

Monitoring sector specialisation of public and private funded business research and development

Michael Dinges, Martin Berger, Rainer Frietsch and Aris Kaloudis

This article investigates whether sector-specific research and development (R&D) specialisation indices are a useful device for R&D policy analysis. We first conceptualise R&D specialisation, and then discuss the usability and limitations of a quantitative benchmarking approach by displaying specialisation indices for Austria, Germany and Norway. We show that the extent of correlation between public and private R&D funding specialisation in firms varies considerably between countries. Reasons for specific specialisation patterns are to be found in government funding decisions and strategies, such as the role of bottom-up research funding or the relevance of defence R&D. Limitations in data availability and lack of appropriate classifications require a combination of quantitative and qualitative measures in order to understand better existing R&D specialisation patterns.

SECTORAL CONSIDERATIONS have always been important in public R&D policy. After World War II, science and technology (S&T) policy was largely dominated by a traditional mission orientation in the areas of (nuclear) energy, space and defence technologies. At this time, the

widespread diffusion and private application of research results played only a minor role in the definition of the mission.

Since the mid-1960s, the promotion of 'key technologies' with considerable commercial potential in many industries (such as information and communications technologies (ICT) in general, new materials or semiconductors) played a prominent role in national R&D policies (Gassler *et al.*, 2006). For the USA, the expansion to civilian key technologies' was seen as an appropriate measure to make use of large public research infrastructures created in the 1950s; for countries such as Germany, France and Japan, which perceived a technology gap relative to the USA, civilian key technologies were seen to initiate a sustainable catching-up process (Bruder, 1986; Giersch, 1987; Fier, 2002: 36 and following; Mowery, 1994: 222 and following).

Nowadays, thematic priorities are again high on the political agenda. The 'new missions' and priorities in S&T policy include life sciences, ICT, nanotechnology, environmental technologies and 'security related' research. Thematic priorities can be found in almost all industrial countries next to generic measures focusing on functional priorities,

Michael Dinges (corresponding author) and Martin Berger are at Joanneum Research Forschungsgesellschaft mbH, Institute of Technology and Regional Policy, Haus der Forschung, Sensengasse 1, 1090 Wien, Austria; Email: michael.dinges@joanneum.at; Tel: +43 1 5817520 2813; Fax: +43 1 5817520 2820. Rainer Frietsch is at Fraunhofer-Institut für System- und Innovationsforschung (ISI), Breslauer Straße 48, D-76139 Karlsruhe, Germany. Aris Kaloudis is at NIFU STEP, Studies in Innovation, Research and Education, Wergelandsveien 7, N-0167 Oslo, Norway.

This article rests on the results of a feasibility study on public R&D specialisation conducted within the framework of the ERAWATCH Network (<http://cordis.europa.eu/erawatch/>). ERAWATCH is jointly carried out by the EC's Directorates-General for Research and Joint Research Centre/IPTS in collaboration with CORDIS. The views expressed in this article are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission or the Joint Research Centre/IPTS.

Michael Dinges is a researcher and project manager at Joanneum Research, Institute of Technology and Regional Policy in Vienna, where he is in charge of the thematic field 'Evaluations'. He graduated from the University of Vienna with a degree in economics. His main areas of expertise are: evaluation methods; technology and innovation policy; S&T indicators; and transition economics.

Martin Berger is an economic geographer who has worked as a researcher at the Institute of Technology and Regional Policy, Joanneum Research in Vienna, Austria since 2005. Previously, he was a research fellow and lecturer at Kiel University, Germany and a visiting researcher at the National Science and Technology Development Agency in Bangkok, Thailand. He received his PhD for research on "Upgrading the system of innovation in late-industrialising countries: the role of transnational corporations in Thailand's manufacturing sector". Current research interests include the internationalisation of R&D and the development of innovation systems in emerging (Asian) economies.

Aris Kaloudis is Head of Research for the area Students and the Academic Work Force at NIFU-STEP, in Oslo. He graduated from the University of Oslo in economics (cand. oecon.) and holds a Master of Arts in Science and Technology Studies from University of Oslo and University Louis Pasteur, Strasbourg (ESST programme). His main areas of expertise are research and innovation policy, R&D programme evaluations, EU-research policy, analysis of RTD Framework programmes.

Rainer Frietsch is researcher at Fraunhofer Institute for Systems and Innovation Research in Karlsruhe. He finished a commercial training in wholesale and export trades, before studying social sciences at the University of Mannheim, Germany, where he placed particular emphasis on sociology and statistical methods. His work focuses on science and technology indicators, and above all on patent statistics. He is doing empirical social and economic research, with emphasis on the connection between the education and the innovation systems.

such as the promotion of collaborations, high-tech start-ups and regional networks, which emerged at the beginning of the 1990s as part of a system of innovation approach to technology policy (Rammer, 2006).

Research so far suggests that some economic sectors have considerable potential for productivity growth. For example, for the electronics sector, Amable (2000) demonstrates that inter-industry specialisation and comparative advantage in electronics have a positive influence on productivity growth using a comparative advantage trade model. Tshipouri (2001) argues that, in countries with a productive structure that demonstrates a high specialisation in electronics, ICT, early life-cycles, capital goods and specialised industries, we would expect R&D to contribute more to growth than in other countries.

However, despite the relevance of certain industries for economic growth on the one hand, and the relatively close nexus between thematic priorities in S&T policy and economic sectors on the other hand, very little is known about which economic sectors are affected most by public research support measures at a country level. Sectoral aspects have been fairly neglected in quantitative public R&D policy analysis and we know little about the fit between

public R&D support of firms and private R&D specialisation. Therefore, we seek to sketch possible ways to analyse public support of R&D in firms. Our primary research questions are:

- Are sector-specific R&D specialisation indices a useful device to contribute to the analyses of R&D policy ultimately aiming to enhance the efficiency and effectiveness of public R&D policies so as to support business R&D?
- Is there an interrelation between public and private funding of R&D in firms in a selection of European countries? What can we learn from such specialisation patterns?
- What are the limitations of the proposed approach, which relies on a benchmarking approach that is built around a concept of R&D specialisation and uses international available data sources?

For the purposes of the analysis, we structure the paper as follows. We attempt to conceptualise R&D specialisation. Displaying the general notion of a national R&D system we outline the perspectives from which we can look at R&D specialisation.

Having defined the concept of R&D specialisation, we discuss the constituent factors for analysing the structure of public and private R&D specialisation in firms' R&D. Therefore, we discuss in particular the availability of data sources, which allow the tracing of thematic/sectoral R&D specialisation. We explain the opportunities and the drawbacks of a benchmarking analysis following the major concept of a revealed comparative advantage analysis (see Grupp, 1997), which we then use to analyse the interrelation between public and private R&D funding of firms.

