be noted, however, that the R&D intensity of these regions is also above EU average; cf. R&D intensity vs. patent intensity presented in Figure 26). With regard to absolute figures, Île de France (3.461 EPO filings in 2001), Oberbayern (3.070), Stuttgart (2.977) and Noord-Brabant (2.677) were the most active patenting regions in Europe.

[7] This does not imply a direct causal relation of any distinct investment in research and any other distinct resulting patent. Instead it refers to the mutual presence of both as an expression of distinct activities within one regional research system.

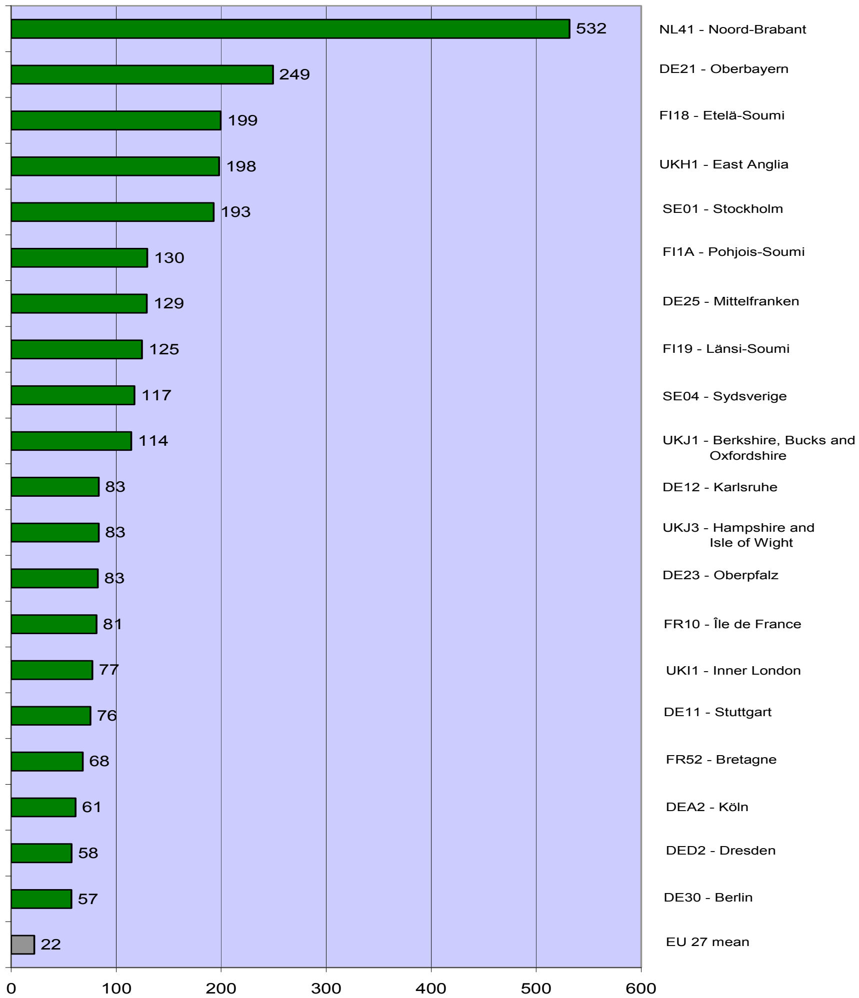
Figure 22: Patents (location by inventor, per million inhabitants), 2001



Note: Since patents which enter the national total of applications via the PCT procedure can take up to 30 months to be accounted for, patent figures have to be considered preliminary for the last two technically available years. Meaningful patent data can therefore only be presented for 2001, even though 2002 and 2003 data are technically available; NUTS 2 data do not include BG, IE, GR13, GR22, GR41, ES63-64, FR93, PT18-30, RO, UKF3, UKM1-4; NUTS0 data used for BG, RO; 1999 data for EU27
Source: Regional Key Figures database, own compilation; 238 regions included

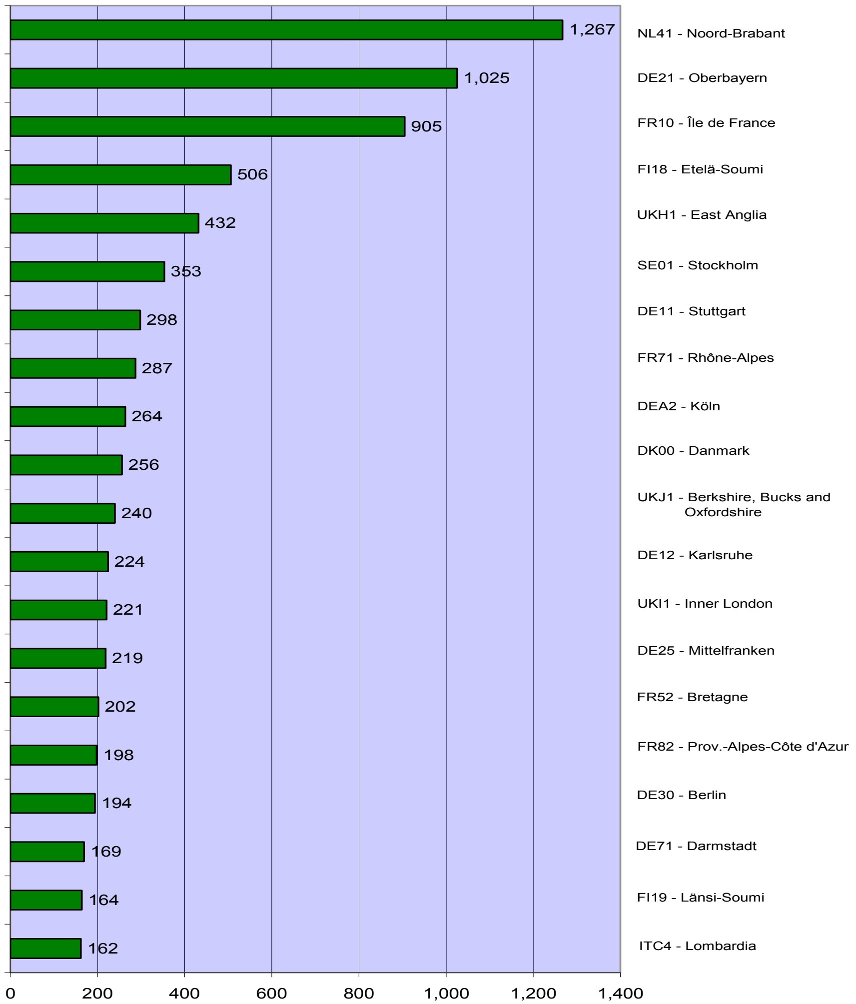
In addition to the total patent filings, high-tech patent activities give evidence of regional specialisation patterns in high-technology industries. Again, Noord-Brabant is by far the top performer among all European regions (1,267 high-tech patents, due to the location of Philips Headquarters). Compared to the EU 27 average (and also compared to the respective national averages), the technological and industry profiles of the regions represented in Figure 24 are clearly high-tech oriented (cf. Figures 23 and 24).

Figure 23: High-tech patent applications (per million inhabitants), 2001



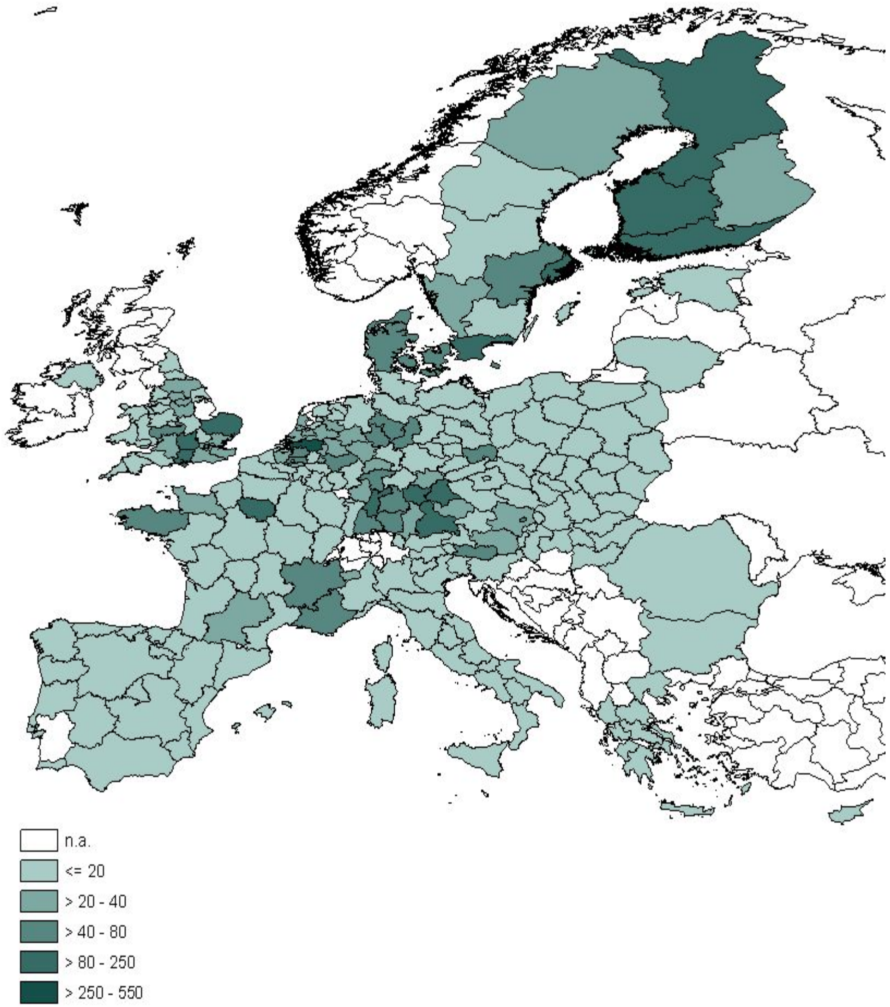
Notes: Regarding topicality of data see Figure 22; NUTS 2 data do not include BG, IE, GR11, GR13, GR22, GR41, ES63-64, FR93, LV, HU23, MT, PT18-30, RO, UKD1, UKF3, UKM1-4; NUTS 0 data used for BG, RO; 1999 data for EU27
Source: Regional Key Figures database, own compilation; 235 regions included

Figure 24: High-tech patent applications total (absolute values), 2001



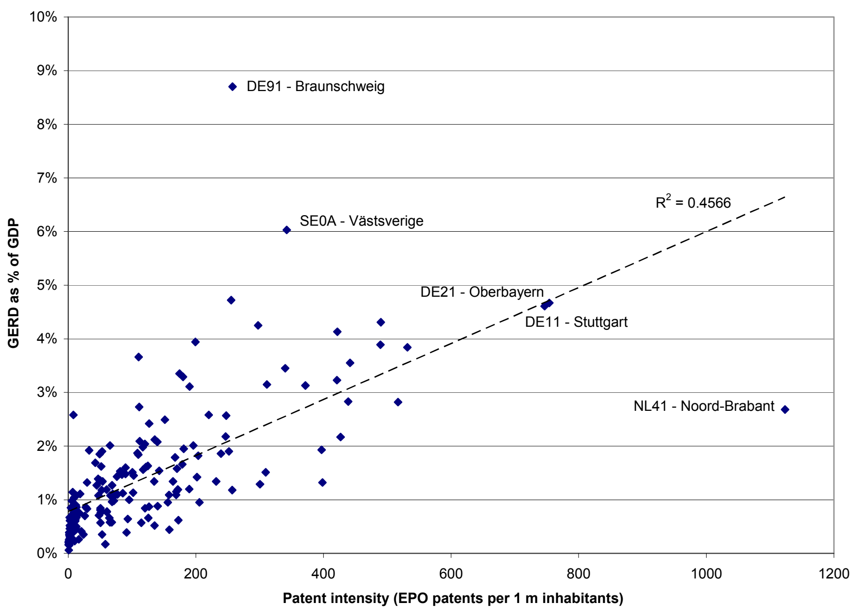
Notes: Regarding topicality of data see Figure 22; NUTS2 data do not include BG, IE, GR11, GR13, GR22, GR41, ES63-64, FR93, LV, HU23, MT, PT18-30, RO, UKD1, UKF3, UKM1-4; NUTS0 data used for BG, RO
Source: Regional Key Figures database, own compilation; 235 regions included

Figure 25: High-tech patent intensity (EPO filings by high technology fields per million inhabitants) 2001



Note: NUTS 2 data do not include BG, IE, RO; NUTS 0 data used for BG, RO.
Source: Regional Key Figures database, own compilation; 235 regions included

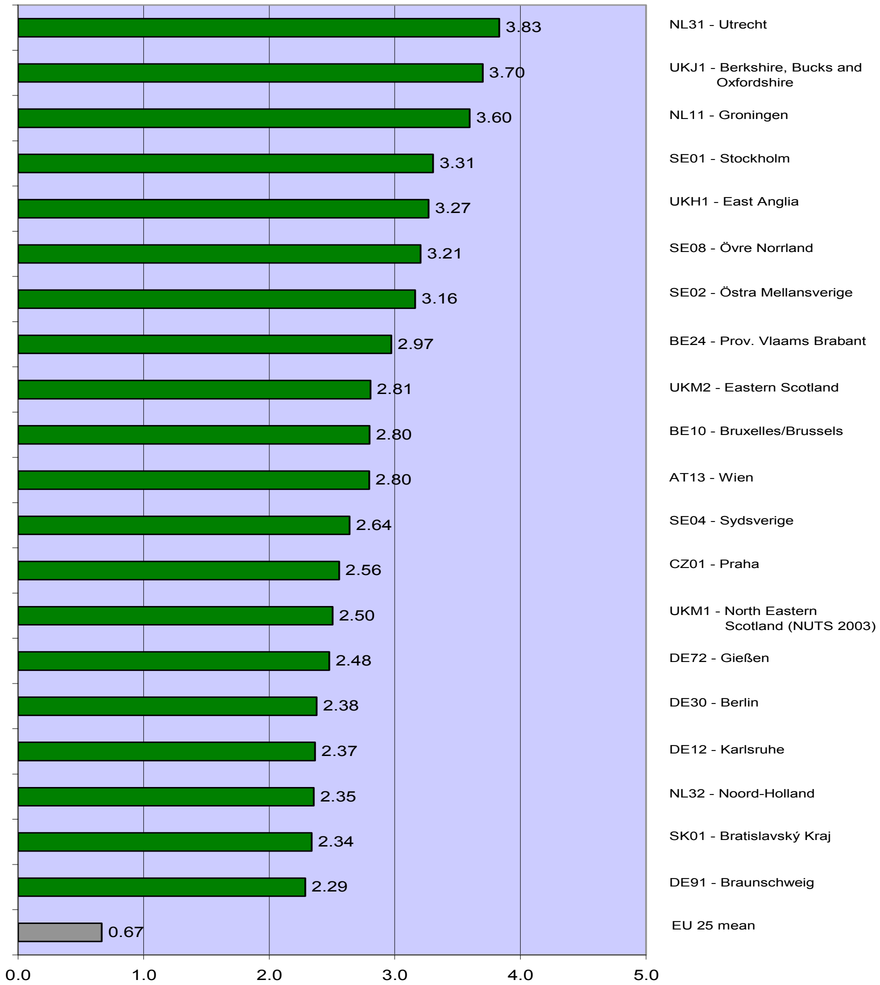
Figure 26: R&D intensity (GERD as % of GDP), 2003 vs. patent intensity, 2001



Note: NUTS 2 data do not include BE21-35, BG, DE22-23, IE, GR11-25, GR41-43, ES63-64, FR91-94, PT18-30, RO, UK; NUTS1 data used for BE; NUTS 0 data used for RO, BG.
Source: Regional Key Figures database, own compilation; 187 regions included

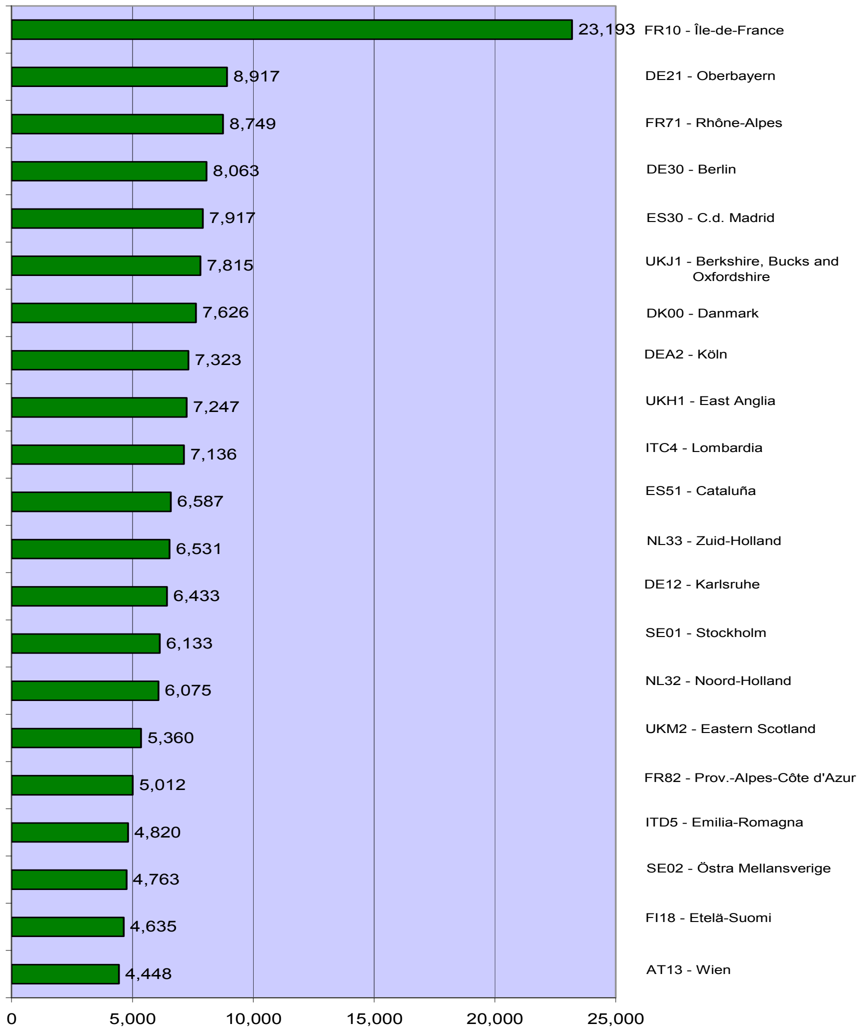
A different spatial pattern can be observed when measuring the scientific output compared with measuring the technological output. Even though the business centres Île de France, Oberbayern and Stockholm are among the regions with the highest scientific output, many of the other leading regions are much more focused. In many cases, those regions with the highest publication intensity are internationally known centres of excellence in public (university) research and education rather than for business sector research activities (e.g. Utrecht; Berkshire, Bucks and Oxfordshire and Groningen).

