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Research / Science / Development

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Abstract

As in other societal realms also in research, science, and development governments and parliaments increasingly have to legitimize their actions and want to base their future activities on informed decisions. Consequently, performance measures, benchmarking, comparative analysis, "foresight studies" are increasingly asked for. Ranking, ratings and evaluations are introduced throughout the system supposedly providing on the one hand the requested transparency and at the same time acting as stimuli to improve the performance. However, to date central questions relating to the underlying methodologies and indicators used are unanswered. These questions concern the availability and appropriateness of the data, indicator construction and methodologies on the one hand, tackle issues as how to deal with effects due to disciplinary, sectoral, regional or national differences, and concern the intended and unintended effects of the instruments used. In the contribution these issues are described and discussed in more detail. In Germany so far infrastructural deficiencies e.g. the fragmentation of research groups addressing those issues prevent adequately addressing the open research questions. Behind this background the two most important tasks identified are them the development of a decentralized data collection system enabling standard definitions and the development of a competitive research infrastructure.

Keywords: Science Indicators, R&D, Research Funding, Governance

1. Research questions

In Germany, the research and innovation landscape is highly diversified and differentiated because of the country's federal structure. Research is conducted in state and non-state institutions, institutes of higher education, non-university research institutions (state-funded) and in industry (two-thirds of invested research funds). Since the 1970s, the interest in assessments and comparative analyses of higher education and research systems has increased massively at an international level. The reasons lie, on the one hand, in the development of a knowledge-based society whose interests are increasingly dependent on research and technology and on the other hand – related to this – in the search for efficient conditions and prerequisites for fostering innovation, top-class research and well-qualified junior scientists. Moreover, more and more, governments and parliaments are demanding performance measures, international comparisons, and "foresight studies", for reasons of legitimisation and of planning. In the course of the 1980s and 1990s, output-oriented research funding gradually increased and, in many European states, the competitive orientation of the academic system grew. Rankings, ratings, evaluations, as well as formula-based allocation schemes, were supposed, and are supposed, to provide necessary transparency, problem diagnoses and performance-raising stimuli.

Michelson (2006) describes the trend in research assessment in the USA as follows:

> First, the standardization and harmonization of performance assessment methodologies has begun to spread across various federal R&D funding agencies. …Second, there has clearly been a turn toward employing quantitative methodologies as a major part of performance assessment initiatives. …Third, the growing use of quantitative bibliometric indicators is also being paired with a renewed focus on utilizing qualitative indicators in an effort to create more appropriate hybrid methodologies that can capture a wider range of variables related to a program's performance.

These three developments can also be observed in Europe.

Analyses of the academic system, assessment and governance instruments and relevant data can be systematically contrasted according to purpose on the one hand and to aggregate level on the other. Purpose can range from academic basic research to the assessment of individual performance, via policy advice, the development of governance systems and public information. Whilst the units of analysis can range from an individual researcher to national academic systems via organisational units (workgroups, institutes, institutes of higher education) and subject units (research fields, disciplines). Essentially, indicators and peer-review procedures apply here, as well as a combination of the two (informed peer review). Because the use of data and assessment procedures in the academic world is as varied as the actors who conduct or commission them, only a few applications are mentioned here as examples: The German Council of Science and Humanities publishes nationwide research ratings for selected subjects. These are based on a series of output data about the examined units of research, which are evaluated by peers according to a particular scale and various criteria (cf. WR 2008). However, in contrast to the British Research Assessment Exercise, which boasts a similar methodological structure, funds are not allocated according to the ratings. Non-university research institutes, such as the Max Planck Society or Wilhelm Gottfried Leibniz Community, conduct regular assessments of their member institutes and have their own departments for carrying out this task.[1] Here, typical indicators (publications, third-party funding, patents, services) for measuring performance are drawn upon and used to reach decisions concerning the allocation of further funds to the establishments. Research funding establishments (e.g. DFG, AvH, ERC) regularly evaluate the outcome of their funding programmes on a selective basis, or they establish monitoring systems, which regularly provide data concerning the performance of a particular programme. Federal states and university faculties alike make use of performance-based fund allocation to distribute part of their budget according to positive and negative performance indicators. Such systems are based exclusively on quantitative positive and negative performance indicators relating to research, and sometimes teaching. Some federal states have their own evaluation institutes (e.g. Lower Saxony – Scientific Commission, Baden-Württemberg – EVA – LAG[2]), which conduct regular or special-purpose assessments of academic establishments. Institutes of higher education develop evaluation and report procedures to collect and disseminate information about performance in teaching and research. They link these assessments to target agreements, in which management and faculties/institutes chalk up common development targets and performance factors. Until now in Germany, the use of performance indicators has not played a significant role in pay negotiations. But with the introduction of elements of performance-related pay, typical research indicators will play an increasingly important role in this area of individual agreements. In some disciplines already (especially in the life sciences) the use of specific indicators (e.g. the Journal Impact Factors for measuring publication activity or the Hirsch Index for quantifying individual research performance) is being used informally – for example within the framework of employment and appointment negotiations (cf. Jaeger 2006; Vahl 2008).

