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University research funding and publication performance—An international comparison

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ABSTRACT

In current science policies, competition and output incentives are emphasized as a means of making university systems efficient and productive. By comparing eight countries, this article analyzes how funding environments of university research vary across countries and whether more competitive funding systems are more efficient in producing scientific publications. The article shows that there are significant differences in the competitiveness of funding systems, but no straightforward connection between financial incentives and the efficiency of university systems exists. Our results provoke questions about whether financial incentives boost publication productivity, and whether policy-makers should place greater emphasis on other factors relevant to high productivity.

1. Introduction

Hand in hand with the rise of the New Public Management and expanding global techno-economic competition, an increasing prominence has been given to the idea that university systems employing output incentives and competition mechanisms are more efficient and productive than systems in which such incentives and mechanisms are employed less or not at all. While there is some evidence of the short-term usefulness of incentives and competition, country-specific comparative information on research performance in relation to the scope and scale of competition seems to be largely missing (Geuna and Martin, 2003; Liefner, 2003). In this article we study this relationship by comparing the funding environments of university research in eight countries. We scrutinize allocation mechanisms for direct government research funding, shares of external funding and compare these systemic characteristics with university publication outputs of countries. Do university research systems that operate in competitive funding environments perform better than others? The question has high policy relevance and we suggest a critical re-examination of the idea that competition and incentives boost the productivity of university research.

In recent decades, university sector research funding has changed in many countries. The share of direct government funding has gradually decreased, while the share of external and industrial funding has increased. At the same time, public funding has faced transformations. Government core funds have been increasingly allocated on the basis of performance, and funding agencies have adopted mission-oriented and contract-based strategic allocation procedures (e.g. OECD, 1998, 2004; Skoie, 1996; Slaughter and Leslie, 1997). Nonetheless, public funding is still the predominant source of funding for university research. For instance, the mean for industry funding of university research in OECD countries in 2003 was only 6% (OECD, 2005, p. 41). Recent studies have also pointed out country-specific differences in universities' public funding. There are, for instance, differences as to the allocation mechanisms of the core university funds. Even though utilized extensively, result-based mechanisms do not fully dominate. In a comparison of 11 OECD countries by Jongbloed and Vossensteyn (2001), it was pointed out that the orientation to output is used to a varying extent as an allocation model. Similarly, one of the conclusions of the broad cross-country comparison by Geuna and Martin (2003) was that there is great variation as to the extent and way of using evaluation for resource allocation.

Funding shifts have not taken place without receiving attention. Some observers have been convinced that changes in resource allocation may lead to unintended negative consequences especially in terms of basic research outputs (e.g. Geuna, 1999; Ziman, 1996). Others have argued that the whole way of science-society interaction is changing in the global knowledge economy, lead-

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ing the science system to produce more socially relevant and applicable knowledge (e.g. Etzkowitz and Leydesdorff, 2000; Jacob and Hellström, 2000; Nowotny et al., 2001). Some other studies have claimed, in contrast, that while researchers utilize new funding opportunities, they succeed in balancing scientific and extra-scientific interests. Therefore, funding shifts do not strongly affect the actual practices of research, for example, publication behaviour (Albert, 2003; Behrens and Gray, 2001; Van Looy et al., 2004).

In this article we focus on the idea that financial incentives either form a macro-level imperative or an opportunity in the development of university-based research. More precisely our research questions are:

1. How do the funding environments of university research vary across countries?
2. Are there differences among countries in their publication performance according to the degree of competitiveness of the funding environment?

The structure of the article is as follows. The conceptual background is introduced in Section 2, including the analytical framework for comparing the funding environments. Data and methods are described in Section 3, followed by the analysis of the allocation mechanisms for government core funding and level and sources of university research funding (Section 4.1). Based on the analysis, the compared countries are placed into the analytical framework (Section 4.2). We then connect the analysis of funding environments with the analysis of publication performance (Section 4.3). Results and their implications are discussed in Section 5.

2. Conceptual background

2.1. Principal-agent dilemma and New Public Management

The major rationale for the shift of public policies towards increasing output orientation and the use of external competitive funding mechanisms relates to the principal-agent dilemma, as well as to the ideas of the New Public Management (NPM) that market-like mechanisms create an incentive towards enhanced performance. The principal-agent dilemma (Van der Meulen, 1998) reflects a situation in which the government or a governmental agency is attempting to enhance its own or wider societal targets, for instance, via public research funding programs. As it does not have the appropriate know-how and human resources to conduct the mission, it needs to "delegate" the actual implementation of tasks (research) to specialized organizations such as universities. It faces at least two problems in the implementation of programs. First, it needs to screen out the best possible actors to conduct the mission and second, it cannot control all the activities of relatively independent actors. If it does not choose to trust the actors, it needs both appropriate selection and control mechanisms, which ensure that the principal's targets are fulfilled.

Ideas rooted in the New Public Management have provided some practical answers to these problems (e.g. Pollitt, 1993). In general, in the science and technology policy the NPM has meant the increasing use of results as a screening mechanism and the use of targeted external funding with related evaluation practices as a control mechanism. The general idea behind competitive mechanisms has been twofold. First, it has included the idea that if money is given to the best performers, it will most likely produce better results. Therefore, the allocation should be based on earlier results. Second, if the allocation is based on results, it creates a general incentive for all the actors to achieve better results in order to become more competitive. Furthermore, the shift of focus to results enables a detailed assessment of activities, which, in turn, means enhanced control possibilities.

In many studies concerning the impact of funding to research activity, the implicit or explicit theoretical assumption is that dependence on external resources (resource dependence theory: Pfeffer and Salancik, 1978) forces research organizations and researchers to alter their activity as conditions for funding change. Our starting point here is that there is no straightforward mechanism from funding incentives to research activity, but rather that it is the complex mix of different allocation mechanisms, funding sources and their varying criteria of funding which creates incentives for change or stability in the system. At times these incentives balance each other and at other times they reinforce each other (cf. Benner and Sandström, 2000; Geuna, 1999).

There is no doubt that research activity is affected by several other contextual elements from cultural practices to the political legitimization of a system. For example, research assessments and the overall science policy "climate"—while not being directly connected to funding—may have consequences on an institutional level (Jongbloed, 2007). On the other hand, researchers and universities are highly able to adapt their behaviour and organization to new external requirements in ways that do not affect their pattern of activity too much if requirements do not match their interests (Calvert, 2000; Krücken, 2003). Furthermore, external policy pressures and incentives are mediated by existing disciplinary cultures (Hakala and Ylijoki, 2001).

2.2. Typology of funding environments

Funding models for university research can be classified on the basis of the degree to which they are based on internal or external funding (Irvine et al., 1990). In general, internal funding can be defined as consisting of governmental core funding and a university assets. While, strictly speaking, from the universities' perspective, governmental core funding is also external funding by nature, it is usually justified to see it as internal funding so far as universities are capable of determining its allocation and use within their organizations. In reality this view is complicated by various earmarked and strategic funds, which can be subsumed into block grants as well as by steering exercised by the state via various funding methods.