Figure 27: Total publications (per thousand inhabitants), 2003



Notes: EU 27 average not available; NUTS 2 data do not include BG, RO, UKI1-2; NUTS 0 data used for BG, RO; abbreviation 'BE1-Bruxelles/Brussels' used for 'BE1-Région de Bruxelles-Capitale/Brussels Hoofdstedelijk Gewest'.
Source: Regional Key Figures database, own compilation; 255 regions included

Figure 28: Total publications (absolute value), 2003



Notes: NUTS 2 data do not include BG, RO, UKI1-2.
Source: Regional Key Figures database, own compilation; 252 regions included

IV A typology of regions within the ERA

IV.1 The multi-level embeddedness of research systems

As evidenced by the trends shown in the preceding section, the available data most clearly show that there are a number of regions in which the research system is the driving force of the economy and intricately linked with the local innovation system. For a sizable number of regions, on the other hand, regional R&D expenditures are not the sole driving force of economic growth. Instead, GDP per capita growth is rather inversely correlated with GERD per capita (cf. FigureAnnex 10). General economic catching-up tendencies in the ERA are apparently not based on knowledge-based growth. While this context is not necessarily relevant to build an abstract typology of research systems, the question whether the regional research system plays a role for the regional innovation system is substantial to understand its function within the ERA. It will therefore be the key aim of the typology to distinguish between regions in which the data suggest that they are R&D-driven, those in which R&D play a supportive role, and those in which R&D is complementary to the local economy. For policy-makers, this information is needed to match regional research systems to regional needs.

Moreover, the growth of GERD as % of GDP rates varies most among regions with low R&D intensities (cf. Figure 7). Moreover, it is often characterised by inter-temporal volatility. This suggests that activities in the research systems in quite a number of regions are of an unstable nature and subject to external factors. For some regions the figures are so low that it even seems questionable if any regional research system has been developed yet. It appears that the instability of research systems is particularly pronounced if regional economic development is strongly below average (cf. FigureAnnex 11).

It appears that a statistical correlation between economic growth and research intensity can hardly ever be found on NUTS 2 level. The conceptual section, however, demonstrates that a linear relation between investments in research to economic growth is not to be expected. In contrast, research investment is an input into a complex, interactive system characterised by a large number of feed-back, feed-forward loops and intermediate steps. Knowledge, however, is not contained within a region and during any of these feedback loops can be transferred to actors and R&D performers outside the region. Hence, regional research systems are open systems from which knowledge diffuses and into which external knowledge is absorbed and thus can only be assessed on the basis of internal indicators to a limited extent.

Consequently, the available data support the notion that regional research systems cannot be comprehensively conceptualised at NUTS 2 level. Systemic contingencies, as suggested in the literature, are often more evident on NUTS 1 than on NUTS 2 level.

Firstly, this applies to the correlation between growth rates of regional GDP per capita and regional GERD per capita (NUTS 1 level: R^2= 0.318 vs. NUTS 2 level: R^2= 0.103, cf. Annex). There are two likely explanations for this result. One the one hand, the preceding sections showed that there are a limited number of regions for which an internal contingency of research and general economic activity appears plausible. Disaggregation from NUTS 1 to NUTS 2 level is unlikely to result in an increase of the number of the (mostly metropolitan) regions which are characterised by a high degree of internal interconnectedness, whereas the number of rural regions for which this is not the case is likely to rise. On the other hand, the literature suggests that not all investments in research have economic effects in the immediate vicinity of the geographic point of investment. It thus seems logical that a NUTS 1 level analysis would cover a larger share of the economic impact resulting from the transfer of knowledge generated through investment in research than a NUTS 2 level analysis.

Secondly, it applies to the correlation between the share of the business sector in GERD and regional R&D intensity (NUTS 1 level: R^2= 0.517 vs. NUTS 2 level: R^2= 0.194, cf. Annex). It appears that on the NUTS 2 level, a high BERD/GERD ratio does not necessarily indicate a healthy research system based on strong business sector activities. In contrast, it could simply point to the presence of a single innovating enterprise in an otherwise weak system.

Thirdly, it applies to correlations between regional R&D intensity and patent intensity as well as between regional R&D intensity and publication intensity (NUTS 1 level: R^2= 0.533 vs. NUTS 2 level: R^2= 0.455; NUTS 1 level: R^2= 0.514 vs. NUTS 2 level: R^2= 0.420, cf. Annex). It appears that overall investment in research, i.e. investment in both academic and applied research, is more evident on NUTS 1 level, as this level of analysis also covers the indirect effects between non-related inputs and outputs. This notion is supported by the weak NUTS 2 and stronger NUTS 1 correlation between unrelated inputs and outputs such as BERD as % GDP vs. publication intensity (NUTS 1 level: R^2= 0.319 vs. NUTS 2 level: R^2= 0.214, cf. Annex). These indirect effects can be read as evidence of systemic interconnectedness on a regional level, which apparently is less present at NUTS 2 level. These results are consistent with the interpretation suggested above concerning the growth rates.

The NUTS 2 level analysis, in contrast, appears to better cover direct contingencies. Relations between related inputs and outputs appear tighter at the NUTS 2 than at NUTS 1 level. Firstly, the correlation between the business sector's expenditure and patent intensity

(R^2=0.065 vs. R^2=0.492, cf. Annex). Secondly, the correlation between the higher education sector's expenditure and publication intensity (R^2=0.506 vs. R^2=0.642, cf. Annex).

Summing up, relationships that, in theory, presuppose interaction and knowledge exchange between players in the regional system are more evident at a NUTS 1 level. In contrast, those that mirror a joint occurrence of investment in- and output from either academic or industrial research are stronger on a NUTS 2 level.

Most likely this is due to the fact that the research system of a small region is much more prone to become structurally determined by one or few players than a larger NUTS 1 region. On the other hand, it demonstrates that a NUTS 1 level necessarily masks differentiation, so that any NUTS 2 level analysis of necessity includes a larger number of low-capacity regions. The remaining systemic correlations found in the field of all NUTS 2 regions are likely based on systemic characteristics of some thriving, innovative regions.

While not questioning the general link between knowledge input and economic development, the data clearly do not support the notion that all NUTS 2 regional socio-economic systems rely on knowledge generated within the region as a core input of their regional research systems, with the possible exception of a few strong metropolitan areas. In contrast, they suggest that regions within the ERA are typically not self-sustaining, but form inter-regional networks of knowledge exchange. Due to their embeddedness in these networks, however, regions need a certain degree of R&D activity to build up the absorptive capacity necessary to make use of the knowledge available from external sources. In practice, unfortunately, it is not easy to uncover the linkages and knowledge flows that practically constitute the fabric of these networks. Meaningful data on knowledge flows are not available on an ERA-wide scale.

As this first booklet is aiming at an ERA-wide overview, it will have to focus on the available data sources. The issue of the position of the regions in the network will therefore be addressed through the characteristics which allow conclusions regarding the function they perform in the overall system (cf. II.2).

As a concluding remark, it is important to point out that the above discussion does not intend to suggest that NUTS 2 is not a useful level of R&D policy intervention. In practice, the most useful level of R&D policy intervention will have to be determined based on the preceding administrative structures in the individual countries.[8]

In the conceptual section, however, it has been pointed out that research systems cover a broad array of R&D activities including those in the business sector. Against this background, this section aims to stress that regional research systems are anchored, but not contained, within the administrative NUTS 2 region in question, as their business system does not intrinsically follow the logic of administrative boundaries, nor does the knowledge exchange between the actors in the system. While this is a general finding that needs to be taken into account on any spatial level of analyses, it becomes the more relevant the narrower the level of analyses becomes.

While NUTS 2 level policy can in many cases certainly make an important contribution, it should not try to do so based on the assumption that it could address a locally contained research system. When assessing the attractiveness of a location for R&D or the functionality of a regional research system, therefore, it would be mistaken to consider the NUTS 2 level alone, which is relevant, but needs to be contextualised within a NUTS1/0 level framework.

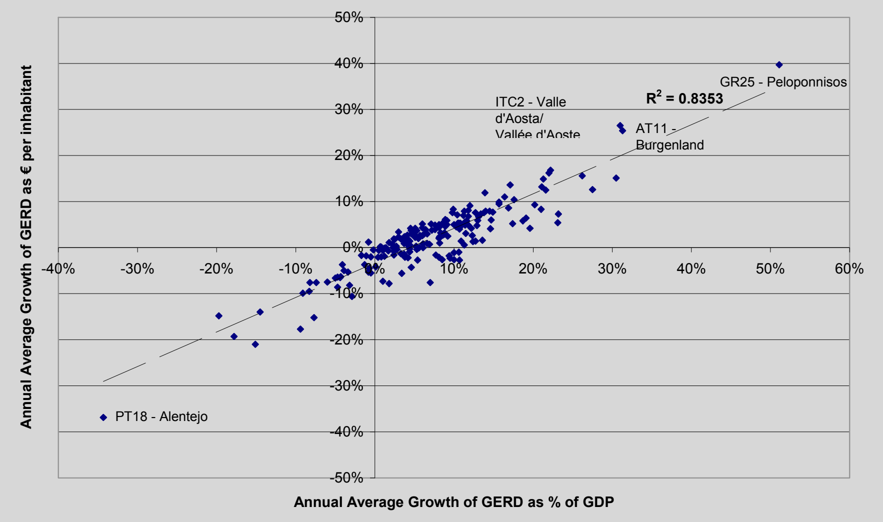
[8] In Spain, for example, the NUTS 2 delineation often follows the administrative boundaries of autonomous regions with quite independent R&D policy, while in other countries, as of today, they constitute little more than statistical units.

IV.2 Methodology

The three pillars of a research system rely on inputs which make it possible to fulfil their functions, and can be associated with certain outputs indicating how well they perform. In an adapted form, the distinction between input (expenditure, personnel), throughput (publications, patents) and output (launch of innovative products) aspects, which is commonly used to measure innovation, can also be applied to the analysis of research systems. In the case of research system analysis, however, the distinction between throughput and output does not apply. As the aim of research is the creation of knowledge rather than its economic exploitation, publications and patents can already be regarded as "output" of the system. The analysis of research systems will therefore be limited to a dichotomous input vs. output approach.

The most commonly used general indicator to describe the relative significance of research in a region and to benchmark it against a desirable level is the "ratio of gross R&D expenditure (GERD) to GDP". For the EU as a whole, the desirable level is defined as approaching the 3 % objective in 2010. Although GERD as % of GDP is a highly popular indicator, some critical discussions can be found in the literature. It is argued that the relation between GERD and GDP cannot be expected to be linear as there are increasing returns to knowledge. Knowledge-driven GDP growth should therefore be higher than the growth of the driving GERD. This would result in a decreasing GERD as % of GDP rate, inviting the mistaken conclusion that the role of R&D for economic performance had decreased, when in fact the efficiency of the investments in R&D has been increased. In practice, however, few such cases can be identified with a view to the ERA as a whole (see Methodological Note 1). Hence, GERD as % of GDP will be used for the following analysis.

Methodological note 1 Methodology



As this booklet aims to focus its perspective on the characterisation of regional research systems as distinct from the common innovation system perspective, we considered measuring R&D intensity as GERD per inhabitant instead of the more common GERD as a percentage of GDP. As outlined above, the measurement of R&D intensity by GERD as a percentage of GDP has several theoretical shortcomings, apart from being strongly contingent on general and potentially non-research-based economic development.

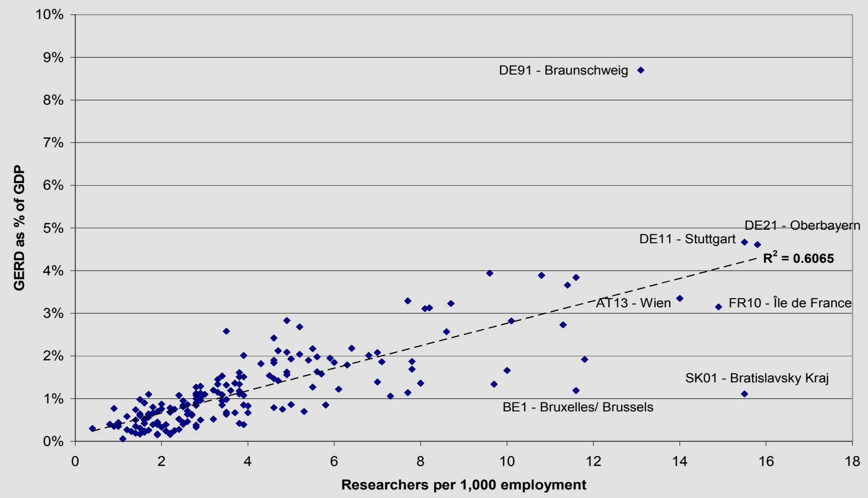
A closer investigation of the available data, however, revealed that with regard to stock figures both measures correlate very strongly. For growth figures, in contrast, some differences can be identified, depending on the extent of general economic growth in the regions in question. Yet even these were not very substantial.

In the following, therefore, we will refer to the better-established and politically well-known measurement of R&D intensity by GERD as a percentage of GDP. Additionally, it can be argued that GERD as a percentage of GDP is better suited to provide information about the *relation* between regional research and regional research system, which cannot be neglected (see IV).

On the input side, i.e. regarding expenditures, R&D and innovation, statistics distinguish between the relative importance of actors *performing* research and the relative importance of actors *financing* research. Usually, the public sector is responsible for the funding of major parts of university research (HERD), governmental research (GOVERD) and for certain parts (basic funding) of certain (not all) private non-profit research organisations. Nevertheless, university research can also be financed by third parties like industry, research associations or the European Commission. The same holds true for the other research organisations. On the other hand, research in the industrial sector (BERD) is mainly funded by industry itself, but in some cases also by the government, other public organisations or the European Commission. Such data, however, are unfortunately not available on NUTS 1 or NUTS 2 level, but on national level only.

As already pointed out, however, R&D does not only rely on financial inputs, but also on human resources. The number of R&D personnel or, more precisely defined, researchers active in a region gives an additional indication of the regional research system's potential. However, the possibility of a meaningful interpretation of such figures is contingent on differentiated case-by-case knowledge about the forms of organisation and national context of the regional research system in question (cf. Methodological Note 2). In the absence of such knowledge, figures on the number of researchers can be interpreted in a number of conflicting ways (high number of researchers equals low efficiency vs. high number of researchers equals high potential). As a tendency, the share of researchers per total employees mirrors the information contained in R&D intensity figures (cf. Methodological Note 2). Other than for specific purposes and particularly if no additional knowledge is available about the regional system, it is therefore justifiable to concentrate on either one of the input indicators (i.e. on expenditure *or* researchers).

Methodological note 2



As shown in the above figure, the correlation between R&D intensity (GERD as a percentage of GDP) and researchers per 1,000 employees is quite high. An R^2 value of over .75 indicates that little additional information can be added to a model by including both variables rather than just one of them. Nevertheless, there are some outlier cases that demonstrate that in some regions expenditures (or the number of R&D employees, respectively) are disproportionately high. To explain these differences, however, an array of different factors has to be considered.

→ What activity is accounted for where, e.g. does the regional assignment of activities in the accounting of firms differ regarding finances and personnel?
→ What kind of research is conducted and how capital-intensive is it?
→ Is there a different degree of efficiency which is explained by the administrative set-up of the local research system rather than the nature of research?
→ Are there wage differences that explain higher or lower number of researchers, even if active in the same field in a comparable administrative context?

Overall, we reached the conclusion that in the context of this booklet GERD as % of GDP is the indicator that yields the more valid and easier-to-interpret information, as it is dependent on a smaller number of framework conditions. Nonetheless it, too, has its deficiencies, particularly with respect to the first point.

Concerning the measurement of research output, on the contrary, the situation is less ambiguous, as less potentially applicable indicators are available in the first place. With publications and patents, however, there are two valid and broadly accepted indicators to measure the output of basic research and applied technological development, respectively. As in the case of R&D expenditure, both are typically used in the forms "intensities", in these cases referring to the total regional population.

As with input indicators, there are a number of validity issues to be taken into account. For example, neither of the output indicators covers any results from classified public research (e.g. defence research). If such efforts are reflected, this happens only indirectly and with significant delay, once they are declassified and transformed into technologies for public use. However, due to its nature, classified research is normally also accounted for differently in terms of expenditure. Hence, it does not appear in GERD figures, either, leaving the overall input/output picture consistent.