We display the results of the approach for a set of three European countries (Austria, Germany and Norway) in order to further demonstrate the usability and the limitations of the proposed approach. We then draw conclusions geared towards the further development of public R&D funding information systems, which allow for policy-relevant benchmarking of national research, technology and development (RTD) funding.

Conceptualising R&D specialisation

The starting point for the analysis is to conceptualise the term 'R&D specialisation'. We refer to the notion of a national R&D system in accordance with the Organisation for Economic Co-operation and Development (OECD) Frascati terminology (see Figure 1), which shows that we may choose several perspectives on a national R&D system:

The first viewpoint on R&D is the funding sector. Several funding sources (government, business, foreign, other) provide money for conducting R&D, which will have an influence on R&D performing sectors and R&D output. The second viewpoint is he

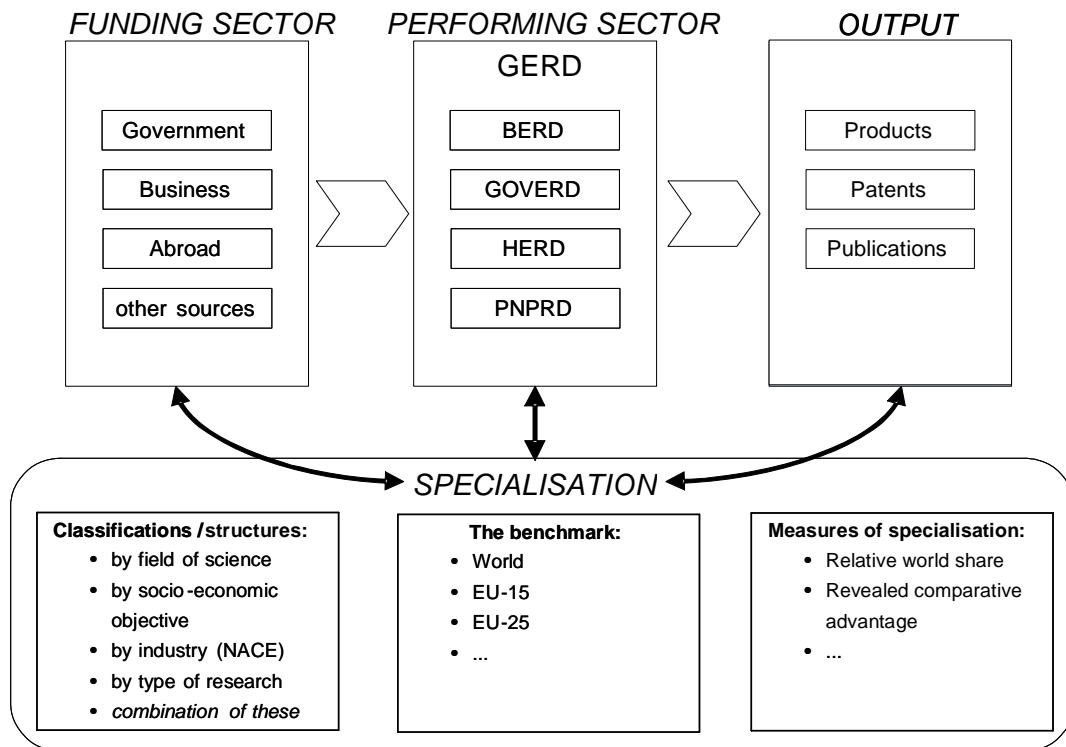


Figure 1. Conceptualising R&D specialisation

Source: Joanneum Research

performance sector, which is roughly differentiated by the business-enterprise sector, the state sector, the higher-education sector and the private non-profit sector. Finally, the third viewpoint is the output of R&D — new products, new routines, patents and publications.

The three dimensions of R&D (funding, performance and output) are closely interrelated and each, together with its available subgroups, may display specific views on R&D specialisation. Therefore, the term ‘specialisation’ needs some elaboration. The following entities are prerequisites for describing R&D specialisation:

- To grasp R&D specialisation, classifications/structures are needed to answer the question ‘what is the area of specialisation?’ For this, several classifications are proposed by the OECD *Frascati Manual* (OECD, 2002) and provided by statistical offices, such as the field of science, the socioeconomic objective or the industry sector (NACE (an EU classification system) or the International Standard Industrial Classification) in which R&D funds are invested or the type of research that is sponsored.
- Since specialisation is a relative term, a benchmark is needed that shows in which areas a given country is specialised compared to this benchmark. The benchmark might be the world, a selection of countries (for instance, EU-15/EU-25) or a single outstanding country as regards R&D performance (best-practice benchmark). The selection of the benchmark has a severe impact on the ‘specialisation’ result, but at the same time the selection of the

benchmark is heavily influenced by the availability of data.

- Specialisation needs to be measured with a particular parameter or measure. The most commonly used specialisation measures are related to trade specialisation, namely the revealed comparative advantage (Balassa, 1965) even though alternative specialisation measures might be available.

Creating a monitoring device

Since the focus of our analysis is the interrelation of the structure of public and private R&D funding of the enterprise sector, we need to define classification, benchmark and the parameter that allows the systematic tracing of sectoral R&D specialisation of firms by public and private funding sources.

Classification

Available R&D statistics of the OECD and the European Union (EU) provide at least some classifications for tracing thematic trends in public R&D funding. First, data on government budget appropriations or outlays for R&D (GBAORD) provide specific labels for public R&D funding. For example, comparing GBAORD data by socioeconomic objectives between the EU-15 and the USA, considerable differences in thematic orientation of public R&D funding are revealed. Based on GBAORD data, Schibany and Jörg (2005) in particular point out that trends in funding of health and environment

programmes and in defence R&D were the main pillars for growth in public R&D funding in the USA. In contrast, the EU level of defence R&D is characterised by diminishing investments. Expenditure on health and environment reach only about one-third of the US level and public growth rates in the field were lower than the US level as well.

Hence, we see that GBAORD data may provide information on shifts in public R&D funding in general, and even contribute to our knowledge of funding channels, since data are differentiated by socio-economic objectives. However, GBAORD data do not provide information on shifts in public funding of R&D in firms and GBAORD data in most OECD countries do not distinguish between beneficiaries in terms of public and private performance sectors.

Apart from GBAORD data, which are derived from annual budgetary accounts, the most frequently used R&D indicators are derived from national R&D surveys according to the OECD *Frascati Manual*. Data from national R&D surveys can be differentiated by sources of funding, performance sectors (Expenditure on R&D in the Higher Education Sector (HERD), Expenditure on R&D in the Business Enterprise Sector (BERD), Government Intramural Expenditure on R&D (GOVERD), Private Non-Profit Institutions (PNP)) and type of research (see also Figure 1).