External funding, in turn, can be defined as public and private research funding which is not part of the core funds. Public external funding is composed of public project funding or grants by public funding agencies and contracts with public administration. While contracts with public administration correspond with contracts with the private sector, funding agencies with varying aims also carry out a science policy steering function (Braun, 1998). The state can use both the allocation of core funds and funding agencies as steering instruments. Because universities' research funds usually consist predominantly of governmental core and agency funding, the targets and criteria of public funding play a major role in the university-system-level steering.

The basic idea in the analytical framework (Fig. 1) is relatively simple: there are country-specific funding environments,[1] which vary due to different funding sources, their shares of total funding and involved incentives. Depending on the internal–external funding ratio and input–output orientation of the core funding allocation, the overall systemic dynamics caused by funding vary. These dynamics, in turn, may have varying impacts on system

[1] There are correspondingly meso- and micro-level funding environments at the university/faculty/department level, which differ significantly across universities and fields of science (Nieminen, 2005). This analysis concerns, however, only macro-level incentives and system-level aggregate performance.

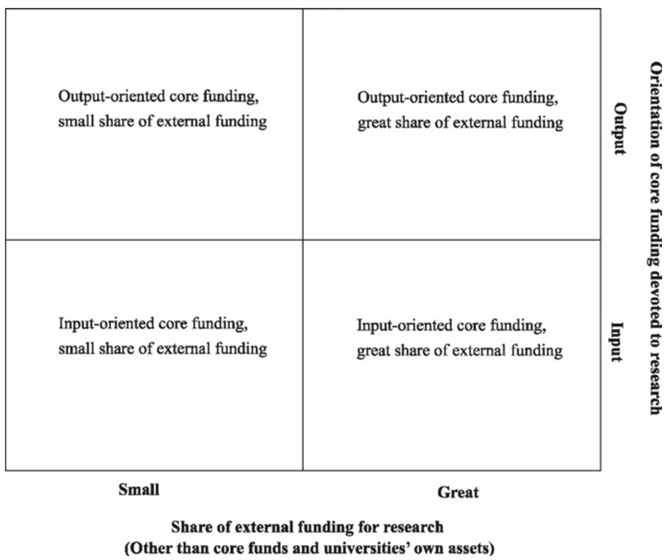


Fig. 1. Framework for positioning university research funding systems. Funding systems (countries) can be positioned in the framework according to their orientation of core funding and share of external funding.

outputs. The continuums are cross-tabulated in order to form a two-dimensional framework for estimating country-specific systemic characteristics (cf. Jongbloed and Vossensteyn, 2001). The position each country has in this two-dimensional framework mirrors the potential susceptibility of the universities in a given country to different steering impulses and activity paths in research.

On the left side of the field, state funding dominates in the form of core funds. The role of the state is important in the steering of the system. Universities are mainly dependent on the state core resources and affected by political steering. On the right side of the field, universities have more funding sources and, part of the governmental steering occurs through funding agencies. The role of the state is not necessarily weaker compared to the situation on the left side but it is more indirect. However, in this case there are also other actors (e.g. industry), which may directly affect the orientation of research while in the previous case these interests are mainly represented indirectly through state steering.[2] The lower part of the field describes input-oriented systems and the upper part systems with an output orientation in government core funding. In an input-oriented system the governmental steering is usually weaker than in output-oriented systems. In input-oriented systems the state is more concerned about the sufficiency of resources, while in output-oriented systems it explicitly expects efficiency and definable results from the universities (Geuna and Martin, 2003, p. 296; Jongbloed and Vossensteyn, 2001, p. 128).

In general, systems in which governmental core funding dominates are sensitive to changes in the allocation mechanisms and incentives of public funding. However, core funding may also increase stability in the system as it covers the salaries of permanent research and teaching personnel as well as basic infrastructure expenditures. Usually it is not possible to use external project funding for these purposes. Therefore, systems in which external funding dominates can be seen as volatile from the perspective of permanent basic structures. On the other hand, external funding and its availability can also be seen as an opportunity for new initiatives and the extension of activities. Input-oriented core funding systems are potentially less dynamic than output-oriented systems (Geuna and Martin, 2003, pp. 297–299).

[2] There are differences among countries as to the degree researchers and other actors such as industry can affect the formulation of science policy agendas (Rip and van der Meulen, 1996).

3. Data and methods

3.1. Data

The compared countries have been selected on the basis that the comparison would include both big and small countries as measured by total R&D expenditures and output of scientific publications. The compared countries are: Australia, Denmark, Finland, Germany, the Netherlands, Norway, Sweden, and the UK. For each country, we collected three types of data: document data on the mechanisms of government core funding, statistical data on the development of level and sources of research funding, and data on publication volumes. Data were collected from various national sources, OECD databases and Thomson Reuters Web of Science databases (the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index).

One problem in the data on funding mechanisms was that the quantity of available information as well as its quality varied across countries. In some cases the data had to be collected from a number of different sources in order to have satisfactory information (see Appendix A for more details). Regarding the structure of research funding in Germany and the Netherlands, we had to rely on a research report (Hackmann and Klemperer, 2000). These figures are therefore older than in the other countries studied.

The data mainly cover the situations in the countries from the beginning of the 2000s to the mid-2000s. There have been and are transformation processes going on in the compared countries' university funding systems. Hence the situation in some of these countries has changed to a certain extent since we gathered the data. Recently transformed or transforming funding systems include at least those of Australia, Finland and Norway. However, as the main aim is to compare the systems and performance of the countries over a certain historical period of time, this does not compromise the analysis.

Even though the OECD and the EU have made recommendations in order to standardize statistical definitions and data collection practices, a number of possible sources of error can be found in the R&D statistics. The most noteworthy is that the data collection methods can differ. This is mirrored, for instance, in the fact that the university sector is defined differently across countries (Irvine et al., 1990, pp. 3–5; cf. Lepori, 2006). One must bear in mind that OECD data often include all higher education institutions carrying out research, not only "research-led" universities.

Web of Science databases are also usually considered methodologically problematic for comparative purposes. They have, for instance, a bias towards journals in the natural and medical sciences and engineering, they favour English-language publications, and cover mainly journal articles excluding much of other research output. Therefore they cover each country's scientific publications only partially and can give misleading information of total performance due to differing scientific profiles (e.g. Bordons et al., 2002; van Raan, 2005; Weingart, 2005).

Despite their limitations, Web of Science databases remain in practice the only available sources for publication measures, since there are no other databases that can provide a wide international coverage of publications. Over the past few decades, international publishing has become increasingly valued and more common also in the social sciences and humanities (Kyvik, 2003; Puuska and Miettinen, 2008, p. 101). Since international publishing is both considered a necessary target for high-standard research and emphasized in science policy agendas, Web of Science can be regarded as reflecting the high-standard international performance of a university system. Still, the number of international publications is not synonymous with scientific quality. In a strict sense, our measurement concerns only country-level publication productivity.