The question of interregional comparability of potentials and results nevertheless arises, as additionally it can be argued that scientific disciplines differ in their propensity to publish, and the form in which this is done, as different industrial branches also have a different propensity to patent. Additionally, research results of entire sections of service sector R&D, such as software development, are only very incompletely covered by patent figures as their research output is not normally legally eligible for patenting.

Finally, it is important to note that valid patent figures only become available with a delay as the last two years' patent figures do not yet include PCT applications of the respective priority year, which can take up to 30 months to be transferred and accounted for by the EPO. As last data are available for 2003, 2001 data will be used.

Against the background of the mentioned challenges regarding the availability and validity of meaningful data, and the first results from the analysis of the data, it is a rather complex task to develop a typology of regional research systems in Europe. Hence, some explanatory remarks should precede a description of the methodology.

Above all, it is important to point out that the available data do not allow for the development of a classification based on measurable systemic properties such as the degree and density of interaction amongst the players in the regional system. For example, data regarding *the financing* of R&D are not available on NUTS 2 level and therefore cannot be related to data concerning *the performance* of R&D. Interrelationships between actors can thus not be reflected.

Instead, the available data allow for a classification based on aggregate information concerning extent and character of the activities in a given research system and the extent and character of the output it generates. It is the aim of this booklet to generate a typology of research systems *as conceivable from the available data* and to use this typology as a template for further analysis.

Secondly, as the aim of the analysis was to identify ERA-wide patterns, the results with regard to the assignment of individual regions to certain groups or "regional types" have not been individually investigated and cross-checked and therefore remain open to debate. This is particularly the case as, due to limited data availability, it cannot be claimed with certainty what the results would have been if data were available for all 265 NUTS 2 regions. While the analysis yields a quite stable overall pattern of "regional types" (cf. Methodological Note 3), some regions will in any such analysis be located at the boundary between two groups and might have been assigned differently if the overall sample could have been enlarged.

IV.3 Regional typology – concept and results

As pointed out above, the concept of the regional research system will in the following constitute both an analytical tool and a conceptual framework of reference. In order to generate an interpretable and easily understandable regional typology, the following analysis was focused on a limited number of indicators. Additionally, as pointed out in Methodological Note 2, models including too many R&D indicators usually display strong multi-collinearity which increases complexity, but does not yield additional explanatory value.

Consequently, it takes into account indicators which reflect the relative socio-economic relevance of the regional research system for the overall socio-economic system of the region, the nature of the activities performed and the relative importance of the actors performing research in the region:

- the overall financial input into research & development
- the relative importance of the types of regional actors active in research and development
- the (measurable) output from basic research
- the (measurable) output from applied R&D

As elaborated above, these dimensions can be operationalised by the following indicators:

- GERD per GDP (in 2003)
- share of BERD in GERD (in 2003)
- publications per million inhabitants (in 2003)
- patents per million inhabitants (in 2001[9])

[9] Due to pending transfers of PCT applications with priority years 2002 and 2003, data for these years cannot be meaningfully interpreted.

Based on the indicators mentioned, a cluster analysis was conducted on all NUTS 2 regions (as well as the NUTS 1 regions of Ireland and the United Kingdom[10]) which yielded a fivefold typology with further subdivisions (cf. table 3):

- regions with far above average business R&D activities
- R&D-driven regions
- R&D-supported regions (public sector centred)
- R&D-supported regions (broadly based)
- regions with complementary R&D efforts.

Methodological note 3

The typology of regional research systems is the result of a partitioning cluster analysis aiming at the creation of 8 clusters (using standardised figures). Regions with any missing values were excluded from the calculations. Based on the distances between the cluster's centres, some of the 8 clusters were merged. In detail these are (cf. Annex):

technical clusters 2&6&7 → grouped as Type 1 Regions; a) (2&6) and b) (7)

technical clusters 3&4 → grouped as Type 3 Regions, a) (3) and b) (4)

technical clusters 5&8 → grouped as Type 4 Regions, a) (5) and b) (8)

To avoid a distortion of the overall results, several regions which during test-runs tended to create "n=1" or "n=2" clusters ("outliers") were excluded from the calculation before the final analysis was conducted. Different modes of iteration and calculation of starting points were tested to corroborate our findings – but yielded only marginally different results. Hence, the main analysis was conducted using SPSS standard procedures for iteration and determination of starting points.

[10] For Ireland and the UK no relevant data on R&D expenditure is available on NUTS 2 level. For this reason NUTS 1 level regional data have been included instead. Data for the UK are available for 1999 only. PPS2000 are not available.

Table 3: Typology of European NUTS 2 regions, average[11] values by type

		Publications per million inhabitants (2003)	**Patents per million inhabitants** (2001)	**GERD as % of GDP** (2003, UK 1999)	**BERD as % of GERD** (2003, UK 1999)
Outliers	n=6	1497.8	579.9	5.24	83.52
Type 1 Regions	n=25	1843.4	323.0	3.23	67.49
1a	n=19	1616.9	284.4	2.98	66.64
1b	n=6	2560.6	445.3	4.00	70.18
Type 2 Regions	n=16	2393.4	114.4	1.64	37.14
Type 3 Regions	n=59	806.2	121.1	1.40	62.17
3a	n=37	916.6	88.7	1.22	52.21
3b	n=22	620.6	175.7	1.68	78.94
Type 4 Regions	n=84	379.3	32.3	0.66	45.76
4a	n=54	465.9	17.3	0.62	28.51
4b	n=30	223.5	59.2	0.72	76.82
total (incl. outliers)	n=190	**909.5**	**122.3**	**1.45**	**54.19**
total (excl. outliers)	n=184	**890.3**	**107.4**	**1.33**	**53.23**

Shading:
dark green:> 100% above average, light green: 25-100% above average
dark red: > 50% below average, light red: 25-50% below average

Source: Regional Key Figures database, own compilation

Methodological note 4

Unweighted means: have been used to describe the average characteristics of a region in a given cluster which, at first sight, may surprise the reader used to the calculation EU 27 means by weighted national averages.

The situation in this case, however, is different, so that unweighted rather than weighted means provide the information needed.

The key point is that it does not make sense to regard e.g. the totality of all "Type 1 Regions" as an entity in the sense of a nation or the EU 27. Consequently, the aim cannot be to calculate an "all Type 1 Regions' average".

On the contrary, the aim of the analysis is to compare structural characteristics of individual regions, which by analysis we have found to belong to a certain category. In the cluster analysis, regions have been treated as equal observations, distinguished only by their characteristics. In our view it is important to be consistent with this notion when describing the group average. It would diminish rather than add clarity if we were to add a weight to certain regions, particularly as these weights would differ according to the indicator in question.

It is true that the underlying assumption that NUTS 2 regions are comparable entities can be made subject to debate. Undoubtedly, in practice, there are significant differences in size between these regions. Nevertheless, a comparison of relative values (e.g. GERD as % of GDP) in NUTS 2 regions of quite different sizes is continuously undertaken for the purpose of policy-making, in this booklet as much as in other publications.

Summing up:

the important point the cluster analysis is trying to answer is: what is (e.g.) the patenting intensity in a certain type of European region likely to be?

It is NOT to suggest that in Europe there were eight "entities" for which averages could be calculated – as this would be at odds with the network-based ERA model we proposed earlier in this booklet.

None of this, of course, disputes that certain considerations about e.g. the contribution of "Type 1 Regions" to the development of the overall ERA would have to be based on either weighted averages or absolute values.

[11] For a definition of unweighted, see Methodological note 4.

In more detail, the types of regions can be characterised as follows:

The six **outlier regions** are **leading R&D performers, favoured by the location of large companies**. In many, but not all cases, these are individual large corporations. The most outstanding shared characteristic of these regions is their very high business expenditure on R&D – mostly accounted for by the dominant firms in question – incurring the highest BERD/GERD and GERD as % of GDP rates in the sample. Due to the business-oriented nature of the local research systems, the local publishing intensities are only moderately high, whereas the local patenting intensities are the highest in the sample.

Type 1 Regions are **R&D-driven regions** characterised by a high publishing and a very high patenting intensity. In these regions the business sector contributes an above average share to regional GERD. Even if R&D intensity is significantly lower than in the outlier regions, the average of the GERD as % of GDP figures in Type 1 Regions exceeds the cross-type average by more than 100%. Type 1 Regions can be differentiated into two main sub-groups:

Type 1a Regions are ***broadly based R&D-driven regions*** with a moderately high publishing intensity and a high patenting intensity. Among them are the German city states, the capital regions of Ile-de-France and Wien, the UK regions bordering London, the state of Denmark and a number of prosperous urban regions in Germany and France (e.g. Rhône-Alpes, Midi-Pyrenées, Köln, Dresden).

Type 1b Regions are ***business-oriented, R&D-driven regions*** with a very high publishing and patenting intensity. Among them are the German regions of Karlsruhe and Tübingen, the capital regions of Stockholm and Southern Finland and two other Swedish regions. Although they have a somewhat stronger focus on industrial R&D input than Type 1b regions, they have a similar focus on R&D output which is a rather even combination of basic and applied results.

Type 2 Regions are **public-sector-centred, R&D-supported regions**, with a very high publishing intensity in contrast to an only slightly above average[12] patenting intensity. The gross expenditures for R&D per GDP are slightly above average in those regions and mostly accounted for by either universities or public research institutions. The contribution of the business sector is clearly below average. Among the Type 2 regions are the capital regions of Brussels, Prague, Bratislava, London and Northern Holland as well as some industrially less developed regions with noteworthy university towns in Germany, the Netherlands, Austria, Sweden and the UK.

Type 3 Regions are **broadly based, R&D-supported regions**, with an average publishing and patenting intensity. Unlike Type 1 or Type 2 regions, they are not home to outstanding centres of excellence in either public sector or business research. This group includes a significant share of all NUTS 2 regions for which data is available (close to one third). Type 3 regions can be differentiated into two main sub-groups:

Type 3a Regions are comparatively **public-sector-oriented,** resulting in a slightly higher publishing and a somewhat lower patenting intensity than other Type 3 regions. Among the Type 3a regions are regions in the Czech Republic, Germany, Spain, France, Italy, the Netherlands, Austria, Sweden and the UK. Additionally, the states of Slovenia and Ireland as well as the capital regions of Madrid and Budapest (Közép-Magyarország) are counted among this type of research systems.

Type 3b Regions are comparatively **business-oriented,** resulting in a lower publishing intensity and a moderately higher patenting intensity than in other Type 3 regions. Among the Type 3b regions are

[12] Considering the average, excluding outliers

the Grand Duchy of Luxembourg as well as regions from the Czech Republic, Germany, France, the Netherlands, Austria, Sweden and the UK.

The group of **Type 4 Regions**, finally, comprises the remaining regions in which R&D plays a less than central role and which for that reason have lagged behind in performance, with a far below average publishing intensity, a very low patenting intensity and an amount of investment in **R&D** that can only be described as **complementary** to the region's main drivers of growth. While R&D is an important input for economic processes in the region, it does not yet determine the logic of thinking of too many socio-economic actors. In the case of Type 4 regions it is questionable whether all of the concerned "research systems" deserve to be designated as "systems", because activities are more often than not singular and isolated, resulting in a high volatility of figures at a low level. For these reasons it is not possible to distinguish between Type 3 and Type 4 regions unambiguously. While some of them can be clearly assigned to either of the groups, others are closer to the line of separation and may switch depending on the extent of activities of the few main regional players in the year in question. An inter-temporal aggregation, however, did not seem advisable. The newest available data are already comparatively old and an aggregation would have had to include even older information and would thus have compromised the topicality of the analysis.

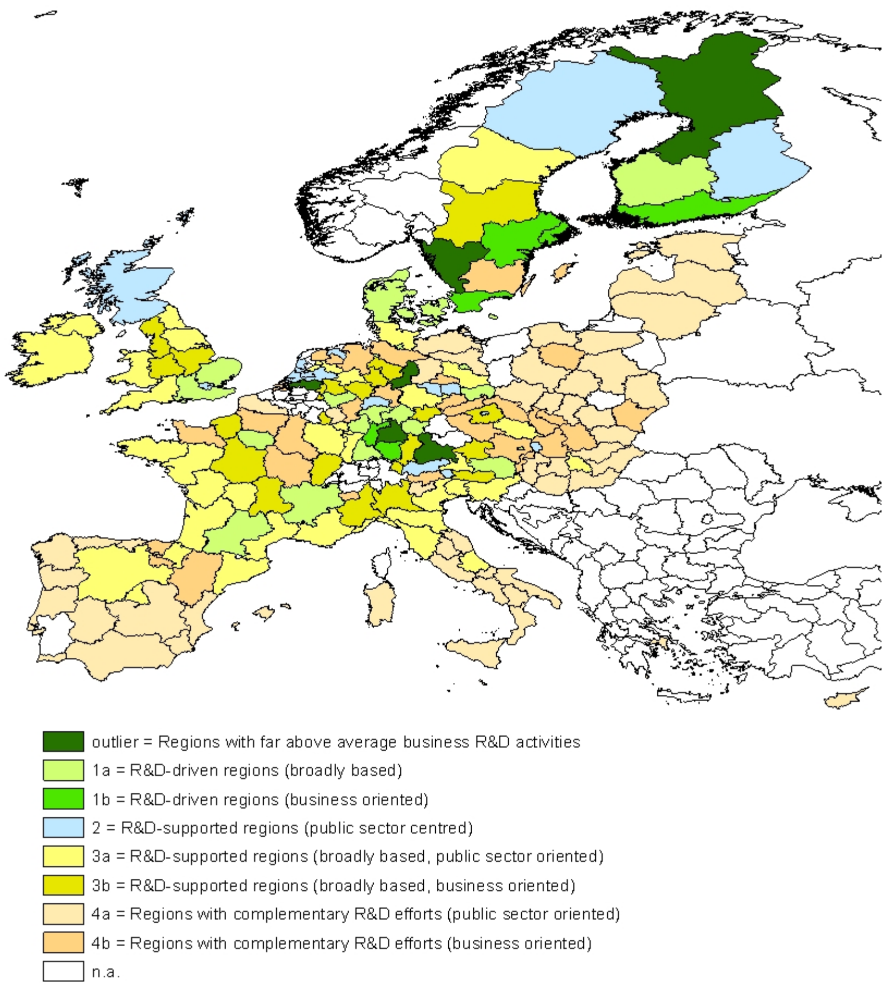
Based on the analysis, Type 4 regions can be further sub-divided into:

Type 4a Regions, which are ***public-sector-oriented,*** lack a significant basis for business sector R&D, resulting in the near absence of patenting activities, particularly with a view to high-tech patents. In contrast, they harbour some noteworthy activities in public research, which result in a limited extent of publishing activities. Type 4a regions are present in Germany, Greece, Spain, France, Italy, Hungary, Poland, Portugal, Slovakia and Finland. Additionally, the states of Estonia, Cyprus, Latvia, Lithuania and Malta display characteristics of Type 4a regions.

Type 4b Regions, on the contrary, are ***business-oriented*** and do not commit any sizeable resources to public research efforts, with a very low publishing intensity as a result. While much of the regional expenditure on R&D is accounted for by business enterprises it is so low on an absolute level that no significant patenting activities result. In fact, the average patenting intensity in Type 4b regions is lower than that in public-sector-oriented medium performing regions (Type 3a).

The following three pages provide the reader with a list of regions according to their affiliation to the mentioned groups. Moreover, they provide an overview of the types of research systems that are present in the individual Member States (Box 1).

