Dorothea Jansen
Editor

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Governance and Performance in the German Public Research Sector

Disciplinary Differences

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Governance and Performance in the German Public Research Sector

Disciplinary Differences

Edited by

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Preface and Acknowledgements

In May 2001, a group of scholars from Europe met at a conference on "International Competitiveness and Innovative Capacity in Universities and Research Organisations" at the German Institute for Public Administration in Speyer. The conference which was supported by the German Research Foundation aimed to discuss the reforms and changes in the governance of the German public research sector in the context of the reforms under way in other European countries. This was the starting point for the establishment of the research group "Governance of Research" who set out to analyse the German higher education and research system from a comparative and inter-disciplinary perspective. In summer 2003, the German Research Foundation approved of the funding for the joint research programme, and in 2006 the funding was renewed. Today the research group comprises six projects complemented by a project on the provision of bibliometric data analysis and the speaker's coordination project. Funding by the German Research Foundation is gratefully acknowledged.

This is the third joint publication of the group which focuses on the question of how disciplinary differences interact with the new forms of governance of research and how these new forms are increasingly becoming implemented into the German research system.

This volume would not have been possible to put together and coordinate for me without the help of Tobias Semmet and Insa Pruisken who supported me as the speaker of the group. Thanks also go to Martina Grammes who helped with the correct use of the English language.

Speyer, Germany Dorothea Jansen
November 2009

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Governance of Research, Inter-disciplinary Differences and Performance – An Introduction to the Research Programme and the Contributions

Dorothea Jansen

1 Introduction

Since the mid-1990s, universities and non-university research organisations have increasingly experienced pressure from reforms of the public research sector. The low degree of differentiation and stratification in the German university system, the highly autonomous position of professors in research and teaching, and the provision of university education as a public good have been the principles behind the German university sector for many years, but they are going to be lost now. Today, publicly funded research organisations are affected by the concepts of New Public Management (NPM) including management by objectives and target agreements, output control by evaluations, rankings and accreditation, and the introduction of competitive elements such as matching funds, or performance-based university funding and salary models.

The reforms aim to transform universities and research organisations into organisations that are decisive and vigorous in national and international competition. Like the reforms in other Western countries, the reforms in Germany try to realise concepts of New Public Management and the claim for economic relevance of research and education. The reforms transfer concepts of strategic management from private sector organisations to the science system, such as prioritising, generating a critical mass, internationalisation and building alliances and networks (Amaral et al. 2003; Kehm and Lanzendorf 2006a; Jansen 2007a; Matthies and Simon 2008; Paradeise et al. 2009). The changes mentioned above reflect a profound change in the relationship between the state and the science system. For a long time the state was the only actor who funded and regulated universities and other public research organisations. Today, other stakeholders and intermediary agencies such as evaluation and accreditation agencies, funding agencies and university councils with external members from economy and society complement state regulation in the steering of the public research sector.

This new mixture of coordination mechanisms and actors is described by the term "governance". "Governance mechanisms" are understood here as the model mode of the coordination of actions, for example instruction, trust, identification, mutual observance, or market competition led by market prices (Benz et al. 2007a; Jansen

2007b: 115 ff.; Jansen 2007c: 236 ff.). "Governance patterns" here means a chain of interconnected mechanisms which can be observed empirically. "Governance patterns" can be roughly defined as "complex regulatory structures coordinating the actions of interdependent actors". Governance patterns can relate to hierarchical as well as to lateral coordination mechanisms. Enforcement can be based on law, professional norms or informal and implicit norms or customs. Moreover, the regulatory structures or individual mechanisms inside them can be established and sanctioned by public as well as by private actors. There is in fact not necessarily an actor in charge of controlling outcomes as for instance in market competition.

In the next section, I will introduce the reader to the changing role of the state in science policy. The third section presents the governance model for the public research sector which was developed by the research group and underlies the contributions in this anthology.[1] The final section gives an overview of the papers.

2 Changes of Statehood and Governance of the Research System

The widespread use of the term "governance" is not only due to real changes of the governmental role, but also to the changed perceptions and evaluations of its actions (Benz et al. 2007b). The reforms of the German public research sector are related to the overall changes of the self-conceptions of the state as well as to the opportunities and tasks attributed to the German state (Braun 2006). From the 1990s onwards the state in terms of self-conception changed from a welfare and intervention state towards a leaner and cooperative state. The tasks attributed to the state, the resources dedicated to those tasks, the modi of accomplishment and the legitimation bases of governing were defined in a different way. In addition, the state experienced a real decline in the tasks it was associated with, for example through privatisations of public infrastructure (Czada and Lütz 2000; Majone and Baake 1996). The decline of state intervention and state activities also reflects the scarceness of public resources including money, human resources, information, knowledge and legitimacy. State actors increasingly realised their dependence on private and societal actors not only to gain legitimacy but also for a successful governance of economy and society. This resulted in an increased cooperation between state, private and societal actors and in a shared responsibility for successful governance (Trute 1999; Trute et al. 2007; Klijn 2005; Skelcher 2005). Next to privatisation and outsourcing of previous state functions the structures of the internal services of the state changed. The New Model of Control ("Neues Steuerungsmodell") took up the idea of Managerialism and New

[1] The inter-disciplinary research group "International Competitiveness And Innovative Capacity in Universities And Research Organizations – New Modes of Governance" was established by the German Research Foundation in July 2003 and renewed in July 2006. The group comprises six projects integrating sociological, political science, economic and legal perspectives on the governance of research and two infrastructure projects for coordination and the provision of performance data. Funding by the German Research Foundation is gratefully acknowledged.

Public Management (Pollitt and Bouckaert 2004). In this perspective, the relationship of politics and administration is considered as an agency problem (Furubotn and Richter 2005) that could be solved through the establishment of output units. These output units were to be responsible for tasks, leadership and resources, and they should represent clear aims of output and outcome as well as corresponding mechanisms of control, incentives and competition.

In this context, science policy, too, is affected by two particular discourses which are used to justify new claims towards science and corresponding policy instruments. First, the discourse on internal administrative reforms has been transferred to the science system. Up to the 1990s, it was considered impossible to govern research and higher education with regard to their contents because of the information deficits of the state (Mayntz and Scharpf 1990). So the state was thought to be able only to fund and provide an organisational framework for science. It was up to the scientific community to coordinate itself. By transferring the new governance model to the science system, administrative and political actors started to use the long-term dependence of scientific communities on organisations (Stichweh 1991) for specific governance aims such as promoting science–industry collaboration or the creation of profiles and clusters within the universities. The most important driving factor was the shortage of public funding for research organisations. State-funded budgets were reduced more and more and research organisations and researchers were referred to third-party funds in order to fund their research. As a consequence since the 1980s, the share of third-party funds in university budgets has been increasing continuously.[2]

The second discourse affecting the new governance of science deals with the question as to what science can and should do for society. Inspired by neoliberalism, first public administration and later science organisations had to deliver "value for money" to justify their existence. So a new "contract" between society and science was defined and put into practice. According to this contract, science no longer should simply produce knowledge as a public good, systemise it and transfer it to interested users and students, but also care about the so-called "Third Mission". This mission called universities and research organisations to engage in the production of knowledge and technologies considered to be useful and to transfer useful knowledge and technologies to economy and society. The Third-Mission discourse referred to concepts from science and technology studies such as the postulation of a new mode of knowledge production, the so-called "Mode 2" (Gibbons et al. 1994),

[2]In 1995, for every €100 in basic funding another €13.64 in third-party funding came in, but in 2005 this ratio had shifted to €21.33. From 2000 to 2005, the third-party funding revenues of universities and medical facilities increased by 29.4%, whereas the basic funding revenues only increased by 6.5% and thus, taking inflation into account, decreased in real terms. However, the expenditures of the German Länder for the German Research Foundation increased by 16.5%. A little less than a third of the third-party funds for universities comes from industry (Wissenschaftsrat=WR 2008). Moreover, the share of the individual grants programme which the German Research Foundation spent next to coordinated grants programmes has decreased also in real terms (2003: 35.1%; 2006: 31.9%, cf. WR 2008: Table 4, p. 27).

or the Triple Helix (Leydesdorff and Etzkowitz 1996), a research alliance of public (large) research organisations, universities and industry. Both approaches share the view that “customers” of science should have more influence on organisations and contents of research. These concepts fitted well to policy aims and became part of the reform concepts more or less without having been confirmed by empirical evidence (for a detailed analysis of the changes in the governance of research cf. Jansen 2009b).

To cope with the various mechanisms that have been newly introduced by these discourses and respective policies into the science system, an empirically productive analytic taxonomy of governance mechanisms of science is necessary. This taxonomy has to integrate the elements of New Public Management, elements of the former university governance, and the coordinating elements of scientific communities being developed inside the science system. Such a taxonomy was developed by the research group “Governance of Research” which closely watched the reform process of the German science system over a 6-year period in its previous work (Jansen 2007a, 2009a). Section 3 introduces this model as the theoretical background of the papers collected in this anthology.

3 An Integrated Model of Governance of Research

The following model of governance of research is based on the assumption that governance mechanisms and the way they are bundled in governance patterns influence the output of the research system. Governance patterns have direct effects on the resources, capacities and skills of research organisations. The model looks into those governance mechanisms that have effects on research organisations from the outside such as state regulation and funding or quasi-market competition for third-party funding. It complements this view from the outside with mechanisms of internal steering of research organisations, such as academic self-organisation and hierarchical self-management. Finally, the traditional mechanisms of coordination within the scientific community have to be taken into account.

Our conceptualisation of governance of universities and research organisations started with the mechanisms of the old governance of universities: state regulation including state funding combined with input-control and academic self-organisation. The New Public Management model was operationalised by the quasi-market competition for research funding and the establishment of strong hierarchical self-management within the organisations (university presidents, deans etc.). External guidance by the state and other stakeholders (steering at a distance) was thought to replace strict state regulations. Intellectual ex post coordination by the scientific community, horizontal coordination by research collaboration networks, cultural orientation, and self-conceptions of different research institutions such as the Max Planck Society or the Fraunhofer-Gesellschaft were identified as governance mechanisms coordinating research within the scientific community (Gläser 2004; Gläser and Lange 2007; Wald and Jansen 2007; Schimank 1999) (Fig. 1).

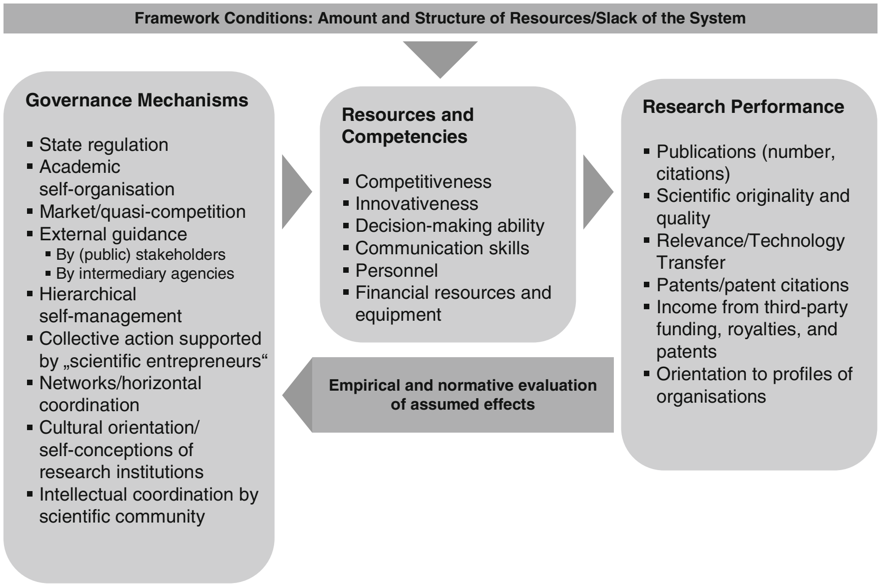

Fig. 1 Theoretical framework of the research group

Our previous research clearly showed that in the course of the reforms a mixed system came into being (de Boer et al. 2007; Jansen 2007a; Kehm and Lanzendorf 2006b). New forms of external governance were indeed added to the traditional governmental regulation. The term "external guidance by stakeholders" describes mechanisms such as target agreements of German Länder and universities or the creation of advisory councils for universities and research institutes as instruments of interest intermediation of public and non-public stakeholders with respect to the governance of these organisations. Seemingly such agreements and proposals are negotiated and exchanged between coequal partners. However, research organisations were actually confronted with Hobson's choice. Proposals given and contracts offered by newly established and old principals of universities and research organisations could hardly be turned down. In addition, the new quasi-markets for students, third-party funding, and performance-based budgets are organised by old and new intermediary agencies, for example the German Council of Science and Humanities (WR = Wissenschaftsrat), the Institute for Research Information and Quality Assurance (iFQ), and accreditation agencies.

Concerning internal decision structures in universities and research institutions, we again found evidence of the parallel existence of hierarchical self-management and traditional academic self-organisation and a decoupling of management in the books and actual behaviour of academics. In addition our empirical studies showed the emergence of an informal but successful mechanism of academic coordination providing collective action in order to generate a research-related collective good (e.g. research training groups, inter-institutional cooperation). Some scientists turned into scientific entrepreneurs that were able to create an innovative coalition and to overcome strong internal and external obstacles (Sadowski et al. 2008; Schneider et al. 2010 in this volume; Heinze and Kuhlmann 2007, 2008).

Already since the 1980s, the competition for third-party funding had been playing an important role among individual researchers and research teams. By the so-called Excellence Initiative, new standards for the resource level of university research and the management of universities were established in 2005 in Germany. Universities for the first time were addressed by a funding programme as organisational actors that were called to organise research applications at the central level. Thus, universities increasingly changed to a proactive management of research in order to assure a steady stream of applications for third-party funding. This is also a reason for the hardening of the competition for third-party funding in general. The allowance quota for individual project grants (the so-called *Normalverfahren)* by the DFG (German Research Foundation) decreased from about two thirds in 1995 to less than 50% in the beginning of the first decade of the twenty-first century; in 2007 it amounted to 52.5% (DFG 1998: 50; DFG 2008: 138). At the same time, the share of the individual project grants in the overall budget decreased from 35.1% in 2003 to 29.3% in 2007, whereas the share of coordinated programmes increased from 48.9% in 2003 to 54.6% in 2007 (DFG 2008: 138; WR 2008: 27).

At the beginning of the reforms in Germany, evaluation of higher education and research was of little importance. In particular, research performance was represented little in evaluation schemes and funding formulas compared to indicators measuring teaching performance. If so, formulas mostly used the indicator of third-party funding which is not an indicator of research output and has problematic unintended effects on research performance (Jansen et al. 2007; Schmoch et al. 2010). However today, an increasing institutionalisation of evaluation, rankings and ratings has emerged (DFG 2003 , 2006; WR 2008, 2004). New forms of competition for students, for third-party funds at the level of universities, for formula-based funds from the Länder, as well as for positions in ratings and rankings were established. These new forms were added to established forms of competition such as competition for reputation and competition for research funds at the level of individual researchers and research teams. Since quasi-markets such as calls for tender by the state or competition in teaching or research performance lack clear-cut price signals, new arrangements for these markets have to be found. Frames for the regulation and management of these new forms of competition were established by new types of intermediate agencies and were authorised to set up frames for regulation and management of these quasi-markets, such as sets of indicators for the evaluation of research and teaching or standards for the accreditation of study programmes. Such intermediaries today indirectly complement the direct mechanisms of state regulation by fulfilling the following functions:

1. Engaging in the definition of coordinated competitive funding programmes (call for tenders) in science-policy discourses (interest representation, interest intermediation). Typical actors here are disciplinary associations, science organisations such as academies or the scientific societies (Max Planck Society,

Helmholtz Association, Fraunhofer-Gesellschaft, etc.) as well as established funding agencies such as the DFG and advisory councils (e.g. the German Council of Science and Humanities).

2. Implementation of competition programmes with different levels of freedom of research and its independence from state intervention (e.g. the joint management of the call for the Excellence Initiative by the DFG and the German Council of Science and Humanities), and
3. The definition and safeguarding of quality standards for competition (e.g. Länder-specific evaluation and accreditation agencies, advisory boards and the newly established Institute for Research Information and Quality Assurance).

Next to the competition for resources less formal governance mechanisms such as self-coordination influence the external relationships of researchers. A lateral internal self-coordination is driven by research networks as an ex ante mechanism of coordination and the joint orientation towards patterns of interpretation having built a collective background of experience. External coordination results from self-concepts and the status received by membership in influential networks, which guide the search for appropriate research partners. In Germany, such cultural self-concepts and orientation in research have formed the so-called domain consensus (Schimank 1999). The differentiation of profiles of research organisations has, however, been reduced because of the reforms in the science system and the opening of the quasi-markets for research funding. Self-concepts and the identification with a specialised research community also cause impersonal ex post intellectual coordination through mutual observation. This is supported by the scientific communication and publication system. In this system, the decisions about scientific relevance are made and incentives for following specific research questions of high relevance are provided. Moreover, research reputation is allocated via the communication system which informs decisions in relation to the appointment of scholars or the choice of collaboration partners. Thus, a differentiation by reputation emerges and scientific elites emerge.

4 Introduction to the Research Programme and the Contributions in This Volume

The point of departure of this volume is the evidence of huge differences between the disciplines with respect to their input, throughput, profiles of output and the typical conditions of knowledge production (Jansen et al. 2007; Schmoch and Schubert 2008; Schmoch et al. 2010). However, these differences are still little understood and are not reflected in science policy and the implementation of new governance forms in the research system. By and large, a policy of "one size fits all" is typical for the design of evaluation schemes, systems of performance indicators and performance-based allocation of funds. This anthology aims to shed some light on the differences between disciplines. In particular we want to explore the differences in the actual governance structures that have emerged from the recent reforms in the research system and how these affect the knowledge production and research performance at the level of research groups and at the system level.