One might also be suspicious whether scientific publications form an adequate indicator of overall research performance. In many countries statistics related to the "third mission" of universities are, however, missing or still in the development phase.[3] While this information would provide, together with domestic publication information, a more profound picture of countries' research-related university performance, we believe that the data are as robust as possible concerning the relations between resources and high-standard scientific performance defined as international publications. In addition, the existing empirical evidence indicates that there is necessarily no decline in academic outputs even though universities receive substantial amounts of industrial funding (Gulbrandsen and Smeby, 2005; Van Looy et al., 2004).

3.2. Methods of analysis

Our analysis consisted of three phases. The first step was to describe the allocation mechanisms of core research funding as well as the level and sources of research funding for universities. The analysis of the allocation mechanisms was based on allocation method(s), funding components and their shares of total core funding, and funding criteria. As funding criteria form the dimension that determines the input–output orientation of core funding in our model, they are described in more detail. As we were interested in university research, descriptions of funding mechanisms focus on research funding components and the associated criteria. Components of funding clearly related to education were excluded. Here we also present data on the "age" (year of implementation) of the respective allocation mechanisms to see how long they have been affecting the university research system in the compared countries. We distinguished between input and output criteria according to the following guideline: when the financier (state) focuses on the sufficiency of resources, it uses input criteria, and when it focuses on the performance and results of the activity, it uses output criteria. Typical input criteria include, for example, the existing funding level of universities ("historical basis"), the number of staff and students, and the strategic and political considerations. Typical output criteria include, for example, the number of produced publications and degrees, the amount of (external) research income earned, and the results of quality assessments.

When analyzing the level and sources of university research funding, we present statistical data on the development of R&D expenditure and recent R&D intensity in the university sector of the compared countries. We also analyze the structure of R&D expenditure at the beginning of the 2000s and show how the share of internal funding (government core funding and university assets) has developed in relation to external funding in 1981–2000.

Second, we positioned the countries in the analytical framework described in Section 2.2. This positioning was based on the results of step 1 of the analysis. Countries with the most competitive funding environments for university research are positioned on the upper right corner of the framework, countries with least competitive environments to the lower left corner.

Third, we analyzed the efficiency of university systems in the compared countries. For this we (a) retrieved from the Science Citation Index Expanded, the Social Sciences Citation Index and the Arts & Humanities Citation Index all the publications attributable to the compared countries' universities in 1987–2006, (b) searched the OECD science and technology database for higher education R&D expenditures (HERD) in the compared countries in 1981–2000, (c) calculated the means of publications and funding for six-year periods for each country, and (d) calculated the funding per publications ratio for each six-year period for each country. We used a six-year time lag between funding and publications, e.g. the six-year mean of HERD in 1981–1986 was divided by the mean of publications in 1987–1992. This funding per publications ratio indicates the efficiency of universities in producing one scientific publication in each country.

By using six-year means of funding and publications we were able to eliminate possible year-to-year fluctuations, thus giving a simple and more solid figure for general trends. We used six-year time lags because the available resources are not immediately realized as publications. Usually there is lag between the change in R&D investments and the change in the number of publications. As funding makes research activities possible, the studies have to be conducted before publishing. In choosing the time lag we followed the results of an econometric approach by Crespi and Geuna (2008), who concluded that there are no significant effects from past R&D (expenditure) on publication output after six years.

We are not able to control all the possible affecting factors in employing the HERD per publications calculation, such as the varying structures of science and technology systems or funding patterns in the compared countries. While the analysis cannot positively confirm which factors are decisive in publication performance, it can, however, illustrate the role of competition.

4. Results

4.1. University research funding in the compared countries

4.1.1. Allocation mechanisms for core funding

One of the crucial elements in the analysis of funding environments is time. When following the changes in publication productivity one must bear in mind that changes in funding systems have been implemented at different times in the compared countries. The countries where there are no radical changes also form an important point of comparison for the other countries. If there are no remarkable differences in publication productivity between the compared countries over the time, also the effect of the competition mechanisms is doubtful. Another issue is the time lag between implementation of the funding system and its possible consequences. While there is no definitive answer on this question, it might be sensible to assume that the lag is the same as in the case of the change of resources, i.e. maximum six years.

In order to find out the length of influence of incentives used in core funding systems that are described here, we ascertained when these systems were implemented in the compared countries. Most of the systems are rather new but there is more variation if we also include the changes in the more distant past (Table 1). The UK, Netherlands and Denmark have older systems while Finland, Australia and Sweden have more recent systems, and Norway the newest. Table 1 also shows that when governments change the principles of allocating core funding to universities, it often happens by changing some elements of the existing system, not by reforming the entire system at once.

We can conclude that possible long-term effects of performance incentives on core funding are to be expected especially in the UK but to a lesser extent also in Denmark and the Netherlands.

The compared countries can be clustered roughly into three groups according to their input–output orientation in government core funding. To start with the output-oriented systems, the UK and Australia were clearly the most output-oriented systems in

[3] Perhaps the most developed follow-up statistics on the third mission can be found in the UK.

Table 1
Year of implementation of the described core funding systems in the compared countries.

Country	Year
Australia	2002 (some features of the system implemented in 1996)
Denmark	1993 (a more output-oriented system adopted at the beginning of the 2000s)
Finland	2004 (some features of the system implemented in 1998)
Germany	1990s or before that (each state (Land) has its own funding system)
Netherlands	2006 (most of the features of the system implemented in 1993)
Norway	2002
Sweden	2000 (most of the features of the system implemented in 1997)
UK	2002 (most of the features of the system implemented in 1986)

Source: Various national sources, see Appendix A.

the early or mid-2000s (Table 2). Unlike in some other countries, the formula was used plainly as an allocation method and the criteria emphasized performance. In Australia the system was to some extent more focused on measurable performance (e.g. the amount of research income and number of publications) than in the UK. In the UK the emphasis has been on the outcomes of the Research Assessment Exercise (RAE) while some input-oriented funding components can be found in the system. The RAE emphasizes qualitative evaluation of university research while using quantitative indicators as part of the evaluation. Both countries, however, devoted a separate segment of their core funding to research and used predefined performance criteria to allocate it. This makes competition an integral component of obtaining core research funding from the government budget. In addition, the core funds have included several subsumed programs or earmarked allocations for certain purposes, i.e. steering has taken place both through specified targets and performance monitoring.