Figure 29: Typology of European regions with regard to R&D



Source: analysis by Fraunhofer ISI, based on Regional Key Figures database; 190 regions included

Box 1: NUTS 2 regions by regional type, including UK and IE NUTS 1

Outliers: **Leading R&D performers**

DE11 – Stuttgart; DE21 – Oberbayern; DE91 – Braunschweig; NL41 - Noord-Brabant; FI1A - Pohjois-Suomi; SE0A – Västsverige

Cluster 1: **R&D-driven regions**

Cluster 1a: **Broadly based R&D-driven regions**

DE30 – Berlin; DE50 – Bremen; DED2 – Dresden; FR62 - Midi-Pyrénées; AT13 – Wien; AT22 – Steiermark; DK00 – Danmark; DE13 – Freiburg; DE25 - Mittelfranken; DE26 – Unterfranken; DE60 – Hamburg; DE71 – Darmstadt; DEA2 – Köln; DEB3 - Rheinhessen-Pfalz; FR10 - Île de France; FR71 - Rhône-Alpes; FI19 - Länsi-Suomi; UKH - EAST OF ENGLAND; UKJ - SOUTH EAST

Cluster 1b: **Business-oriented R&D-driven regions**

DE12 - Karlsruhe; DE14 - Tübingen; FI18 - Etelä-Suomi; SE01 - Stockholm; SE02 - Östra Mellansverige; SE04 - Sydsverige

Cluster 2: **Public-sector-centred R&D-supported regions**

BE10 - Région de Bruxelles-Capitale; CZ01 - Praha; DE72 - Gießen; DED3 - Leipzig; DEE2 - Halle; NL11 - Groningen; NL22 - Gelderland; NL31 - Utrecht; NL32 - Noord-Holland; NL33 - Zuid-Holland; AT33 - Tirol; SK01 - Bratislavsky kraj; FI13 - Itä-Suomi; SE08 - Övre Norrland; UKI - LONDON; UKM - SCOTLAND

Cluster 3: **Broadly based R&D-supported regions**

Cluster 3a: **Public-sector-oriented, broadly based R&D-supported regions**

CZ06 - Jihovychod; DE42 - Brandenburg - Südwest; DEA3 - Münster; DEC0 - Saarland; DEF0 - Schleswig-Holstein; DEG0 - Thüringen; ES22 - Comunidad Foral de Navarra; ES30 - Comunidad de Madrid; ES41 - Castilla y León; ES51 - Cataluña; FR41 - Lorraine; FR42 - Alsace; FR51 - Pays de la Loire; FR52 - Bretagne; FR53 - Poitou-Charentes; FR61 - Aquitaine; FR63 - Limousin; FR81 - Languedoc-Roussillon; FR82 - Provence-Alpes-Côte d'Azur; ITC3 - Liguria; ITD3 - Veneto; ITD4 - Friuli-Venezia Giulia; ITD5 - Emilia-Romagna; ITE1 - Toscana; ITF1 - Abruzzo; HU10 - Közép-Magyarország; NL21 - Overijssel; NL23 - Flevoland; AT32 - Salzburg; SI00 - Slovenija; SE07 - Mellersta Norrland; IE0 - IRELAND; UKC - NORTH EAST; UKE - YORKSHIRE AND THE HUMBER; UKK - SOUTH WEST; UKL - WALES; UKN - NORTHERN IRELAND

Cluster 3b	**Business-oriented, broadly based R&D-supported regions**
CZ02 - Stredni Cechy; DE24 - Oberfranken; DE27 - Schwaben; DE92 - Hannover; DEA1 - Düsseldorf; DEA4 - Detmold; DEA5 - Arnsberg; FR23 - Haute-Normandie; FR24 - Centre; FR43 - Franche-Comté; FR72 - Auvergne; ITC1 - Piemonte; ITC4 - Lombardia; LU00 - Luxembourg (Grand-Duché); NL42 - Limburg (NL); AT21 - Kärnten; AT31 - Oberösterreich; AT34 - Vorarlberg; SE06 - Norra Mellansverige; UKD - NORTH WEST; UKF - EAST MIDLANDS; UKG - WEST MIDLANDS	
Cluster 4:	**Regions with complementary R&D efforts**
Cluster 4a	**Public-sector-oriented regions with complementary R&D efforts**
DE41 - Brandenburg - Nordost; DE80 - Mecklenburg-Vorpommern ; DEB2 - Trier; DEE3 - Magdeburg; EE00 - Eesti; GR30 - Attiki ; ES11 - Galicia; ES12 - Principado de Asturias ; ES13 - Cantabria; ES42 - Castilla-La Mancha ; ES43 - Extremadura; ES52 - Comunidad Valenciana ; ES53 - Illes Balears; ES61 - Andalucía; ES62 - Región de Murcia ; ES70 - Canarias ; FR30 - Nord - Pas-de-Calais ; ITD2 - Provincia Autonoma Trento; ITE2 - Umbria ; ITE3 - Marche ; ITE4 - Lazio; ITF2 - Molise ; ITF3 - Campania ; ITF4 - Puglia ; ITF5 - Basilicata ; ITF6 - Calabria ; ITG1 - Sicilia; ITG2 - Sardegna ; CY00 - Kypros / Kibris; LV00 - Latvija; LT00 - Lietuva; HU21 - Közép-Dunántúl ; HU22 - Nyugat-Dunántúl; HU23 - Dél-Dunántúl ; HU31 - Észak-Magyarország ; HU32 - Észak-Alföld ; HU33 - Dél-Alföld ; MT00 - Malta; PL11 - Lodzkie; PL12 - Mazowieckie; PL21 - Malopolskie; PL22 - Slaskie; PL31 - Lubelskie; PL41 - Wielkopolskie; PL51 - Dolnoslaskie ; PL52 - Opolskie ; PL62 - Warminsko-Mazurskie; PL63 - Pomorskie; PT11 - Norte; PT15 - Algarve; PT16 - Centro (P) ; PT17 - Lisboa ; SK04 - Vychodne Slovensko ; FI20 - Åland	
Cluster 4b	**Business-oriented regions with complementary R&D efforts**
CZ03 - Jihozapad; CZ04 - Severozapad; CZ05 - Severovychod; CZ07 - Stredni Morava; CZ08 - Moravskoslezsko; DE73 - Kassel; DE93 - Lüneburg; DE94 - Weser-Ems; DEB1 - Koblenz; DED1 - Chemnitz; DEE1 - Dessau; ES21 - País Vasco; ES23 - La Rioja; ES24 - Aragón; FR21 - Champagne-Ardenne; FR22 - Picardie; FR25 - Basse-Normandie; FR26 - Bourgogne; ITC2 - Valle d'Aosta/Vallée d'Aoste; ITD1 - Provincia Autonoma Bolzano/Bozen; NL12 - Friesland; NL13 - Drenthe; NL34 - Zeeland; AT11 - Burgenland; AT12 - Niederösterreich; PL32 - Podkarpackie; PL61 - Kujawsko-Pomorskie; SK02 - Zapadne Slovensko; SK03 - Stredne Slovensko; SE09 - Småland med öarna	

Source: cluster Analysis by Fraunhofer ISI

IV.4 Regional typology – interpretation of results

Overall, the analysis supports the above conceptual statements that R&D capacities in the ERA are highly unevenly distributed and that different regions fulfil different roles within this overall framework.

As is to be expected, the number of high performing regions is comparatively limited, whereas the number of regions in which R&D does not (yet) play a central role for economic development ("with complementary R&D") is comparatively high. However, there is indeed a notable number of regions (>40%) which is situated in middle-field regarding the relative regional relevance of their research systems. These regions are of particular interest to policy-makers as they contribute a notable share of overall EU GERD, causing their fate (catching-up vs. falling behind) to significantly affect the development of the ERA as a whole. Regarding the relative importance of the type of regional actors concerned, as well as the structure of the output of the research system, the findings of the cluster analysis corroborate the assumption that a regional orientation towards industrial R&D tends to result in increased patenting intensities, whereas an orientation towards research in higher education or public research tends to lead to higher publication intensities.

While the above is a comparatively non-remarkable finding as such, it is noteworthy that different specialisation profiles can be found at all levels of regional R&D performance, except for the few leading regions which are dominated by the presence of large enterprises (and possibly the fact that those enterprises account for some of their activity in their headquarter regions which is actually performed elsewhere). However, it is important to bear in mind that a high relative importance of the business sector in a weak region may actually only reflect an overall absence of activity which is particularly pronounced in the public research sector.

Nevertheless, the differences concerning the relative importance of actors by type are much higher at the NUTS 2 than the NUTS 1 level. It seems plausible that this is partially the result of the comparatively small size of the NUTS 2 regions which, if non-urban, are much more likely to become dominated by individual public or private actors (or a small group of these) than the larger NUTS 1 regions. This is in line with the findings of the correlation analysis in the preceding section.

Moreover, the meaningful results suggest that the utilised classification approach based on the characteristics of regions is appropriate. The collected empirical evidence supports the idea that it is much more meaningful to conceive regional research systems in terms of their relevance for and role within the framework of the overall ERA rather than as individual self-sustaining entities, which they are not in practice, as the variance of different types suggests. While the flow of knowledge from the stronger to the weaker regions cannot technically be shown with the available data, the number of regions in which R&D has only a complementary function strongly suggests that such knowledge flows are in fact taking place. Moreover, the variety of different regional types indicates that these knowledge flows are not a one directional trickle-down process, but a network sourced by a number of regions with different profiles of knowledge generation, particularly among the regional Types 1 to 3.

With a view to the different EU countries, it is clear that some countries cover quite a broad range of different types of research systems (Table 4). In accordance with the above said, this not only suggests that R&D activities are highly dispersed, but also that any national system of innovation in the EU (with the possible exception of the NUTS 2 level states) is composed of different types of regional research systems that serve different functions in the national context. Only in their entirety can these individual NUTS 2 regions be considered to create a dynamic national research system. It is noteworthy that the variety of regional research systems is particularly high in the countries which are the key drivers of research in Europe. Additionally, it deserves mentioning that there are still a number of low performing regions in all of these leading countries.

That being said, certain conclusions result for the merits of the overall ERA, particularly for the countries which feature only a certain type of regional research system within their own territory and thus face greater challenges in establishing a dense and dynamic network of intra-national knowledge flows. A number of countries consist of Type 3 or Type 4 regions only. It is likely that within their national context they lack sources of knowledge to which an enlarged ERA network could provide access. Due to the cumulative nature usually ascribed to the process of learning and knowledge creation, however, even countries with many R&D-driven regions can profit from the integration in a larger network with increased diversity as an increase in and increased diversity of knowledge interchange promise to generate increasing marginal returns for research efforts.

Table 4: Regional research systems in the EU Member States

	M	O	Type 1a	1b	Type 2	Type 3a	3b	Type 4a	4b
Belgium	10	-	-	-	1	-	-	-	-
Bulgaria	6	-	-	-	-	-	-	-	-
Czech Republic	-	-	-	-	1	1	1	-	5
Denmark	-	-	XXX	-	-	-	-	-	-
Germany	2	3	10	2	3	5	6	4	6
Estonia	-	-	-	-	-	-	-	XXX	-
Ireland	-	-	-	-	-	XXX	-	-	-
Greece	12	-	-	-	-	-	-	1	-
Spain	2	-	-	-	-	4	-	10	3
France	5	-	3	-	-	9	4	1	4
Italy	-	-	-	-	-	6	2	11	2
Cyprus	-	-	-	-	-	-	-	XXX	-
Latvia	-	-	-	-	-	-	-	XXX	-
Lithuania	-	-	-	-	-	-	-	XXX	-
Luxembourg	-	-	-	-	-	-	XXX	-	-
Hungary	-	-	-	-	-	1	-	6	-
Malta	-	-	-	-	-	-	-	XXX	-
Netherlands	-	1	-	-	5	2	1	-	3
Austria	-	-	2		1	1	3	-	2
Poland	4	-	-	-	-	-	-	10	2
Portugal	3	-	-	-	-	-	-	4	
Romania	8	-	-	-	-	-	-	-	-
Slovenia	-	-	-	-	-	XXX	-	-	-
Slovakia	-	-	-	-	1	-	-	1	2
Finland	-	1	1	1	1	-	-	1	
Sweden	-	1	-	3	1	1	1	-	1
United Kingdom	-	-	2	-	2	5	3	-	-

"M" = missing values; "O" = outlier
Source: cluster analysis by Fraunhofer ISI

IV.5 Characteristics by regional types (input side)

Figure 30 shows the average absolute amount of GERD and the average growth of GERD as a percentage of GDP (periods from 1995-1999 and 2000-2003) by type of regional research system.

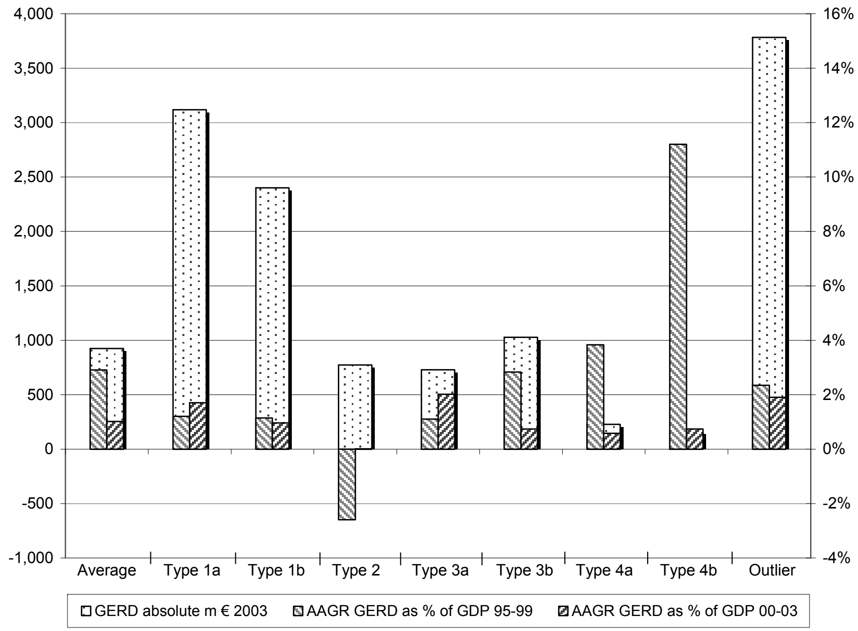
It becomes clear that the regions in which R&D efforts have a high relative importance (as measured in GERD as % of GDP) are also those in which high absolute amounts are invested in R&D. Overall, the results for the different groups mirror a strong correlation between absolute expenditure on R&D and relative importance of R&D efforts (R&D intensity) in a region[13]. While all outlier and R&D-driven regions realise a far above average expenditure on R&D, public-sector-oriented R&D-supported regions spend around average and regions with complementary R&D efforts lag behind.

A number of points are worth indicating concerning growth:

- The relative importance of R&D activity grows at the highest rates in regions where the current level of activity is low. To a degree, however, this should be interpreted as a statistical artefact due to the volatility of growth when the basis is low.
- Among the remaining regions, the highest and most stable increase in the relative importance of R&D is to be found in the already leading outlier regions.
- The relative importance of R&D activity grows least in public-sector-oriented R&D-supported regions where it actually decreased from 1995-1999.
- It is relevant to differentiate between the periods from 1995-1999 and the period from 2000-2003 for all groups.

[13] which can be confirmed as being 0.621, significant at the 1% level

Figure 30: GERD and growth of GERD as % of GDP by regional type[14]



Note: regional coverage limited to the regions included in the cluster analysis; coverage of years may vary according to availability of data (e.g. GERD absolute for UK: 1999).
Source: Regional Key Figures database, own compilation

- Fluctuations are higher among broadly based R&D-supported regions than among R&D-driven regions, which cannot merely be explained by a general difference in amount of growth, since that is similar.
- Growth for business-oriented R&D-driven regions and business-oriented, R&D-supported regions was higher from 1995-1999 than it was from 2000-2003. The opposite is true for public-sector-oriented R&D-supported regions or broadly-based R&D-driven regions.
- All regions with complementary R&D efforts experienced a strong decrease in growth from 1995-1999 vs. 2000-2003. The decrease is higher for the business-oriented regions, levelling their formerly superior catching-up performance.

As a tendency, the data seem to indicate that a broadly based or even public-sector-based orientation of research activities in a regional research system has helped to stabilise or even increase the development of the regional relevance of R&D in the period of the economic downturn from 2000-2003. The case of the public-sector-centred R&D-supported regions, however, demonstrates that public sector activities alone seem to be insufficient to trigger a relative rise in importance of regional R&D efforts. This is an indication that the regional research systems in the public-sector-centred R&D-supported regions are so specialised in academic output that their output cannot be directly absorbed by the business R&D system. Single higher education institutions or public research institutes responsible for the characteristics of the regional systems may not be sufficiently connected to or networked with the local innovation, or even the broader research system. Even if the individual institutions are performing outstandingly, any multiplier effects are unlikely to arise in such a setting, limiting the overall dynamics of the system.

In a similar manner, the data also show that during the period of economic boom it was a strong business orientation which helped regions to improve their research orientation.

The above suggestions are corroborated by a review of the figures of the absolute level of business expenditure on R&D (BERD) as well as the respective growth rates of relative regional importance of

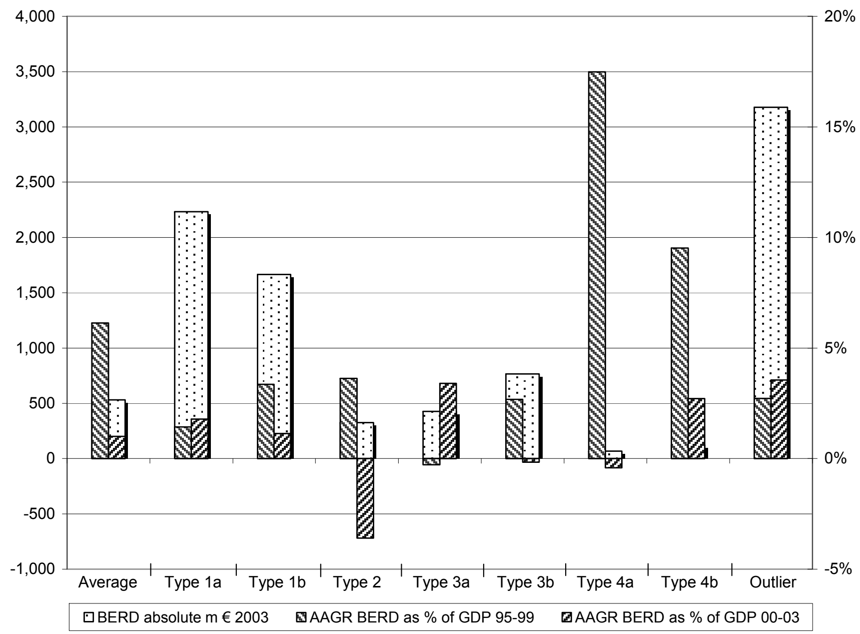
[14] based on unweighted means, cf. Methodological note 4

business research (BERD as % of GDP) by regional type (Figure 31).

With regard to this figure the following findings deserve mention:

- In the course of the 2000-2003 economic downturn, business R&D intensity growth increased (compared to 1995-1999) in public-sector-oriented R&D-driven regions and public-sector-oriented broadly based R&D-supported regions.
- The opposite is true for business-oriented R&D-driven regions and business-oriented R&D-supported regions where the business R&D intensity decreased from 2000-2003, whilst from 1995-1999 it had grown.
- The opposite is also true for regions with complementary R&D efforts among which, however, the decrease in business R&D intensity growth was more pronounced in public-sector-oriented regions (where it turned negative) than it was in business-oriented regions (where it remained positive).