Looking in particular at government funding of business R&D, we can see that an enormous structural change occurred in the last 25 years (see Figure 2). Throughout the OECD, the level of government funding of business R&D declined from 23% to 17% in 1990, and finally to a mere 7.4% in 2003. Rammer

(2006) states that this decrease in public financing of R&D in firms was most pronounced in the USA, Great Britain and France and mainly affected military research.

On the other hand, he also highlights that government funding of business R&D does not take into account indirect measures to support business R&D, such as tax credits or R&D allowances on social security fees of researchers, which are substitutes for direct funding of business R&D (Guellec and Pottelsberghe, 2003). Rammer (2006) shows that total subsidy ratios of R&D increase to almost 15% for France, and 12% for the USA and Great Britain when taking indirect measures into account. Germany, in contrast, has not applied such indirect measures.

BERD can not only be differentiated by sources of funding, but also by industrial branches. This allows us to propose a classification to investigate the branch-specific investment of public and private intramural business R&D at the NACE 2-digit level. We define private R&D funding in firms for sector i (PBERD $_i$) and government funding of R&D in firms for sector i (GBERD $_i$) as follows:

- PBERD $_i$ investment is defined here as all intramural business R&D financed by the enterprise sector plus all funding from abroad for sector i . This means that supra-national funds, such as EU grants, for which private enterprises are eligible, are included within PBERD, since funding from abroad includes both private and supranational (EU) funds.
- GBERD $_i$ investment is defined here as total national public R&D funding of intramural business R&D for sector i . Hence, it includes all R&D

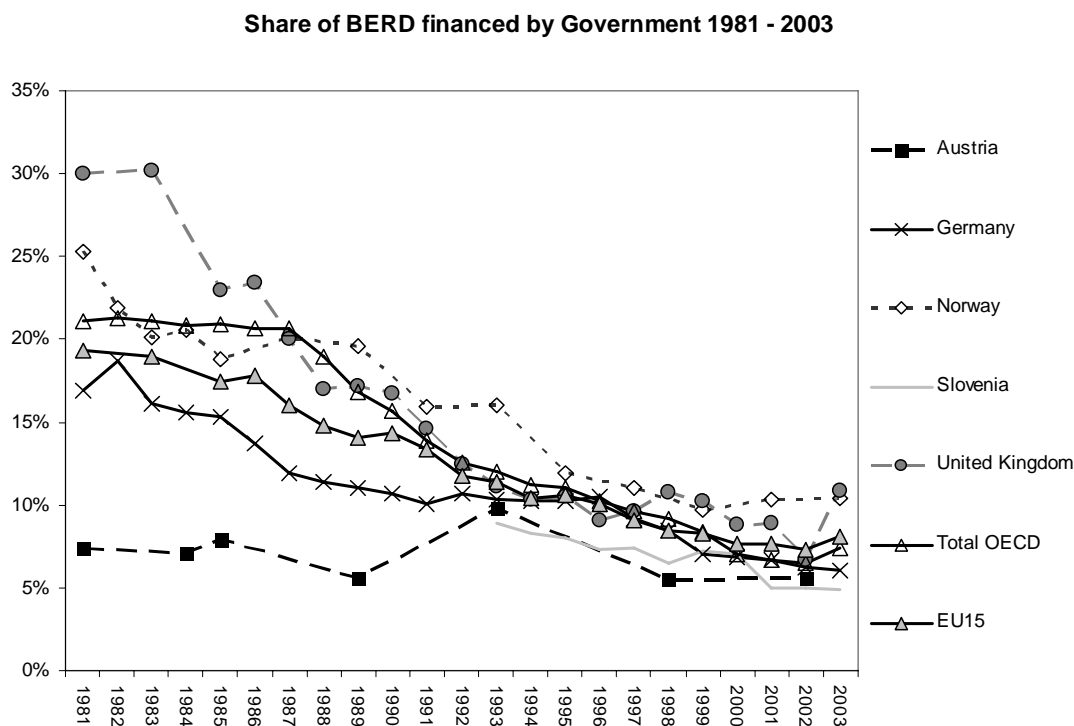


Figure 2. BERD financed by Government 1981–2003
Source: OECD (2005a); calculations Joanneum Research

funding from the federal state, federal regions and municipalities.

The proposed classification can be derived directly from the OECD Research and Development Statistics database (formerly Basic Science and Technology Statistics) (OECD, 2005b), which is the data source for the exercises performed in this paper and for which details on national specifications and comparability issues are available. A particular limitation of the proposed classification is that not all public funds are included in GBERD, nor is PBERD exclusively private money. PBERD includes some public funds, because the foreign funding source includes public (for instance, EU) as well as private funds. Because of the statistical classification in the Eurostat and OECD databases, these two groups cannot be divided. However, data for Austria (2002) shows that the share of EU funds for BERD funded from abroad is only about 3% (BMBWK, 2005: 168). In Germany, sources from abroad funded about 2.4% of BERD in 2003 (no separate figures for EU funding are available (BMBF, 2006)).

Benchmark

The common market of the European Union is among the most important markets in the world and is of particular importance for most of the R&D and technology-intensive companies within Europe. As a result of methodological/data restrictions and the decision to start with an 'internal' view in the ER-AWATCH¹ R&D specialisation project, the EU-15 was chosen as the main benchmark throughout the project. However, R&D specialisation, technological orientation and economic performance are still heterogeneously distributed among the member states. Furthermore, the largest competitors as well as the largest R&D-conducting nations, namely the USA and Japan, are outside Europe.

For the specific analysis of public R&D specialisation in funding business R&D, data availability for the whole EU-15 and the USA was very scattered. This prevented us from using an EU-15 plus USA plus Japan benchmark. Instead, we decided to construct one consisting of 11 countries, among which four (Austria, Norway, Germany and the United Kingdom) have been especially tackled and additional national R&D data retrieved in the framework of the ERAWATCH R&D specialisation project. The remaining seven countries within the benchmark are France, Italy, Spain, Poland, Finland, Sweden and Japan. Hence, the benchmark consists of a good mix of large and small countries, ones with a very distinct R&D profile (Finland, Sweden) and those that are characterised by relatively low or catching-up R&D investments (Spain, Poland, Italy).

The limited data availability shows that it is worth discussing the implications of alternative benchmarks for the calculation of R&D specialisation indices. Therefore, German BERD

specialisation profiles were compared with EU-15 in relation to the sum of EU-15, USA and Japan (Frietsch and Dinges, 2006). The study shows that specialisation profiles are indeed sensitive to the benchmark. For example, in relation to EU-15 only, Germany has a small under-specialisation in agriculture, whereas in relation to EU-15, USA and Japan, the German business R&D expenditure reaches a strong positive value. The same holds for aerospace and other businesses.