The second group includes Norway, Finland, and the Netherlands (Table 3). All these countries used a formula, evaluation and quantified criteria, but the extent of existing activities, number of students and circumstantial considerations played a bigger role in the allocation than in the UK and Australia: competition-based incentives were used, but not as exhaustively. The funding component, usually called the basic component or basic allocation, covered a significant proportion of core funding and it was largely based on the extent of existing activities. It also has to be noted that the utilization of formula as such does not make a system output-oriented. In many countries the elements of the formula consisted of input information or one element was the current resource situation (e.g. the Netherlands and Norway). In addition, it seems that

Table 2
Dimensions of allocation mechanisms of government core funding for university research in Australia and the UK.

Australia
Method: Formula
Components: Teaching and learning allocations (81% in 2004) and research and research training allocations (19% in 2004): research and research training allocations include block funding for research (Institutional Grants Scheme, Research Infrastructure Block Grants Scheme, Regional and Rural Assistance) and block funding for research training (Research Training Scheme, Australian Postgraduate Awards, International Postgraduate Research Scholarships Scheme)
Criteria: Institutional Grants Scheme: amount of research income (60%), number of publications (10%), and number of higher degree research student places (30%). Research Infrastructure Block Grants Scheme: university's share of Australian Competitive Grants income. Regional and Rural Assistance: targeted to regional universities for avoiding deterioration in research funding in the first three years of the new funding system. Research Training Scheme, Australian Postgraduate Awards, International Postgraduate Research Scholarships Scheme: number of successful research degree completions (50%), amount of research income (40%), number of research publications (10%)
UK (information not available on Northern Ireland)
Method: Formula
Components: *England*: Funds for teaching (76%) and funds for research (24%): funds for research include Quality-related research funding (Mainstream QR, Research-degree programme supervision fund, Charity support element, London weighting, 'Best 5*' allocation, Transitional special funding for research libraries) and Research Capability Fund
Scotland: Grants for teaching, research and knowledge transfer: Grants for research and knowledge transfer include the Main Quality Research Grant, Research Development Foundation Grant, Research Postgraduate Grant, Strategic Research Development Grant, Science Research Investment Fund, Knowledge Transfer Funding (Knowledge Transfer Grant, Promotion of Knowledge Transfer), The Scottish Institute for Enterprise, Research Support Libraries Programme
Wales: Funds for teaching, postgraduate research training and research: funds for research include quality research funding, the Research Investment Fund, and the Science Research Investment Fund.
Criteria: England: Mainstream QR: RAE rating (only ratings 4–5* (scale 1–5*) attract funding) proportioned to number of research staff and relative costs of subject area. Research-degree programme supervision fund: cost-weighted UK and EC postgraduate research student numbers in departments rated 4 or above in RAE. Charity support element: amount of charity research income, to universities with departments rated 4 and above in RAE, or rated 3b or 3a and receiving grant from the Research Capability Fund. London weighting: 12% (for inner London) or 8% (for outer London) of the total of mainstream QR funding to universities in the London area. 'Best 5*' allocation: to universities with departments rated 5* in RAE of 1996 and 2001. Transitional special funding for research libraries: to heavily used libraries of national importance. Research Capability Fund: to subject areas with low proportions of staff in departments rated 4–5* in the 2001 RAE, and relatively high proportions of QR funding in 2002–2003 attributable to 3b or 3a-rated departments, proportioned to the number of research staff and the relative costs of the subject area
Scotland: Main Quality Research Grant: RAE rating (only ratings 3̂a–5* (scale 1–5*) attract funding) proportioned to the number of research staff and students, the amount of research income and the relative costs of the subject area. Research Development Foundation Grant: average amount of research income of the previous two years, to universities with departments not funded through the Main Quality Research Grant. Research Postgraduate Grant: number of full-time equivalent student places, proportioned to the costs of the subject area. Research Development Grant: strategic considerations, based on Scotland's strategic priority areas in research. Science Research Investment Fund: strategic considerations, based on the research infrastructure needs of universities. Knowledge Transfer Grant: amount of income from various "outreach" activities. Promotion of Knowledge Transfer: strategic considerations, funding intended to promote research expertise, commercialisation and knowledge transfer. The Scottish Institute for Enterprise: support for teaching management and business skills to students and researchers. Research Support Libraries Programme: strategic considerations
Wales: Postgraduate research training: number of previous year's student enrolments proportioned to the costs of the subject area, only to departments rated 3b or above in RAE or departments rated 2 whose RAE return included Research Council income. Quality research funding: RAE rating (only ratings 4–5* (scale 1–5*) attract funding) proportioned to the number of research staff and students, amount of charitable income, the relative costs of the subject area and the average ratings of the subject areas in RAE. Research Investment Fund: volume of research staff in 3a and rising/new 3b departments. Science Research Investment Fund: amount of a university's QR funding and combined total amount of a university's external research income and QR funding

Table 3
Dimensions of allocation mechanisms of government core funding for university research in Finland, the Netherlands and Norway.

Finland
Method: Negotiation and formula

Components: Core funding, including the extent factor (19%, including the basic component, new students, facilities), education appropriation (44%), research appropriation (30%, including graduate schools, doctorates), and societal services appropriation (7%, including open university activities and other societal services), project funding and performance-based funding. Funding for teaching and research are not separated.

Criteria: Basic component: university's operational expenditure in the last year of the previous performance agreement period. New students: target numbers set in performance agreements. Facilities: university's realised budgetary expenditure in the middle year of the previous performance agreement period. Graduate schools: decision based on assessment. Doctorates: target number of PhD degrees (2/3), number of completed PhD degrees (1/3). Open University: target number of FTE student places (2/3), number of realised FTE student places (1/3). Other societal services: intended to support equipment-intensive activities and university's regional impact, partly R&D expenditure and research personnel. Project funding: strategic priorities. Performance-based funding: number of centres of excellence in research in the university, amount of funding from the Academy of Finland, amount of other external research funding.

Netherlands
Method: Formula

Components: Teaching component and research component: research component includes basic allocation (17%), allocation for PhDs and designer certificates (12%), allocation for research schools (3%), allocation for top research schools (3%), strategic considerations allocation (60%), Smart Mix (4%)

Criteria: Basic allocation: extent of existing activities. Allocation for PhDs and designer certificates: two-year average number of completed degrees. Allocation for research schools: university's share of basic allocation, allocation for PhDs and designer certificates and strategic considerations allocation. Allocation for top research schools: strategic choice based on assessment. Strategic considerations allocation: extent of existing activities. Smart Mix: amount of competitive research funding

Norway
Method: Formula

Components: Basic component (57%), teaching component (21%), and research component (23%, including result-based funding and strategic funding)

Criteria: Basic component: extent of existing activities. Result-based funding: completed PhD degrees (30%), amount of EU research income (20%), amount of research council research income (20%), number and level of scientific publications (30%). Strategic funding: number of PhD student places, decisions on special funding for scientific equipment, strategic considerations

Table 4
Dimensions of allocation mechanisms of government core funding for university research in Denmark, Germany and Sweden.