Figure 31: BERD and BERD as % of GDP growth by regional type[15]



Note: regional coverage limited to the regions included in the cluster analysis; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation

Overall, these findings suggest that a certain involvement of the public sector can stabilise the growth of the relative importance of regional business sector R&D activities. This, however, does not apply when the local basis of public research is too strongly basic-research-oriented as in public-sector-centred R&D-supported regions, or the local expenditure for R&D in the business sector is below a critical threshold, as in public-sector-oriented regions with complementary R&D efforts.

[15] based on unweighted means, cf. Methodological note 4

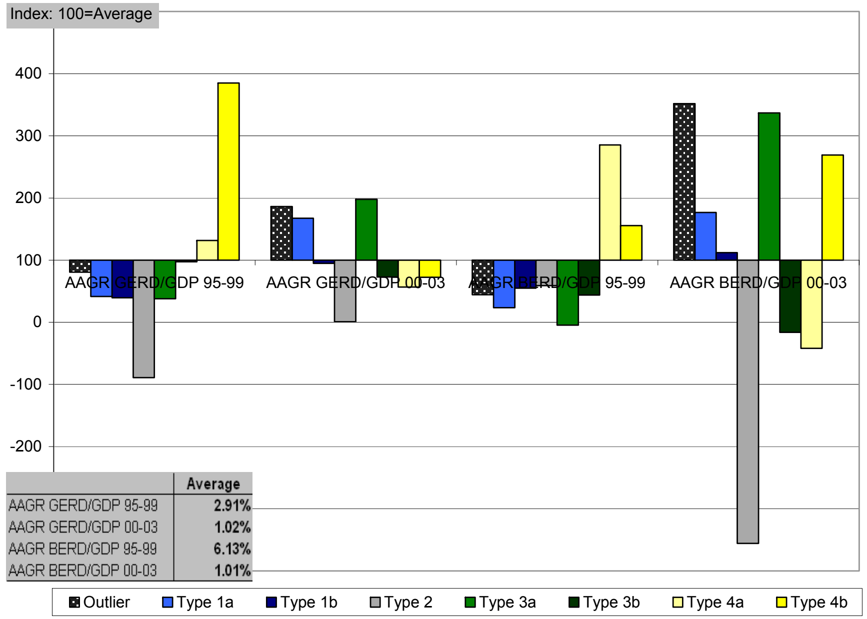
The results from Figure 31 seem to suggest that, to reduce vulnerability and increase the prospects for catching up in terms of technology-orientation, broadly based R&D-supported regions profit from a diversification of their R&D activities, whereas regions with complementary R&D efforts profit from reaching a critical threshold in business R&D activity.

A possible additional explanation could also be that the link between public sector research and business sector research and thus the degree of mutual stabilisation is better in broadly based R&D-supported regions than in regions with complementary R&D efforts regions. This, however, cannot be verified.

If the GERD as % of GDP growth data are displayed in an inter-temporal perspective (figure 32) and against the average of the respective period, it becomes clear that some overall trends have changed.

- The period from 1995 to 1999 was characterised by a clear catching-up tendency with regard to the less R&D-oriented regions with complementary R&D efforts, while the period from 2000-2003 was not.
- Accordingly, the growth of R&D intensity in R&D-driven regions and outlier regions was below average in the period from 1995 to 1999 while it was above average from 2000-2003
- In the more public-research-oriented medium performing regions (public-sector-centred R&D-supported regions & public-sector-oriented broadly based R&D-supported regions) R&D intensity growth was lower from 1995-1999 than it was from 2000-2003.

Figure 32: Total R&D intensity growth and business R&D intensity growth by period average[16]



Note: regional coverage limited to the regions included in the cluster analysis; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation

An inter-temporal analysis of business R&D intensity growth figures (against their respective period mean) confirms these findings.

- The period from 1995 to 1999 saw below average growth in all but the regions with complementary R&D efforts. Interestingly, particularly high growth was realised in the public-sector-oriented regions with complementary R&D efforts.

[16] based on unweighted means, cf. Methodological note 4

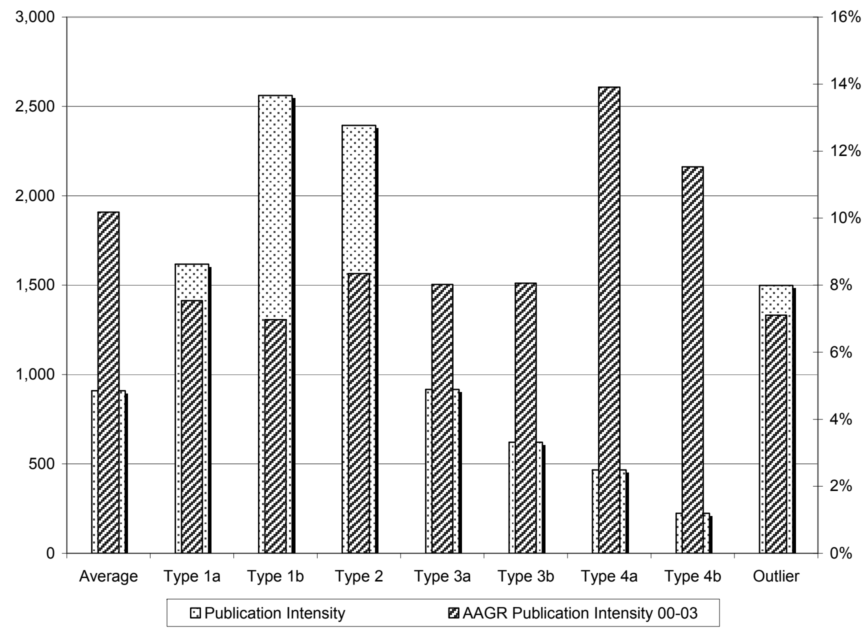
- The period from 2000-2003 saw very high growth in the outlier and the public-sector-oriented broadly based R&D-supported regions, whilst growth in the public-sector-centred R&D-supported regions had dropped far below average.
- Whereas business-oriented regions with complementary R&D efforts continued to grow above average, public-sector-oriented regions with complementary R&D efforts did not. Among broadly based R&D-supported regions the opposite was true, with a relative increase in business R&D intensity growth in public-sector-oriented broadly based R&D-supported regions, and a relative decrease in business-oriented broadly based R&D-supported regions.

IV.6 Characteristics by regional types (output side)

An analysis of publication intensity and its growth (not separated by periods, cf. figure 33) can be summarised as follows:

- Growth of publication intensity has generally been positive.
- As a result of the generation criteria for the typology, publication intensity is highest in broadly based R&D-driven regions and public-sector-centred R&D-supported regions, followed by the outlier and business-oriented R&D-driven regions, and, after a gap, the broadly based R&D-supported regions and regions with complementary R&D efforts.
- Growth of publication intensity differs surprisingly little by regional types, indicating that the regional distribution of strengths within the academic system remained quite stable.
- There appears to be a catching-up tendency with regard to the regions with complementary R&D efforts, which, however, could be a result of the small numbers in question.

Figure 33: Publication intensity and its recent growth by regional type[17]



Note: regional coverage limited to the regions included in the cluster analysis; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation

Figure 34 shows similar results for patent intensity:

- Growth of patent intensity was positive in all regional types.
- By definition, patent intensity is highest in business-oriented R&D-driven regions and the outlier regions, followed by the broadly based R&D-driven regions, and after a gap, the public-sector-oriented broadly based R&D-supported regions, public-sector-centred R&D-supported regions and business-oriented broadly based R&D-supported regions.

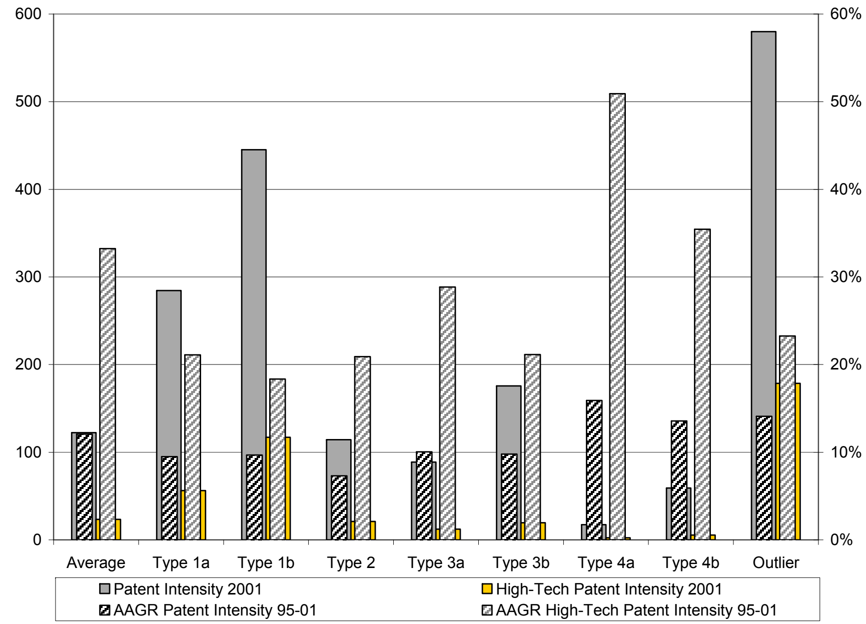
[17] based on unweighted means, cf. Methodological note 4

- Growth of patenting intensity is quite similar among all regional types, indicating a general increase in performance, but stability in distribution in the applied research system.
- There appears to be a catching up tendency between broadly based R&D-supported regions (leading) and regions with complementary R&D efforts, particularly between business-oriented regions with complementary R&D efforts and public-sector-oriented broadly based R&D-supported regions, whose patenting intensities do not differ too much.

For high-tech patent intensity (cf. figure 34) the situation looks only slightly different.

- The differences between the regional types in both growth and current high-tech patenting intensity are higher than for general patenting. Broadly-based R&D-supported regions remain remarkably weak.
- Overall, the average growth in high-tech patenting intensity is higher than the average growth in general patenting intensity. Interestingly, this difference is as (or even more) pronounced as in the less R&D-oriented regions.
- Again, growth of patenting intensities does not differ very much among the regions with more than complementary R&D efforts.
- There appears to be a catching-up tendency between broadly based R&D-supported regions and regions with complementary R&D efforts, particularly between business-oriented regions with complementary R&D efforts and public-sector-oriented broadly based R&D-supported regions, whose high-tech patenting intensities do not differ very much.
- Compared to the development of general patenting intensities there is a clearer tendency that, among the sub-groups of a certain regional type, growth is higher in those regions with a broadly based, rather than a business-oriented research system, irrespective of overall strength. However, this is not the case for the overly public-research-centred research systems in the public-sector-centred R&D-supported regions.

Figure 34: Patent intensity and its recent growth by regional type [18]



Note: regional coverage limited to the regions included in the cluster analysis; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation

[18] based on unweighted means, cf. Methodological note 4

Apparently, with a view to the business sector (i.e. more applied) side of the research system, the regional differentiation in the ERA develops somewhat more dynamically than in the academic system. As the business side of the systems is driven by the forces of the market that support concentration and agglomeration, while the public side is driven by policy-makers' efforts to sustain (and even increase) cohesion in the overall system, this finding does not come as a surprise. It is still noteworthy that these two different logics of development can be discerned with clarity.

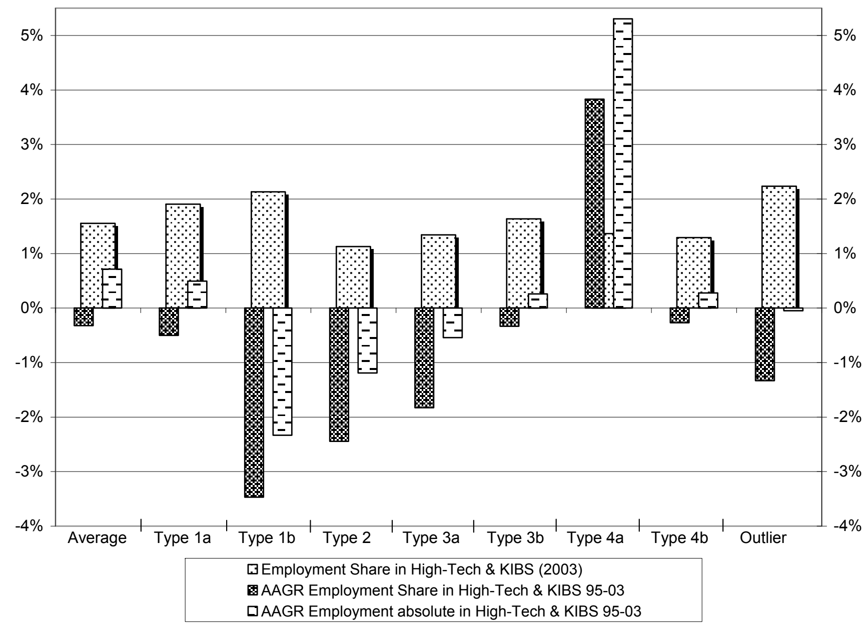
In the academic system, change is mostly evident for the less R&D-focused regions which started to build up capacities in the late 1990s and early 2000s. In general, the situation in the applied research system does not differ too much (with the exception of very high growth rates in the regions which are performing well anyway). Nevertheless, some differences can be identified in the field of high-tech patents where it seems that there are also catching-up tendencies for Type 3a regions, even if the gap between them and the broadly based R&D-driven regions is large.

IV.7 Strength of links between the research system and the overall socio-economic system

Another differentiating view of the regional types can be taken via the average share of employment in high-tech manufacturing industries (NACE 24.4, 30, 32, 33, 35.3) (figure 35). In this context, it is important to take into account that this indicator mirrors the *overall employment* in these knowledge-intensive branches rather than the number of personnel actually performing R&D. Consequently, it gives an indication of the *socio-economic leverage* research efforts can create in a given region, rather than providing knowledge about the current extent of research activities.

Due to a number of interfering factors (rationalisation, differences in capital intensity between different industrial branches) employment indicators have to be interpreted with caution, even though they provide valuable complementary information.

Figure 35: Employment share in high-tech industries, 2003 and its recent growth (1995-2003) by regional type[19]



Note: regional coverage limited to the regions included in the cluster analysis, share of employment: high-tech manufacturing (delineation Eurostat) employment as a share of overall employment in the region; coverage of years may vary according to availability of data.
Source: Regional Key Figures database, own compilation

[19] based on unweighted means, cf. Methodological note 4

Overall, the following statements can be made with a view to the average share of high-tech manufacturing employment and its development:

- The growth of the employment share in high-tech manufacturing industries is negative, except for public-sector-oriented regions with complementary R&D efforts. There seems to be a general tendency to reduce the relative share of employment in the high-tech manufacturing field, irrespective of the degree of R&D orientation in the region.
- In business-oriented R&D-driven regions, public-sector-centred R&D-supported regions and public-sector-oriented broadly based R&D-supported regions, there are negative growth rates even for absolute employment in the high-tech manufacturing sectors. In the outlier cases, they are close to zero.
- Among R&D-driven regions, growth of the relative share on employment is least negative in broadly based regions; pointing to an advantage resulting from a broadly based orientation of the regional research system.
- Among broadly based R&D-supported regions, the opposite is the case, as business-oriented broadly based R&D-supported regions display less negative growth rates than public-sector-oriented broadly based R&D-supported regions. In broadly based R&D-supported regions, a broad orientation of the business system does not seem to result in a higher growth of the share of the high-tech manufacturing fields in overall employment.
- Among regions with complementary R&D efforts, there is again a clear difference in favour of public-sector-oriented regions with complementary R&D efforts, which are the only ones where the relative importance of employment in the high-tech manufacturing fields increases rather than decreases. This statistical finding most likely mirrors the relocation of high-tech assembly and non-leading edge development tasks to the New Member States. Robust growth can, for example, be found in Hungary and parts of Romania.

In summary, the results indicate that it depends on the general level of development of the regional research system, which type of orientation (academic or applied research) results in a stronger increase (or lesser decrease) in employment. While both strong and very weak regions seem to profit from a broad orientation with elements from both public and business research, regions at a medium level of development seem to fare better when they are clearly oriented towards business research. Possibly, much of this can be interpreted as evidence of ERA-internal relocation of industrial research.

In this context, it must be pointed out that the development of (business sector) high-tech manufacturing industries' employment does not cover the employment effects that may have occurred in the public research or the higher education sector.

V Summary and conclusions

In summary, the analysis performed in this booklet comes to the following conclusions:

- The differences in R&D intensity among regional research systems are substantial. While multiple internal dynamics can be observed in the ERA, R&D intensity in the leading regions continues to increase, so that a significant internal differentiation is likely to persist.
- There is tentative evidence that regional R&D intensity is less volatile and less susceptible to general economic cycles when regional research system are less exclusively focused on business sector R&D. The most robust set-up seems to be a mixture of public and private activities.
- From many perspectives there is a tendency for weak research systems to catch up in terms of R&D intensity, albeit from low levels. This trend, however, was weakened in the course of the economic downturn from 2000-2003.
- Regarding patenting intensity, there is also a moderate catching-up trend between regions at the upper end of the scale.
- The trend of relative employment in high-tech manufacturing is often negative, pointing to the fact that the connection between the regional research and innovation systems are complex and not always present. The RKF data underline that even in a knowledge-driven economy, high-tech employment effects do not mirror the results of R&D investment alone. Currently, the re-location of high-tech manufacturing to the NMS and elsewhere (e.g. Asia) seems to superpose evidence of possible growth effects induced by R&D investment.

In summary, this first booklet has established two main findings of relevance for future policy-making. Firstly, is has conceptually defined the notion of regional research systems as units of reference for research policy-making. Secondly it has established a typology of such systems on the basis of available RKF data[20].