For the case of public versus private R&D specialisation in firms, it is important to note that the benchmark population is relatively small. Consequently, large countries with high R&D investments, such as Germany, have a strong impact on the benchmark, which causes them to be closer to the benchmark average and therefore they may display less pronounced specialisation patterns.

The benchmark approach further requires that methods and classification across countries are comparable. This is not generally the case (see OECD, 2000): For example, classification of public/semi-public research institutes and allocation to industry classes differ among countries: large research and technology organisations (in a national context) such as the Austrian research centres Seibersdorf and Joanneum Research are classified as business enterprise sector, whereas comparable institutions in Germany, such as the Fraunhofer Society, Helmholtz Association and Leibniz Society, are classified as government sector.

As regards industry classes, Japan, for instance, does not report data for the sector "office mach etc." (NACE 30), and the data seem to be included in the sector "electr. equipment" (NACE 32). As Japan also has a high influence on the benchmark because of its size and some activities in these fields that are not displayed properly, we had to apply a correction method. This is that 20% of total BERD and GBERD of these two sectors have been assigned to sector 30 and 80% to sector 32. This seems to be a rather arbitrary choice. However, the specialisation profiles, especially in sector 30, are closer to reality after this correction. Otherwise, the performance of this sector in most countries would have been over-estimated.

Parameters of specialisation

As a parameter to determine PBERD and GBERD specialisation we use the revealed comparative advantage (RCA) methodology as introduced by Balassa (1965). This RCA value, also known as the relative world market share (RWS) (Grupp, 1997) has the following definition for GBERD:

$$RCA_{ki}(\text{GBERD}) = 100 \times \tanh \ln \left(\frac{\text{GBERD}_{ki} / \sum_k \text{GBERD}_k}{\sum_k \text{GBERD}_{ki} / \sum_{ki} \text{GBERD}_{ki}} \right)$$

where

$GBERD_{ki}$ indicates the amount of government funding of country k in the economic sector i .

The RCA value for PBERD is constructed in the same manner.

The log function centres the data around zero and the hyperbolic tangent multiplied by 100 limits the RCA values to a range of +100 to -100. Positive values for sector i point to the fact that the sector has a higher weight in the portfolio of the country than its weight in the world (all government funding from all countries taken together). Negative values indicate specialisation of government funding below the average.

The main advantage of the RCA indicator is that it allows the assessment of the relative position of an economic sector in a country beyond any size effects. Neither the size of the technological field nor the size of the country has an impact on the outcome of this indicator. Therefore, it is possible to compare countries and technologies directly.

This also has negative impacts. For instance, Germany's relative strengths or comparative advantages in public- and private-funded business R&D lie in the automotive sector, the chemicals industry, and metals and machinery (see Figure 5). The ERAWATCH specialisation report (IPTS, 2006) also concluded that the automobile sector increased its specialisation. However, the specialisation index for 2002 does not show that the structural change in specialisation of the German R&D-conducting businesses was heavily affected by the developments of the automobile sector. While the share of the automobile sector was about 21% in the early 1990s, it increased to about one-third of all business R&D (Legler *et al.*, 2006; Legler and Gehrke, 2006).

At the same time, the electronics, electrical machinery, computer and related sectors had to face a decrease in their share of national R&D expenditure from about 30 to 23%. A similar development can be seen in the chemicals industry, whose share was reduced by about 6 percentage points. However, in both absolute and real terms, both sectors still increased their efforts, but not in the same way as the automotive industry. These are just two examples of developments that are barely reflected and can

To describe R&D specialisations, classifications/structures are needed to determine the area of expertise, a benchmark is needed to compare countries and the specialisation needs to be measured with a particular parameter or measure

hardly be detected by focusing exclusively on specialisation indices. The reason for this is the standardisation of values in the RCA parameter. The fact that the RCA indicator distils size effects from the specialisation profiles results in specialisation changes, if (*ceteris paribus*):

- more/less money is spent on that sector (in absolute terms) in the analysed country;
- the structure of spending within the analysed country changes (that is, the money spent on the given sector changes in relative terms);
- more/less money is spent on the given sector (in absolute terms) in one/some of the benchmark countries.

Results of the exercise

We now turn the discussion towards the results of the benchmarking analysis. The performance of the outlined methodology according to the concept of public and private business R&D specialisation by industrial sector results in four distinct specialisation quadrants portrayed in Figure 3:

1. Sectors with neither specialisation in PBERD nor in GBERD (lower left)
2. Sectors with a specialisation in PBERD and GBERD (upper right)
3. Sectors with a specialisation in PBERD but none in GBERD (lower right)
4. Sectors that display a specialisation in GBERD but not in PBERD (upper left)

The picture allows the following interpretations:

- It shows the extent of correlation between public specialisation and private R&D funding specialisation in firms.
- It allows us to distinguish between sectors of high and low public specialisation as compared to the benchmark.

Sectors showing up in the upper right quadrant are ones with above average public and private R&D investment compared with the benchmark, which comprises a pool of 11 countries. The lower right quadrant characterises sectors in which private investment is above the international average, but public investment is below the international average. This could be interpreted either as the results of public R&D efforts, sectors with no need for public specialisation, or sectors for which public support mechanisms other than R&D funding apply, such as price regulations for pharmaceutical industry or indirect fiscal measures.

The upper left quadrant points to sectors with high public demand/interest as public R&D financing is above the international average but private R&D financing is below the average of the benchmarking countries. Hence, the upper left quadrant may reflect