Denmark
Method: History and formula
Components: Appropriation for education (activity-based), appropriation for research (performance-based, including basic research grants and new research grants), and building and rent grants (including building taximeter grant related to education, research overheads and basic grant).
Criteria: Basic research grants: extent of existing activities. New research grants: amount of educational grants (50%), amount of external research income (40%), and number of awarded PhD degrees (10%). Research overheads: total research turnover of a university. Basic grant: rent of special university buildings.

Germany
Method: History, formula
Components: Most of the states (Länder): core funding budget. Funding for teaching and research are not separated.
Criteria: Most of the states (Länder): extent of existing activities.

Sweden
Method: History
Components: Core teaching funding and core research funding: core research funding includes four funding areas: the humanities/social sciences, medicine, the natural sciences, technology.
Criteria: Extent of existing activities, strategic considerations.

these countries used less specific programs or earmarking in the allocation, giving more leeway for universities' own considerations in their internal allocation of funding.

The least output-oriented countries in this comparison were Sweden, Germany and Denmark (Table 4). The significance of the formula-based allocation decreases in these countries compared to the two previous groups. The extent of the activities (historical basis) and political considerations have played a more prominent role. They have been rather input-oriented in the allocation of core funds, even though some indicators have been used. If an evaluation of activities was carried out, it was usually linked to the development of activities. Denmark was to some extent an exception, as performance indicators were used in the allocation of new research grants. Allocations based on the previous expenditure of resources are not etched in stone, however: they can be changed by political decisions. For instance, in Sweden, which is one of the clearest examples of input-oriented systems, most of the increase in direct government research funding in the period of 1997-2002 was allocated to three "new" universities (Högskoleverket, 2004, pp. 51–52). What is also of interest is the fact that these countries have used less strategic allocations or earmarked funds for specific science and technology policy goals than the other compared countries have done. Earmarked or strategic funding components appear to have been especially typical in the UK, but also Finland, and to a lesser extent Australia, the Netherlands and Norway have used them (Tables 2 and 3).[4]

4.1.2. Level and sources of research funding

The volume of university R&D expenditures has increased between 1981 and 2001 in all the countries compared (Table 5). There are some country-specific trends. Especially Australia and Finland have increased their research volume during this period. The volume of university research funding per capita was rather low in these countries at the beginning of the 1980s, which partially explains the growth rate. At first glance, the relative position

[4] Examples of earmarked or strategic funding components: UK: London weighting, 'Best 5*' allocation, Strategic Research Development Grant, Promotion of Knowledge Transfer; Finland: Open University, Other societal services, Project funding; Australia: Regional and Rural Assistance; Netherlands: Strategic considerations allocation; Norway: Strategic funding in research funding component.

Table 5
Higher education R&D expenditure (HERD, million constant US dollar 2000 prices and PPPs), HERD of gross domestic R&D expenditure (GERD, %) in 1981, 1991 and 2001, and change of HERD in 1981–2001 (%) in the compared countries.

Country	HERD 1981	HERD of GERD 1981 (%)	HERD 1991	HERD of GERD 1991 (%)	HERD 2001	HERD of GERD 2001 (%)	Change of HERD 1981–2001 (%)
Finland	218	22	465	22	826	18	279
Australia	740	29	1202 (1)	26	2124 (2)	27	187
Denmark	277	27	439	23	700	19	153
Norway	310	29	461	27	673	26	117
UK	2910	14	4036	17	6243	22	115
Netherlands	1080	23	1955	30	2245	27	108
Sweden	1050	30	1447	27	2053	20	96
Germany	5096	17	7185	16	8584	16	69

Source: OECD (2006).
Notes: (1) 1990. (2) 2000.

of universities in science and technology systems seems to have weakened to some extent over the same period of time. The share of universities in the compared countries' research and development expenditures has increased clearly only in the UK, while in other countries the share has decreased to some extent. This can be explained, however, by industrial research and development, which has grown strongly during the past ten years. While at the same time the share of public research institutes has decreased, it can be claimed that the relative position of universities has actually strengthened, not weakened (see e.g. OECD, 2004, pp. 195–196). There is also cross-country variation in this respect, which can be explained by differences in system structures. For instance in Sweden, universities have a very strong position due to the fact that universities carry out tasks which in some other countries are the responsibility of public research institutes. In contrast, in Germany, the role of public research institutes is strong.

A somewhat better estimation of the relative university sector research investments can be obtained by comparing the proportion of expenditures with the population (Table 6). Big countries rather self-evidently dominate the scene when looking at the volume of university research expenditures, but when these figures are proportioned to the population, it turns out that the Nordic countries invest relatively more in university research than does, for instance, the UK or Germany. The Nordic countries have the biggest university sector research investments per capita among the compared countries, Sweden being well ahead of the other Nordic countries. The Netherlands is in the middle ground, while the UK, Germany and Australia invest the least. Again, when we look at these figures, we have to remember systemic differences among the compared countries. On the other hand, Finland, for instance, has both rather extensive university and public research institute networks, indicating that systemic characteristics do not exhaustively explain differences in research investments.

These differences can also be due to the structure of funding. The more additional or external funding there is, the higher are total expenditures. The comparison of countries indicates, however, that high research expenditures per capita do not necessarily go hand in hand with large amounts of external funding (Figs. 2 and 3). The share of external funding is high in Sweden and Finland, which also rank high in per capita research expenditure, but the same does not apply to the UK. Also, Norway and Denmark invest a great deal in university research in relation to population size, but rely more on governmental core funding. In addition, the structure of external funding varies. Research funding agencies are rather clearly more significant financiers in Finland and the UK than, for instance in Sweden or Australia. The varying shares of funding agencies vs. other external funding sources, however, do not seem to affect the publication productivity among countries, as we will see later.

At the beginning of the 2000s the UK, Finland and Sweden were the most competitive funding environments for universities when looking at the shares of internal and external funding. In the rest of the countries the role of core funding and university assets in research was more significant, the Netherlands emerging as the least competitive funding environment. Longitudinal data (Fig. 3) show that the funding environments have become more competitive in all the compared countries as the share of internal funding has decreased in all of them in 1981–2000. The extent of this development has varied, the largest changes having happened in the UK and Finland.

It could be argued that variation in funding structures mirrors, in addition to differences in science and technology policy agendas, also wider political and economic differences. The strong position of governmental core funding in some of the Nordic countries may reflect the traditionally strong position of the state and the maintenance of the welfare policy tradition. Also economic structures and potential vary. Large industrialized countries usually have more accumulated capital and large-scale industry, thus having more leeway to finance university research than their smaller counterparts. On the other hand, Norway has a wealthy national economy due to its oil industry, which gives Norway greater potential to finance universities directly through the state budget.