The conceptual section illustrates that research policy in the ERA needs to take into account the many dimensions of research beyond the utility-driven generation of knowledge to directly benefit innovation. Although the research and the innovation system are connected by a number of feed-back and feed-forward loops, the path from research to innovation is winding and subject to uncertainty. The same applies to the exchange of knowledge among different sub-sections of the research system itself, particularly between the more utility-driven and the more academic sections of the system. Undoubtedly, sub-sections of the European research system are driven by an internal logic different from that of the surrounding innovation system. Consequently, research policy needs to closely cooperate with both regional and innovation policy, yet maintain a distinctive perspective.

Moreover, the typology of regional research systems illustrates that the high degree of differentiation among regional research systems applies not only to regional R&D intensity, but also to the type of research effort undertaken and the type of research output generated. This suggests that different regional research systems perform different functions in the overall ERA system. This is not surprising as due to their cumulative nature knowledge-based activities are subject to economies of scale and scope and thus prone to agglomerate.

[20] The characteristics of these different regional types are presented in Table 5.

The multi-level network concept proposed for the ERA (cf. II and IV.1) nevertheless suggests that agglomeration and differentiation in the ERA system should not be seen as a negative. Much rather, a regional division of tasks within the ERA is both natural and desirable.

Unfortunately, however, the available RKF data do not permit us to directly investigate into or even map the complex networks of knowledge linking functionally differentiated regions in the ERA.

Nonetheless, the analysed RKF data is consistent with the notion of inter-regional feedback loops within the ERA in a number of ways:

Firstly, business data underline that business actors in a number of leading regions control and finance research activities performed beyond the borders of the region (but within the ERA). The near absence of research activities in a number of regions, in contrast, suggests that other regional research systems in the ERA remain dependent on the inflow of external knowledge.

Secondly, the degree of embeddedness into the regional socio-economic system seems to differ, depending on the orientation of the local innovation system: Mostly science-oriented research systems, which follow the internal logic of academic science in both operation and funding, are less responsive to general growth trends in R&D expenditure. Academic R&D seems to be less susceptible to economic cycles than other sub-sections of the research system.

Thirdly, cross-section analysis suggests that linkages between the academic and the utility-driven research system are not necessarily present at NUTS 2 level. While input-output correlations are clearly present at NUTS 2 level within each of these systems, they are far more obvious at the NUTS 1 level.

Consequently, it can be concluded that regional research systems are not self-contained entities, but intricately linked with their national research systems and, increasingly, the overall ERA. The findings support the notion that different, distinct inter-regional networks of knowledge exchange exist in parallel and that not all these networks are necessarily interfaced in all regions.

Regional research systems are thus best managed based on the notion that many regional actors are embedded in inter-regional networks of control and knowledge exchange and likely to react based on that logic. The useful understanding of term "regional research system" would be that of a node in an inter-regional research system anchored within a region.

In general terms, thus, the booklet has soundly established that efficient research policy-making needs to adapt to the particular initial conditions in the individual regions where it is to be applied. Due to the diversity and internal differentiation of the ERA, research policy can serve many, quite different purposes.

In leading regions, research policy has a key, prospective function to shape scientific and technological development. It is of utmost importance to ensure the future competitiveness of Europe’s leading research performers that operate at the technological frontier. Moreover, at these hubs of the ERA network, research policy has the opportunity to influence the development far beyond the region itself.

A second key point, however, is to ensure that research policy performs a supporting function. This applies to many ERA regions which may not be leading in knowledge generation, but are nonetheless capable of generating relevant knowledge input, both for the ERA and their own regional research and innovation system. To support the forging of localised linkages between the business and the public research sector is therefore a key issue throughout the ERA. The data clearly suggest that it is a key challenge for research policy to prevent the disconnection of the academic and the utility-driven side of the research system, different in internal logic as they may be.

Thirdly, there are undoubtedly some regions in the ERA in which R&D intensity is so far quite low. Even in such a context, however, research policy can play a significant role. As an important first step, external support and mutual learning can enable these regions to build up the relevant capacities and competences to integrate into and to profit from the inter-regional knowledge flows in the multi-level network of the ERA.

Finally, this study supports the notion that research policy should aim to reinforce networking between regional research systems to enable the overall ERA system to benefit from the regional division of tasks. To achieve this, freedom of knowledge exchange and mobility of human capital ("5th freedom") should be high on the agenda.

It should be emphasised that the analysis indicates that the division of tasks between regional research systems evolves dynamically. An increase in mobility may thus not only reaffirm the existing regional disparities but also help to dynamically shape the system to its overall benefit. The presented typology is in this sense an assessment of the status quo which will very likely look different in five years' time. Even though the general hub and spoke networks within the ERA show a certain persistence it is unlikely that many regions will continue to perform the exact same function in the long run.

An adapted research policy can therefore help very different regions to evolve to their own benefit and to that of the overall ERA. This, however, remains a challenging task requiring a great deal of sensitivity to the local context, which goes far beyond the mere identification of starting conditions. In this booklet, therefore, only general policy conclusions could be drawn as it did not yet reflect the policy side of local framework conditions.

Table 5: Overview of the average characteristics of the regions by regional type[21]

	Average	Type 1a	Type 1b	Type 2	Type 3a	Type 3b	Type 4a	Type 4b	Outlier
GERD absolute € million 2003 (UK 1999)	**924**	**3118**	**2401**	**775**	**729**	**1028**	**2289**	**163**	**3783**
AAGR GERD as % of GDP 95-99	2.91	1.21	1.15	-2.59	1.10	2.84	3.83	11.20	2.35
AAGR GERD as % of GDP 00-03	1.02	1.71	0.97	0.01	2.02	0.74	0.58	0.74	1.90
BERD absolute € million 2003	**531**	**2234**	**1666**	**325**	**428**	**765**	**69**	**123**	**3177**
AAGR BERD as % of GDP 95-99	6.13	1.43	3.36	3.63	-0.28	2.68	17.49	9.53	2.72
AAGR BERD as % of GDP 00-03	1.01	1.78	1.13	-3.59	3.40	-0.16	-0.42	2.72	3.55
Publication Intensity 2003	**910**	**1617**	**2561**	**2393**	**917**	**621**	**466**	**224**	**1498**
AAGR Publication Intensity 1995-2003	10.18	7.54	6.97	8.35	8.02	8.06	13.91	11.53	7.10
Patent Intensity 2001	**122**	**284**	**445**	**114**	**89**	**176**	**17**	**59**	**580**
AAGR Patent Intensity 1995-2001	12.06	9.50	9.68	7.29	10.04	9.78	15.90	13.56	14.10
High-tech Patent Intensity 2001	**23**	**56**	**117**	**21**	**12**	**20**	**2**	**6**	**179**
AAGR High-tech Patent Intensity 1995-2001	33.23	21.11	18.35	20.92	28.85	21.14	50.92	35.44	23.25
Employment Share in High-tech Manufacturing	**1.6**	**1.9**	**2.1**	**1.1**	**1.3**	**1.6**	**1.4**	**1.3**	**2.2**
AAGR Employment Share in High-tech Man. 1995-2003	-0.32	-0.50	-3.47	-2.44	-1.83	-0.34	3.83	-0.27	-1.33
AAGR Employment absolute in High-tech Man. 1995-2003	0.71	0.49	-2.33	-1.19	-0.54	0.26	5.30	0.28	-0.05

Note: regional coverage limited to the regions included in the cluster analysis
Source: Regional Key Figures database, own compilation

[21] based on unweighted means, see Methodological note 4

Annex

TableAnnex 1: Distances between the different mathematical clusters

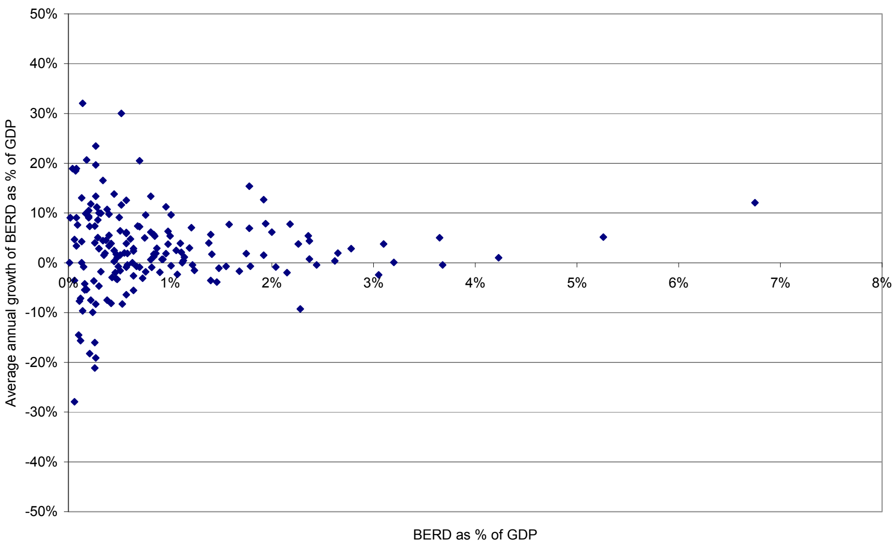
Cluster	1	2	3	4	5	6	7	8
1		2.13	2.08	2.96	3.46	2.94	4.00	2.87
2	2.13		2.62	2.56	3.69	1.80	2.73	3.79
3	2.08	2.62		1.49	1.50	2.94	4.77	1.46
4	2.96	2.56	1.49		1.51	2.19	4.19	2.78
5	3.46	3.69	1.50	1.51		3.66	5.64	2.12
6	2.94	1.80	2.94	2.19	3.66		2.04	4.25
7	4.00	2.73	4.77	4.19	5.64	2.04		6.02
8	2.87	3.79	1.46	2.78	2.12	4.25	6.02	

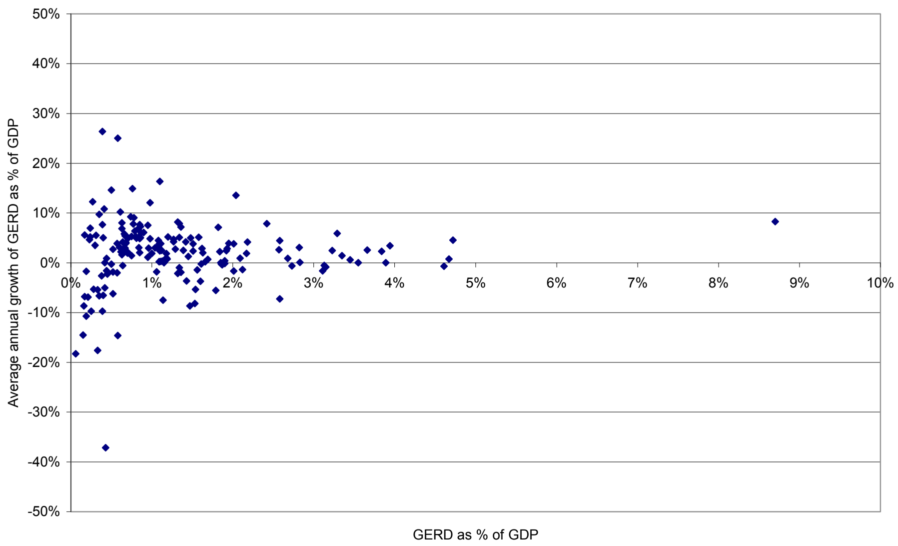
Table A1 shows the distances between the different mathematical clusters technically resulting from the cluster analysis.

- As clusters 3 and 4 are quite close to each other, they were associated in one general regional type.
- As clusters 2 and 6 are quite close to each other, they were merged into one regional sub-type.
- As clusters 6 and 7 are quite close to each other and cluster 2, all three were associated in one general regional type.
- As clusters 5 and 8 are quite close to each other, they were associated in one general regional type.

As the table showed, one could argue in favour of other associations of clusters e.g., cluster 5 with clusters 3 and 4 instead of cluster 8 or clusters 3 and 8 instead of clusters 5 and 8. However, a closer look at the data reveals that an unambiguous decision cannot be made. The decisive question is if one takes general research potential (as measured by GERD as % of GDP) or structure of the system as the guiding principle. Based on the elaborated theoretical considerations, we decided to look at general research potential (i.e. potential role within the ERA context) first and internal structure second. Additionally, our decision is based on detailed observations as to which groups of regions remained most associated (i.e. which groups remained most stable) when different models of iteration or different starting points for iteration were used.

FigureAnnex 1: R&D intensity vs. average annual growth rate of business R&D intensity (left: business R&D intensity, right: total R&D intensity)

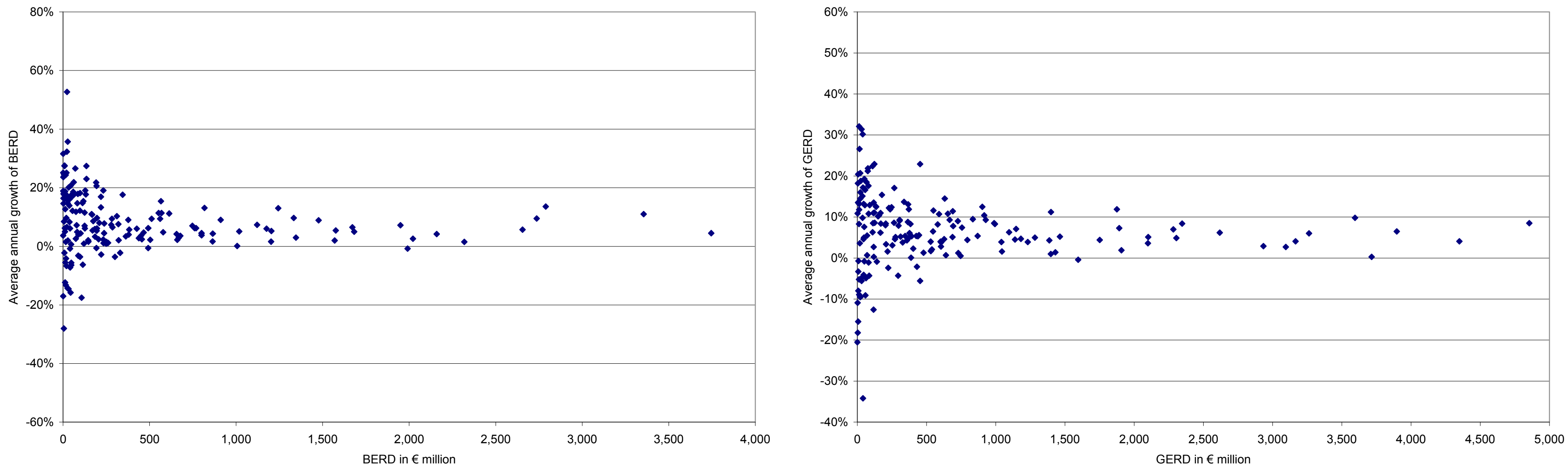




Source: Regional Key Figures database

The data clearly show that the **variations in growth are higher among regions with lower R&D intensities**. A clear numerical threshold, however, cannot be determined. Against the background of the known regional diversity in regional and national institutional set-ups, as well as constellations of local actors, there is no reason to assume that any critical mass will be reached across the board at a pre-determined numerical level. Nonetheless, the overall tendency becomes quite obvious with regard to the scatter plots. The issue of inter-temporal volatility will be explored in the following booklets.

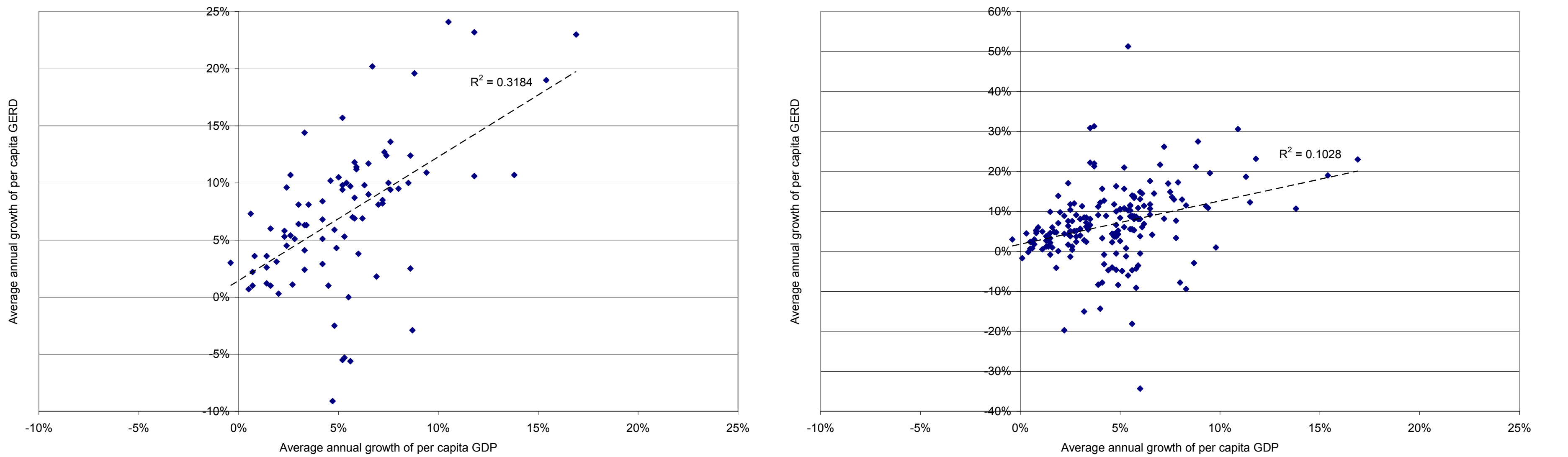
FigureAnnex 2: R&D expenditure vs. average annual growth of R&D expenditure (left: business expenditure, right: total R&D expenditure)



Note: without Île-de-France, Oberbayern, Stuttgart; growth rates from 1995-2003 (subject to availability)
Source: Regional Key Figures database

The data clearly show that the **variations in growth are higher among regions with lower overall expenditures on R&D**. A clear numerical threshold, however, cannot be determined. Against the background of the known regional diversity in regional and national institutional set-ups, as well as constellations of local actors, there is no reason to assume that any critical mass will be reached across the board at a pre-determined numerical level. Nonetheless, the overall tendency becomes quite obvious with regard to the scatter plots. The issue of inter-temporal volatility will be explored in the following booklets.