Public versus private R&D Investment specialisation

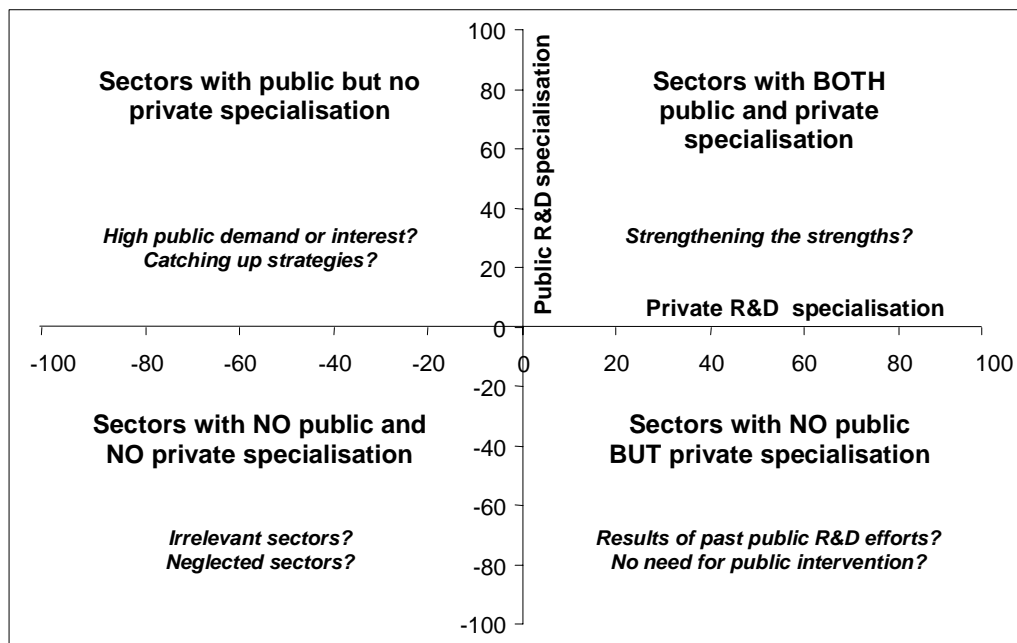


Figure 3. Public and private specialisation in business R&D

Source: Joanneum Research

sectors for which public catching up strategies are currently in place, or sectors for which market restrictions are in place. For Austria, Germany, and Norway we now discuss the results of the PBERD versus GBERD specialisation analysis.

PBERD and GBERD specialisation in Austria

In the last decade, investment in R&D has experienced a remarkable increase in Austria. GERD as a percentage of gross domestic product has grown from 1.4 in 1993 to 2.1 in 2002 and finally 2.53 in 2006. This growth is almost exclusively caused by an upsurge of business R&D, while both higher education R&D and Government R&D stayed fairly stable in relative terms, although public R&D considerably increased in absolute terms.

As well as the overall increase in business R&D, funding from abroad has increased dramatically: in 1993 foreign funds accounted for only 2.6% of total GERD, in 2002 it was 21.4%. This is caused by an increased presence of foreign subsidiaries in the Austrian economy, especially in technology-intensive sectors (for instance, Siemens and Infineon in electronics) and by mergers and acquisitions taking place in Austria. A further internationalisation of the Austrian economy occurred, which is also reflected by the funding sources of BERD/GERD. Nowadays, the lion's share of BERD is funded by a few, large subsidiaries of multinational corporations whose headquarters transfer R&D funds to Austria (see Schibany *et al.*, 2004).

Compared with the EU-15 Austria displays a distinct BERD specialisation in several industries, such as textiles, non-metallic minerals, basic metals,

fabricated metals, electronic equipment, other transport nec., furniture, trade, R&D and other business activities (IPTs, 2006). Also some drastic changes have been observed between 1993-95 and 2001-03. Mining, financial intermediation and community services lost much of their specialisation in BERD. Overall, a simple correlation analysis in the IPTs report shows that BERD specialisation (especially in 2001-2003) is strongly and significantly correlated to patents, exports and value added.

Figure 4 shows that a certain interrelation between private and public R&D specialisation in firms exists: there is a medium (0.583) correlation between GBERD and PBERD, which may be best explained by the strong relevance of bottom-up research promotion schemes of R&D in firms; the Austrian Research Promotion Agency (FFG) provides about two-thirds of total business R&D funding via bottom-up funding procedures not limited to specific technologies.

The Austrian R&D activities sector also exhibits a distinctive high specialisation in PBERD and GBERD. This might be because in the official statistics the Austrian business sector comprises a private business sector and a co-operative sector, which includes large semi-publicly owned research companies (see discussion under "Benchmark"). It is also worthwhile to mention that positive PBERD and GBERD specialisations are non-R&D intensive sectors such as wood and paper, non-metallic minerals and fabricated metals. For those industries, specific national and regional thematic cluster programmes exist for a long time and they seem to have resulted in above average public and private R&D investments compared with the benchmark.

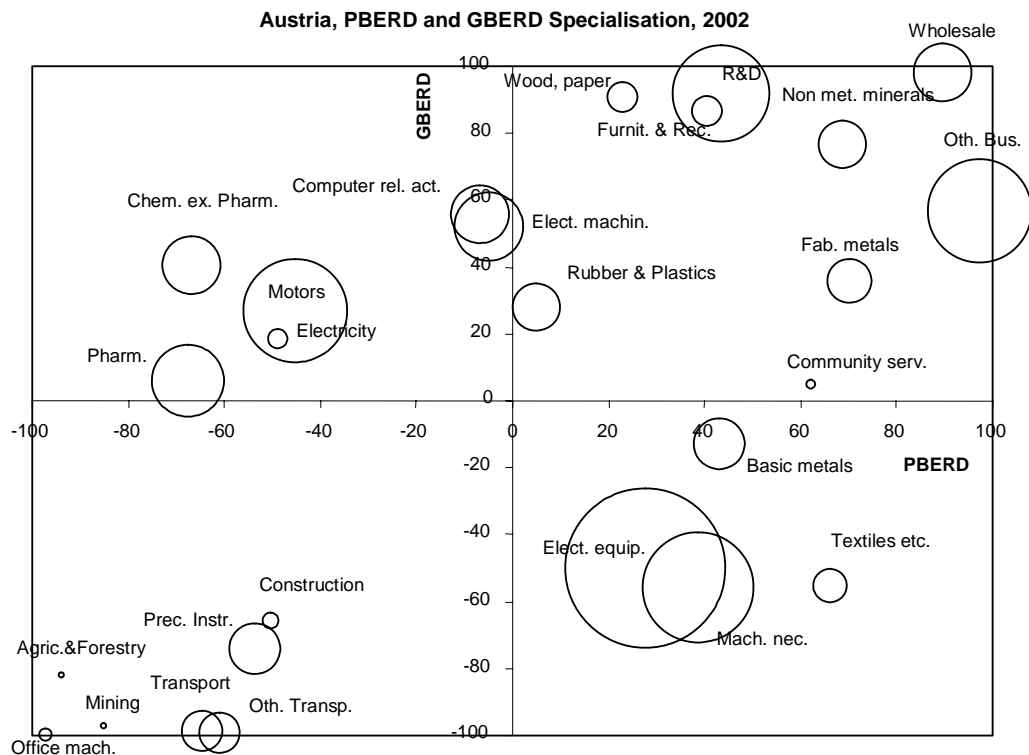


Figure 4. PBERD vs GBERD specialisation in Austria, 2002

Source: Joanneum Research, based on OECD RDS database (OECD, 2005b)

Outstanding examples for high specialisation in GBERD but no specialisation in PBERD are chemicals and motors. Interestingly, also for these sectors the above mentioned bottom-up funding scheme of FFG plays a prominent role: in 2003, of the €127 million cash value of total funding, 18.5% was provided for chemicals and chemical products, 13.4% for computer-related activities, and 6.6% for motor vehicles (BMBWK, 2005).