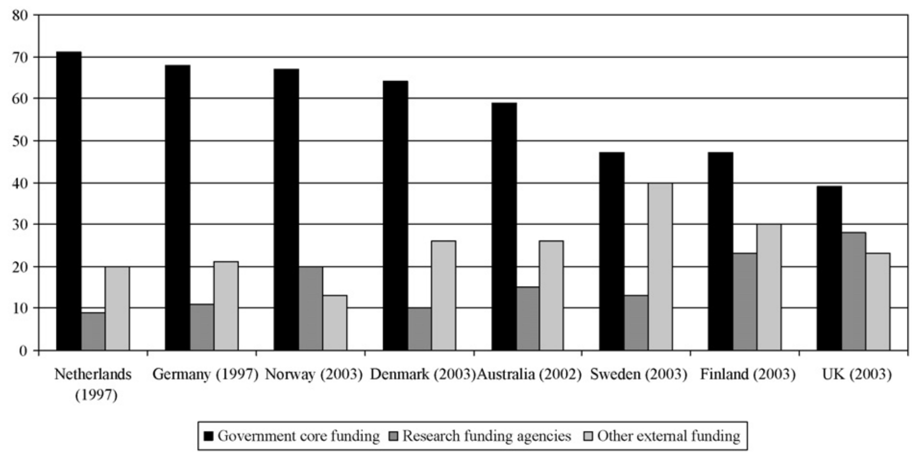
Table 6
Higher education R&D expenditure (HERD, million current PPP US dollars) and HERD per capita (current PPP US dollars) in 2003 in the compared countries.

Country	HERD	HERD per capita
Sweden	2293	256
Finland	952	183
Denmark	982	182
Norway	823	180
Netherlands	2543	157
Australia	2566 (1)	130
UK	7358	125
Germany	10,037	122

Source: OECD (2007b).
Notes: (1) 2002.

4.2. Funding system characteristics in the analytical framework

By using allocation mechanisms of core funding and the proportion of external funding as rough indicators, the overall conclusion of the comparison is that there are country-specific differences among national university systems in relation to steering impulses and competition incentives (Fig. 4). In countries where the relationship between target-setting and funding of research is less pronounced, governmental core funding does not steer research activity significantly, or steering takes place indirectly via funding agencies (Sweden, Denmark, the Netherlands, Norway). If at the same time the proportion of external funding is low (Germany), the influence of external steering and competition incentives over research is limited. In these countries the degree of systems' built-



Sources: Various national sources, see Appendix A.

Notes: Based on the OECD recommendations, the share of core funding devoted to research is a calculation. It is based on time-use coefficients usually derived from national university personnel surveys, in which the allocation of time resources to research, education and other activities is studied. Funding from research funding agencies includes Deutsche Forschungsgemeinschaft (DFG) in the case of Germany and Australian Competitive Research Grants and Commonwealth schemes in the case of Australia.

Fig. 2. Shares of government core funding, funding from research funding agencies and other external funding of universities' total research expenditures (%) in the compared countries.

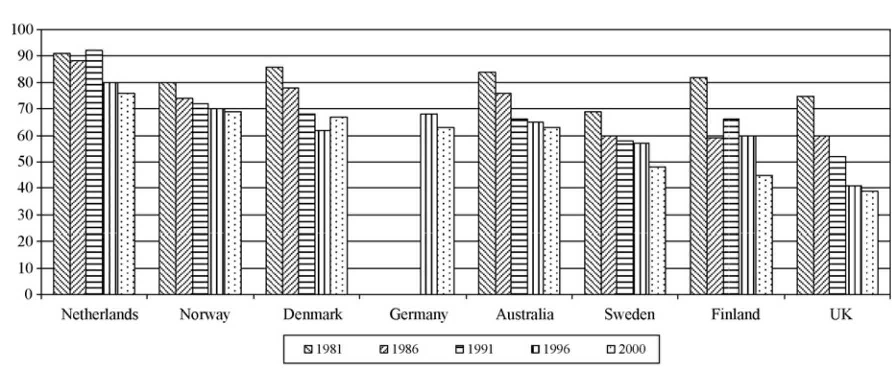
in competition is also low or moderate. Input-oriented core funding systems may balance the competitive effects of external funding. This holds true for Sweden and to a lesser extent for Finland.

The situation is clearly different in the UK and Australia, where the core funding systems emphasize funding through performance, giving a lot of weight to steering incentives and competition. Furthermore, as research is to a large extent externally funded especially in British, but also in Australian universities, these university systems include cumulative competitive elements.

Despite the fact that policy influences are internationally mobile and countries imitate each other's policy solutions rather effectively (Ruivo, 1994), the dispersion of countries within these two dimensions also suggests that funding transformations do not take place in a uniform manner (cf. Geuna and Martin, 2003; Jongbloed and Vossensteyn, 2001). There may be a number of interconnected reasons for this (Hood, 1995; Kivinen et al., 1993; Rip and van der Meulen, 1996; Van der Meulen, 1998; Senker et al., 1999):

- Economic, structural and cultural elements slow down the pace of reforms.
- The adaptation of new ideas to local conditions takes time.
- Not enough political will or leverage exists to change the system.
- Political affiliations or participation structures in policy-making resist changes.
- Rhetoric and policy targets usually change faster than actual practices.
- Policy-makers wait to learn from the experiences of path-breaking countries and avoid possible problems.
- Past decisions and actions restrict the scale of possible policy actions (path dependency).
- Actors (universities, their units, researchers) may react to changes in a way that slows down changes.

Germany is an example of a country in which structural and cultural elements have apparently delayed reforms. It is a federation in which states (Länder) have relatively broad autonomy in university issues. Federation-wide reforms in universities are therefore relatively difficult to implement. Furthermore, as the Humboldtian tradition of closely linking teaching and research has been strong, core funding does not separate teaching and research. A funding system in which teaching and research would have separate performance-based portions would undoubtedly go against



Source: OECD, 2007a.

Note: Missing values in original data have been replaced by the means of closest possible years.

Fig. 3. Share of internal funding (government core funds and university assets) of the higher education R&D expenditure in 1981, 1986, 1991, 1996 and 2000 (%) in the compared countries.