The volume is structured into three parts and an appendix. The disciplines studied in the assembled papers were chosen for the joint research programme of the research group "Governance of Research". They represent natural science fields oriented to basic research (astrophysics), two application-oriented fields from the natural sciences (nanoscience and biotechnology), a social science field (economics) and a humanity field (medieval history). For those fields that are covered in bibliometric databases (SCI, Scopus), the appendix presents detailed descriptions of publication and – in the case of application-oriented fields – patent data, data on research promotion and on institutional structure of the fields in Germany and their international integration. Since for humanities comparative standardised data are hard to find, available data on funding and the development of academic staff numbers are described in Chapter 4 which is devoted to the governance effects on research in medieval history.

Part I deals with the effects of the implementation of New Public Management governance mechanisms such as the increase of competitive third-party funding and hierarchical self-management of universities and research organisations on the research system from a system's level perspective. Schubert and Schmoch pose the question whether research performance at an individual level is enhanced by NPM reforms, and whether the changes that result from the new incentive structures will lead to a sustainable long-term performance at the level of the research system. On the basis of a large empirical data set covering a variety of disciplines (astrophysics, nanotechnology, biotechnology, and economics), they raise reasonable doubts that the evaluation schemes and systems of the implemented performance-based allocation of funds will help to create a long-term high performing research system. Broemel, Pilniok, Sieweke and Trute look into the changes of the governance patterns of the research system from the perspective of science law. They determine contradictions between the traditional legal conception of the science system where there was no need to look into the peculiarities of disciplinary differences in the process of knowledge production, and the NPM reforms that have been established in the German research system in the last decade.

Part II assembles two papers that look into governance effects on research and performance for selected disciplines in more detail. Jansen, Heidler and von Görtz cast doubt on the concept of a new Mode 2 of knowledge production and exemplify this with a detailed comparative analysis of research teams from nanoscience, astrophysics and economics. However, the concept is readily taken up by science policy, since it fits well to the NPM instruments and to the discourse on science having to deliver "value for money" and to be engaged in a "Third Mission". Again negative effects of new governance instruments at the individual level of research teams can be shown. In Chapter 4, Kehm and Leiðytë present data from four qualitative case studies of medieval research comparing Germany, England, The Netherlands and Austria. They question the widely felt crisis in the humanities, and in particular a harsh decline in funding and staff cannot be verified. However, the competition for funding, the need to integrate one's research into priority funding programmes and larger often inter-disciplinary research units are understood by some researchers – mostly the older and established ones – as signals of crisis. Younger researchers cope quite well with the new challenges. Larger and inter-disciplinary research environments may even open up chances for unorthodox research and scientific entrepreneurs. The attention paid to medieval history research from the public, from a variety of funders and from research organisations interested in sharpening their profiles has even increased. Nevertheless, there is also a lot of symbolic compliance and window dressing to match one's own research interest to the priorities of funders and institutions.

Part III deals with the new governance mechanisms in PhD education. Unger, Pull and Backes-Gellner study the performance of German research training groups funded by the DFG using their reports on research performance to the DFG. Schneider, Thaller and Sadowski present evidence from comparative studies of PhD-programmes of 14 economics departments from Germany, the Netherlands, Switzerland, Italy, France and Great Britain. While the focus of the latter study is on the comparison of structured PhD-programmes to the traditional master–apprenticeship model, the study by Unger et al. enquires on the effect of disciplinary affiliation (humanities and social sciences versus natural and life sciences) of the training groups. The comparison of outputs of research training groups from the different fields again reveals large differences in publication forms and type and in the degree of inclusion of doctoral students in conferences and article writing. However, there is no significant difference in completion rates. The study by Schneider et al. (2010) is based on the theoretical sampling of economics departments according to their research intensity and the type of PhD-programme (structured collective education vs. individual master–apprenticeship relations). With complex Boolean combination logic the authors identify those conditions that characterise departments with an academic placement above average compared to those with an academic placement below average and disentangle the relationship between necessary conditions and sufficient ones. An important result is the utmost importance of the emergence of a coalition of faculty staff who is willing to contribute extra effort to the running of a PhD-programme. Combined with some slack in time budgets such a coalition of academic entrepreneurs can even overcome a lack of funding whilst all cases of below-average placement success are characterised by the lack of entrepreneurial spirit and effort.

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Part I
Effects of Science Law and Science Policy on Performance

Chapter 1
New Public Management in Science and Incentive-Compatible Resource-Allocation Based on Indicators

Torben Schubert and Ulrich Schmoch

1.1 Introduction

New Public Management (NPM) is the new governance paradigm for the university sector. Though there are country-specific differences in interpretation and implementation (Lange and Schimank 2007; de Boer et al. 2007b), this holds true for all western societies as the discussion in the literature shows (de Boer et al. 2007a; Meyer 2007; Frohlich 2005; Smith 2004). In this light it might therefore be more appropriate to talk about a NPM revolution rather than NPM reforms.

However, rarely so many myths, especially in public debate, have been added to changes in a governance model. While some argue that NPM is the (one and only) way to stop European universities from losing ground in comparison to their Anglo-American counterparts, others believe that NPM will "economise" the university sector, turning the former places of free speech and thought into factories where knowledge is produced rather than discovered, thus, leaving no space for an intrinsic value of knowledge beyond the economic potential of an idea.

Often unrealistic hopes as well as unrealistic fears accompany the introduction of NPM, which is a result also of a lack of a precise definition of what NPM actually is or how it works. Therefore, to understand the presumable effects of the NPM reforms, it is necessary to find a unified wording for NPM as well as to present the theories underlying its central ideas.

The primary objective of this article is to judge the opportunities and threats that arise from the NPM approach in general and, more precisely, the use of indicators to measure scientific performance and to allocate resources according to the results of this process. We will argue that, although we can observe positive effects stemming from many NPM instruments on the microlevel of individual research units, the functional balance on the macrolevel might be disturbed, possibly leading to negative overall effects. However, we will also argue that the incentive schemes set

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by the use of indicators may counteract the welfare-deteriorating effects intrinsic to the process of scientific production. In any case, indicator sets have to be chosen wisely because they also have power to make things even worse.

1.2 Characteristics of New Public Management

Within the last 40 years, NPM has swept like a wave over Western countries and has changed profoundly the governance structures not only in universities but also in practically all other public authorities. Especially concerning NPM in public authorities and public health care, there has been invested a substantial amount of scientific work, explaining what this governance setting is, how it should work and what its costs might be (see e.g. Pollitt 2006; Naschold and Bogumil 2000; Pollit et al. 2005). Yet, on the other hand, NPM in universities is not comparable as a result of the profoundly differing working conditions. After all, scientific activities cannot easily be compared to activities of bureaucratic organisations. Unfortunately, up to now much less scientific work has been devoted to NPM in public science and its effects. Also among scientists, there seems to be a lack of common understanding and terminology in the discussion of NPM. Therefore, we define clearly what we understand under NPM.

We regard it as helpful to trace its theoretical justifications first. Its main roots are the property rights theory (Buchanan 1984) and the principal agent theory (Jensen and Meckling 1976; Holmstrom 1979). The first claims that institutions are inefficient whenever property rights and control are separated, which undoubtedly is a characteristic for universities. The second stresses that the unobservability of the agents' behaviour may cause co-ordination problems because the principal will never be able to distinguish completely if failures result from bad luck or if they result from selfish behaviour. Therefore, the agents are able to use this information asymmetry to abuse public funds to follow fully private objectives. This is known as moral hazard. In this context, the principal would be the society giving funds for research, while the agents would be the researchers. The "lazy professor" directly originates from this theory.[1] To reduce the possibilities of misusing funds, the governments traditionally resorted to a strict financial regulation of spending, for which the cameralistic account system is only one expression. Nothing actually comes for free: In this case the price has to be paid in terms of financial inflexibility of both the universities and the individual research units, which constituted a major source of inefficiency in resource spending in its own right.

The NPM approach is an organisational setting that tries to restore operational flexibility, while, at the same time, it tries to limit moral hazard problems. This is done by giving financial autonomy to universities and chairs but also increasing hierarchical self-control, i.e. by increasing the power of deans, chancellors and other

[1] For an ironical contribution on this compare Schubert and Schmoch (2008).

internal management positions, as well as competitive elements such as an indicator-based performance-dependent resource allocation (which is a major topic of this contribution), evaluations or higher dependence on third-party funds. This leads to the NPM parole of "More autonomy, more hierarchy and more competition". For a more extensive discussion see Schubert (2009) and Schubert (2008b).

Of course, NPM is not a unified theory of how things should be done. It mainly gives general advice into which direction to proceed. In fact, in different countries, each with its own institutional background, the national translation and implementation into public-science-reforms show remarkable differences (de Boer et al. 2007b, 2007).

1.2.1 New Public Management in the German University Sector

Judging the influence of the NPM paradigm on practical policy decisions is a heavy task, especially in the German context. This is because of the special rules set out by the constitution, where the federal states may decide independently on the research and higher education policy. An overview is given in Schubert (2008b, Chapter 2). However, the main results may be briefly summarised as follows.

1. The influence of the deans, the presidents and chancellors, both in financial and strategic terms, has increased drastically. This is what is usually referred to as *hierarchical self-control*.
2. Financial *operative flexibility* has increased both at the level of the university/departments and at the level of the individual research unit. The extent to which operative flexibility was increased is, however, much lower than that of the increase in hierarchical self-control.
3. The *competition for resources* has increased for the research units. This results mainly from the rising importance of third-party funds. The competition for basic grants induced by indicator-based resource distribution is still rather low; they refer to shares of the budget that usually do not exceed 5%.

All in all, we summarise that NPM in Germany is characterised by increasing internal hierarchical control, greater operative steering flexibility and increasing importance of competitive mechanisms, though not each element was implemented with equal importance.

1.2.2 Effects of New Public Management

In the light of the NPM-reforms in Germany, in this section it shall be tested whether they have achieved their declared goal, which is increasing the efficiency of public resource spending on science.

To derive at testable hypotheses we think of the following model. The research units transform inputs (e.g. capital equipment and researchers) into research outputs (publications, PhD students, advisory service for companies). This process can be described by an efficiency measure, which can be estimated by standard methods of efficiency analysis (DEA or FDH). However, the research units take the governance model under which they have to operate as exogenous. The governance conditions clearly have an influence on the production process and, by that, on the efficiency of production. Therefore, in a regression framework, we will test whether the previously estimated efficiency scores are significantly affected by the exogenous governance variables. For a more in-depth discussion see Schubert (2009).

Here we use original data from a large online survey that was conducted within this research project between February and June 2007. The sample consists of 473 research units from the disciplinary fields of astrophysics, nanotechnology, biotechnology, and economics. This corresponds to a return rate of approximately 25% (1908 research units received a questionnaire). With this selection of disciplines we could guarantee that basic research fields from natural sciences (astrophysics), applied disciplines from natural sciences (biotechnology and nanotechnology), and a field which has both applied and basic research characteristics from the social sciences (economics) are included. Astrophysics makes up about 7% of the sample, nanotechnology about 42%, biotechnology 22%, and economics 29%, which corresponds quite well with the shares in population as indicated by Table 1.1.

In this Section (1.2.2) we will restrict our dataset to university institutes, which, in a nut-shell, is done, because the extra-university institutes did not have to cope with state interference to the same degree. They already had relatively great steering autonomy in the past. Inasmuch as reforms have taken place in extra-university institutes, they were based on completely different legal grounds (Schubert 2008a). Including the extra-university institutes here as well would induce a great deal of governance-related heterogeneity, probably confounding the effect of NPM reforms targeted to universities. According to Table 1.1, the restricted sample consists of 333 units. Deviations with respect to the actual sample sizes given in Table 1.3 are due to item-non-response of these 333 institutes.

On the contrary, the discussion of Section 1.3 does not relate to changing governance regimes but to knowledge production itself. As far as we believe that university and non-university institutes use comparable inputs and produce the

Table 1.1 Structure of the sample and the population in comparison

	Population size	Sample size	University groups in sample	Overall response rate
Astrophysics	97	34	24	35.05
Nanotechnology	674	201	110	29.82
Economics	477	102	85	21.38
Biotechnology	687	136	114	19.80
Total	1,935	473	333	24.44

same kinds of outputs, it is more justified to use the complete sample (gross size 473).

Remark: Since the overall response rate of 25% is certainly far away from a full survey, it allows one to ask whether the sample is biased. Such biases might for example occur, when surveyed units self-select into participation, and this self-selection is partly determined by observable or unobservable characteristics.[2] More specifically, this becomes a severe problem, if the self-selection rule is in some way related to decisions of the sampled units concerning the research question(s). In our case, it would be particularly pitiful, if for example research groups that are especially favoured by NPM tended to respond more often. This would lead to overoptimistically estimated effects of NPM. Contrary, if only groups answered which feel that they are disfavoured by NPM, then results would be too pessimistic. Of course, although we cannot reject such sample-selection effects a priori, we do not readily see why over- or undersampling of certain groups is likely to occur as a result of past experience with the governance system. In fact, we think that participation is more related to idiosyncratic effects, such as personal willingness to spend time on answering surveys. However, the latter should be independent of the NPM constellation so that we expect small biases due to self-selection in our results.

Before discussing the results we give a short descriptive overview of some of the results from our survey.

Of special interest are the governance variables (see Table 1.2). Eighty percent of the research units indicated that they were subjected to rigid personnel quota. Thirty percent replied that they have made research-related goal agreements. Fifty-three percent said that an accounting scheme existed which controlled their resource spending (apart from the cameralistic), 70% that their university had a university council, and 39% were regularly evaluated. The mean perceived de facto influence (a subjective measure admittedly) was 3.20 for the deans and 3.65 for the higher hierarchical positions (chancellors and presidents), which is well above average (3.00 on a 1–5 Likert scale). The average fraction of research time spent on third-party projects is about two thirds, that is, only 33% of the time spent on research is financed by basic funds. Summarising, in our dataset we find structures that are comparable to the conclusions presented in the previous section: The influence of the deans and other central managing positions has increased. The operative inflexibility, especially the personnel regulation, was reduced, but it is still a prominent instrument to control the research groups. And the competition, especially that for third-party funds, is enormous.

The aim of this section is to determine whether the differing governance variables are efficiency enhancing or deteriorating. Now, efficiency in scientific production clearly depends on the definition of research outputs. Because of the

[2]For example it is often claimed that the Community Innovation Survey conducted by the EU is biased towards more innovative firms because noninnovators do not answer. This might be due to social desirableness or simply because noninnovators falsely think they are not the correct addressees of "innovation surveys".

Table 1.2 Descriptive survey results

Variable	Shorthand (if used)	Time period	Unit/Type	Mean	S.D.	Min	Max
Research outputs							
Advisory service for companies		2004–2005	Count	0.56	1.44	0	11
Co-operations with companies		2004–2005	Count	2.05	3.46	0	26
Conferred doctoral titles		2004–2005	Count	4.25	4.86	0	52
Conferred state doctoral titles		2004–2005	Count	0.50	1.07	0	13
Number of publications in the SCI/SSCI-database		2004–2006	Count	31.47	40.78	0	320
Number of citations in the SCI/SSCI-database		2004–2006	Count	118.82	177.73	0	1359
Research inputs							
Number of scientists excluding PhD students		2005	Count	6.68	8.48	1	77
Number of Scientists including PhD students		2005	Count	14.47	14.18	1	129
Age of computers when replaced		2005	Count	4.54	1.37	2	10
NPM governance variables							
Existence of personnel quotas	PERSONNEL	2006	Binary	0.80	0.40	0	1
Perceived de facto influence of the deans	DEANS	2006	1–5 Likert Scale	3.20	1.02	1	5
Perceived de facto influence of the presidents	PRESIDENTS	2006	1–5 Likert Scale	3.65	0.97	1	5
Existence of goal agreements	GOAL	2006	Binary	0.30	0.46	0	1
Existence of an accounting scheme	ACCOUNT	2006	Binary	0.53	0.50	0	1
Existence of research councils	COUNCIL	2006	Binary	0.70	0.46	0	1
Existence of regular evaluations	EVAL	2006	Binary	0.39	0.49	0	1
Fraction of time spent on third-party research	TPF	2006	Percent	65.79	29.26	0	100

multidimensionality of scientific output (see Section 1.3.1, as well as Jansen et al. 2007; Schmoch and Schubert 2008; Schubert 2008b, Chapter 2 and 5) this is far from trivial. Depending on the concrete output definition, also the effects of the NPM-instruments may change. We therefore decided not to impose a uniform output definition but rather give differentiated results where in each case one of the three dimensions, knowledge transfer, graduate teaching, and generation of new knowledge (corresponding to the three missions, see Häyrinen-Alestolo and Peltola 2006), is given high weight, where the exact schemes are given as follows:

The transfer-oriented scheme: The variables included are fraction of time spent on third-party research as a proxy for third-party funds, number of advisory services for companies and number of co-operations with companies as separate dimensions, and conferred doctoral plus state doctoral degrees. This output definition highlights the task of technology transfer to companies.

The graduate-teaching oriented scheme: The variables included are fraction of time spent on third-party research as a proxy for third-party funds, conferred doctoral and state doctoral degrees as separate dimensions, and number of advisory services for companies plus number of co-operations with companies. By using this set of output indicators, the focus is set on the task of education and qualification.

The publication-oriented scheme: The variables included are number of publications, number of citations per publication as a measure for impact, number of advisory services for companies plus number of co-operations with companies, and conferred doctoral plus state doctoral degrees. This output definition is dominated by the task of conducting basic research as measured by bibliometric indicators.