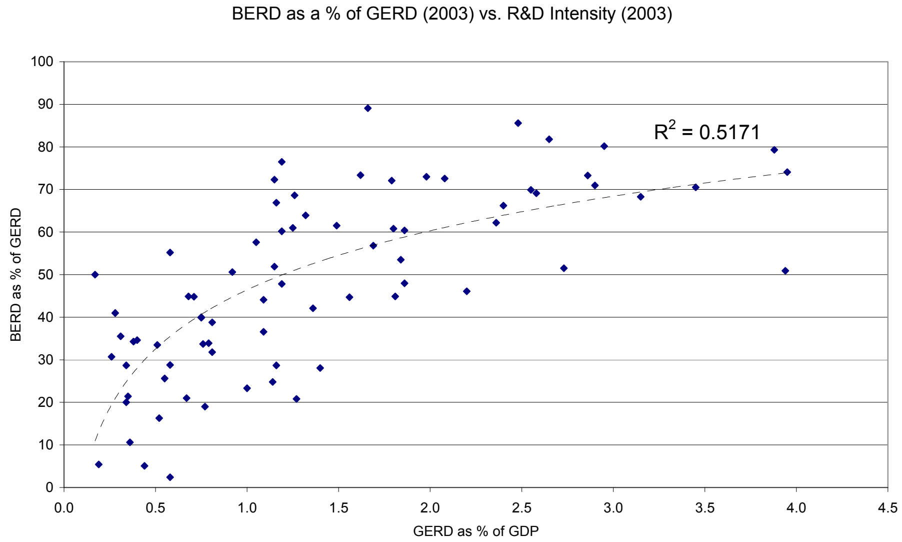
FigureAnnex 3: Av. Annual growth of GERD per capita vs. av. annual growth of GDP per capita, 1995-2003 (left: NUTS 1 level, right: NUTS 2 level)

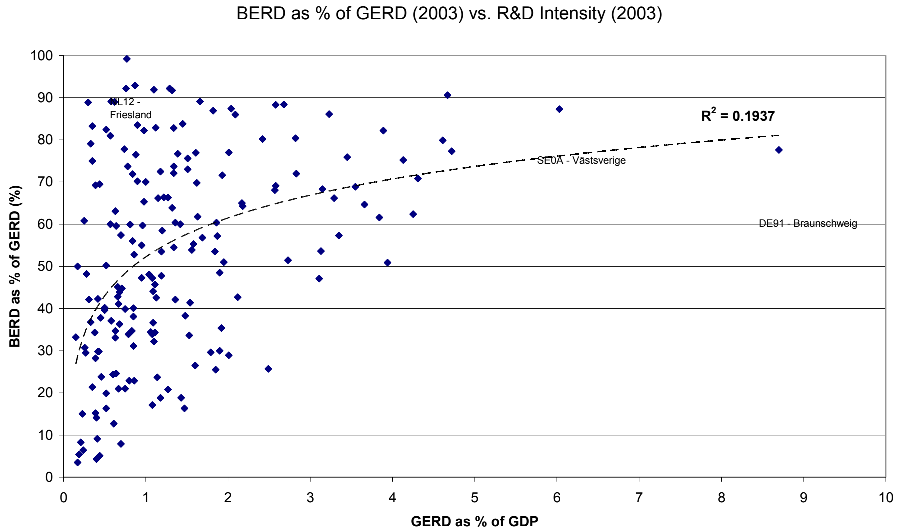


Notes: periods covered for growth rate calculation may differ in single cases due to data availability
Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

FigureAnnex 4: BERD as % of GERD vs. R&D intensity (2003) (left: NUTS 1 level, right: NUTS 2 level)

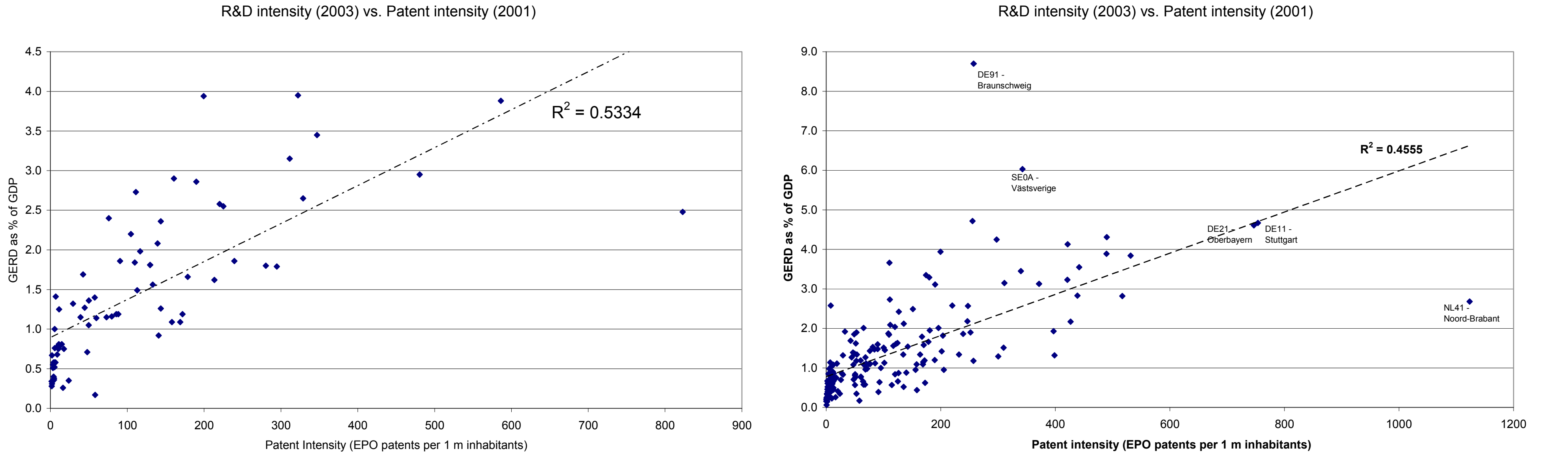




Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

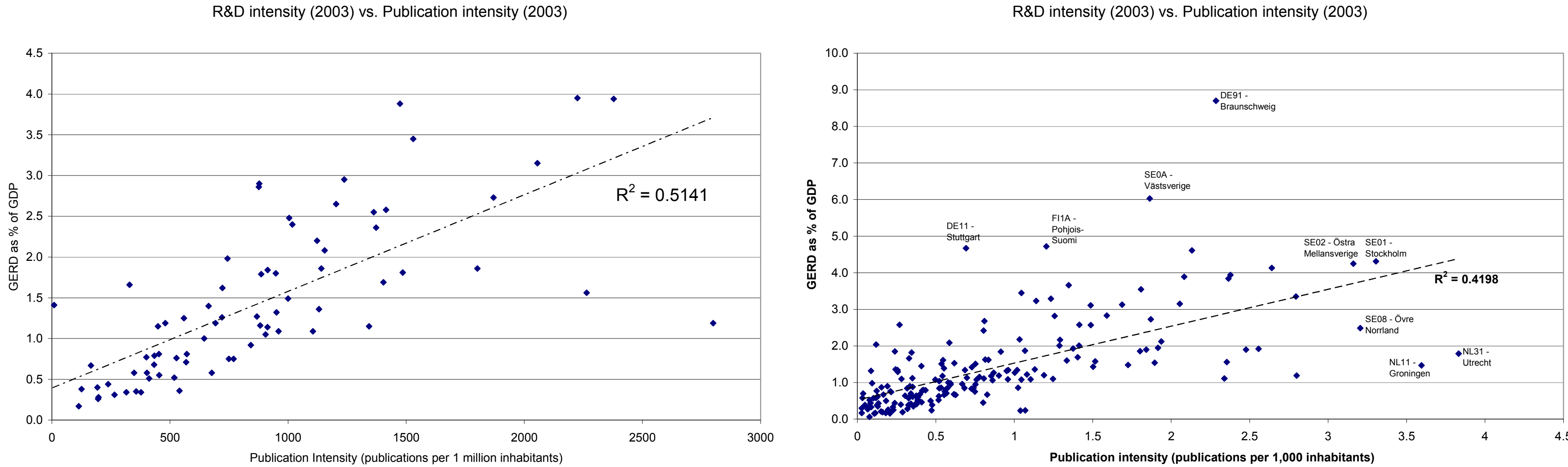
FigureAnnex 5: R&D intensity (2003) vs. patent intensity (2001) (left: NUTS 1 level, right: NUTS 2 level)



Note: Due to the fact that patents which enter the national total of applications via the PCT procedure can take up to 30 months to be accounted for, patent figures have to be considered preliminary for the last two technically available years. Meaningful patent data can therefore only be presented for 2001, even though 2002 and 2003 data are technically available.
Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

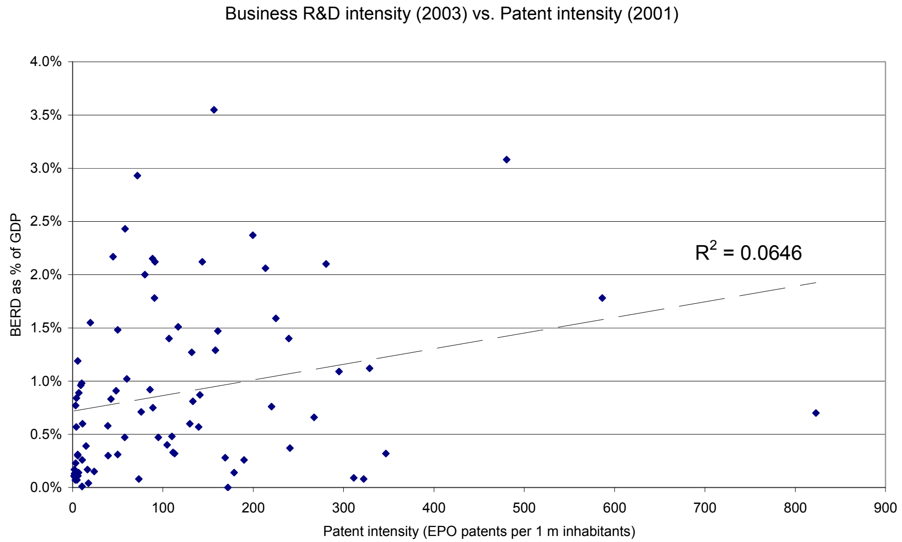
FigureAnnex 6: R&D intensity vs. publication intensity, 2003 (left: NUTS 1 level, right: NUTS 2 level)

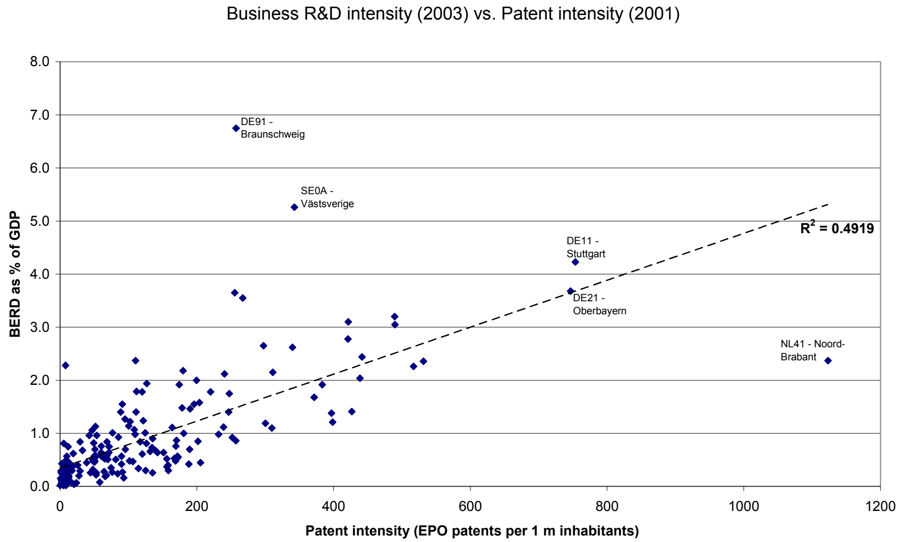


Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

FigureAnnex 7: Business R&D intensity (2003) vs. patent intensity (2001) (left: NUTS 1 level, right: NUTS 2 level)

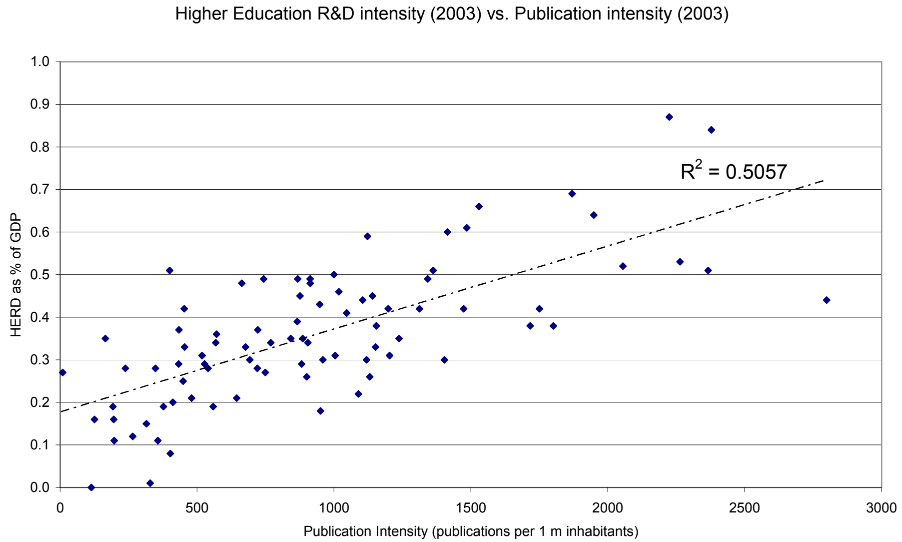


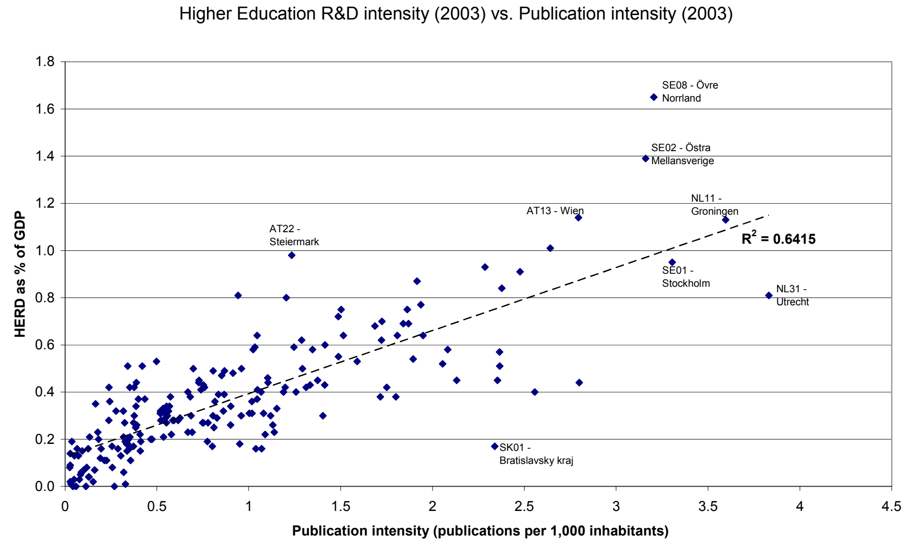


Note: Due to the fact that patents which enter the national total of applications via the PCT procedure can take up to 30 months to be accounted for, patent figures have to be considered preliminary for the last two technically available years. Meaningful patent data can therefore only be presented for 2001, even though 2002 and 2003 data are technically available.
Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

FigureAnnex 8: Higher education R&D intensity vs. publication intensity, 2003 (left: NUTS 1 level, right: NUTS 2 level)