1 Max Planck Society: http://www.mpg.de/ueberDieGesellschaft/profil/evaluation/index.html, Wilhelm Gottfried Leibniz Community: http://www.wgl.de/?nid=veva&nidap=&print=0.

2 Wissenschaftliche Kommission Niedersachsen: http://www.wk.niedersachsen.de, Evaluationsagentur Baden-Württemberg: http://www.evalag.de.

With the significant increase in quantitative indicators and the easy availability of complex indicators, expectations relating to data quality and knowledge of governing factors have grown considerably, even among non-specialists. The error tolerance when small units are analysed is drastically lower than when larger units are taken into account. This is also true of the use of indicators – often not assessed – that are often used for a different purpose from that originally intended. The Journal Impact Factor was developed to characterise academic journals but is generally usually used to provide an indication of the quality of individual publications. It is difficult to assess the impact of bias effects, especially when small units are being compared, because there are very few foolproof error theories. Moreover, selected procedures and indicators cause learning affects among the concerned academics. Behaviour, which is directly geared towards "indicator polishing", can – although it by no means has to – bring about unwanted effects (cf. Moed et al. 2005).

1.1 Indicators

The call, which is still relevant today, to develop appropriate indicators for measuring performance in research and development and measures of potential indicators came about against this backdrop. Central questions in this area are:

- What mechanisms can be used to measure academic performance? Apart from survey techniques (reputation surveys, Delphi surveys etc) and the analysis of monetary funding data, bibliometric mechanisms and techniques from patent data analysis in particular have been developed as well as peer reviews of performance.
- How can national, disciplinary and sub-disciplinary specifics be taken into account in the development of indicators (publication and citation analyses)? Publication and citation behaviour and intensity of third-party funding or patenting strategies differ considerably according to discipline, which means that standardisation mechanisms are needed for comparative analyses and descriptions. Additionally, the use of national languages for academic publications in the larger non-English speaking realm poses a problem when it comes to making comparisons. Publications in a national language necessarily reach a smaller audience and thus have fewer chances of being cited. Bibliometric mechanisms are mainly applied to the life and natural sciences. At the same time, the increasing use of bibliometric mechanisms is having such a magnetic effect that, across Europe, the humanities and social sciences are developing appropriate bibliometric databases and indicators (cf. Hornbostel 2008a).

- How can research performance be assessed in the applied disciplines? Classic bibliometry has a limited function in these areas and is often substituted by analyses of patenting activities. Here too, there exists a series of problems related to content and methodology. How far do the most-used triad patent data relate to the income from licence agreements, what patenting strategies are used in which fields, how are patents related to academic literature, and how far these indicators offer a reliable indication of innovation processes are all questions that research is currently focussing on (cf. Butler 2006; Butler and Visser 2006).
- Can standard and internationally-applicable definitions of input, process and output values be developed? Already at national level it is difficult to compare uniform compilations of input values (monetary values, personnel etc) at a level of national comparison because of the heterogeneity of the research system, and this is most definitely true of the international arena also. In the 1970s, the OECD started standardising the variables for evaluating R&D. However, many problems remain unresolved – especially when institutions with different legal and organisational structures are compared.
- International cooperation has become a very important political issue over the course of the past 30 years ("academic foreign policy") and will continue to grow in significance in view of demographic development (junior scientists, specialists). The conditions for successful international cooperation, the consequences of such cooperation and the question of how to measure the intensity and impact of international academic cooperation are some of the current questions in terms of method and content. They are mostly addressed within the realm of the above-mentioned indicators (co-authorship analyses, international patent announcements, citation networks, CV analyses, mobility analyses) (cf. Schmoch et al. 2006).
- R&D expenditure is evaluated within the framework of official statistics and treated as far as possible according to international OECD standards. Agreements have been met between the Science Council, the Federal Statistical Office, the Conference of the Ministers of Education and the Federal Ministry of Education and Research (BMBF) to compile data about academic staff (cf. Hetmeier 1998). Questions regarding qualifications and subject expertise cannot, however, be answered by these data.
- It is harder to assess so-called third-party funding. Competitive third-party funding that is granted after the expert opinion of a subject specialist has been given is an