Note that in none of the above-mentioned cases have we assumed that an output definition is exclusive in that it gives absolute priority to one of the three dimensions. Rather we believe that universities try to develop profiles which convey a certain preference for a dimension, however, not at complete expense of the others.

As said above, we use the data of outputs and inputs to estimate efficiency scores, in this case using the FDH score (Deprins et al. 1984) and then regress the efficiency scores on the governance variables. This regression is performed using a truncated regression framework, where the standard errors come from a complicated bootstrap algorithm, which is needed to adjust the asymptotic variance estimation for the fact that the dependent efficiency scores are estimates themselves. For a more in-depth discussion of the econometric methodology see Simar and Wilson (2007).

We present the results in Table 1.3, where we refrain from presenting the results in the form of a regression table, because the interpretation of the results is tricky. In our opinion the form of Table 1.3 is more intuitive. Anyhow, for the readers interested in the regression table we refer to Schubert (2009).

In Table 1.3, a “+” indicates a positive impact at the 10%-level, as well as “++” and “+++” positive impacts at the 5- and 1%-levels. The same notation holds of course for the “-”, “–”, and “– – –”. For example, in the row of the existence of research councils the “+++” in the transfer-orientation column indicates that a research council increases the efficiency in providing transfer-oriented outputs, and this positive effect is significant at the 1%-level.

Table 1.3 Influence of NPM on research efficiency in German universities

	Transfer-oriented	Graduate-teaching oriented	Publication-oriented
Operative flexibility			
PERSONNEL		+++	+++
Increasing hierarchical self-control			
DEANS			
PRESIDENTS	+		
GOAL	+++		
ACCOUNT	−−−	-	−−−
COUNCIL	+++	++	
Competition			
TPF	+/-	+/-	+/-
EVAL			+++
n	243	243	266

An interesting fact in Table 1.3 is that the only variables that may have negative efficiency effects are the existence of an accounting system to control the resource spending apart from the cameralistic one and the fraction of time spent on third-party research. Where the existence of accounting systems exerts negative efficiency effects over all output definitions uniformly, the “+/-” for the third-party funds shall indicate that for low levels of these funds there is a positive effect, which turns negative if the third-party funds are increased beyond certain thresholds, i.e. if third-party funds become excessively dominant. This finding is in line with the results in Jansen et al. (2007) as well as Schmoch and Schubert (2008). Except for strong deans, where the variable does not have a noticeable effect under any output definition, all other NPM instruments increase efficiency at least under some output definitions, while not doing damage under the others.

The main conclusion is that NPM seems to have a positive effect overall. So the efficiency in public resource spending in the science sector may be increased by fostering the ongoing NPM reforms.

Despite the fact that a higher NPM orientation increases the efficiency of individual research units, this does not necessarily imply higher performance of the university sector as a whole. The reason lies in the interdependency of activities of the research unit. As far as NPM affects the decisions of these units, their functional balance (a term we will introduce and explain in the next section) may be disturbed, which deteriorates the overall performance.

1.3 Scientific Production

In principle, scientific output generation can be viewed as any other production process if we define a production as a process where specified inputs are transformed into specified outputs. So in our wording, production does not necessarily imply anything technical or material. Rather its constituent feature is the transformation of inputs into outputs, without any reference to what activities might or might not be necessary to achieve this. To put this in simple terms, our definition of production is that of a black box.

1.3.1 Hypotheses About the Structure of the Production Process – Multidimensionality, Interdependencies and Functional Balance

This simple definition of a production process shall not lead us to think that scientific production is a simple process in itself. Indeed, output generation in science probably is much more complex than output generation in most companies. Notably this complexity including the social shaping of scientific production usually is not accounted for in the literature. Instead uni-dimensional production functions are imposed which try to explain, for example, publications by past university expenditures (see Crespi and Geuna 2006; Adams and Griliches 1996).

In our opinion, this might be too great a simplification. To see this, in the following, we will present four hypotheses about the structure of scientific production that will guide the subsequent argumentation.

T1: The production in science has multi-input multi-output characteristics.
T2: The production process is vertically and horizontally integrated.
T3: The returns of the outputs are not fully appropriable by the units and are partly socialised.
T4: Because of inherent abilities and learning effects specialisation advantages arise.

Thesis T1 is, at least implicitly, recognised by many authors (Rousseau and Rousseau 1997; Nagpaul and Roy 2003; Warning 2004; Johnes 2006). Scientific production is a process in which manifold inputs (e.g. capital equipment, trained scientists, etc.) are transformed into various outputs (e.g. publications, patents, knowledge transfer, etc.).

Yet, besides this widely recognised fact, scientific output generation must also be seen as a vertically integrated or even partly self-dependent process (T2). This may be illustrated by the training of new scientists who are, as already mentioned, an input to the scientific production process. However, at the same time, they are an intermediary output, as they are trained inside the system. The horizontal integration occurs for new scientific knowledge, which is, on the one hand, a final output and yet, on the other hand, an input for distinct research efforts. Other examples may be found in activities such as editorships, which could be described as the keeping up of scientific infrastructure. So besides the final output of research – new knowledge – also numerous intermediate outputs are created which serve as inputs at later stages. The system becomes self-dependent because it relies to a large extent on inputs that have been created inside the system. Therefore, the efficiency of the system as a whole depends on the ability to provide an optimal mix in the activities driving the production agenda. These considerations direct the attention to the incentives for the different activities inside the system and especially their appropriateness.

T3 states that the returns of the produced output may not be appropriated completely by the producing units. The correctness of this claim clearly depends on the output under consideration. For example, it is well known that a very important reward for scientists is reputation (Merton 1957, 1973; Luhmann 1990) which is now widely recognised also in the other disciplinary branches of the literature (see e.g. David and Dasgupta 1994). In any case, reputation can best be achieved by conducting extraordinary research; it is usually not or to a lesser extent awarded for the production of intermediary outputs, such as the training of young scientists. Additionally, as young scientists may freely move between the units, most of the returns in the form of capable scientists may be appropriated by other units that did not incur the cost of the training. Similar arguments could hold for activities which are linked to academic self-organisation (e.g. being a dean). Therefore, problems of appropriation are likely to be more severe as it comes to intermediate and infrastructural outputs, while these problems are less important as the generation of basic knowledge is concerned. This statement has to be seen in the context of the social shaping of scientific production, especially the effects of the de facto self-deployment of scientists to specific tasks, i.e. generally scientists can individually choose which tasks they want to comply with. Therefore, this freedom of selection in junction with the disincentives for the production of intermediate outputs may lead to an undersupply of intermediary goods because of positive externalities.

From a basic economic perspective, it might be most effective that research units – like firms – tend to specialise in activities they are best at. So some units will mainly conduct research, some will primarily train scientists and others might focus on infrastructure activities such as editing journals or organising scientific associations (T4). Disincentives for intermediary outputs would imply a too weak specialisation, because units which would be more effective at producing intermediary outputs would shift resources to research in order to gain some of the reputation-based rewards.

This argument is supported by the results of a cluster analysis in Section 1.4. First, it is shown that specialisation exists to some degree, but this specialisation is far from being overwhelming. About 50% of the units do not have a clear specialisation profile. Second, and most important, this non-specialised group is – though not dramatically – below average in every respect. This could indicate that the units not specialising in one activity are unable to reap the benefits of inherent abilities or learning effects.

In essence, we claim that an efficient science system has to maintain an optimal mix of activities. This is what we denote by the term *functional balance*. The term comprises the idea that an adequate balance between the different activities must be achieved in order to guarantee high performance of the science sector in total.

1.3.2 Linking Micro and Macroperformance

In Section 1.2.2 we have argued that NPM proves useful in increasing the research performance of individual research groups. However, does this imply that NPM increases the performance of the systems as a whole? In the light of the considerations of Section 1.3.1, the answer clearly is “Not necessarily”. The reason is obvious; although NPM increases individual performance, it potentially could decrease the system performance by disturbing the functional balance (that is: by distorting the optimal mix of activities). For example, it might set incentives for an oversupply of transfer activities at the cost of original research, thereby lowering performance in the long run.

In any case, because of the incomplete and biased reward structures (see T3 in Section 1.3.1) we cannot expect this pareto-optimal status to be reached in a self-regulatory framework of the decentralised decision-making of individual research units either, because research groups favour writing papers over all other activities (Merton 1973; Dasgupta and David 1994), which would lead to an undersupply of teaching and transfer. To speak in terms of economics, we expect “market failure“. By manipulating the incentive structures, NPM instruments have the potential to cure these problems but also to worsen them by reinforcing one-sided incentives. In this context it is striking that NPM theoretically could have the seemingly counterintuitive effect that it makes each research unit more efficient but lowers the aggregate performance of the system at the same time. We call that the *paradox of the efficiency trap*.

1.3.3 The Role of Indicator Systems in Increasing Scientific Performance

With special reference to indicator systems, the considerations of Section 1.3.2 provide a hint on the role of indicator systems to steer and control the resource flows: By carefully setting up indicator systems it is possible to improve the functional balance.[3] Therefore, the positive effects NPM has on the research performance of individual research groups could carry over to the macrolevel of the research sector as a whole and will probably be even reinforced.

Therefore, the function of a well set-up indicator system is two-fold and affects both the micro and the macrolevel. Its role at the microlevel is to increase incentives for hard work by rewarding individual success. This effect is well documented and relates to what is known as moral hazard. Once an indicator system is implemented, this effect comes for free, provided the financial incentives are severe enough. The

[3] What happens when it is not set up carefully is discussed by Weingart (2005). Another problem comes from the fact that indicator sets might be chosen to “construct, reproduce and consolidate” the status quo (Münch 2008). In consequence, for practical purposes, they might not be even open for a “wise setup”.

system's role at the macrolevel is hardly ever mentioned in the literature and relates to the functional balance. Indicator systems have an overall co-ordinating function to restore or improve the functional balance. However, the latter contribution may only be achieved if the indicator system is set up wisely. On the contrary, if an indicator-based system does not provide appropriate incentives for what we called intermediate outputs (e.g. graduate teaching, research infrastructure), it will enforce the trend towards an undersupply of them. In consequence, resource allocation based on indicators should enforce incentives for all types of outputs and comprise also intermediate ones.

1.4 A Sensible Set of Indicators

As a basic conclusion, scientific performance is multidimensional and cannot be described by one single indicator. To construct a working indicator system, i.e. an indicator system that fosters functional balance, it is necessary to acquire a good understanding of what scientific output actually is. We do not follow a normative approach here by defining outputs, but rather look at the empirical specialisation profiles of the research units in our sample.

Against this background, we collected a variety of different activity indicators which we then regarded as scientific outputs. All in all, we collected the following 11 measures: SCI publications per scientist, citations per publication, conference articles per scientist, fraction of international co-publications, professorial job offers per scientist, expert reports for companies per scientist, co-operation with companies per scientist, membership in advisory boards per scientist, number of doctoral theses per scientist, number of state doctoral theses per scientist, editorships per scientist.

With these output measures we were able to empirically determine research units which are similar in their profile. If research units really specialise, they have clearly distinct output profiles and can be classified into typical groups or clusters.

The empirical methodology followed two steps. First we extracted four factors out of the 11 output variables[4] by factor analysis to reduce dimensionality.[5] Fortunately, these factors were easily interpretable and the first three were linked to typical and intuitive dimensions of scientific performance. The first one could be described by publication-related activities. The second one consists of transfer- and infrastructure indicators. The third factor highly correlates with graduate teaching.

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[4]The observations were pooled because of the small sample size. In order to avoid the trivial cluster-shape (astrophysics, nanotechnology, microeconomics) which might have resulted from pooling, we standardised the output values along the discipline-specific means and standard deviations. In any case, the clusters of the following analyses do not reflect a conceivable pattern of concentration of disciplines.

[5] This is consistent with the rule of letting the number of extracted factors be equal to the number of Eigen-values greater than 1.

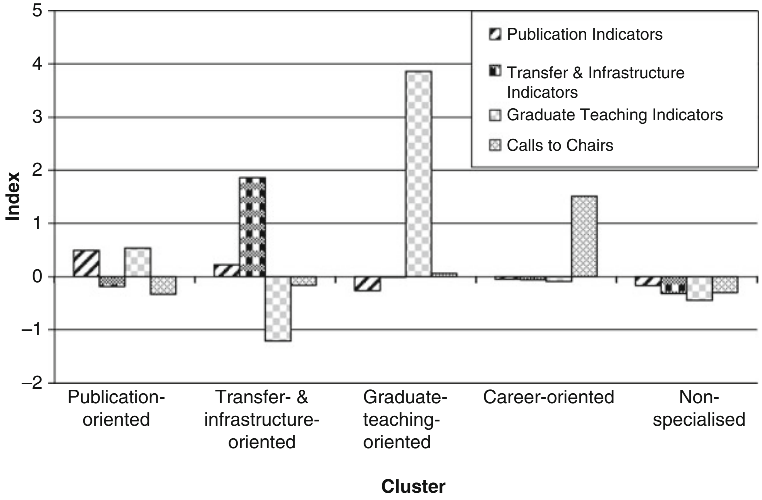

Fig. 1.1 Output profiles for research groups

The fourth dimension (calls to chairs) seems to reflect a social capability rather than scientific output in its genuine sense.

In the second step we clustered the research units along these five dimensions[6] whereof the resulting specialisation profiles are depicted in Fig. 1.1.

The first thing to notice is that the cluster results are highly similar to the results from earlier work, where the same analysis was conducted but based on a different dataset (see Jansen et al. 2007). The first three output profiles (publication-related activities, transfer- and infrastructure-related activities, and graduate teaching activities) are clearly linked to an intuitive understanding of what scientific output actually is. The remaining two clusters are definitely interesting in their own right because it is worthwhile to determine how some professors manage to be offered jobs very often while being quite average in the other performance dimensions. Also the fact that the cluster of unspecialised units is below average in any respect is an interesting observation as it confirms thesis 4 (Section 1.3.1): The units not specialising cannot reap the benefits from learning by doing or inherent abilities.[7]

For the construction of a "good" set of indicators, however, only the first three clusters (respectively factors) are relevant because they are related to our notion of scientific output rather than to social artefacts. To retain functional balance an

[6] Clustering was performed by the Ward method.

[7] In a broader context it can be shown that there are increasing returns to scale in scientific production, which makes specialised units more productive than unspecialised ones (compare Schubert 2008c).

indicator system must be broad enough to cover these three dimensions: publication-related output, transfer- and infrastructure-related output, and graduate-teaching output.

We tentatively propose a guideline for the construction of indicator sets which includes the following ten indicators[8]:

Publication-related outputs:

Number of publications in appropriate databases (e.g. SCI/SSCI or Scopus) and number of conference contributions to measure the quantitative dimension of knowledge generation

Citation rates as a measure of impact

Transfer- and Infrastructure-related outputs:

Number of advisory services and reports for companies
Number of projects or project volume with companies
Number of editorships and number of reviews
Membership in scientific committees
Leading positions in scientific societies
Positions in academic self-management (e.g. position as a dean)
Graduate-teaching related outputs: Number of conferred doctoral and state doctoral titles as a measure of the quantitative aspects of graduate teaching
Fraction of papers authored or co-authored by the non-professorial staff as a measure for the de facto amount of scientific training of the young scientists

1.5 Summary

The main objective of this contribution was to judge the opportunities and risks that accompany the latest reforms in the publicly funded research sector. Specifically, our first question was, whether there were any visible positive effects from the New Public Management reforms on research performance. Indeed such positive influences can be observed. Especially greater internal hierarchy (*strong deans*) and greater operative flexibility for the research units (abolishing rigid personnel quota) increased performance. However, despite these encouraging results we argued that NPM must maintain functional balance, i.e. the incentive structures set by the reforms and their implementation must take into account that research groups are not "lonely riders" but depend on each other through interdependencies in the production process. If NPM instruments for resource allocation (for example indicator models) fail to consider these interdependencies appropriately, it may well be the case that the performance of the system in total is decreased despite the fact

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[8] We stress the necessity to adapt this indicator set to the needs of the disciplines and organisational, most likely country-specific, settings. For example, it will be necessary to incorporate additional discipline-specific indicators.

that each research group has become more efficient. This counterintuitive and perverse effect might show up because the research units may – although being more efficient in spending their resources – simply produce the "wrong" outputs (maybe only publications). In this context, we demonstrated the role of indicator systems to allocate financial resources on a performance basis. Specifically, they must set incentives which foster functional balance, that is, an optimal mix of different activities. Therefore, indicator systems should be broad, encompassing measures for knowledge generation, graduate teaching as well as knowledge transfer and infrastructural activities. We therefore provided a simple set of ten indicators which can be used as a guideline and basis for constructing workable indicator sets. We stress that this list is not dogmatic but should be used flexibly in each discipline. However, we also stress that good indicator sets should stay simple and should not involve more than 10–15 indicators to prevent an information overflow.

In summary, we think the mechanisms and tools provided by the NPM approach have the potential to increase the efficiency of the use of the public resources in the university and science sector. But it is important to take into account not only individual efficiency of single research groups but also the performance of the system as a whole.

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Chapter 2
Disciplinary Differences from a Legal Perspective

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2.1 Introduction

Production conditions differ among the various academic disciplines. This becomes particularly clear in the "two cultures" contrast (as in the classical formulation by Snow 1959; cf. Stichweh 2008), which points out the differences in method and self-perception between the humanities and social sciences on the one hand and the natural sciences on the other. The idea of looking at this differentiation amongst disciplines in the academic system from the viewpoint of legal science is not exactly compelling. However, on closer consideration, there is a multiplicity of reference points that appear particularly if we focus on the regulatory structures of (university) research that apply to them all.