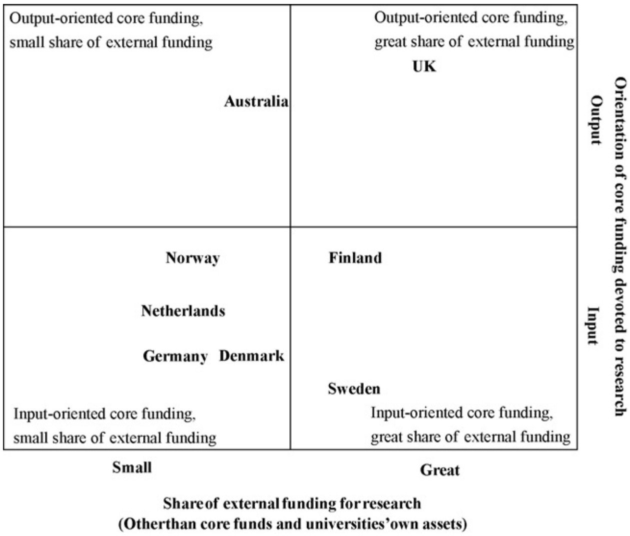


Fig. 4. University research funding systems according to orientation of core funding and share of external funding in the compared countries. Situation at the beginning of the 2000s.

the idea of a close teaching–research nexus. However, as in practice the funding needs of universities have been defined primarily on the basis of educational needs, research staff have been increasingly forced to seek external funding sources. There are, however, clear indications that Germany is moving towards a more output-oriented system (Orr, 2004; Schimank and Winnes, 2000; Senker et al., 1999). The Netherlands seems to be an example of a country where policy-makers have not had enough leverage to change the system. Even though there have been continuous debates on changing the Netherlandic funding system to a more output-oriented one, universities have successfully resisted these plans (Jongbloed, 2005).

4.3. Publication performance and efficiency

Fig. 5 presents the answer to the second research question: are there differences among countries in their publication performance according to the degree of competition in the funding environment? As we can see from the figure, the compared countries are divided into two groups based on their efficiency: UK, Finland, Australia and Denmark form the group of more efficient systems, while the Netherlands, Sweden, Norway and Germany are less efficient. The latter group is less coherent than the former. Countries in the latter group come closer to each other towards the end of the period of analysis while starting relatively far from each other. Since the UK, Australia and also Finland are more competitive funding environments for universities than the rest of the countries, the result appears to support the idea that competition for money makes universities more productive in research.

However, the relationship between competition for money and publication performance is more complex than that. Several observations support this conclusion. First we can note that the efficiency ratios remain unchanged in nearly all the countries during the entire period. The most competitive countries have introduced their funding systems at different times during the period of analysis. The UK was the first to increase competition, using the RAE-based core funding since the mid-1980s while Australia and Finland started to use more competitive funding instruments from the mid-1990s. Despite these efforts, there is no rise in efficiency ratios in these countries. Finland even goes down at the end of the period. Second, Denmark is in the group of more efficient countries while the funding environment for Danish universities has been one of the least competitive ones. The same partly applies to the Netherlands, although we must note that the efficiency of the Dutch university system is clearly lower than of the top four countries. Third, Sweden demonstrates a substantial increase in efficiency although it has been a quite non-competitive environment. Similarly, the efficiency of German university research increases, although Germany has been an even less competitive

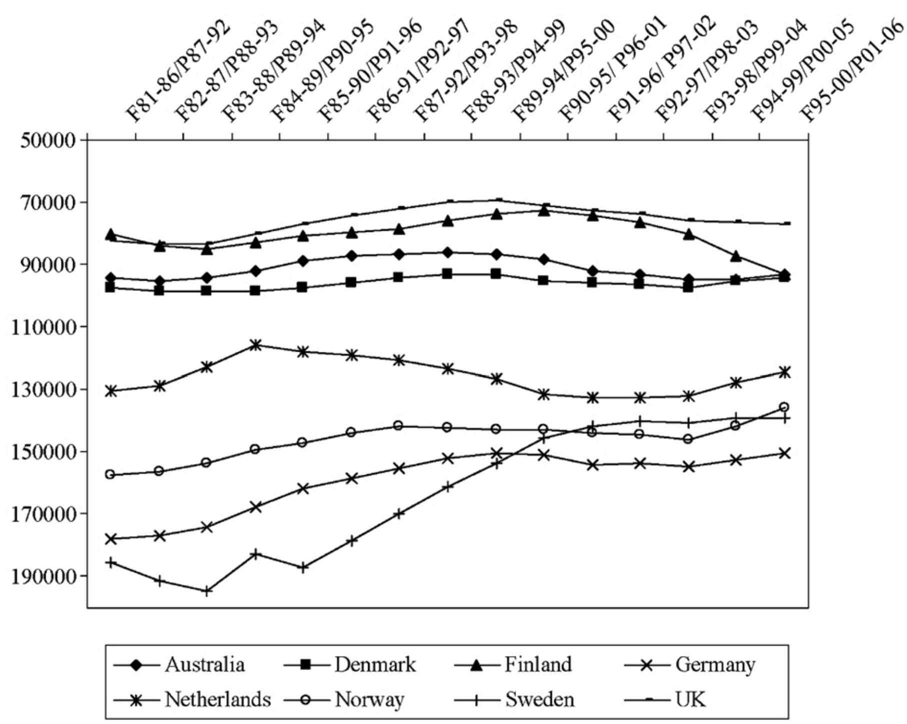


Fig. 5. Higher education sector R&D expenditure (HERD) per publications ratio in constant US dollars 2000 prices and PPPs in the compared countries (six-year means of HERD (F) 1981–2000, six-year means of publications (P) 1987–2006 and six-year time lags).

funding environment than Sweden. One must remember that external research funding has clearly increased in Swedish universities in 1981–2000, which has tightened the competition for funding. On the other hand, the government core funding system in Sweden has remained input-oriented.

Furthermore, some cultural and system-related reservations with respect to university sectors in the compared countries are in place. The UK and Australia may have a relative advantage as English-speaking countries in producing articles for mainly English-language international journals. The language factor may partially explain why especially Germany as a "big" science system does not get higher values in this comparison: its scientific community is oriented to producing publications also for the Germanic language area. These publications are less extensively covered by the Web of Science databases. Also some country-specific reasons for differences in publication performance most likely exist. For example, Swedish universities perform activities, which in some other countries are carried out by public research laboratories and institutes. This might result in a situation where relatively more resources devoted to universities are spent on research and development activities that do not lead to international scientific publications.

Our results suggest that output and competition incentives have a positive effect on publication productivity, at least to a certain degree. But if we take into account the "deviant" cases of Denmark, Sweden and Germany, as well as the aforementioned language-related, cultural and systemic intervening factors, we may conclude that the idea of competition for funding as a promoter of productivity in university research is not a straightforward issue. In any case, efficiency ratios tend to stay on the same level with some fluctuations or increase over the years.

5. Conclusion and discussion

Our aim in this article has been twofold: first, to see how the funding environments of university research vary across countries. The theoretical idea behind this analysis was that financial incentives form a macro-level imperative in the development of university-based research. There is, however, no straightforward mechanism from funding incentives to research activity. Incentives sometimes balance and sometimes enforce each other. Thus, one needs to study both the allocation mechanisms of core funds and the share of external competitive funding in order to assess the overall degree of competition in the system of university funding. The second aim of the article was to analyze the compared countries' scientific productivity in terms of international publications. The overall rationale behind funding incentives is usually that if money is given to the best performers, it will most likely produce better results and give an overall incentive for better performance. From this logic it follows that the most competitive systems should also be the most productive systems when resources are taken into account.