Whereas the motors sector has generally gained momentum in the Austrian economy, the chemicals/pharmaceutical sector is internationally rather small but relatively competitive in terms of research performed. Furthermore, the Austrian chemicals sector is a very important sector as regards manufacturing employment (approximately 10.85% in 2003) and manufacturing production (11.4%) (Aiginger and Novak, 2004).

PBERD and GBERD specialisation in Germany

For Germany (see Figure 5), the ERAWATCH R&D specialisation study reveals a clear and stable portfolio of the German R&D landscape. Germany is characterised by a broad portfolio of research activities in many fields with some strong specialisations in medium-high technology and industry and some disadvantages in leading-edge (or high) technologies. In particular, the German specialisation profiles (in BERD, patents, value-added and employment) show strengths in automobiles, engineering, instruments and chemicals. This is also reflected in the correlation analysis of the selected specialisation indicators across sectors (see IPTS, 2006).

The statements on German specialisation patterns also hold true for public and private funding of BERD. Apart from the well-known strengths of the German economy, a clear and strong correlation pattern of PBERD and GBERD is not visible in Germany, the correlation being only 0.25. As can be seen, the sectors are scattered all over the graph. A few distinctions may shed some light on this.

The upper left quadrant shows that German GBERD is more specialised in sectors that have no specialisation in intramural business R&D expenditure. The inspection of GBERD reveals that aerospace (other transport) still receives only slightly more than 5% of total spending on R&D of the German Government (GOVERD), but it receives more than 55% of the total funding of business R&D (GBERD).

This means that, within intramural business funding activities of the Government, it plays a very prominent role. The reasons here are strong public interest and an expected market failure that justifies these massive investments, along with the state being the most important customer of aerospace goods and services. Strong public interest and market failure arguments may also be the reason for GBERD specialisation in electricity, water and recycling.

Electrical machinery, electronic equipment and office machinery have lost some of their relative importance/weight in the recent past, as a result of an enormous increase of R&D investment in other sectors, namely automobiles and because of a stronger emphasis on these sectors in other European countries that form an important part of the benchmark here (Sweden, Finland). Since the electrical

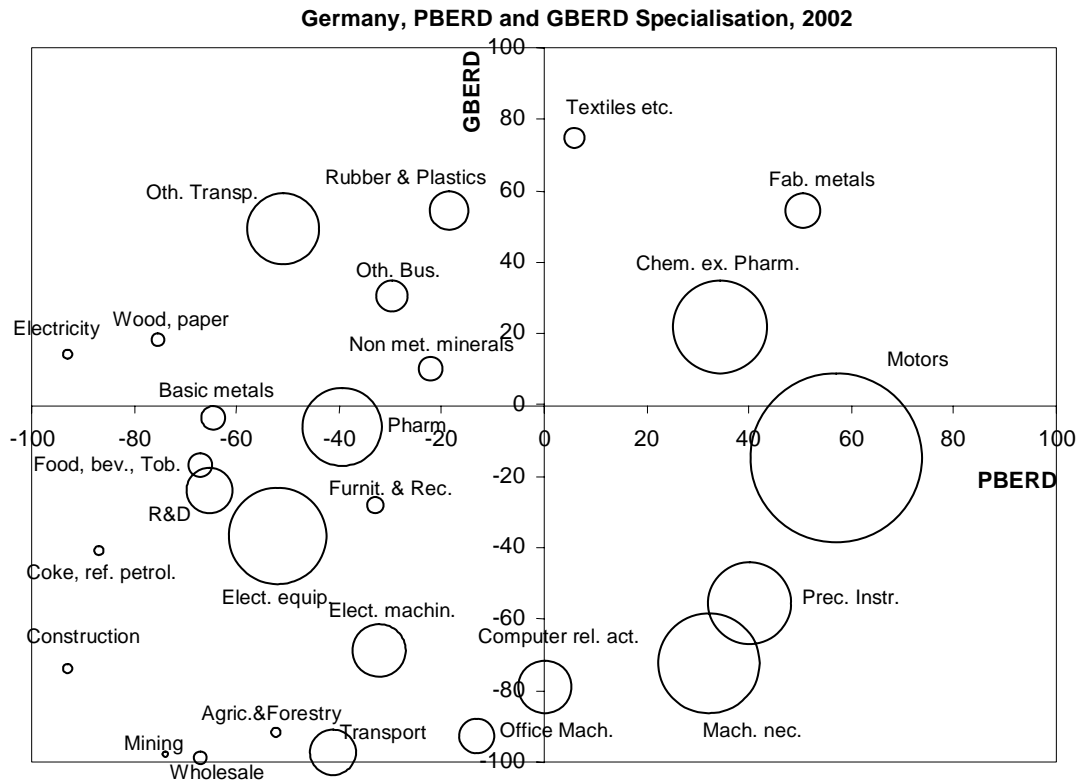


Figure 5. PBERD vs GBERD specialisation in Germany, 2002

Source: Joanneum Research, based on OECD RDS database (OECD, 2005b)

machinery and the electronic equipment sectors represent two of the most important and most enabling technologies of our times, this is a disadvantage and shows that the developments of the recent years have passed by German companies.

In this respect, the German innovation system has to catch-up in several technological fields. However, GBERD data for Germany show that this is fairly neglected by public RTD support of firms compared with the benchmark: the sectors not only show no specialisation in PBERD expenditure but also no specialisation in GBERD.

Overall, the automobile sector together with the chemistry and mechanical engineering sectors are among the driving forces of the German economy. All three sectors lead to large effects that spill over to other sectors and branches. Besides, when looking at the automotive sector as a source of inventions, it can be seen that it covers an extremely broad spectrum, ranging from textiles, fibres, paint and lacquers to traditional engineering technologies and communication and software solutions. On the other hand, public R&D funding of firms seems to be driven mostly by public demand and not by considerations of technological change. This strong separation might limit exploitations of spillovers to other industrial sectors of the economy.

PBERD and GBERD specialisation in Norway

In very general terms, the feasibility study on R&D specialisation (IPTS, 2006) shows coherent specialisation patterns in terms of public R&D funding,

business R&D expenditure, and economic specialisation. In terms of value added, the country appears to be highly specialised in mining (mainly petroleum and gas), ship building and transport (both transport via pipelines and general water transport). Norway also exhibits an increasing specialisation in electricity, gas and water supply. This is the footprint of the petroleum cluster in the Norwegian economic system.