As functional subsystems of the academic system, disciplines receive exogenous signals in accordance with their own rationality, and therefore in a way specific to each of them. And the signals changed with the implementation of "New Public Management" in the university sphere after the end of the 1990s. The German Länders' academic-policy rules no longer come exclusively through governmental and administrative regulation, but increasingly – alongside other shifts – through the move from an input-oriented to an output-oriented governmental funding. The yardstick for output here is particularly the level of external funding and the number of graduates. The resulting linkage of university funding to external conditions leads to effective incentives, which are however processed differently by individual disciplines. The pressure of financing adds a further dimension to the individual character of the disciplines, namely a sensitisation to external expectations.

The legal framework regulations do not leave unaffected the development of the disciplines in accordance with their own rationality (Section 2.2), but instead transport, moderate or correct the processing of the exogenous signals. While substantive

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rules may be couched that are sufficiently broad to be followed by the individual disciplines differently, or procedural rules that leave room for the generation of standards and the assessment of the disciplines' specific intrinsic rationality within the discipline itself thus guaranteeing academic adequacy, institutional arrangements may orient the disciplines' structural framework conditions to the financial incentives (Section 2.3). It is the law's task to give normative form to the linkage of disciplines to altered forms of funding, while taking account of those disciplines' intrinsic rationalities, and finally guaranteeing the normatively underpinned sphere of disciplinary intrinsic rationality (Section 2.4). One important example of this is the legal shape given to financial stimuli in formula-based funding (Section 2.5). This gives rise to effects specific to individual disciplines at various levels (Section 2.6). Against this background, the constitutional requirements on the funding are discussed (Section 2.7).

2.2 Discipline Formation Affected by the Conditions of Academic Production

Disciplines can be understood as subsystems of the academic system. Both the academic system, as a subsystem of the functionally differentiated society, and the internal differentiation of the academic system into disciplines date back to the nineteenth century, and have since constituted decisive structural features from the viewpoint of the sociology of science (Stichweh 1984, 1994: 17f.; cf. for other descriptions in sociology of science Weingart and Schwechheimer 2007: 42ff.). This meant a replacement of the hierarchical order of disciplines by a heterarchical system marked by a "heterogeneity of disciplinary cultures" (Stichweh 2005). The differentiation of the academic system into disciplines continues apace; it is a stable system, but not a static one (Weingart and Schwechheimer 2007). Even if in the sociology of science, in the context of the "Mode 2" debate, an "end of disciplines" is called for, disciplines nonetheless continue to constitute the decisive structural feature of the academic system (cf. Schwechheimer and Weingart 2007: 218f.). The disciplinary scientific communities constitute communities that communicate through academic publications and generate reputation within the system, hence the key issue here is the associated differentiation among disciplines. These develop extremely varied methods, standards, forms and media of publication and ways of attributing reputation (cf. Stichweh 1994: 23, with many references). The various logics of production are thus primarily distinguished by the disciplines' intrinsic meaning and intrinsic logic, which are portrayed and taken into account by the law to differing extents. To that extent, legal provisions governing the organisation and funding of research institutions and research-funding organisations take this internal differentiation into consideration.

2.3 Legal Frameworks for the Disciplines and Their Development: An Overview

Law shapes the normative part of the structural framework that determines individual actors' actions according to their intrinsic rationality in the academic system (in general on this, in the context of the governance perspective, see Trute et al. 2004, 2008). Disciplines as a differentiation of the academic system can act here as the focal point to which law can attach (Trute 1994: 86, 91), since this is the only way in which the disciplines' intrinsic rationality can be taken into account in normatively appropriate fashion and consequences drawn for a "scientifically adequate constitution for institutions of promotion, evaluation and monitoring" (Trute 1994: 91, fn. 25, translation by the authors). The call for academically adequate law (Groß 2002) thus also implies the need for law adequate to each discipline. Openness to disciplinary peculiarities in the context of substantive rules of law and incorporation of the disciplinary viewpoint are, then, an expression of academically appropriate regulatory structures.

Legal regulations at the level of researchers and research groups are normally phrased in terms that embrace all disciplines and leave room for applications specific to a given discipline. This applies, for instance, to rules of appointment. Among the differing logics of production of the disciplines are specific career and appointment patterns and the resulting strategies. The linkage of academic careers to positions within disciplines associated with an interaction among institutions may be counted among the features of internal differentiation (Stichweh 2003: 4). However, the rules of appointment are not worded in terms specific to the disciplines. Instead, the procedure embodied in the Universities Acts and the universities' own supplementary internal regulations allow a linkage with the different disciplinary performance standards in the appointment decision. Much the same is true for the salary reform for professors. The shift to a system of time-limited performance bonuses tied to functions and negotiated criteria is supposed to achieve more of a performance orientation for professors. The rules and procedures for making these performance payments are not codified by law specifically for each discipline. Nevertheless, within this legal framework the differences between disciplines are incorporated in negotiations since inter alia the associated professions and the occupational alternatives are taken into account as negotiating positions.

The structuring of university organisation along lines of disciplinary differentiation (Trute 1994: 89; Stichweh 1994: 18ff.) indicates the point to which the legal treatment of disciplines are connected, but also shows its limits. The Universities Acts of the Länder and the universities' own internal regulations provide for internal differentiation oriented towards the academic disciplines. Accordingly there is a close linkage between the disciplinary differentiation of scholarship and the internal organisational structure of universities. While it cannot be said that the organisational structure of universities can reflect the disciplines or wishes to, all the same the internal structures are manifestly oriented towards differentiating according to the differing logics of production. Admittedly, this finding must be nuanced in several respects. First, universities' internal structures, and thus the linkage with the disciplines, are subject to a process of transformation. While the *Ordinarienuniversität* was typified by large faculties that represented more of a collection of heterogeneous Chairs (Wissenschaftsrat 1968: 9), with the establishment of the *Gruppenuniversität* a countermovement set in. Thus, the German Federal Legislature provided in § 64 (1) of the Universities Framework Act of 1976 that departments should act as "basic organisational units for teaching and research". As a consequence, the universities have been almost entirely subdivided into departments, which have often embraced only one single discipline. The legislation thus took disciplinary differentiation fairly far in the direction of a homogenisation of structures. A countermove began with the university reforms of the 1990s. The organisational structures of the universities were changed in many ways, with the differentiation into departments as a rule being reduced, in order to improve control possibilities at decentralised level (cf. the revealing analysis by Winter 2004; see also Nickel 2004). A striking thing about these reform processes is the legislature's inflexibility and limited capacity for control. When departments have been brought together into larger units – usually in accordance with the criterion of disciplinary "closeness" –subunits with a stronger disciplinary orientation emerge, whether that is foreseen by the law or not.[1]

The institutional pattern can also move away from the disciplinary orientation so as to optimise the structures in relation to the demands of outside funding, as shown notably by matrix structures that organisationally separate teaching and research tasks (Winter 2004: 126; Wissenschaftsrat 2006: 76ff.). Gläser et al. describe this development as the setting up of "profit centres" that as a rule embrace several disciplines, based equally on the research interests of the academics, the strategic intentions of management self-governance and the capacity for securing third-party resources (Gläser et al. 2008: 150). This restructuring within and across disciplines into profit centres allows opportunities to be optimised for third-party funding by freeing scientists from teaching burdens and providing personnel and material resources. This strategic specialisation of the university structure into "time-limited trans-disciplinary research hybrids" (Krücken 2006: 7, translation by the authors) can be seen as a loss of importance by the academic disciplines that has been provoked by the legal constitution of a competition over funding.[2] The setting up of

[1] One example of this is the process of faculty formation at the University of Hamburg. The legislature reformed the university's internal structure by combining 18 departments into six faculties, which at the same time were markedly strengthened in their tasks and powers. The associated combination of heterogeneous disciplinary departments into faculties has meant that the subunits below faculty level are again oriented towards the original structures; similar effects from Baden-Württemberg are reported by Winter (2004: 109).

[2] Such as the demand contained in § 3(1), third indent, of the agreement between the federal government and the Länder on the excellence initiative, for an "overall concept for networking the disciplines".

matrix structures like this, largely detached from a disciplinary orientation, can accordingly be presumed to be a major effect of the Excellence Initiative.[3]

At the level of research-funding organisations, incorporating the specific disciplinary perspective favours the academic adequacy of the regulatory structure, while the abstraction associated with the Europeanisation of research hampers the integration of highly differentiated intrinsic rationalities.

Firstly, the German Research Foundation (DFG) constitutes a classic example of the reflection of disciplines in a research-funding organisation. As a consequence of the DFG's perceived mission as the self-management organisation of science in Germany its decision-making structure reflects its internal differentiation (Trute 1994: 89; Markl 1990). Thus, its statutes state that in the composition and number of *Review Boards* (Fachkollegien) it should be ensured "that all fields of science and the humanities are represented and that their research interests and inter-disciplinary relationships be duly taken into account".[4] Additionally, in its research support decisions, the Joint Committee (Hauptausschuss) is to "weigh the needs of the different branches of science and the humanities".[5] The Review Boards, central to the evaluation of applications for funding, have proved extremely stable in their disciplinary structure, something that may cause difficulties for inter-disciplinary co-operation (Schwechheimer and Weingart 2007: 197ff.; Internationale Kommission 1999: 2; on the structure of the reformed decision-making procedure cf. Koch 2006: 25ff.). It should also be borne in mind that the focus of DFG funding has shifted from the normal procedure to the co-ordinated procedures and the Excellence Initiative, which highlights the need for focusing and for inter-disciplinary co-operation. The differing production logics of the disciplines often mean that there are differing prospects of securing third-party funds, something that also has repercussions on strategic decisions within the university (Krücken 2008: 76).

Considering by contrast the European Research Council as the European organisation for promoting fundamental research, the disciplinary structure is less institutionalised. The European Research Council consists of a scientific council and an executive agency for handling administrative tasks. The members of the scientific council are meant to come from all research areas in the European academic community[6]; but that means at best a loose disciplinary connection in the legal act setting it up. In funding procedures and the selection of expert evaluators, by contrast, disciplinary differences are much less reflected than in national procedures. Thus, the assessment structures are differentiated, though not directly according to

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[3]This is one of the positions arrived at in the WZB research project on "rejected clusters"; see project outline at http://www.wzb.eu/gwd/wipo/pdf/AbgelehnteCluster.pdf (as at 1 April 2009).

[4]§ 6(7) of the Statutes of the German Research Foundation, at http://www.dfg.de/dfg_im_profil/struktur/satzung/index.html (as at 1 April 2009 – English version available).

[5]§ 7(3) of the DFG Statutes (footnote 4).

[6]Article 4(2) of the Commission Decision of 2 February 2007 establishing the European Research Council, OJ 2007 L57, p. 14ff.

national disciplines.[7] Of course, it should also be borne in mind that the European Research Council cannot simply link up with disciplinary communicative communities, since their constituencies throughout the European Union differ significantly. Applications may be made in any academic discipline, but the European Research Council's budget is divided into just three disciplinary groups.[8]

By contrast with research-funding organisations that can be reckoned as forming part of the academic world's self-governance, the funding systems of actors in the political and administrative system do not directly reflect disciplinary structures. Instead, by financing research projects they affect the performance dimension of the academic system for other social subsystems (Braun 2004). Organisational structures and funding programmes are accordingly oriented towards the various political control intentions of the governmental actors. The latter seek in various ways to bridge the disciplinary differentiation of the academic system by the requirement for inter-disciplinary and trans-disciplinary co-operation. For instance, the European Community's Research Framework Programme and the specific implementing programmes frequently stress the objective of inter-disciplinary and trans-disciplinary co-operation pursued through their funding (on the connection between the problem approach and interdisciplinarity cf. Stichweh 1994: 38; an instructive case study using the example of climate research is found in Schützenmeister 2008). In formulating the funding programmes and in evaluating the proposals, government actors are however dependent on the co-operation of representatives of the disciplinary communities: "social problems have to be translated into scientific ones, quality must be measured by the standards of the disciplinary communities" (Gläser and Lange 2007: 446, translation by the authors). Research funding presupposes and challenges disciplinary differentiation at the same time (Weingart and Schwechheimer 2007: 51). To refer to the research funding by the European Community once again (cf. on the German Ministry of Education and Research Stucke 1994; Trute 1994: 585ff.), the approach to the problem is reflected in the structures of the funding programmes, but also in the Commission's advisory bodies and the organisational structure of the Directorate-General for Research. All the same, an effort to recognise and incorporate differing disciplinary production logics can be noted. This can be seen in, for instance, the Community's effort to give the social sciences and humanities a separate place in European research funding. But high-level Community activities too, such as comparing the performance of

[7]This can be clarified on the example of legal science. Whereas the DFG regards legal science as a discipline on its own and in its internal differentiation follows the classical trichotomy into civil law, public law and criminal law, the European Research Council ranks legal science as a part of the disciplinary group of the social and human sciences and forms the subgroups "Legal systems, constitutions, foundations of law", "Private, public and social law" and "Global and trans-national governance, international law, human rights".

[8]According to the European Research Council's working programme for 2009 (Commission Decision C(2008) 5673 of 23 July 2008, p. 24), around a third of the budget each goes to the research domains of physical sciences and engineering and of life sciences, while about a sixth goes to social sciences and humanities and another sixth to an inter-disciplinary domain.

European universities or analysis of the market for academic publications, have to face the question of how the specific features of various disciplines are to be handled (cf. European Commission 2001: 7; European Commission 2007).

2.4 The Change in Governance: Financing Incentives and Disciplines

Academic law shapes the normative part of the university regulatory structure and thus influences the orientation of disciplines through changes to external funding. The changes in institutional regulations have moulded a type of university governance that is oriented towards strategic capacity (on the lines of development cf. de Boer et al. 2007, 2008; Trute et al. 2007a; Trute and Pilniok 2009). On the one hand, this calls for academically appropriate, and therefore discipline-specific, allocation mechanisms and on the other hand, it harbours a danger of cutting-off from funding disciplines whose production conditions do not fit the strategy well.

Both university models, the *Ordinarienuniversität* and the *Gruppenuniversität*, were typified by strong academic self-governance (Trute et al. 2007a). Management self-governance through the management levels was by contrast rather weakly developed at both departmental and central levels. Competition within the organisations or between departments and universities barely existed. Governmental control of universities was marked by an administrative regulatory system that was conspicuously governmental. The focus was on detailed rules in the Universities Framework Act and from the education ministries in the Länder. Financial control through highly detailed bureaucratic budget and staffing plans were of central importance. No external governance was provided for, such as the conclusion of contractual agreements between the Länder and the universities or by university boards with external memberships. In this model of the professorship and *Gruppenuniversität* there was adequate room for disciplinary differences from a legal viewpoint – over and above the organisational viewpoint as detailed above; "academic self-governance through the principle of Chairs (*Lehrstuhlprinzip*), the faculty structure and a structurally weak university management left a lot of room for disciplinary differentiation" (Wissenschaftsrat 2006: 34, translation by the authors). A typical feature here was the separation of academic and resource-related decisions (ibid.). Resource endowment, differentiated by discipline, was, like the – barely existent – profiling in individual departments, largely shifted into the political arena, where decisions on resources could be taken in nuanced fashion. The academic self-governance levelled out differences among disciplinary cultures through equal distribution and negotiated solutions. External demands, linked to the performance vis-à-vis other societal subsystems, did not constitute a challenge.

All this shifted considerably with the multiplicity of reforms under the banner of *New Public Management* (Trute and Pilniok 2009: 23ff.). Academic self-governance was markedly weakened in favour of management self-governance through university presidents and deans (Trute et al. 2007b: 168ff.). State regulation through contractual agreements has replaced detailed governmental administrative control (Trute et al. 2007a: 166ff.). At the same time, on the financial side block grants were introduced and staffing schedules dropped. This greater autonomy was often combined with indicator-based provision of funds by the Länder to the universities. Because of this increasingly differentiated funding, competition gained in importance at all levels. This comes out not least in the Excellence Initiative, which was directed primarily at universities as corporate actors.

Universities accordingly need researchers to take financial consequences into account if they are to prevent deterioration in their financial endowment. In order to ensure their future competitiveness, universities are forced to transfer the incentives set at State level further into the research level. There follows from this, firstly, the need to measure performance and in so doing take into account the specific production conditions of the disciplines. For if there is no unity of the sciences (cf. Stichweh 2007), there can only be limited unitary performance assessments. One example that expresses the growing need for discipline-specific performance evaluation is the pilot procedures of the Wissenschaftsrat (German Council of Science and Humanities) on research rating in chemistry and sociology (Wissenschaftsrat 2008). Both studies show how it is possible to reach differentiated statements about the performances in the various disciplines at individual institutions by bringing in the disciplinary associations. They also point out the need in the first place to develop inter-disciplinary standards that can link up with legally constituted decisions on resources (for the example of sociology, Wissenschaftsrat 2008; cf. on the discussion in legal science Schulze-Fielitz 2002). But the research ratings at the same time make it clear that the associated transaction costs are not negligible and need not necessarily outweigh the advantages of a comparative approach and the associated performance enhancement.