important research indicator. On the one hand, it is registered by the recipients, and, on the other, funding bodies also hold the relevant data (cf. Hornbostel 2001; Hornbostel and Heise 2006). After considerable teething problems, the situation has improved considerably in this field but it remains problematic, especially with regard to European funding (e.g. Framework Programme). This especially concerns the blurred cut-off line between funds for basic research and those for development or contract research. The use of third-party funds can lead to considerable bias in disciplines or sub-disciplines, which are strongly theoretical and where there is often a comparatively limited need for third-party funding. The interpretation of third-party funding indicators also creates problems because only the assessor's evaluation of quality is important during the approvals process and not the actual quantity of funds, which can amount to significant investment in the infrastructure.

- Data about junior scientists, especially the number of PhD candidates, are often used as research indicators. Doctoral candidates often find themselves on the border between the teaching and research systems. The Bologna process regards the doctorate as the third cycle within the academic training process. Unfortunately, apart from the number of completed doctorates, there exist very few data about the quality of academic training and the selection process, and just as little information about the career paths of doctoral students. The increasingly used code of “doctoral students” for allocating funds is, therefore, purely quantitative and does not take quality into account at all. This needs to be addressed urgently (cf. Berghoff et al. 2006; Hornbostel 2008b; Hornbostel 2009).
- In the field of innovation research, the question revolves less around typical performance measures than around the identification of scientific “breakthroughs” and their possible application in products and services. Apart from the question of how such “breakthroughs” can be recognized at an early stage, there is the related question of what conditions are needed to enable a rapid transfer of knowledge about the essential research questions to other social sectors.

R&D data do not adequately fit these purposes, especially as, for historical reasons, their compilation has very much been geared towards industry, and it is correspondingly difficult to chronicle knowledge-based innovations in the service sector.

1.2 Effects analysis / Governance

A second set of questions arises around the theme of appropriate governance structures – the conditions for innovative and efficient research such as the prerequisites necessary for enabling knowledge transfer between the research system and other social sectors, and the linkages between economic growth and the breadth and type of R&D investment. However, the heterogeneity of the research and funding systems only allows for analyses that provide limited information because of the lack of compatible data and several unresolved problems concerning indicators, especially in comparative analyses at an international level.

Over the past 15 years, the governance structures of the higher education system in Germany have changed dramatically. There has long been a shift in research funding because of increased third-party funding and the simultaneous decrease in access to standard basic equipment. This trend is aggravated by growing competition among institutes of higher education and within institutes themselves for basic equipment, which, increasingly, is allocated according to performance (cf. Jansen 2007). The statutory framework, and sometimes the statutory position of institutes of higher education themselves, institutes of higher education bodies, internal organisations and management structures, the creation of a competitive profile in research and teaching, the distribution of expertise between the federal government and the states, and not least the "European research realm" have all contributed to creating a process whereby institutes of higher education have gradually gained more and more autonomy and have, at the same time, been compelled to develop stronger strategy and management skills. Within this context, information about academic performance gains extra significance – as comparative data for stakeholders, as an internal monitoring system, as an instrument of accountability for financiers and as a component of governance systems (cf. ESF 2008). This is true not only of institutes of higher education but of all actors in the academic system. Until now, however, the necessary data have been compiled, if at all, in situ and according to very different standards. Performance indicators have also been defined in equally different ways. Technical systems have not been developed in a view of promoting interoperability, which means that data are often compiled several times but do not exist in formats, which easily enable their exchange.

1.3. Data compilation

At an early stage, the increased significance of R&D triggered attempts to compile data about input and output variables on a regular basis. The first international Science Indicators Report was published in the US in 1973 by the National Science Board of the National Science

Foundation. The OECD followed this up in the 1980s and has since regularly published the OECD Science, Technology and Industry (SCI) Scoreboard and the OECD Science, Technology and Industry Outlook on an alternating basis. Each publication gives an overview of the trends in the sciences, technology and innovation policy backed by data. Eurostat has been compiling data since the beginning of the 1980s with its Science, Technology and Innovation in Europe series. In Germany, the Federal Report Research and Innovation publishes information about R&D activity. Regular compilation of data also takes place at an institutional level or within the framework of research funding (e.g. DFG ranking) (cf. National Science Board 2006a; 2006b; OECD 2008a; 2008b; BMBF 2008; Europäische Kommission 2008; Statistisches Bundesamt 2008; DFG 2006).