It is noteworthy that there is a positive correlation between specialisation indices in value added and BERD, between employment and BERD and between export and BERD (see IPTS, 2006). In terms of intramural business R&D (BERD), Norway appears to be highly specialised in:

- primary sectors, in particular petroleum and gas (but also agriculture and fisheries);
- several low-tech and medium-tech manufacturing sectors, such as food, printing and publishing, ship building, basic metals and recycling.
- services and other non-manufacturing activities, except electricity and water supply.

Figure 6 shows that there is a strong correlation (0.68) between Government support of BERD and private R&D funding. Only for machinery and equipment and fabricated metals is there a specialisation in GBERD but not in PBERD. For construction and other business activities there is a specialisation in PBERD but not in GBERD.

What the picture does not show is that two sectors receive more than 70% of total funding in GBERD: research activities, and machinery and equipment.

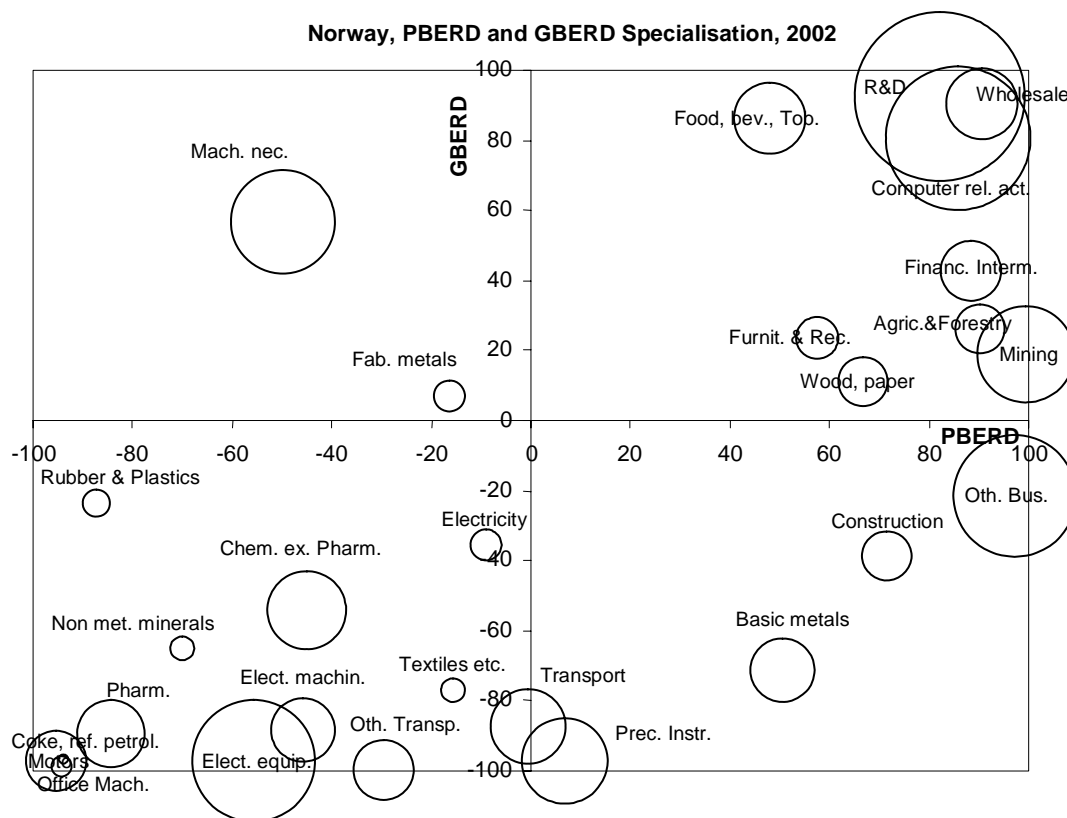


Figure 6. PBERD vs GBERD specialisation in Norway, 2002/2003

Source: Joanneum Research, based on OECD RDS database (OECD, 2005b)

Next to these, we find ICT-services receiving 7.8% of total GBERD. All other sectors receive less than 3% each of GBERD. This highlights that, as well as looking at specialisation patterns, it is important to focus on the types of flow of R&D funding from Government to industries: in total, the industrial sector received NOK800 million (1 NOK = €0.126) as R&D support from the Norwegian Government, of which NOK156 million was through the Research Council of Norway (RCN). In addition, the industrial sector received NOK531 million as tax deduction through the new tax credit scheme, SkatteFUNN, introduced in 2002. The entire Government funding of R&D amounted to NOK11.4 billion, indicating that the industrial sector received about 7% of total Government funding in 2003.

More than half of this is allocated to the manufacture of machinery and equipment necessities, which also includes weapons and ammunition. This leaves us with an almost negligible volume of funds supporting civil R&D activities in Norway. In addition, research institutes serving enterprises, which in OECD statistics are classified as private companies, received NOK843 million from Government funds of which NOK510 million was through the RCN. These institutes received an additional NOK100 million through the national tax credit scheme as a result of co-operation with R&D-performing firms.

The main conclusion to be drawn here is that Government funding of civil R&D expenditure is negligible in Norway, especially when compared with the volume of industrial sector intramural R&D

expenditure in 2003 (NOK13.5 billion). This is, however, not the same as saying that the effects of Government funding are negligible, as complex issues of input and output additionality have to be taken into account for an assessment of this matter.

Conclusions and paths for future research

The presented PBERD versus GBERD specialisation analysis provides a simple quantitative tool to analyse national emphases in public funding of firms' R&D and coherence between public and private R&D funding in firms. We have highlighted national specialisation indices in terms of public and private funding of firms' R&D for Austria, Germany and Norway.²

In interviews with 11 national-policy experts from research councils and ministries in charge of S&T policy in Austria and Norway, we tested whether the picture on GBERD and PBERD provides additional and useful information for policy-makers. The policy experts stated that specialisation indices offer new and relevant information. The most relevant remarks related to the issue of dynamics in R&D specialisation: the present structure of business R&D specialisation may be the result of past funding activities provided by government, and current public specialisation may result in private BERD specialisation in the future.

This could result in specialisation patterns in which the constructed variables of PBERD and

By looking at changes in public and private firms' R&D specialisation over time, the methodology could be used to survey the effects of public investments in specific sectors of private R&D as well as a warning system to indicate increasing specialisation or de-specialisation of sectors

GBERD move independently from each other. By looking at changes in public and private firms' R&D specialisation over time, the methodology could be used to survey the effects of public investments in specific sectors of private R&D as well as a warning system or monitoring device that indicates increasing specialisation or de-specialisation of sectors.