Secondly, the re-orientation of funding modalities raises the question of the relationship between disciplines within the universities in the context of resource allocation which – if the allocation is to be according to performance – requires cross-disciplinary methods of evaluating performance, but also makes a performance-independent strategic orientation for universities possible. The increased autonomy of universities, associated with their strategic capacity generated by organisational reforms (Whitley 2008; Krücken and Meier 2006) and further promoted by external governance, can no longer let "the mutual indifference of the disciplines" (Wissenschaftsrat 2006: 34, translation by the authors) continue. One consequence of the enhanced competition is the need to prioritise areas of research within the universities. According to the Wissenschaftsrat, if the universities' success in competition as a whole is dependent on the performance of all units, then the stronger units can no longer afford to be indifferent to the weaker ones (cf. again Wissenschaftsrat 2006: 34). Correspondingly, strategic decisions of university and faculty managements rely on "strong" disciplines or subdisciplines at the university concerned. Strength is often established by the amount of third-party resources collected, not least because third-party resources are a decisive factor in indicator-based funding. Third-party resources, however, fit the production logics and intrinsic cultures of the various disciplines to very different extents. Moreover, they are available in differing amounts and from differing funding sources according to discipline. Accordingly, those representing a discipline that is not at the focus of research-funding organisations and university managements are forced to start justifying themselves. Disciplines characterised by small, highly specialised academic communities, a concentration on individual research with no possibilities or needs for fundraising from third parties and a discipline-specific publishing culture that does not rely on international journals with a high impact factor may easily come to suffer in allocation decisions within the organisations (Lange 2007). Rational allocation decisions by universities taken independently of each other may possibly in the upshot mean that individual disciplines lose their working basis because they cannot with the remaining resources any longer link up with disciplinary standards (cf. also Schimank 2007: 256).

These consequences of the reforms are debated particularly on the example of the so-called "small disciplines" (Hochschulrektorenkonferenz [German Rector's Conference] 2008). In this context "small disciplines" are those with at most three professorships at a university, or present at no more than eight universities on German federal territory (Hochschulrektorenkonferenz 2008: IIIf.). While not a small subject by this definition, agricultural science shows a structurally parallel example (cf. the discussion contributions by Rohe and Schimank in Jansen 2009: 119ff.). The resource-intensive agricultural sciences (and their subdisciplines), represented at only 11 universities in the whole of Germany, suffer from disadvantageous allocation decisions, described by the Wissenschaftsrat as "erosion of the institutional bases" (Wissenschaftsrat 2006: 14, translation by the authors), but also from lack of demand for teaching and a shift in the objects of the discipline (for a diagnosis in detail cf. Wissenschaftsrat 2006: 15ff.; and similarly, DFG 2005). Here university-wide unitary criteria and performance expectations that do not take adequate account of disciplinary peculiarities are seen as a problem (Wissenschaftsrat 2006: 17). This development with agricultural science at universities is in striking contrast with the importance attributed by political and administrative actors to this discipline (for a prominent example see European Commission 2008). All in all, then, the question arises whether there is an obligation on government to guarantee disciplinary variety that balances out this "failure of autonomy", and if so, how it ought to be implemented. The Wissenschaftsrat suggests, for instance, a co-ordinating committee for agricultural science, made up of representatives of central government and the Länder, and calls on university managers to make justified decisions that can be reached only on a basis of adequate knowledge about the whole of the system (Wissenschaftsrat 2006: 61). Behind this obviously lies the notion of a responsibility of these actors for the academic system as a whole, which cannot be expected from the universities, especially in a competitive model. In relation to the federal government and the Länder, moreover, the question remains open whether harmonisation decisions do not inevitably clash with the recently established university autonomy.

On the whole, it may be said that the various new public management reforms make one look closer at whether there ought to be more differentiation made among disciplines as regards staffing, organisation and in particular funding, in order to achieve an academically adequate institutional design. Thus, for instance, the combination of research evaluation and funding contains the possibility of misguidance from outside the academic world (BVerfGE 111, 333). Performance indicators such as citations and third-party funds are, as a rule, applied across disciplines regardless, although – as other articles in this volume show – they are discipline specific. If resource decisions, such as professors' performance-oriented salary, internal resource allocation and governmental funding, are linked to performance indicators, the procedures for funding have to be considered. This applies in particular to the generation of criteria and the involvement of the academic world that the Federal Constitutional Court has called for. Formula-based funding legally establishes the financial incentives deriving from the indicators, and at the same time enables the procedural incorporation of the discipline-specific viewpoint. A viewpoint that embraces the whole regulatory structure (Trute et al. 2004, 2007b, 2008) leaves open the structural effects of academic law in linking up external financing incentives and the intrinsic rationality of the sciences, and thus specifies constitutional limits.

2.5 Legal Structuring of Financing Incentives in Formula-Based Funding

The legal structuring of financing incentives and their effects on the orientation of academic disciplines is exemplified by formula-based funding. This is a component of the introduction of output-oriented funding into the university sphere, one of the major reform elements to incentivise performance enhancements (BR-Drs. 724/97, S. 23f.). Formula-based funding operates on at least two levels: between university and State, and within the university. Within a university, a distinction has to be drawn between allocation of resources over the faculties by the central level and allocation within the faculty. Article 5 of the Universities Framework Act, added in 1998, obliged the Länder to introduce performance-oriented funding.[9] By now almost all Länder Universities Acts have made this sort of resource allocation compulsory both at the State-university level[10] and within the universities.[11] Almost all the German Länder and universities practise it – albeit to differing extents.

[9]The introduction of performance-oriented funding through Article 5 of the Universities Framework Act was intended by the legislature to operate not just between universities but also within them (BR-Drs. 724/97, p. 23) even if this cannot be unambiguously derived from the tenor of the provision. This was no doubt regarded as necessary in order to prevent the increase in performance incentives intended by the funding shift to be evaded within the universities.

[10]§ 13 II S. 1 LHG B-W; Art. 5 II BayHSchG; § 2 VIII LHG Bbg; § 106 II S. 2 BremHG; § 6 I HmbHG; § 16 I S. 1 LHG M-V; § 1 II S. 1 NHG; § 5 I HG NRW; § 102 S. 1 HG R-P; § 8 I S. 2 UG Saar; § 11 VII S. 2 SächsHSG; § 8 I S. 3 HSG S-H; § 13 V ThürHG.

[11]§ 13 II S. 7 LHG B-W; Art. 20 II S. 1 Nr. 6 BayHSchG; § 65 I S. 4 Nr. 5 LHG Bbg; § 81 II S. 3 BremHG; § 100 II HmbHG; § 16 III LHG M-V; § 37 I S. 3 Nr. 3 NHG; § 102 S. 3 HG R-P; § 15 V S. 2 Nr. 4 UG Saar; § 11 VII S. 3 SächsHSG; § 13 V ThürHG.

Performance-oriented funding can be brought about in three forms, namely formula models, contractual agreements or discretionary decisions (Schröder 2004: 30). The practical simplicity of formula models, with their high degree of transparency, their relatively low cost of implementation and the high degree of objectivity ascribed to the measurable indicators (Salais 2007: 193) must, admittedly, be qualified on a closer look by the need to take account of the intrinsic rationalities of specific disciplines. Apart from the fact that strategic decisions like the creation or funding of research and teaching centres of excellence can be reflected only with difficulty using a formula mechanism (Breitbach and Güttner 2008: 84), the indicators have, depending on the strategy within the university, differing effects on the production conditions, and in the medium term also on the self-perception, of the disciplines. The actual legal implementation of formula-based funding at all levels and the (non-) differentiation by disciplinary production logics that is emerging are the first focus here.

2.5.1 Provision of Governmental Funds to Universities

With the exception of Saarland and Saxony-Anhalt, all German Länder are now using formula models for distributing State funds to universities (Jaeger 2008: 90). These formula models are not regulated in the Universities Acts. They are either, as for instance in Berlin, agreed contractually between government and universities, or as for example in Rhineland-Palatinate set unilaterally by the government.

Here three groups can be distinguished: first, in several German Länder the whole state subsidy is distributed using formula models (examples: Rhineland-Palatinate, Brandenburg). For this, indexes that are not performance-oriented are predominantly used (Jaeger 2008: 91). Thus, in Brandenburg 75% of the funds are provided in accordance with the indicators to students in normal study courses and to professors, weighted in each case with cost norms specific to disciplines (Leszczensky and Orr 2004: 22). Secondly, some of the Bundesländer use the formula models to supplement contractual agreements (Jaeger 2008: 91). Part of the money promised in the agreements – in Berlin, for instance, 30% – is distributed on a performance-related basis. Länder in the third group distribute only limited funds through formula models, but with no systematic link to contractual agreements. In this way, Lower Saxony allocates 10% of its university funds, but Bavaria only 1.5% of them (Jaeger 2008: 91). As for the performance indicators, the focus is primarily on teaching (students and graduates) and research performance (as well as third-party resources, and, to a markedly lesser extent doctorates). Alongside this – as specified in § 5, second sentence, of the Universities Framework Act – equalisation criteria are often applied (Jaeger 2008: 91). Despite demands from some universities (Leszczensky et al. 2004: 26), publications are only included in rare cases. Most German Länder allocate a fixed proportion of their funding to all universities using formula models. On this basis a university may have its subsidy cut even if performance is enhanced, if other universities have enhanced their performance more. In order to counteract the associated negative incentive effects, the models, notably in Baden-Württemberg and Bremen, provide that in the event of corresponding performance enhancements additional funds will be made available. However, the provision of extra resources is not certain even then, as the example of Bremen clearly shows: for this reason, the formula-based funding had to be abandoned in both 2008 and 2009.

In order to take account of the differences in discipline-specific production conditions and the resulting difficulties of inter-disciplinary performance comparisons (Leszczensky et al. 2005: 28; Leszczensky and Orr 2004: 63), practice at government level essentially follows three approaches, which admittedly only approximately correspond to the intrinsic rationalities of the various disciplines. First, the indicators are partly chosen in such a way that the advantages and drawbacks of the disciplines (ought to) balance out. Thus, for the formula model in North Rhine-Westphalia, exclusively the indicators of graduates, third-party funding and doctorates are used, without weightings. This model can be employed without great administrative burden. In view of the not inconsiderable differences among disciplines, however, it is scarcely possible to develop the set of indicators in such a way that all disciplines can have the same chance to reflect their performance (Arbeitskreis Hochschulkanzler 2006: 10). It remains open how far it is possible to find indicators that are overall discipline-neutral. The third-party funding and graduate indicators are likely, at any rate, each to favour particular disciplines over others considerably. It seems by no means certain that combining them will lead to a neutralisation effective for all disciplines.

Second, is the widespread use of discipline-specific weighting of indicators. Some of the German Länder, such as Baden-Württemberg and Rhineland-Palatinate, and over half of all universities (Leszczensky et al. 2005: 24) have chosen this approach. The factors weighted are third-party funding and numbers of students and graduates (Leszczensky et al. 2005: 24f.), with the weightings frequently being derived from curricular standard values. The positive aspect of this is that all disciplines are in direct competition with each other and that differing weighting factors make fine-tuning possible (Jaeger 2006: 62). A disadvantage of this approach is that it leads to an increase in the complexity of the model, an increase in administrative burdens and a decline in transparency (Jaeger 2006: 62; Fangmann and Heise 2008: 53). The recourse to weighting factors has an inherent tendency to make the dangers of structural effects invisible. Correction factors shift the risk of distortions and can thus, depending on their adequacy to the problems and their quality, lead to distortion and over- or under-correction. Setting the correction factors calls for highly developed knowledge about the inter-disciplinary equivalence of performances, which cannot simply be deduced from teaching-related, expenditure-based curricular standard values.

Lastly, performance-oriented resource allocation can ultimately only be done within an academic domain. This is practised in Berlin with the domains of the human and social sciences and of the natural and engineering sciences. The problematic thing here is the makeup of the domains. They should not be too small, since otherwise competition cannot function (Leszczensky et al. 2005: 45). On the other hand, variance within the group should not be too large, or further weighting will be necessary (Leszczensky et al. 2004: 14). Hence, this approach leads to a certain imprecision, but with limited domains is not too complex and thus provides a compromise model between the first two approaches (Leszczensky and Orr 2004: 66). Admittedly, it does not fully solve the problems, since it is still necessary to regulate the allocation of resources among domains.

2.5.2 Resource Allocation Within Universities

By 2005 90% of universities were already applying formula models for resource allocation to faculties (Leszczensky et al. 2005: 12). Two-thirds of the resources allocated on a formula basis were provided according to performance-dependent indicators (Leszczensky et al. 2005: 18). The proportion of funds allocated in this way is, however, still small: only in exceptional cases is it over 10% of the governmental funding (Leszczensky et al. 2005: 14f.). This is in the first place because of the linkage with agreements on appointments. In the past these were concluded without time limits, so that the material and staffing resources were fixed for the professor's period of appointment. By now, however, in almost all Universities Acts a retroactive time-limitation regulation has been laid down, so that in the medium term considerably fewer resources will be tied in this way (cf. Breitbach and Güttner 2008). Secondly, performance-oriented resource allocation is limited by the professor's guaranteed basic endowment, though this is not particularly high.[12] It is accordingly to be presumed that the extent and therefore importance of funds allocated by formula will increase still further. On average six indicators are applied in internal resource allocation (Leszczensky et al. 2005: 23). Teaching indicators account for 57%, almost exclusively with indexes relating to students and graduates being used to measure student demand and the success of courses (Leszczensky et al. 2005: 20). The average weighting for research indicators is 38%. Usually used are third-party funding (100%) and number of doctorates or postdocs (80%). Publication figures are rarely used (16%) (Leszczensky et al. 2005: 20f.). The remaining 5% go to the criteria of equalisation and internationality (Leszczensky et al. 2005: 21f.).

Universities' various options for action in allocating resources can be illustrated in exemplary fashion in Baden-Württemberg. Except for Konstanz[13] all universities in Baden-Württemberg use internal formula-based resource allocation. The models used differ considerably. This is clear from, for instance, the number of indicators used, which ranges from four (Heidelberg) to eight (Stuttgart). Some universities do not consider disciplinary differences at all (Mannheim, Ulm), while

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[12] For instance, the University of Konstanz provides every professor with a basic endowment of between €1,000 and €3,000 for material plus the money for an academic assistant, equivalent to costs amounting to 1.8 million Euros.

[13] The University of Konstanz no longer uses a formula model since according to the administration it did not bring the "necessary fairness" and had to be constantly re-adjusted. For these reasons it was no longer accepted.

other universities form domains (Heidelberg) or use weighting factors (Fribourg, Tübingen). Only the University of Karlsruhe uses the weighting factors from the State government's model.

2.5.3 Resource Allocation Within Faculties

Finally, resource allocation within faculties is also partly indicator based. According to available studies, allocation within faculties is regarded by (almost) all university administrations as a matter for the faculties, and not made the subject of special rules (Jaeger 2006: 57). Thus, indicator-based allocation at central level does not automatically lead to the same thing in faculties (Handel et al. 2005: 82; Minssen et al. 2003: 75f.). Where faculties employ formula models, they are often oriented on the procedures at central level (Jaeger 2008: 97; Minssen et al. 2003: 96). However, the differentiation of procedures at faculty level is tending to increase. This is true of both the breadth of the indicators and the quantities measured (Jaeger 2006: 69ff.). It is intended to increase acceptance by university members, something even more important at faculty level (Jaeger 2006: 71). Since acceptance of the models depends at least partly on how they fit in with the relevant disciplinary standards, the disciplinary character of formula models at internal university levels is tending to increase.

2.6 Discipline-Specific Effects of Indicator Models

Since the indicators determine the allocation of funds, they have, alongside other factors (Jaeger 2006: 67), incentive effects at the level both of the individual researcher and of the faculties and the central level. In their respective interactions, the indicators can help shape both the environment and the self-perception of the disciplines.

2.6.1 Problems of Discipline-Specific Performance Enhancement at Research Level

Although performance-oriented funding is supposed to offer incentives to performance enhancement (on the objectives of performance-oriented funding differentiated according to levels see Jaeger 2006: 55, 69) and thus operates at the level of researchers as the producers of academic performance, the effect of financial incentives on the individual behaviour of single persons depends on a multiplicity of factors. In the academic sphere this can lead to effects on conduct that differ according to the individual case. In general, indicators tend to have a focusing effect which on the one hand increases the intensity of effort and on the other concentrates the focus of attention (Frey 2007: 209). According to a survey of rectors of the Berlin universities, the formula models bring about an increase in performance awareness (Leszczensky et al. 2004: 41). Minssen et al. by contrast see control effects primarily towards researchers who positively evaluate the output-oriented funding and have low intrinsic motivation (Minssen et al. 2003: 62). The (small) proportion of this type of academic is allegedly comparable in the various disciplines (Minssen et al. 2003: 60, 63). Irrespective of the individually differing motivation, indicators strengthen disciplinary differences because they alter discipline-specific performance standards with varying forcefulness. Schröder has thus been able, in a survey of 44 professors, to show a discipline-specific pattern of answers. While a majority of engineering academics would affirm an enhancement of readiness to perform and a guidance of academics in a particular direction through formula-based funding, those in the humanities would seem to have an opposite view (Schröder 2004: 44). Accordingly, different discipline-specific control effects should be expected (Schröder 2004: 45). Gläser et al. also presume differing effects on the disciplines, allegedly because of their different dependency on resources (Gläser et al. 2008: 166).