2. Status Quo: Databases and Access

Germany's federal research report records the growing demand for contemporary data about the development of these investments in the future. However, as yet, the data about R&D investment tend to be published after considerable delay because data from the federal government, the states and industry have to be combined. The data are not appropriate for an outcome-oriented analysis. Apart from the official data, there is a wealth of data about rankings, ratings and evaluations that are compiled more or less regularly but it is limited or not accessible and very different in terms of quality (cf. Hornbostel 2007; 2006). The Science Council has an exemplary attitude because it makes accessible its ratings in a file for scientific use (cf. WR 2008).

Publication and citation data are accessible thanks to two large commercial databases (Web of Science and Scopus) and an abundance of specialised subject databases; however they do not usually enable citation analysis. Recently, Google Scholar and researchable open access repositories have started providing publication and citation analyses.

Many of these databases offer a series of bibliometric codes. But these impressive masses of data hide a series of problems. Whereas in other European countries, some extremely well-performing institutes have been established over the past 20 years that observe the academic system empirically and are at times specialised in bibliometric analyses and have in-house databases and the capacity to develop specific indicators, in Germany only very small workgroups have come about. These are ill-equipped for dealing with the task ahead both in terms of staff and from a technical point of view and cannot afford to accumulate expertise over the long-term.

At the moment, the BMBF is promoting a consortium[3] of German establishments, which is trying to close this gap by creating a "bibliometry expertise centre".

Research about patent data can be conducted with the DEPATIS[4] system of the German Patent and Trade Mark Office. But the EPO Worldwide Patent Statistic Database (also known as EPO PATSTAT[5]) is more appropriate. It has been specifically developed for use by government/intergovernmental organisations and academic institutions. Distribution of this database is restricted, and commercial use is not foreseen.

Substantial data compilation about academic performance and related staff and material input requires the combination of heterogeneous information from different sources. Sources of information include academics (self-input), institutes of higher education, bibliometric and patent databases, information about third-party funding bodies etc. The Norwegian research information system Frida[6] can be named as an example for how output data is collected at institutes of higher education and combined with other data. Since 2004, Frida is used as a quality controlled author based registration of research publications and other types of research outputs. The driving force behind Frida was the new result based financing system for Norwegian universities and colleges. The institutions now have to document what they do in order to get their proper share of government funding. The system is associated with the Norwegian Open Research Archives (NORA),[7] which was launched at the same time. The objective is to develop a central OAI harvesting service that will be open to all Norwegian research institutions that have online material in full text, and metadata in harvestable format.

Germany lacks such a coordinating body for collecting data. Not only are definitions of data very different but technical systems are developed on a decentralised basis and are not generally geared towards an exchange of information. Therefore, it is almost inevitable that chaos should ensue.

3. Conclusions and Recommendations

Overall, data compilation about science and research in Europe is far from standard, sophisticated and outcome-oriented, although the Frascati Manual (1963) did make very early attempts at standardisation. In Germany, like in other European countries, there is an

3 Consisting of the IFQ (Institute for Research Information and Quality Assurance), ISI-Fraunhofer, IWT University Bielefeld and FIZ Karlsruhe.
4 www.depatisnet.de/.
5 http://www.epo.org/patents/patent-information.html.
6 https://wo.uio.no/as/WebObjects/frida.woa/wo/0.0.27.2.
7 http://www.ub.uio.no/nora/noaister/search.html?siteLanguage=eng.

increased interest in observing, analysing and evaluating the academic system substantially, and this will presumably grow significantly. The reasons lie less in an academic interest than in the consequences of higher education and research reforms, which have brought about some serious changes to governance mechanisms. Knowledge of structures and of the effects of measures and structures has a significant role to play across the board. Fast-growing competition worldwide, at an academic and technological level, especially from emerging nations is also increasing the political pressure to act. The competition can already be perceived in the massive shifts in the worldwide distribution of publications, citations and patents to producing countries.

Alongside qualitative analyses and peer review-based expert opinions, quantitative procedures in the compilation, analysis and evaluation of research data are gaining in importance. There are several reasons for this, which range from an already perceptible overuse of peer reviews, through the need for methodological, controlled comparisons and unanimous indicators to the fact that certain questions can no longer be answered from the perspective of individual experts.

Overall, the situation of data, the coordinated collection of data and the training of experts for processing and evaluating data about the academic system is deplorable. Data about certain important areas simply do not exist, the comparability of existing data is often limited, and in the field of bibliometric analysis Germany risks falling behind. The two most important tasks, therefore, consist, on the one hand, in developing a decentralised data collection system (CRIS Current Research Information System)[8] that will also enable standard definitions to be developed and for centrally-compiled data to be interoperable, as well as, on the other, developing a competitive research infrastructure.

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8 http://www.eurocris.org/.

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