For Austria we have calculated changes in public and private R&D specialisation for the period 1993/2002. The strongest changes are shown in Figure 7. This shows a mix of increasing specialisation and de-specialisation processes over time, of which the most interesting are the sectors electrical machinery and machinery necessities. Whereas in 1993 the electrical machinery sector in Austria was characterised

by below average public and private R&D investments, the sector nowadays shows a distinct public specialisation and private investments close to benchmark average. The machinery necessity sector already showed a slight public specialisation in 1993, but, as private investments increased dramatically, public de-specialisation processes took place.

Public and private de-specialisation processes also occurred in pharmaceuticals. Whereas in 1993 funding for pharmaceutical industry was highly specialised, public R&D specialisation is nowadays just about at the average of the sample countries.

However, the reasons for these changes may be numerous and the interpretation is far from straightforward. As outlined already, size matters in the assessment of developments and changes over time. Hence, though the specialisation index has clear and strong advantages, it also has some disadvantages, making a broader analysis, including both relative and absolute measures, in the future absolute necessary.

Besides size effects, which have to be taken into account in future analysis to avoid misinterpretation and to evaluate the practical applicability of the analysis, the approach also suffers from a missing match between sectors and technologies. While RTDI policy tends to 'think' in terms of technology programmes, it is difficult to relate these clearly to economic sectors (see Schmoch *et al.*, 2003). In particular, new cross-sector technologies (such as nanotechnology or ICT) pose an attribution problem. Hence, the change of specialisation patterns can be observed, but it cannot be directly related to specific

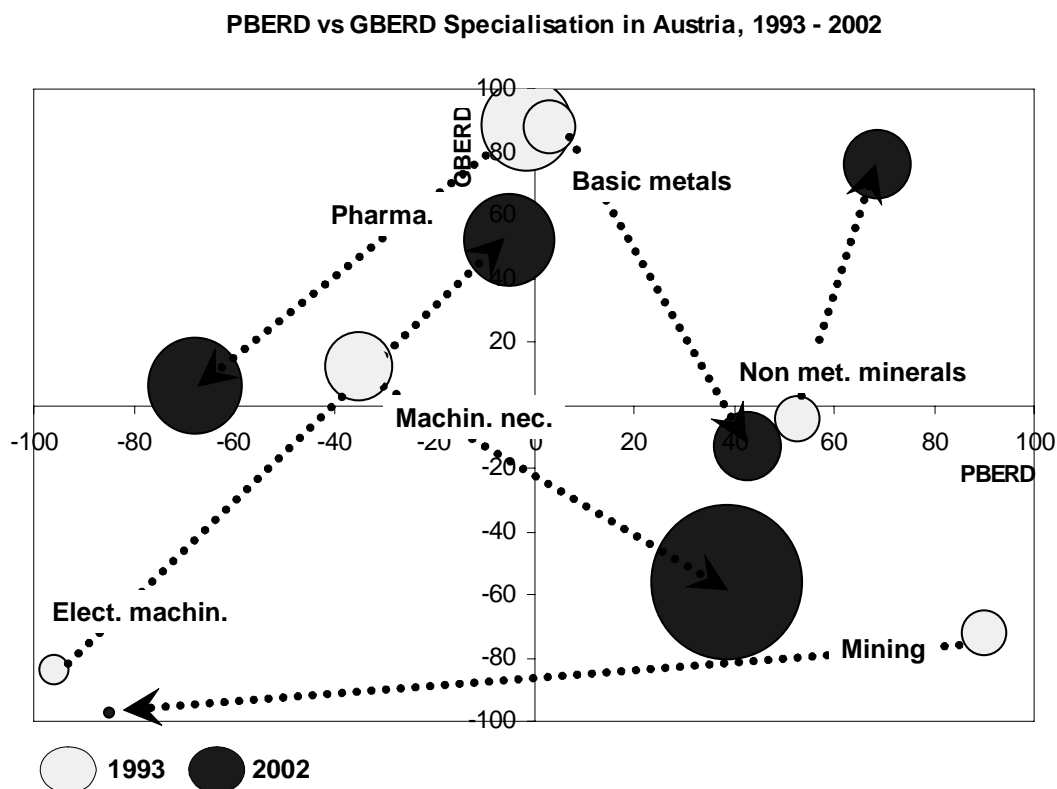


Figure 7. Specialisation processes: the case of Austria, 1993–2002

Source: Joanneum Research, based on OECD RDS database (OECD, 2005b)

policy measures. Consequently, three issues are critical for future research.

First, international data availability on GBERD and PBERD should be made available for more countries and it would be helpful if data that has been specially prepared for international comparison (see OECD's analytical BERD database (OECD, 2005c)) were to allow a clear distinction to be made between private and public funding of business R&D.

Second, in discussing the reasons for specific PBERD and GBERD specialisation patterns for Austria, Norway and Germany we have shown that quantitative information always requires additional qualitative measures and good knowledge of the national research support system to understand better the existing specialisation patterns. Specific reasons for specialisation patterns that need more attention in future research are to be found in government R&D funding strategies, such as public R&D intervention models, which tend to favour loose bottom-up industrial research funding (for instance, Austria), the impact of foreign subsidiaries (Austria), and the strong relevance of military R&D (Norway, Germany).

Other areas that need particular attention are: the presence of national and European structural policy (for instance, the R&D specialisation impact in aerospace); the underlying industrial structure of the economy (especially in the case of small countries where business R&D is dominated by a few large companies); and different structures in public/private research interactions, such as the Austrian

Competence Centres or the Norwegian model of research laboratories that serve as intermediaries between the public and the private sector.

Third, direct R&D funding of firms as analysed in this paper is only one promotion mechanism out of an array of available measures. An important challenge for future work would be to distinguish between different channels or sources of direct and indirect government funding of R&D in the business sector. Moreover, the presented analysis could not consider the distinction between foreign and national public funding (such as EU funds). Therefore, it would be appreciated if future research could distinguish among three domestic and one foreign (that is, EU) instruments/sources that deliver public R&D funds to private firms.

Though official R&D statistics for these categories are poor, methods could be employed to gather additional data from funding agencies. For example, within the ENIP (European Network of Indicators Producers) project an approach has been developed and tested for a small group of countries (Austria, Italy, France, Norway, Netherlands, and Switzerland) to analyse the evolution of project funding by using data from funding agencies (Lepori *et al*, 2006). Basically, the methodology allows information to be gathered on three of these categories (general, thematic and EU funding) (see Dinges, 2006; Lepori, 2006; Poti and Reale, 2005), but it also has limitations as it does not allow for a sectoral disaggregation level as used in this study, and data availability in terms of available countries is even more constrained.

Notes

1. ERAWATCH® was conceived to support policy-making in the research field in Europe. Its objective is to provide knowledge and a better understanding of national and regional research systems and of the environment in which they operate.
2. For all other countries included in the benchmark analysis, the specialisation indices are available.

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