2.6.2 Problems of Discipline-Specific Performance Measurement

Decisive factors for the effect of formula models on performance incentives are said to be the weighting of the criteria (Leszczensky and Orr 2004: 62) and the amount of funds disbursed (Schröder 2004: 48). The associated effects on how the discipline perceives itself depend here on how far the performance covered by indicators coincides with the version of performance measurement specific to the discipline. The viewpoint of administrative burden in practice favours quantitative indicators, which in each discipline meet with differently patterned quality-control mechanisms. Quantitative measurements are limited in their appraisal of, and to differing extents in each discipline, quality and academic performance [Röbbecke 2007: 165f.; Schmid 2006: 11; Seidler 2004: 22; by contrast Münch assumes a positive correlation between quantity of published output and attributed quality (Münch 2007: 191)]. At the same time, indicator-based funding in many academic domains uses journals that have peer-reviewed articles for the quantitative assessment of publications. They attribute high normative value to these informal quality standards and thus add a financial dimension to their dominance in the attribution of reputation. But where legal indicators cannot be based on such standards generated within a discipline, quantifying performance becomes even harder. With monographs and articles in other periodicals a serious assessment is only possible if the frequency of citations can be added as a quality marker, something that is, however, controversial (cf. Bornmann 2004: 110). Additionally, in many academic areas a citation analysis is not possible because the necessary databases are lacking. At that point if not before, the publications have to be read and evaluated (Wissenschaftsrat 2008: 6, 46; but cf. Schenker-Wicki 1996: 123f.). This problem arises particularly with less clearly demarcated disciplines where work can appear in a multiplicity of journals (Wissenschaftsrat 2008: 19). In such subjects, selective procedures are required to reduce the administrative burden, in particular a restriction to journals contained in selected databases. However, this may be to the detriment of particular ways of working or approaches (for instance inter-disciplinary working groups, or application-oriented researchers) (Wissenschaftsrat 2008: 37f.). On this basis it seems scarcely avoidable that with formula-based funding it is primarily quantitative performance that is measured. If performance indicators do not correspond with the relevant disciplinary standards, they nonetheless remain relevant for the behaviour of the individual and can accordingly in mediated fashion even change standards in the medium term. This sort of shift may however come into conflict with substantive requirements on good academic practice.

2.6.3 Level-Specific Formula Models and Their Consequences

While the universities can only to a very limited extent influence the set of indicators in relation to the State, they design the allocation criteria within the universities. For two reasons the universities should take over the formula models, as set out by the respective Land, when introducing performance-oriented internal allocation of funds: firstly, applying these formula models saves development burdens, and secondly it means the incentives provided by the Länder governments are transferred to the faculties (on all this see Leszczensky et al. 2005: 6, 25, 43; Minssen et al. 2003: 78; Handel et al. 2005: 81f.). Retrospectively, this harmonisation can be perceived as a costs-by-cause principle, in which financial gains and losses are passed on to those responsible (Leszczensky et al. 2005: 44). Looking forward, the harmonisation of indicators aims at optimising resource allocation within the university in connection with the forthcoming allocation by the State government. The allocation of resources within the university is oriented to the Länder preferences expressed in the indicators and thus brings about similar structural effects as are produced in chains of value creation subject to dynamic competition. Only taking over the criteria laid down by the Länder, however, conveys the stimulus intended by the Länder in their policies for academic development in an unchanged manner, incentivising a trend to a corresponding stratification of university departments.

The use within universities of specific models in each case, by contrast, enables adjustment to the specific conditions within the universities, which are not too different from those at governmental level (cf. Gläser et al. 2008: 149), as well as to the strategies that may be pursued by the various rectorates (Minssen et al. 2003: 78). Not least, with internal university models, high importance is attributed to acceptance by university members, so that minimal orientation effect is produced by negatively assessed Länder models (Jaeger 2006: 60). The managing bodies can therefore adapt their own models through the setting of the indicators. By using allocation models of their own, accordingly, the universities can themselves develop strategies with performance incentives that take account of the disciplines' intrinsic rationalities. Such models as, for instance, the introduction of weighting factors or cluster formation, admittedly presuppose – if they are not to be arbitrary – knowledge of the special features and the common features of the disciplines.

2.7 Legal Requirements on Formula-Based Funding

Formula-based funding serves to implement the performance-oriented funding laid down in the Universities Acts. In its judgment on the Brandenburg University Act, the German Constitutional Court made it clear that both the assessment of academic quality and associated performance-related fund-allocation are in general compatible with the academic freedom laid down in Art. 5 (3) of the German Basic Law [BVerfGE 111, 333 (359)]. The Court bases this on the fact that assessments have a tradition in the academic world and that alternative allocation procedures, notably equal distribution or the setting of political preferences, can contain dangers for academic freedom [BVerfGE 111, 333 (359)] as well. The Federal Constitutional Court accordingly stresses that performance-oriented funding in general and formula-based fund allocation in particular are compatible with Art. 5 (3) of the German Basic Law only if an academically appropriate performance evaluation is made [BVerfGE 111, 333 (359)]. From a correct starting point, with this demand for academic adequacy of the indicators, the Federal Constitutional Court is taking up the disciplines' self-referential intrinsic rationality. Making this obviously desirable approach operational, however, is anything but simple. Especially since it is not clear whose obligation it is to do so and what the reference point of the obligation ultimately is.

It cannot be taken as meaning that the reference point of this demand is to maintain a specific financial endowment for the disciplines. Formula-based funding in universities cannot have the object of ensuring the maintenance of those disciplines which are institutionalised over all the institutions. This could – if at all – be only a component of a guarantee responsibility on the State. And in view of the fact that universities are, after the changes to their governance, supposed to profile themselves as strategically operating institutions in competition, this sort of obligation on institutions would be hard to reconcile with notions of competition. Erratic consequences arising, such as the disappearance of disciplines as part of competition institutionalised in this way, cannot then be attributed to the individual actor. Generally applying obligations to the common good can accordingly be addressed only to the State. In reality the point can only be to ensure an allocation of funds for and within the institution that is appropriate and takes account of discipline-specific peculiarities and the institution's own performance capacity and specific profiles. The indicators must accordingly link up with specific production conditions, though without necessarily being able to reflect them fully. The consequence is not only a coarsening, which is tolerable, but also certainly the maintenance of freedom for creative self-modification of production conditions. In this connection, a gradation of the obligation of due consideration differentiated by levels might prove to be too static. Classen, for instance, sees the constitutional requirement to give consideration to disciplinary differences as less stringent in relation to the Länder model than to the internal university model (Classen 2008: Rn. 101). It is true here that most universities have a broad spectrum of subjects. The disadvantaging of particular disciplines thus as a rule affects (almost) all universities, thus limiting the financial and therefore also structural effects. The internal university models tend to produce a greater incentive effect upon scholars to orient their performance by these indicators. The internal university fund allocation thus more clearly affects academics' production conditions and thus affects academic freedom more strongly.

This estimate must however be qualified in the light of the dynamic across all levels produced by the universities' strategic capacity. If universities convey Länder funding criteria internally into the universities in order to optimise future funds coming from the Länder, then distortions among disciplines induced by the indicators will also be passed down. Changes to the indicators pursuing different strategies for optimising funds will also have structurally distorting effects on disciplines, or at any rate not follow their intrinsic rationalities. In reality the expectation of a fleshing out of the criteria at university level to make them appropriate to the disciplines obliges the universities to make an academically appropriate redistribution of the funds obtained from the Länder while putting up with future financial disadvantages. Whoever wants the institutions to have strategic capacity in competition has to accept the ensuing consequences within extreme limits.

In view of the wide-ranging practical problems of comparing performance among disciplines, the constitutionally required disciplinary weightings are in the first place to be brought about through procedural guarantees, not substantive rules of law. This affects the two levels, State and universities, differently. Accordingly, in the first place, unilateral setting of the indicators by the State is ruled out, since as the Federal Constitutional Court rightly finds, *appropriate involvement* of representatives of the academic world is essential [BVerfGE 111, 333 (359)].[14] For this, the governmental actors must inter alia engage in a dialogue with the universities that is largely open as to its outcomes. This is the only way to make use of the universities' informational advantage in order to construct a formula-based funding model that is adequate in disciplinary respects and thus academically adequate (on the basic duty of co-operation of State and university in the interests of science cf. Trute 1994: 314). All the same, the Federal Constitutional Court's viewpoint reaches beyond the organisations; an appropriate involvement of representatives of the academic world could also, for instance, be brought about through the professional associations.

[14] In this light it is troubling that a survey in North Rhine-Westphalia found that according to their own assessment 50% of rectorates possess no influence over the development of criteria by the Ministry (Minssen et al. 2003: 81).

On the same considerations, requirements can also be derived from Art. 5 (3) of the German Basic Law for the setting of indicators within universities. The evaluation scheme need not of course be developed solely by a bottom-up procedure. Thus, the institutions are not prevented from having recourse to externally generated criteria – such as those of the Wissenschaftsrat – as long as these have been arrived at with adequate involvement of the academic world. Where there are indicators generated through a time-consuming procedure, there is presumably a considerable burden of proof, particularly on the institutions' managing bodies, for any departure from them – say in the interest of uniformity. Nor should anything different apply where there are established indicators. This point can be generalised without becoming tantamount to a status quo of indicators already introduced. Instead, the latter have to be justified by the current state of knowledge and practice in the disciplines. In view of the special features in the institutions, the scheme must additionally be adequately debated within the university (on possible inclusion of collegiate bodies cf. Fehling 2004: Rn. 237). Even if these rules are complied with, formula models may lead to academically inadequate effects in general and more specifically in relation to individual disciplines. Given this danger, the operations of the models have to be evaluated. This may relate to knowledge about the effect of indicators on research performance and on effects specific to institutions. However, studies to date also make clear the difficulties inherent in determination of facts concerning effects within an appropriate time. As soon as any mismanagement effects become notable here, the State or the university would have to make changes [BVerfGE 111, 333 (360)]. A self-evident idea would be to limit the amount of resources allocated in this way as long as the system of performance-oriented funding retains the danger of being inadequate, because of lack of experience notably with quality assessment among disciplines (cf. Classen 2001: 860). Account will also have to be taken of the point that the transaction costs of this sort of model may be high and thus justify effort on it only above an adequately large amount for allocation. Again, incentive effects probably arise only after a certain size of the funds to be allocated. Those wishing to observe the effects cannot accordingly be over-hasty in narrowing-down the room for experimentation. Otherwise they are likely simply to see the preservation of the status quo.

2.8 Summary

The object was to enquire into disciplinary differences from a legal perspective; this opened up a broad field. Scientific disciplines can be understood as subsystems of the academic system that constitute contexts of action and communication. While organisational and funding rules are often linked up with disciplines that range across institutions so that there is a mediated connection, it has been shown that recruitment, organisational and funding rules at the level of research organisations and research funding are oriented in a more-or-less detailed manner to the differentiation of the academic system into disciplines. However, the dynamics brought by the reform of university governance have to be emphasised. The creation of actors with strategic capacity has a variety of consequences for subjects and disciplines. This is true particularly in the interplay with the new funding orientation in this context, which has accordingly been studied as an exemplary case. Processing the disciplinary differences accordingly presents a central problem that arises in extremely heterogeneous fashion. Closer consideration of the constitutional requirements here makes it clear that the constitutional criteria for universities' changed governance structures are still at an early stage.

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Part II
New Governance of Research and Effects on Performance

Chapter 3
Is Nanoscience a Mode 2 Field? Disciplinary Differences in Modes of Knowledge Production

Dorothea Jansen, Regina von Görtz, and Richard Heidler

3.1 Introduction

In times of intense economic competition, sciences are seen increasingly as an important engine for economic growth. Policy-makers thus try to encourage a stronger orientation of the sciences to societal needs. Recently, science policy has been transformed by two discourses justifying new demands on science and its respective policy instruments. On the one hand, the discourse on New Public Management and Public Management Reforms (e.g. Amaral et al. 2003; Pollitt and Bouckaert 2004) is changing the science system: Until the 1990s, the state confined itself to financing and regulating the organisational framework for science within which the scientific community was left to coordinate itself. Ever since Bush argued so persuasively for basic science to be funded with public money (Bush 1945), controlling the contents of scientific research had been seen as impossible due to information deficits by the state (Mayntz and Scharpf 1990). However, transferring the concept of New Public Management to the science system has meant that science policy-makers now try to influence the direction of research. The second discourse influencing science policy deals with what science can do for society at large. Science is not only being asked to produce knowledge as a public good, to systemise it and to make it accessible, it is also supposed to engage in a "Third Mission" alongside research and teaching. The term "Third Mission" relates to technology transfer, whereby knowledge and technology are made available to interested stakeholders to be further developed and exploited by them. A variety of concepts have tried to capture and describe this transformation in science (e.g. Funtowicz and Ravetz 1993; Ziman 1996; Etzkowitz and Leydesdorff 1998). One of the most prominent is Gibbons et al.'s (1994) concept of a new mode of knowledge production in the sciences called Mode 2. Policy-makers have taken this concept on and science policy is increasingly shaped in accordance with Mode 2 (Weingart 1997b), thereby almost turning the Mode 2 concept into a "self-fulfilling prophecy". According to

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Gibbons et al., complex application-oriented tasks are best performed in transdisciplinary, transient networks. Traditional, truth-oriented scientific quality criteria are being replaced by pragmatic, demand-driven criteria of functionality as defined by the stakeholders. Although the existence of such a trend towards transdisciplinarity and application-orientation is widely accepted, the extent, the exclusiveness and the novelty of the trend have attracted controversy (Weingart 1997a; Godin 1998; Jacob 2001). According to Weingart (1997a), the "new production of knowledge" is nothing more than a surface phenomenon. It is not replacing traditional scientific modes of knowledge production but adding to them whilst the "epistemic core" of science remains untouched. To what extent this new mode of knowledge production applies to different scientific disciplines is a question that has yet to be answered, and at the moment is lacking empirical grounding (Jacob 2001). Hicks and Katz (1996) try to provide some of this grounding for the British research system. With bibliometric data they show that the proportion of articles published in inter-disciplinary journals concerning application-oriented fields, co-authored with extra-academic institutions is increasing progressively, indicating a shift of the British research system towards Mode 2. However, the disadvantage of such a bibliometric approach is that it cannot describe the rationale of those involved in the knowledge production process. Wald (2007), using qualitative interview data gathered for German research groups in nanoscience, tries to assess to what extent nanoscience can be considered a Mode 2 field. The field of nanoscience is often described as a cardinal Mode 2 field (Gibbons et al. 1994[1]; Jotterand 2006). However, Wald finds that those working in the field of nanoscience do not consider it to be a Mode 2 field; rather it is treated as such by policy-makers.

This article builds on previous work of the research team "Network Strategy and Network Capacity of Research Groups" (Jansen, Franke, Wald).[2] We use data from a second wave of a panel study of research groups to assess to what extent characteristics of "Mode 2 knowledge production" can be found in nanoscience. This scientific field is compared with astrophysics, a field strongly oriented towards basic research and thus considered a traditional Mode 1 field, and economics, a social science. The article tries to assess whether the Mode 2 characteristics found are inherent to knowledge production in nanoscience or whether they are induced by policy-makers. In addition, the effects of science policy on scientific performance are analysed. The article proceeds as follows: In Section 3.2, Gibbons et al.'s concept of Mode 2 of knowledge production is described in detail. In Section 3.3, a short overview of the evolution of the field of nanoscience follows. The research design is presented in Section 3.4. In Section 3.5 a set of indicators is presented which measure the prevalence of Mode 2 in all three fields and applied to our data, including a discussion of the results. Section 3.6 presents a preliminary answer to

[1]Even if Gibbons et al. do not mention the term Nanoscience, which was not yet in popular use at this time, they clearly describe this kind of research (Gibbons et al. 1994: 45, cf. also p. 19).

[2]cf. Wald (2007), Franke et al. (2006), Wald et al. (2007), Jansen et al. (2007) and Jansen (2006, 2007).

our research question. In the further parts of the paper we deal with the question to what extent the evolution of Mode 2 is induced by science policy and what the likely effects of such a science policy on scientific performance might be. This is done for one aspect of a Mode 2 science policy: the fostering of science–industry relations. Section 3.9 concludes.

3.2 Attributes and Characteristics of Mode 2 of Knowledge Production

According to Gibbons et al. (1994), a new mode of knowledge production has been evolving since the mid-twentieth century which they named “Mode 2 knowledge production”. Knowledge produced in this Mode 2 forms in an application context, is oriented towards problem solving, and is transdisciplinary in nature. “Mode 2 knowledge” is generated by trans-disciplinary teams working together on specific problems for short periods of time. The teams generally consist of “practitioners” from both inside and outside academia who interact closely in heterarchical, transient and flexible networks. The search for knowledge is application-driven, i.e. looking at the utilisation of knowledge with a view to solving specific practical problems. Accordingly, this way of producing knowledge involves a continuous exchange between practitioners and stakeholders (e.g. the public). The stakeholders’ role in the production of knowledge is twofold: they co-determine the problems on which research is concentrated and co-control the quality of research output. Increased stakeholder involvement results in the “Mode 2 production of knowledge” being more socially accountable and reflexive than has hitherto been the case. The five central characteristics of “Mode 2 of knowledge production” are summarised in Table 3.1. They are contrasted with the characteristics of what is perceived as the traditional Mode 1 model of knowledge production.

“Mode 2 knowledge production” is no longer driven by problems defined within the boundaries of specialised academic disciplines; it is application-driven instead. The interests of the users are already considered in the production process, this means that it includes the interests of a number of societal stakeholders. The

Table 3.1 The central characteristics of Modes 1 and 2 of knowledge production

Mode 1	Mode 2
Problem definition by the scientific community	Problem definition in the context of application
Disciplinarity of actors	Transdisciplinarity of actors
Homogeneity of knowledge, actors and organisations	Heterogeneity of knowledge, actors and organisations
Hierarchical and permanent organisational structures	Heterarchical and transient organisational structures
Quality control within the academic system, resting primarily with the academic peers	Quality control outside the academic system, resting primarily with the group of practitioners

application context of Mode 2 does not imply that basic research is no longer relevant, but it means that the objectives of the programmes are generated for the most part outside the academic community. Mode 2 type knowledge is produced by teams working together in closely linked networks. The team members come from various academic disciplines. In the trans-disciplinary working context, the boundaries of specific academic disciplines are transcended and new theoretical concepts are developed which lie outside the individual disciplines. The competencies, expertise and experience with which the practitioners of Mode 2 contribute to knowledge production are heterogeneous. Teams' composition may change over time. Mode 2 working groups are not in general institutionalised and they exist for only short periods, breaking up when a problem is solved or newly defined. The ways in which the working groups are financed are just as diverse as the ways in which they are composed. Contributions are made by interested organisations to which the specific application is of relevance.