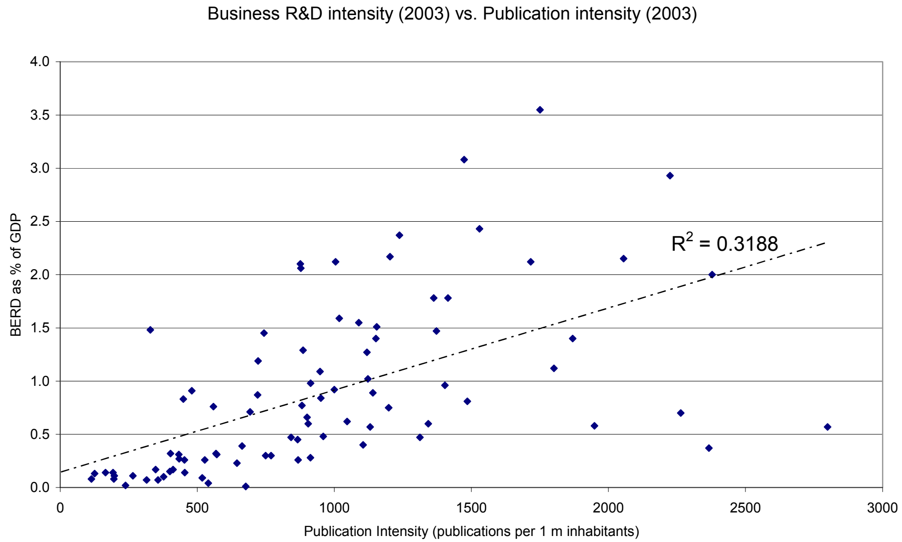


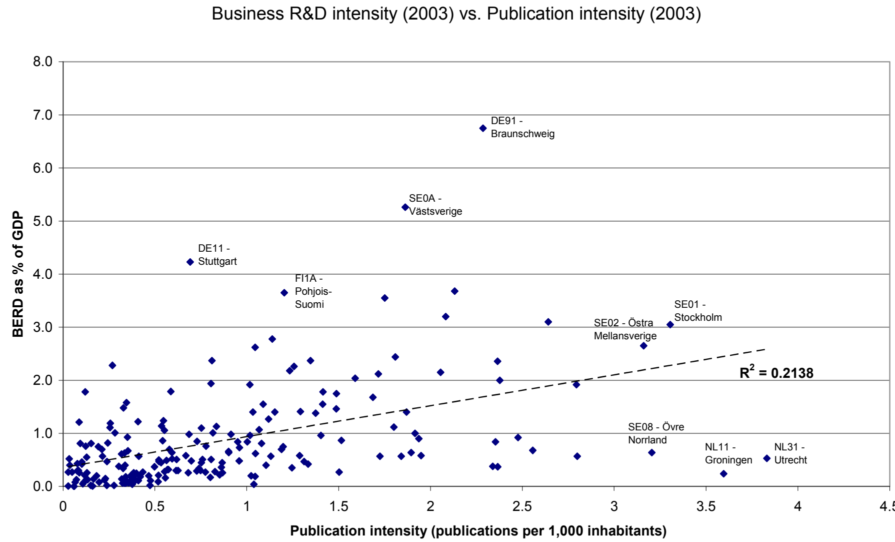


Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

FigureAnnex 9: Business R&D intensity vs. publication intensity, 2003 (left: NUTS 1 level, right: NUTS 2 level)

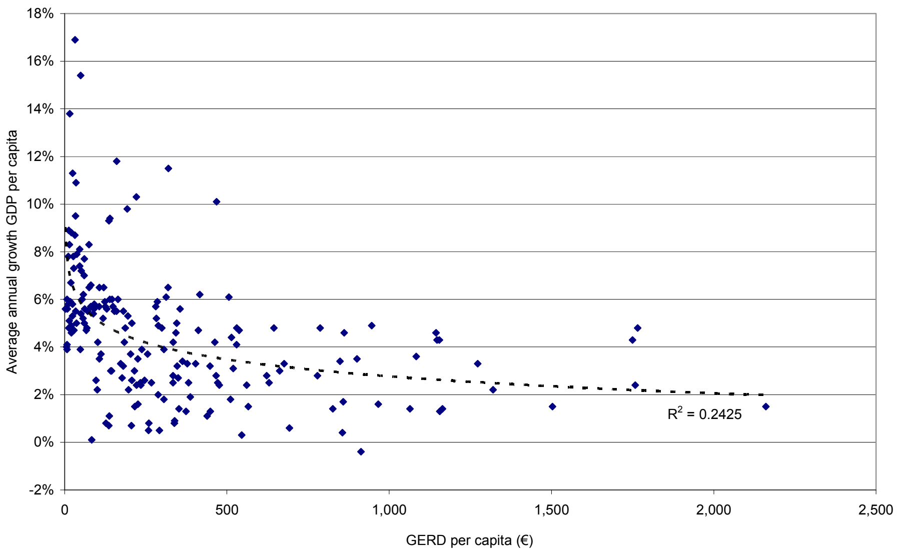




Source: Regional Key Figures database

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model. To clarify this notion, correlation coefficients and significance levels have not been included.

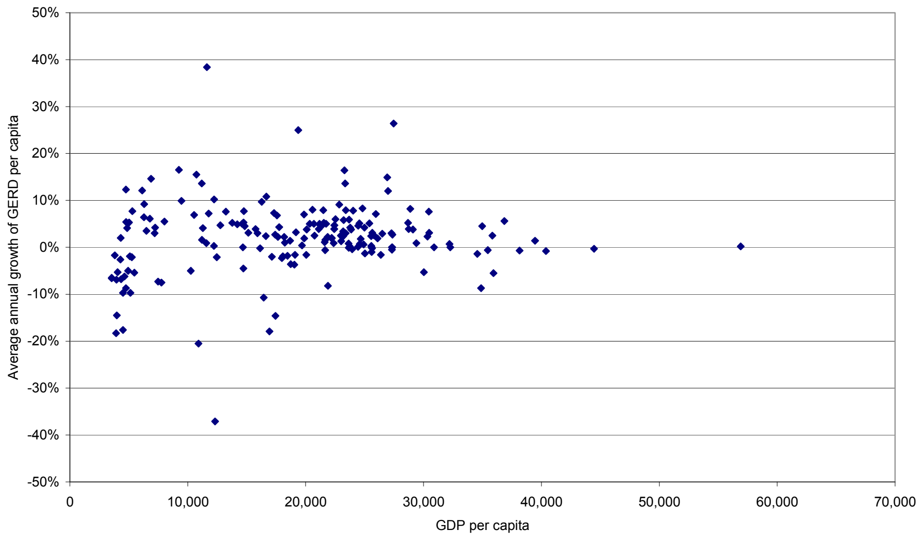
FigureAnnex 10: GDP per capita growth vs. GERD per capita, 2003



Source: Regional Key Figures database; growth rates from 1995-2003 (subject to availability)

Given the high differentiation of regional research systems and the presence of outliers, R^2 values should in the context be read as general indications of contingencies rather than the result of a stable bi-variate model.

FigureAnnex 11: GERD per capita growth vs. GDP per capita, 2003



Source: Regional Key Figures database; growth rates from 1995-2003 (subject to availability)

TableAnnex 2: List of the NUTS 2 regions – as used in the Regional Key Figures database

BE10 - Région de Bruxelles-Capitale/	DE26 - Unterfranken	GR11 - Anatoliki Makedonia, Thraki	FR24 - Centre
Brussels Hoofdstedelijk Gewest	DE27 - Schwaben	GR12 - Kentriki Makedonia	FR25 - Basse-Normandie
BE21 - Prov. Antwerpen	DE30 - Berlin	GR13 - Dytiki Makedonia	FR26 - Bourgogne
BE22 - Prov. Limburg (B)	DE41 - Brandenburg - Nordost	GR14 - Thessalia	FR30 - Nord - Pas-de-Calais
BE23 - Prov. Oost-Vlaanderen	DE42 - Brandenburg - Südwest	GR21 - Ipeiros	FR41 - Lorraine
BE24 - Prov. Vlaams Brabant	DE50 - Bremen	GR22 - Ionia Nisia	FR42 - Alsace
BE25 - Prov. West-Vlaanderen	DE60 - Hamburg	GR23 - Dytiki Ellada	FR43 - Franche-Comté
BE31 - Prov. Brabant Wallon	DE71 - Darmstadt	GR24 - Sterea Ellada	FR51 - Pays de la Loire
BE32 - Prov. Hainaut	DE72 - Gießen	GR25 - Peloponnisos	FR52 - Bretagne
BE33 - Prov. Liège	DE73 - Kassel	GR30 - Attiki	FR53 - Poitou-Charentes
BE34 - Prov. Luxembourg (B)	DE80 - Mecklenburg-Vorpommern	GR41 - Voreio Aigaio	FR61 - Aquitaine
BE35 - Prov. Namur	DE91 - Braunschweig	GR42 - Notio Aigaio	FR62 - Midi-Pyrénées
BG31 - Severozapaden	DE92 - Hannover	GR43 - Kriti	FR63 - Limousin
BG32 - Severen tsentralen	DE93 - Lüneburg	ES11 - Galicia	FR71 - Rhône-Alpes
BG33 - Severoiztochen	DE94 - Weser-Ems	ES12 - Principado de Asturias	FR72 - Auvergne
BG34 - Yugoiztochen	DEA1 - Düsseldorf	ES13 - Cantabria	FR81 - Languedoc-Roussillon
BG41 - Yugozapaden	DEA2 - Köln	ES21 - Pais Vasco	FR82 - Provence-Alpes-Côte d'Azur
BG42 - Yuzhen tsentralen	DEA3 - Münster	ES22 - Comunidad Foral de Navarra	FR83 - Corse
CZ01 - Praha	DEA4 - Detmold	ES23 - La Rioja	FR91 - Guadeloupe
CZ02 - Strední Cechy	DEA5 - Arnsberg	ES24 - Aragón	FR92 - Martinique
CZ03 - Jihozápad	DEB1 - Koblenz	ES30 - Comunidad de Madrid	FR93 - Guyane
CZ04 - Severozápad	DEB2 - Trier	ES41 - Castilla y León	FR94 - Réunion
CZ05 - Severovýchod	DEB3 - Rheinhessen-Pfalz	ES42 - Castilla-la Mancha	ITC1 - Piemonte
CZ06 - Jihovýchod	DEC0 - Saarland	ES43 - Extremadura	ITC2 - Valle d'Aosta/Vallée d'Aoste
CZ07 - Strední Morava	DED1 - Chemnitz	ES51 - Cataluña	ITC3 - Liguria
CZ08 - Moravskoslezsko	DED2 - Dresden	ES52 - Comunidad Valenciana	ITC4 - Lombardia
DK00 - Danmark	DED3 - Leipzig	ES53 - Illes Balears	ITD1 - Provincia Autonoma Bolzano-
DE11 - Stuttgart	DEE1 - Dessau	ES61 - Andalucia	Bozen
DE12 - Karlsruhe	DEE2 - Halle	ES62 - Región de Murcia	ITD2 - Provincia Autonoma Trento
DE13 - Freiburg	DEE3 - Magdeburg	ES63 - Ciudad Autónoma de Ceuta	ITD3 - Veneto
DE14 - Tübingen	DEF0 - Schleswig-Holstein	ES64 - Ciudad Autónoma de Melilla	ITD4 - Friuli-Venezia Giulia
DE21 - Oberbayern	DEG0 - Thüringen	ES70 - Canarias	ITD5 - Emilia-Romagna
DE22 - Niederbayern	EE00 - Estonia	FR10 - Île de France	ITE1 - Toscana
DE23 - Oberpfalz	IE01 - Border, Midlands and Western	FR21 - Champagne-Ardenne	ITE2 - Umbria
DE24 – Oberfranken	IE02 - Southern and Eastern	FR22 – Picardie	ITE3 - Marche
DE25 - Mittelfranken		FR23 - Haute-Normandie	ITE4 - Lazio

List of the NUTS 2 Regions (continued)

ITF1 - Abruzzo ITF2 - Molise ITF3 - Campania ITF4 - Puglia ITF5 - Basilicata ITF6 - Calabria ITG1 - Sicilia ITG2 - Sardegna CY00 - Cyprus LV00 - Latvia LT00 - Lithuania LU00 - Luxembourg (Grand-Duché) HU10 - Közép-Magyarország HU21 - Közép-Dunántúl HU22 - Nyugat-Dunántúl HU23 - Dél-Dunántúl HU31 - Észak-Magyarország HU32 - Észak-Alföld HU33 - Dél-Alföld MT00 - Malta NL11 - Groningen NL12 - Friesland (NL) NL13 - Drenthe NL21 - Overijssel NL22 - Gelderland NL23 - Flevoland NL31 - Utrecht NL32 - Noord-Holland NL33 - Zuid-Holland NL34 - Zeeland NL41 - Noord-Brabant NL42 - Limburg (NL) AT11 - Burgenland (A) AT12 - Niederösterreich AT13 - Wien AT21 - Kärnten	AT22 - Steiermark AT31 - Oberösterreich AT32 - Salzburg AT33 - Tirol AT34 - Vorarlberg PL11 - Lódzkie PL12 - Mazowieckie PL21 - Malopolskie PL22 - Slaskie PL31 - Lubelskie PL32 - Podkarpackie PL33 - Swietokrzyskie PL34 - Podlaskie PL41 - Wielkopolskie PL42 - Zachodniopomorskie PL43 - Lubuskie PL51 - Dolnoslaskie PL52 - Opolskie PL61 - Kujawsko-Pomorskie PL62 - Warminsko-Mazurskie PL63 - Pomorskie PT11 - Norte PT15 - Algarve PT16 - Centro (PT) PT17 - Lisboa PT18 - Alentejo PT20 - Região Autónoma dos Açores PT30 - Região Autónoma da Madeira RO11 - Nord-Vest RO12 - Centru RO21 - Nord-Est RO22 - Sud-Est RO31 - Sud - Muntenia RO32 - Bucuresti - Ilfov RO41 - Sud-Vest Oltenia RO42 - Vest	SI00 - Slovenija SK01 - Bratislavský kraj SK02 - Západné Slovensko SK03 - Stredné Slovensko SK04 - Východné Slovensko FI13 - Itä-Suomi FI18 - Etelä-Suomi FI19 - Länsi-Suomi FI1A - Pohjois-Suomi FI20 - Åland SE01 - Stockholm SE02 - Östra Mellansverige SE04 - Sydsverige SE06 - Norra Mellansverige SE07 - Mellersta Norrland SE08 - Övre Norrland SE09 - Småland med öarna SE0A - Västsverige UKC1 - Tees Valley and Durham UKC2 - Northumberland, Tyne and Wear UKD1 - Cumbria UKD2 - Cheshire UKD3 - Greater Manchester UKD4 - Lancashire UKD5 - Merseyside UKE1 - East Yorkshire and Northern Lincolnshire UKE2 - North Yorkshire UKE3 - South Yorkshire UKE4 - West Yorkshire UKF1 - Derbyshire and Nottinghamshire UKF2 - Leicestershire, Rutland and Northants UKF3 - Lincolnshire	UKG1 - Herefordshire, Worcestershire and Warks UKG2 - Shropshire and Staffordshire UKG3 - West Midlands UKH1 - East Anglia UKH2 - Bedfordshire, Hertfordshire UKH3 - Essex UKI1 - Inner London UKI2 - Outer London UKJ1 - Berkshire, Bucks and Oxfordshire UKJ2 - Surrey, East and West Sussex UKJ3 - Hampshire and Isle of Wight UKJ4 - Kent UKK1 - Gloucestershire, Wiltshire and Bristol/Bath area UKK2 - Dorset and Somerset UKK3 - Cornwall and Isles of Scilly UKK4 - Devon UKL1 - West Wales and The Valleys UKL2 - East Wales UKM1 - North Eastern Scotland UKM2 - Eastern Scotland UKM3 - South Western Scotland UKM4 - Highlands and Islands UKN0 - Northern Ireland

TableAnnex 3: List of the NUTS 1 Regions – as used in the Regional Key Figures database

BE1 – Région de Bruxelles–Capitale/ Brussels Hoofdstedelijk Gewest BE2 – Vlaams Gewest BE3 – Région Wallonne BG3 – Severna i iztochna Bulgaria BG4 – Yugozapadna i yuzhna centralna Bulgaria CZ0 – Czech Republic DK0 – Denmark DE1 – Baden–Württemberg DE2 – Bayern DE3 – Berlin DE4 – Brandenburg DE5 – Bremen DE6 – Hamburg DE7 – Hessen DE8 – Mecklenburg–Vorpommern DE9 – Niedersachsen DEA – Nordrhein–Westfalen DEB – Rheinland–Pfalz DEC – Saarland DED – Sachsen DEE – Sachsen–Anhalt DEF – Schleswig–Holstein DEG – Thüringen EE0 – Estonia IE0 – Ireland GR1 – Voreia Ellada GR2 – Kentriki Ellada GR3 – Attiki GR4 – Nisia Aigaiou, Kriti ES1 – Noroeste ES2 – Noreste ES3 – Comunidad de Madrid ES4 – Centro (ES) ES5 – Este ES6 – Sur ES7 – Canarias (ES)	FR1 – Île de France FR2 – Bassin Parisien FR3 – Nord – Pas–de–Calais FR4 – Est FR5 – Ouest FR6 – Sud–Ouest FR7 – Centre–Est FR8 – Méditerranée FR9 – French overseas departments ITC – Nord Ovest ITD – Nord Est ITE – Centro (IT) ITF – Sud (IT) ITG – Isole (IT) CY0 – Cyprus LV0 – Latvia LT0 – Lithuania LU0 – Luxembourg (Grand–Duché) HU1 – Közép–Magyarország HU2 – Dunántúl HU3 – Alföld és Észak MT0 – Malta NL1 – Noord–Nederland NL2 – Oost–Nederland NL3 – West–Nederland NL4 – Zuid–Nederland AT1 – Ostösterreich AT2 – Südösterreich AT3 – Westösterreich PL1 – Centralny PL2 – Poludniowy PL3 – Wschodni PL4 – Pólnocno–Zachodni PL5 – Poludniowo–Zachodni PL6 – Pólnocny PT1 – Continente PT2 – Região Autónoma dos Açores	PT3 – Região Autónoma da Madeira RO1 – Macroregiunea unu RO2 – Macroregiunea doi RO3 – Macroregiunea trei RO4 – Macroregiunea patru SI0 – Slovenia SK0 – Slovakia FI1 – Manner–Suomi FI2 – Åland SE0 – Sverige UKC – North East (England) UKD – North West (England) UKE – Yorkshire and the Humber UKF – East Midlands (England) UKG – West Midlands (England) UKH – Eastern UKI – London UKJ – South East UKK – South West (England) UKL – Wales UKM – Scotland UKN – Northern Ireland

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