Our results indicate that there are significant country-specific differences among university systems in relation to steering impulses and competition incentives. Despite the fact that often countries effectively emulate each other's policy solutions, such as the NPM principles, transformations do not take place in a uniform manner. Governments adapt policy solutions to their own systems and have to take into account the political and systemic conditions under which changes can be implemented. Thus, university research is conducted in rather different country-specific funding environments.

The efficiency calculations suggest, in turn, that the idea of output and competition-based incentives promoting productivity in science is more complex than policy-makers seem to believe. Even though the countries with a competitive funding environment for university research (the UK, Australia and Finland) appear more efficient than the rest, they have not been able to increase their efficiency in publication output. At the same time, some university systems with a less competitive funding environment are either almost as efficient as the more competitive systems (Denmark) or have been able to increase their efficiency despite the relatively low level of competition for funding (Sweden and Germany).

This result raises a crucial question in terms of policy-making. While there is an evident need to find ways to enhance a country's research activity, is it possible that funding incentives and competition can be used too excessively and that they do not after all significantly affect research productivity? Too much competition may even be dysfunctional from the perspective of productivity since competition for funding takes time and energy away from research and writing. Might it be that incentives that have traditionally been part of the institution of science (e.g. researcher's reputation, mission to produce new knowledge, competition for tenure) are more decisive than recent funding-related incentives? Research processes and productivity can also be enhanced by other means, which relate to the conditions under which research is conducted. The literature on the quality and creativity of science suggests that, among others, multi-level communication, continuity in funding, and peace and quiet in working environments, are factors which support creativity and productivity (Amabile, 1994; Gulbrandsen, 2000; Hurley, 1997).

Our results cast doubts over the widespread and self-evident use of funding incentives in research policy and management. More detailed country-specific studies on the relations between funding incentives and the dynamics of research activity are needed (cf. Cherchye and Abeele, 2005). There is some evidence that, at the grass-root level of research, researchers are able to adapt to increased competition for funding. Adaptation can happen through careful selection of funding sources, "creative" use of funding or through shaping the research content (Laudel, 2006). Our macro-level approach is not able to reveal these kinds of processes. Strong funding incentives may have unintended and negative system-level consequences, such as the emphasis on quantity instead of quality, orientation to less innovative, mainstream research and weaker societal impacts in the long run (Butler, 2003; Langford et al., 2006; Laudel, 2006). Policy-makers should take these risks into account.

Acknowledgements

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Appendix A. Data sources

A.1. General sources

OECD, 2006. Research & Development Statistics—Gross Domestic Expenditure on Research and Development by Sector of Performance and Source of Funds (Table 1), vol. 2006 release 01. URL http://oberon.sourceoecd.org/vl=1404917/cl=78/nw=1/rpsv/∼3954/v209n1/s1/p1.

OECD, 2007a. Research & Development Statistics—Gross Domestic Expenditure on Research and Development by Sector of Performance and Source of Funds (Table 1), vol. 2007 release 1. URL http://titania.sourceoecd.org/vl=5960719/cl=15/nw=1/rpsv/ij/oecdstats/16081242/v209n1/s42/p1.

OECD, 2007b. Main Science and Technology Indicators, vol. 2007 release 02. URL http://titania.sourceoecd.org/vl=8087228/cl=20/nw=1/rpsv/ij/oecdstats/16081242/v207n1/s1/p1.

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A.2. Country-specific sources

A.2.1. Australia

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Appendix B. Data used in the calculation of efficiency ratios

See Tables B.1 and B.2 for details.

Table B.1
Higher education R&D expenditure in 1981–2000 in the compared countries (million constant US dollars 2000 prices and PPPs).

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Australia	747	827	827	908	970	1033	1062	1058	1130	1203	1342	1481	1523	1565	1705	1904	1992	2081	2102	2123
Denmark	267	274	288	303	320	354	377	407	430	434	438	459	483	539	596	546	604	594	628	685
Finland	212	237	262	279	298	319	348	369	374	377	452	456	428	435	466	497	623	684	788	792
Germany	5114	4981	4942	5038	5147	5337	5561	5732	5858	6072	7282	7462	7419	7504	7699	7945	7947	7997	8142	8414
Netherlands	1106	1323	1304	1280	1325	1369	1420	1382	1426	1984	2043	2040	2078	2096	2174	2253	2249	2211	2310	2372
Norway	303	299	306	311	332	337	342	369	395	423	452	478	504	510	516	548	580	621	662	663
Sweden	1059	1141	1224	1277	1330	1432	1534	1608	1681	1571	1460	1503	1545	1522	1500	1558	1616	1708	1800	1931
UK	2895	2932	2969	3139	3310	3523	3793	3847	3838	3954	4001	4054	4287	4787	4793	4798	4831	4944	5288	5728

Source: OECD (2007a).
Note: Missing values have been replaced by the means of closest possible years.

Table B.2
University publications in 1987–2006 in the compared countries.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Australia	8900	9105	8842	9251	9686	10,639	11,459	12,162	13,797	14,772	15,381	16,434	17,252	17,596	18,563	17,999	21,208	20,793	23,651	25,886
Denmark	2953	2891	2893	3046	3142	3651	3812	4197	4396	4539	4872	5190	5281	5467	5546	5533	6334	6390	7406	7403
Finland	3306	3193	2997	3293	3378	3799	4049	4551	4762	5234	5666	5921	6142	6361	6508	6209	6869	6871	7299	7631
Germany	29,308	27,686	25,656	28,747	28,774	31,583	32,652	34,774	38,536	42,061	46,696	49,811	49,798	49,335	50,296	47,530	52,079	51,203	59,494	60,117
Netherlands	9023	9288	9220	9950	10,173	11,361	12,308	12,828	14,114	14,583	15,584	15,996	15,783	16,002	16,282	15,916	17,317	17,401	20963	21,298
Norway	1996	1926	1825	1934	2019	2267	2369	2538	2829	2928	3144	3522	3430	3447	3712	3598	3976	4292	5208	5605
Sweden	6601	6628	6225	6679	6813	7311	7820	8321	9044	9566	9909	10,515	10,770	10,588	11,241	10,990	11,962	11,528	13,413	13,505
UK	38,373	36,948	34,976	36,946	37,958	42,973	45,092	48,829	55,269	58,199	58,005	60,588	62,317	63,652	62,279	60,070	63,472	63,764	72,364	73,921

Source: Thomson Reuters (2008).
Notes: Advanced search; search phrase OG = (Univ SAME CU = country name) AND PY = XXXX. For each search, timespan was defined as the same as publication year in the search phrase. UK includes England, Northern Ireland, Scotland and Wales. A search was also conducted using the search terms UK and United Kingdom, but the result in these cases was zero. Both Germany and Fed Rep Ger were used for country name in the case of Germany in 1987–1991 and results added together.

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