Traditionally, quality control has rested with the "peers" of academic disciplines, some of which function as gatekeepers ensuring certain standards are adhered to and influencing the choice of topics researched. Problems considered to be relevant often reflect the intellectual interests of the gatekeepers such as journal editors or referees. Publishing is vital for academics given that reputation is gained almost exclusively in this way. Thus, it is necessary to conduct research that is seen as valuable and valid by the gatekeepers. In Mode 2, quality control no longer rests only with academic peers but with a greater variety of actors; this is because of the increased heterogeneity of the players involved and also because the research is generally application-driven. In Mode 2, success means a problem solved. This is determined and controlled by all parties interested in the results. Hence, quality control does not rest primarily with purely "academic peers" but with the whole "community of practitioners". The increased involvement of stakeholders in the process of knowledge production also leads to increased social accountability of the research and to increased reflexivity of the practitioners regarding their work. Practitioners have to take into account the interests of society as a whole and have to justify their work accordingly. While not all of the characteristics mentioned above are present in each case of "Mode 2 knowledge production", they supposedly typify a radically new way in which relevant knowledge is being produced today (cf. Hellström and Jacob 2000; critically: Weingart 1997a; Godin 1998; Shinn 1999).

3.3 Nanoscience as a Paradigmatic Field of Knowledge Production in Mode 2?

The field of nanoscience is often seen as a paradigmatic Mode 2 field (Jotterand 2006). Nanoscience is usually defined as the studying and manipulation of material at the nanoscale level (one nanometre is approximately 80,000 times smaller than a human hair). At this scale materials can show specific and novel characteristics which might lead to interesting applications (Bonaccorsi 2008). Operations at this scale became feasible mainly with the invention of the Scanning Tunnelling Microscope (STM) (Mody 2004), which allows for the identification and visualisation of the position of individual atoms. The popularisation of the concept of nanoscience ultimately began with Drexler's book *The Engines of Creation: The coming Era of Nanotechnology* (1986) in which he predicts plenty of application possibilities and solutions for pollution, medical, food or economic problems by molecular manufacturing using nanobots to "shape the world atom by atom". Although Drexler was criticised seriously because of the notional character of his ideas (Selin 2007), his vision became powerful and the hope for societal advance through nanotechnology seems now stronger than ever.[3]

Two central features of the postulated "Mode 2 of knowledge production" are the context of application and the social accountability of research. The history of the field of nanoscience shows that the hope for a beneficial societal impact has been one of the driving forces behind the development of the field. The growth of nanoscience was strongly driven by a demand for the solution of societal problems and for economic growth through technological advance (Johnson 2004; Whitman 2007). Whilst in the mid-1990s governmental funding of the nanosciences was virtually nonexistent, by the end of the 1990s it had multiplied in the USA, Europe and Japan and has been growing rapidly ever since. According to Johnson (2004), the common military justification for the funding of science has lost its power after the end of the Cold War and is being replaced by the striving for global competitiveness. Government funding driven by this aim has played a central role in the formation of the field of nanoscience. Official papers justifying nanoscience funding almost always focus on the expected utilisation possibilities of research in this field, often accompanied by the description of long-term remedies for a multitude of societal problems (BMBF 2004; EU 2007). Nanoscience is commonly mentioned in combination with a long list of possible inventions to which it should lead (Kearnes and Macnaghten 2006; Selin 2007).[4] The submission of nanoscience under the norm of utility could quite possibly lead to a shift in what is regarded as valid quality criteria. Following Jotterand (2006: 659), nanoscience as a cardinal Mode 2 field is no longer aiming for "the ideal of the quest for truth (pure science)" but viewed as a "source of economic and, by extension, political power." Classical scientific quality criteria, such as the search for truth, are replaced by utility-driven criteria.

Another main feature of the Mode 2 of knowledge production is transdisciplinarity. Transdisciplinarity can be viewed partially as a result of the application orientation of knowledge production. Technological problems can cross

[3]The term Nanotechnology implies a stronger emphasis of the application possibilities of the field than the term Nanoscience. In the following we use the term Nanoscience.

[4]Exemplary of this phenomenon is the 2002 report "Converging Technologies for Improving Human Performance" for the National Science Foundation, edited by Roco and Bainbridge (2002), two major actors in the nano-policy area. According to the report, nanoscience should lead to an enhancement of the human mind, cognition, body, to the remedy of illnesses, military advancement, better food-production, new machine–body interfaces, etc.

the borders of different scientific fields and therefore can only be solved in a trans-disciplinary manner. Transdisciplinarity implies not only the dissolution of disciplinary boundaries but also the dissolution of institutional boundaries (Lenhard et al. 2006; Jotterand 2006). A trans-disciplinary approach in nanoscience is encouraged strongly by funding agencies. Virtually no report lacks remarks about the importance of trans-/interdisciplinarity[5] in this field. Moreover, the dissolution of institutional boundaries is promoted for the field of nanoscience. Besides heterogeneous collaboration between university and extra-university institutions, the importance of science–industry relations is often asserted. It can be assumed that such heterogeneous collaborations have to be organised in research networks. Summing up, there are some theoretical and historical arguments that support the idea that nanoscience is a Mode 2 field. Especially actors from funding agencies and science policy view and treat nanoscience as such a field. In the following sections it is assessed whether this view can be verified empirically.

3.4 Research Design

The identification of the population of research groups for the three academic fields astrophysics, nanoscience and economics in Germany was completed in two steps (Wald et al. 2007). In a first step, a bibliometric analysis of the Science Citation Index (SCI) revealed all researchers that published at least one article in the field.[6] Since the SCI-data are based on individuals, the affiliation of researchers to research groups had to be uncovered with the help of secondary information from directories and web pages. A research group was defined as the smallest stable unit within an organisation that conducts research. The micro-level approach of studying research groups allows assumptions about the way knowledge is produced at the microlevel and about the effects of Mode 2 policy on research groups. A research group often corresponds to a formal organisational unit, for example a chair or a subdivision, but this must not necessarily be the case. In a second step, this group-level list was validated by experts from the different fields. For the nanoscience sample this was done by the federal funding agency at the Federal Ministry of Education and Research, which manages the funding programmes relevant to nanoscience. This two-step procedure led to a total population of 223 research groups in nanoscience, 122 in astrophysics and 483 in economics. From the total population thus determined, random samples of 25 research groups for each field (27 for economics)

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[5]The terms transdisciplinarity and interdisciplinarity are distinguished differently by various authors. We consider transdisciplinarity to be an especially intensive form of interdisciplinarity (Jansen 2007: 110–112).

[6]The accordant articles were identified by a search strategy developed by the Fraunhofer Institute for Systems and Innovation Research.

were drawn. A qualitative explorative study based on face-to-face-interviews with the leaders of these research groups was conducted in 2004. On the basis of a qualitative analysis of these interviews (Franke et al. 2006), a standardised questionnaire was developed with which the research groups were polled again in 2006/2007. Additionally, qualitative semi-structured phone interviews were conducted. As only 60% of the original sample answered in 2006/2007, the missing 40% were replaced by a new random sample from the original population. Table 3.2 shows the composition of the sample in the second panel wave in comparison to the population.

Both, universities and extra-university institutions are part of the sample. A comparison of the institutional composition of the sample with the population shows that the make-up of the sample is similar to that of the population, and that the different kinds of institutions into which the German extra-university research system is differentiated are represented. There is a small bias in the under-representation of universities and an over-representation of extra-university research in astrophysics, whereas nanoscience shows a small bias in the other direction. This could lead to a small underestimation of the Mode 2 character of nanoscience in comparison to astrophysics, but all in all the effect should be quite small. The institutional heterogeneity of the population is a first indicator of the Mode 2 character of the nanoscience field and will be described later.

The central topics of the 2006/07 standardised questionnaire included questions about the formation and change of research lines and projects and the influence of external and internal governance mechanisms on them. Also, questions about the emergence, importance and composition of the groups' research networks were posed; this was based on qualitative analyses of the explorative interviews. With the help of a network generator, ego-centred network data were collected. Further information about the collaboration partners of the research groups was then gathered in the phone interviews.

Table 3.2 Population and sample

	Astrophysics		Nanoscience		Economics	
	Population	Sample	Population	Sample	Population	Sample
University	67 (54.9%)	11 (44.0%)	143 (64.1%)	18 (72.0%)	465 (96.3%)	26 (96.3%)
Max Planck Society	38 (31.1%)	6 (24.0%)	29 (13.0%)	3 (12.0%)	2 (0.4%)	0 (0.0%)
Leibniz Association	2 (1.6%)	2 (8.0%)	6 (2.7%)	0 (0.0%)	9 (1.9%)	0 (0.0%)
Helmholtz Association	5 (4.1%)	1 (4.0%)	16 (7.2%)	1 (4.0%)	0 (0.0%)	0 (0.0%)
Fraunhofer Association	0 (0.0%)	0 (0.0%)	7 (3.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Other	10 (8.2%)	5 (20.0%)	22 (9.8%)	3 (12.0%)	7 (1.4%)	1 (3.7%)
Total	122	25	223	25	483	27

3.5 Measuring Mode 2

The central characteristics of knowledge production in Mode 2 were introduced and discussed in Section 3.2. The aim of this section is to develop and apply a set of indicators actually measuring Mode 2 following the précis in Table 3.1. This is carried out by comparing research groups in nanoscience to research groups in astrophysics and economics. Astrophysics was chosen as a comparison group because it is a field primarily concerned with basic research, whilst nanoscience is often viewed as application-oriented. This comparison is interesting because Gibbons et al. conceive most of the characteristics of Mode 2 as a result of the increasing orientation of science towards applications and use nanoscience as an example of a Mode 2 field. The differentiation between natural science and social science was chosen as the second contrast dimension. Gibbons et al. regard social science as a field resembling the traditional Mode 1 of knowledge production.[7] The research design thus not only allows insight into the differentiation between Mode 1 versus Mode 2 but also into the importance of the natural science versus social science distinction and the basic research versus applied research distinction in modes of knowledge production (cf. Franke et al. 2006: 27 for a more detailed explanation and justification of the selection of comparison groups in this study). The significances of the field differences were computed and are reported in the respective tables.[8]

3.5.1 Context of Application

The Mode 2 thesis postulates that academic disciplines and scientific communities no longer drive research; instead, research is application-driven. It is still open to question whether this thesis holds true for the case of nanoscience. Patent data analysis suggests that relatively little nanoscientific research leads to patents (Hullman and Meyer 2003). This indicates that the practical utilisation of research results in nanoscience lags behind the numerous potential practical applications which have been postulated. Whilst the analysis of patent data provides a picture of successful and marketable research results, it does not make evident the researchers' drive, motivation or rationale. The same holds true for bibliometric analysis as it cannot elucidate the importance of the context of application for the researchers' work (see analyses by Hicks and Katz 1996; Schummer 2004).

[7]Gibbons et al. contrast knowledge production in social sciences with knowledge production in the humanities; they consider the social sciences as being nearer to Mode 1 than the humanities. For a critique cf. Godin (1998).

[8]Rather then computing the significance of the field differences with a t-test, a bootstrap-t algorithm is used because of the small sample size (Efron 1982). The bootstrap method has the advantage of estimating the significance interval from the sample by drawing (in this case 1,000) samples (with placing back cases) from the sample.

The data presented here attempt to close that gap by highlighting the inspiration behind research projects and by assessing the actual time spent working on application-oriented research, experimental development and basic research. Leaders of research groups were asked to reveal the sources of inspiration for their work. The analysis shows that 21% of the nanoscientists in the sample claim that the ideas for new projects arise from an application context, compared to only 15% of economists and none of the astrophysicists (differences are significant at 1% level). However, whilst the researchers' own ideas and creativity are by far the biggest source of inspiration in all fields, this was especially evident in nanoscience where 74% of the researchers named it as a source of inspiration; the figures in astrophysics and economics being 64 and 65%, respectively. Conversely, literature and academic peers have only limited influence on research topics in nanoscience when compared to astrophysics and economics. Only 42% of nanoscientists attribute their research ideas to literature in contrast to 55% of astrophysicists and 65% of economists. The academic community was named as a source of inspiration by 37% of nanoscientists, 55% of astrophysicists and 45% of economists. These figures support the notion that knowledge production in nanoscience resembles the methods claimed by the Mode 2 thesis. Compared to the other two fields, research is more application-driven and the influence of the scientific community, represented through inspiration by colleagues and/or literature, is lower. This picture changes slightly when assessing the actual time spent on different types of research. Researchers in nanoscience devote 22% of their time to application-oriented research and 12% of time to experimental development. However, 66% of their time is dedicated to basic research. Economists on the other hand, with only 15% claiming an application context as inspiration for their research, nevertheless dedicate 32% of their time to applied research; 65% of their time is spent on basic research. Only 3% of their time is spent on experimental development reflecting their low reliance on machinery and equipment. Astrophysicists devote 82% of their time to basic research, 12% to experimental development and only 6% to application-oriented research with no inspiration arising from an application context. Regarding the way in which research problems are defined in the different fields, astrophysics clearly fits what has been described as the traditional Mode 1 of knowledge production. Research topics are identified within the discipline and researchers are not concerned with the practical usability of their work. In the fields of nanoscience and economics, the results are more mixed. Whereas the choice of research topics in economics is hardly influenced by their practical relevance, economists devote a third of their time to applied research. In nanoscience the application context plays a greater role in inspiring research, although still most of the working-time is spent conducting basic research. The data show that the application context plays a different role in all three fields. While it is irrelevant to the astrophysicists, it is of greater importance to nanoscientists and economists. However, research groups from all fields still devote most of their time to basic research. This sets them far apart from Gibbons et al.'s vision of knowledge production being dominated by considerations concerning applications. But concerning the three fields compared here, nanoscience is the one with the greatest affinity towards applications.

3.5.2 Trans-/Interdisciplinarity

Schummer (2004) analysed the degree of interdisciplinarity in nanoscience using a bibliometric approach. For his analysis he studied eight core journals of nanoscience. He distinguishes between *multi*disciplinarity and *inter*disciplinarity. A field was considered *multi*disciplinary if a lot of different disciplines were involved in it, without there necessarily being any actual collaboration of researchers from different disciplines. *Inter*disciplinarity, in contrast, was operationalised as the co-authorship of an article by authors with different disciplinary backgrounds. For his analyses, Schummer identified the disciplinary backgrounds of researchers by departmental affiliations. He then compared the results with the disciplinary structure of articles published in the Journal of the American Chemical Association. He concludes that the field of nanoscience is quite *multi*disciplinary because a lot of disciplines are being involved to a relatively similar scale; the *inter*disciplinarity, in contrast, is not very high. It is only slightly higher than the interdisciplinarity in the Journal of the American Chemical Society (JACS) (with 36.5% of articles being written by authors of at least two different disciplines on average in nanoscientific journals in comparison to 30% for the JACS). Bonaccorsi (2008) argues that such a multi-disciplinary research style with a lack of real inter-disciplinary cooperation does not mean that there is no intellectual fertilisation between the disciplines involved. According to him, mutual intellectual stimulation in nanoscience is determined mainly by a higher diversity inside the research teams through an intermixture of instrumentation and conjunct expertise. Furthermore, he states that during their socialisation nanoscientists increasingly come in contact with complementary theories and methods, even though disciplinary boundaries remain quite intact.

Gibbons et al. use the term *trans*disciplinarity when describing the new “Mode 2 of knowledge production”. In our eyes the term does not describe anything qualitatively different to the term interdisciplinarity; transdisciplinarity is merely a high level of interdisciplinarity. Thus, in the following we use the term interdisciplinarity. For the analysis in this paper three types of interdisciplinarity were measured: network heterogeneity, in-group interdisciplinarity and collaboration interdisciplinarity. Network heterogeneity was measured using Blau’s heterogeneity index (Blau 1977).

$$H = 1 - \sum_{i=1}^{n} s_i^2$$

n is the number of disciplines involved and s_i is the proportion of collaboration partners from these disciplines. The index varies between zero and one, value 1 represents maximal heterogeneity. The value is high if a lot of disciplines are involved in the network to a similar scale. The values are computed for all research groups and the average values for the fields are compared. The analysis shows that nanoscientists have by far the most inter-disciplinary networks; however, the networks are still mostly dominated by one discipline: physics. Network heterogeneity is not a direct measure of interdisciplinarity since not all network partners necessarily work together. Interdisciplinarity can be measured in two different ways: in-group interdisciplinarity and collaboration interdisciplinarity can be distinguished. Scientific work is considered interdisciplinary if the research group itself consists of researchers from different disciplines. Nanoscience has clearly the most heterogeneous research groups with a mean of 1.9 disciplines per group. Even if one research group can consist of researchers from different disciplines, the dominant disciplinary background of the groups can be identified in most cases by their departmental affiliation. Collaboration interdisciplinarity can be measured by the proportion of network partners coming from other disciplines than the research group questioned. Here the value for astrophysics is the highest, with nanoscience reaching nearly the same value. However, it must be asserted, that the high value for astrophysics results mainly from collaborations between astrophysicists and physicists, while the inter-disciplinary collaborations in nanoscience cover more dissimilar disciplines. The inter-disciplinarity value for economists is smaller than for the other two fields. The results can be summarised as follows: network heterogeneity is relatively high in nanoscience. The interdisciplinarity of collaborations is not outstandingly high. That means that the existing inter-disciplinary collaborations in nanoscience are more heterogeneous than in astrophysics. Inter-disciplinary research groups are far more widespread in nanoscience. These results are consistent with Schummer's results but show some new aspects, such as the interdisciplinarity of nanoscience working groups inside the institutions. They are also consistent with the assumptions of Bonaccorsi (2008) (Table 3.3).

Table 3.3 Trans-/interdisciplinarity

	Astrophysics	Nanoscience	Economics	Significance
Disciplinary heterogeneity of the network (Blau index)	0.16	0.31	0.20	+
Valid cases	18	22	23	
Average number of different disciplines of researchers in the research group	1.3	1.9	1.2	**, +
Valid cases	20	20	27	
Proportion of collaborations with partners of a different discipline	42.2	37.6	33.1	•••,*
Valid cases	18	21	23	

Significance level: Nano-Econ ***1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ••• 1%, •• 5%, • 10%

3.5.3 Organisational Diversity

The institutional composition of research networks allows inferences on the strength of organisational boundaries in the academic fields. The Mode 2 thesis diagnoses the dissolution of boundaries, especially between science and industry (Gibbons et al. 1994:6). Thus, an analysis of the permeability of organisational boundaries will be carried out. For the German case we analyse not only the porosity of the science–industry boundary but also the stability of boundaries between universities and extra-university organisations. The analysis of the sample shows that research in astrophysics is almost exclusively conducted in universities and institutes of the Max Planck Society, whilst research in economics is performed almost exclusively in universities. Although research in nanoscience is conducted mainly in universities, in the extra-university system it is not strongly bound to one kind of institution. The results are affirmed by a study of Heinze and Kuhlmann (2007) who analysed the institutional affiliation of researchers publication outputs in nanoscience. In their study the proportion of research published in the different types of institutions corresponds to the proportion of institutions in nanoscience listed here. But how heterogeneous are the networks of nanoscientists in comparison to the other two fields? And how large is the proportion of collaboration partners that are from a type of institution different from their own? A first glance at the institutional affiliation of network partners shows that science–industry relations are most common in nanoscience. Collaborations with extra-university researchers are much more common for astrophysicists. In economics most of the researchers collaborate with universities. The analysis of the proportion of collaboration partners from different types of institutions reveals that both natural sciences display a large amount of heterogeneous network relations. In economics the prevalence of heterogeneous collaborations is low. The value for nanoscience would probably be higher if the affiliations of the extra-university partners were differentiated further. However, in our sample such a differentiation is only possible for the national relations but not for the international ones. Overall, in this analysis nanoscience displays some Mode 2 characteristics but the networks of nanoscientists show no exceptional organisational diversity (Table 3.4).

3.5.4 Heterarchical and Transient Organisational Structures?

To what extent is scientific work organised in heterarchical, transient networks? Which role do research networks play in the field of nanoscience? According to Powell (1990), networks are less hierarchical than organisations and, according to Gibbons et al. (1994), cross-sectional complex tasks are usually not solved in hierarchically organised institutions but in heterarchical research networks. The importance and size of research networks is an indicator of the Mode 2 character of fields. So how is work organised in the networks and in the research groups in the different fields? The data show that nanoscience research networks consist of

Table 3.4 Institutional affiliation of network partners (in %)

Institutional types of network partners	Astrophysics	Nanoscience	Economics	Significance
Proportion of university network partners	58.6	65.4	76.0	●●
Prop. of extra-university network partners	38.9	24.3	18.7	++, ●●
Prop. of network partners from industry	2.5	10.4	5.3	+++
Prop. of partners from a heterogeneous institution	53.8	44.6	25.5	**, ●●●
Valid cases	25	25	27	

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

10.3 actors on average. In astrophysics the networks are slightly bigger with 11.2 actors; economists have clearly smaller networks with 7.1 actors. The importance of research networks is most strongly emphasised by nanoscientists: 68% of the nanoscientists say that research networks are essential for their work. This value is slightly lower for astrophysicists (60.0%) and for economists (51.9%). For nanoscientists and astrophysicists the technological equipment of the network partner is important besides their complementary knowledge. For economists equipment is not mentioned as a network incentive. But all in all, Table 3.5 shows that the size of the networks is probably rather determined by the importance of technological devices in the scientific work than by the application orientation of the discipline.

The degree of heterarchy/hierarchy is compared in the networks and an analysis is also made of how the networks are built. A heterarchical, transient network combined with task-oriented and thus strategic network behaviour is typical for Mode 2. In a first approach we analysed the network behaviour of the research groups and differentiated between strategic and path-dependent network behaviour.[9]

Table 3.5 Function of networks (in %)

	Astrophysics	Nanoscience	Economics	Significance
Knowledge	95.8	91.7	77.8	●●
Technical equipment	37.5	45.8	3.7	***, ●●●
Reputation	45.8	37.5	29.6	
Valid cases	24	24	27	

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

[9]The operationalisation of network behaviour builds upon the qualitative analysis of the interviews with research group leaders in the first panel wave. A more detailed description is given in Franke et al. (2006).

Strategic behaviour distinguishes itself through the purposeful, directed approach of selecting network partners. Path-dependent network behaviour does not exhibit such characteristics, collaborations result from more or less random events, such as meeting at a conference. Strategic behaviour can be differentiated into an open strategy based on an open search for partners and a closed strategy where partners are selected from an established pool of partners. It is assumed that the more closed a network is, the more hierarchical it is. An open network behaviour combined with strategic behaviour is an indicator for Mode 2 knowledge production. A comparison of the different research groups in the fields shows that more astrophysicists and nanoscientists than economists behave in a strategic way with 67% of economists reporting that their choice of research partners is path dependent versus 54% of astrophysicists and 57% of nanoscientists. An open network strategy is most common in nanoscience (25%, versus 13% of astrophysicists and 4% of economists, difference to nanotechnologists significant at 5% level). Astrophysicists are most rigid in the choice of their network partners; 46% choose their partners using a closed network strategy as opposed to 29% of nanoscientists and 23% of economists. So nanoscientists have less rigid, thus probably more heterarchical networks than astrophysicists. Further analysis shows that nanoscientists have more transient networks; network ties are younger on average, probably because they regularly choose new partners. Nanoscientists have less stable, less closed networks than astrophysicists whilst behaving in a strategic way; this is consistent with the Mode 2 thesis. However, economists show even more transient networks; so the results for nanoscience are not as clear as the thesis which predicts that nanoscience is a Mode 2 field (Table 3.6).

Nanoscientists have the largest research groups consisting of 11.8 members. This does not inevitably mean that the groups are more hierarchical, but bigger groups may imply a more hierarchical working style as opposed to a collegial non-hierarchical working style in smaller groups. This is measured by a question put to the research-group leader about where ideas for research projects come from. The

Table 3.6 Research ideas and network data

	Astrophysics	Nanoscience	Economics	Significance
Research ideas coming from the team (%)	82	58	30	●●●
Research ideas coming from the leader (%)	64	74	65	–
Valid cases	22	19	20	–
Average size of research networks	11.2	10.3	7.1	**, ●●●
Average duration of collaborations (years)	10.4	8.2	7.4	–
Valid cases	25	25	27	–

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

extent to which the team and not the leader him/herself was mentioned as a source of ideas can be interpreted as a proxy for in-group hierarchy. The analysis shows that in nanoscience the leaders are less open to ideas from the team than the leaders in astrophysics. The size and structure of research networks and research groups are determined by the size of the research tasks. In this section especially the comparison of size and structure between astrophysics and nanoscience was interesting. Nanoscientists have more heterarchical networks but bigger research teams with a stronger hierarchy than astrophysicists. So the postulated heterarchical and transient organisational structures that characterise the new production of knowledge are, at least for nanoscientists, only true for the extra-mural collaborations, not for the knowledge production process inside the teams.

3.5.5 Quality Control

Another central characteristic of knowledge production in Mode 2 is that quality control no longer rests solely with the scientific community but increasingly with the stakeholders. One way of measuring this is by comparing the influence of the scientific community on the choice of research projects with the importance of their application relevance. These measurements reflect the role of reputation within the scientific community. Traditionally, reputation is seen as the "currency" of academia, and it is gained almost exclusively through publications in academic journals. To publish articles in academic journals, it is necessary to conduct research that is seen as valuable and valid by the majority of the scientific community and its gatekeepers. Thus, the motivational function of reputation is coupled to the truth-criterion (Luhmann 1973).

If the gaining of reputation is the main driving force behind academic research, it can be expected that research projects are chosen accordingly. A good example of this is astrophysics. Here, 88% of researchers say that they choose and develop projects with regard to their scientific relevance as perceived by the scientific community. In nanoscience and economics, only 63 and 62% of researchers agree respectively. Conversely, only 4% of researchers in all three fields claim that the scientific relevance is of no importance when developing a project. This shows that, in contrast to the Mode 2 theory, reputation-based truth-oriented quality criteria are still important in all fields of research. Interestingly, when asked whether the factor "scientific relevance" has increased or decreased in the past 2 years when developing a project, 23% of the nanoscientists say that it has increased, and none that it has decreased (Table 3.7). Rather than supporting or weakening the Mode 2 thesis, these findings support Whitley's (2000) thesis that scientific disciplines develop in phases according to which, at the birth of a new discipline, industrial–scientific relationships are close, but soon drift apart with each sector following its own specific rationale (cf. Shinn 1999).

When astrophysicists develop a project, the application relevance does not concern most of them (78%). This is true for only 29% of nanotechnologist groups (significant at 5% level) and 46% of economist groups (significance level 1%).

Table 3.7 Influence of scientific relevance/scientific community on project development (in %)

	Astrophysics	Nanoscience	Economics	Significance
Scientific relevance (influence of scientific community) ("applies")	88.0	62.5	61.5	**, ●●
Scientific relevance (influence of scientific community) ("does not apply")	4.0	4.2	3.8	–
Valid cases	25	24	26	–
The factor "scientific relevance" has increased in importance (past 2 years)	16.0	22.7	18.5	–
The factor "scientific relevance" has decreased in importance (past 2 years)	4.0	0.0	7.4	***, +++
Valid cases	25	22	27	–

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

Instead 25% of nanogroups and 19% of economics groups report that application relevance is of importance for their project choices. As confirmed by 23% of the nanoscientists and economists and 13% of the astrophysicists, application relevance has increased in importance over the past 2 years. This quite possibly reflects the growing influence of stakeholders and their call for "relevant" research that even the long-established astrophysicists cannot escape from. Thus, while quality control clearly rests with the scientific community for the nanoscientist groups, too, there is evidence for a stronger affinity of this field to strategic research. Nanoscientists indeed spend more time on application-oriented research than astrophysicists (Table 3.8). Astrophysics and nanoscience show a similar time budget for developmental research; but while applied and developmental work increased for the astrophysicists, the share decreased in the case of nanoscience in the last 2 years. The relatively strong engagement in developmental work of both natural science fields originates from their interest in scientific instrumentation. The construction of scientific instruments has long been a field of work for basic science-oriented

Table 3.8 Allocation of time budget to basic research, applied research, and development

Research type	Astrophysics	Nanoscience	Economics	Significance
Basic	82.3	66.3	64.6	+, ●
Applied	6.0	21.9	32.2	+++, ●●●
Development	11.7	12.4	3.2	**, ●●
Valid cases	24	24	27	–

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

researchers that has stimulated major advances in fundamental science and industry, too (e.g. Jansen 1995).

To understand why nanoscientists strive for basic science goals but have an affinity for applied research we must turn to the cognitive characteristics of the new sciences. As Bonaccorsi (2008) observed the new sciences such as materials sciences, nanoscience and the life sciences are characterised by divergent dynamics in science, in contrast to the old sciences with convergent research dynamics which reduce the uncertainties of the accepted paradigm. The new sciences are characterised by very complex multi-layered systems (such as the human mind) combined with a reductionist approach trying to explain their functioning and to construct intervention programmes at the elementary level. As Bonaccorsi (2008: 13) puts it "for the first time in history of science [there is] the possibility to manipulate and observe matter at lower levels of resolution at the same time". The complexity of the systems calls for a research strategy that bears cognitive similarities to the logic of construction. This logic is typical for the involvement of basic researchers in the development of scientific instruments. Both approaches are characterised by the search for a concatenated type of knowledge (Nagi and Corwin 1972) which tries to represent a complex phenomenon in all its varieties, in interaction with potential context disturbances. This contrasts with the old experimental logic which studies simple systems with few elements and strives for universal, generic knowledge (Nelson 1989: 233).

3.6 Nanoscience as a Mode 2 Field?

Three different scientific fields were evaluated against the five main characteristics of Mode 2. The results show that a clear-cut differentiation between Mode 1 and Mode 2 is not possible. The results concur with considerations of Weingart (1997a), Shinn (1999) and Gläser (2001), who see a continuum between Mode 1 and Mode 2 rather than a distinct new mode of knowledge production. Traditional scientific values such as quality control through peers and reputation are still important in all three fields. The application orientation is relatively low, even in nanoscience. Weaker institutional and disciplinary scientific boundaries are found mainly in the natural sciences. However, the application orientation does not seem to be a central determining factor for this dissolution of boundaries. Heterarchical, transient networks and science–industry relationships are more important for nanoscientists than for astrophysicists and economists although the difference is not especially great. These results are surprising, especially if one takes the strong policy pressure in the direction of a Mode 2 of knowledge production into account. The German Government has made significant efforts to push nanoscience to the forefront. Nanoscience funding reached €290 million in 2004; this was more than a third of the nanoscience funding in the whole EU (€740 million), EU-Funding included. The USA spent €850 million and Japan €800 million (BMBF 2004). The latest figures show that Japan has outrun the USA and that German nanoscience funding reaches nearly half of the funding of the whole EU (TTC 2007). This massive funding of nanoscience is allocated mainly to Mode 2-type projects (cf. Wald 2007). In the next section a short description of policy instruments promoting Mode 2 is given. Further results of analyses examining the effect of Mode 2 policy funding are presented.

3.7 Policy Instruments Promoting Mode 2

Weingart (1997b) stated that Mode 2 is not so much an empirical description of change but rather a powerful normative concept. Part of its attraction is that it gives policy-makers leverage and legitimacy to shape science policies. A look at the funding programmes and policies reveals the influence that Mode 2 and related concepts[10] have had on science-policy making. The conditions tied to a lot of third-party funding show a general impetus to promote Mode 2-type structures and working conditions. For instance, funding programmes typically call for a mixture of inter-disciplinary, inter-organisational or international networks with international or regional industry ties (cf. DFG 2006; BMBF 2006: 11ff.; Cordis 2007). This is true for all fields of science but especially for nanoscience where industry ties in particular are considered an asset and are often required; the purpose being to increase the marketability of nanoscientific research results and to advance patenting activity. The influence and pressure of third-party funding agencies on project development and network formation is increasingly felt in all academic fields. The data shows that 32% of the astrophysicists, 36% of the nanoscientists and 19% of the economists feel that third-party funding agencies have increased their influence on the way in which projects have been developed in the last 2 years. It has made the strongest impact in nanoscience, with 20% of the nanoscientists claiming that third-party funding actively influences project development. In astrophysics and economics this is only true for 12 and 11% of the research groups, respectively. The same holds true for the influence of third-party funding agencies on the choice of research partners. Across all three disciplines roughly a third of the research groups say that the formation of research networks is essential for securing third-party funding (39% of astrophysicists, 33% of nanoscientists and 31% of economists). This pressure has increased the most in astrophysics (22%) and economics (19%; versus 8% in nanoscience) indicating that there is growing pressure on them to develop in a Mode 2 type of way. At the moment, however, the only field in our sample clearly being encouraged to build up ties with industry is nanoscience. This is in line with the agenda set out for nanoscience by the German Ministry of Science (Bundesministerium für Bildung und Forschung, BMBF) which made a point in highlighting the slow incorporation and adoption of nanoscience in industry.

[10] Compare the concepts of "post-normal science" (Funtowicz and Ravetz 1993), "post-academic science" (Ziman 1996), "triple helix" (Etzkowitz and Leydesdorff 1998).

> Germany is strong in the nanosciences, but it still has some catching up to do in their industrial implementation. As fascinating as the opportunities in nanotechnology are, German industrial customers and others in this market still appear hesitant to seize and use them for innovative products (BMBF 2004, p. 21).

In nanoscience, 33% of the researchers claim that relevant third-party funding calls for an industry partner, 25% of them say that this trend has increased in the past 2 years. The same does not apply for astrophysics and economics; relevant funding for them does not request links with industry (Table 3.9).

Table 3.10 shows the proportion of time spent working on projects funded by different third parties. Nanoscientists have the highest rate of external funding with

Table 3.9 Influence of third-party funding on network formation (in %): promoting science–industry ties

	Astrophysics	Nanoscience	Economics	Significance
Third-party funding calling for industry ties	8.3	33.3	3.8	**, +++
Third-party funding calling for industry ties has increased (past 2 years)	0	25.0	3.8	***, ++, ●●●
Third-party funding calling for industry ties has decreased (past 2 years)	0	0	0	–
Valid cases	24	24	26	–

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

Table 3.10 Proportion of research time spent working on projects funded by third parties (in %)

	Astrophysics	Nanoscience	Economics	Significance
Prop. of time spent working on projects funded by third parties in total	50.0	76.4	38.7	***, +++
Prop. of time spent on research financed by industry	0.4	5.3	3.6	***, ●●●
Prop. of time spent on research funded by science foundations (DFG, Thyssen, VW)	30.1	40.5	16.8	***, ●●
Prop. of time spent working on projects funded by the German Government (BMBF. other ministries) and the EU	18.2	28.7	9.1	+++, ●●
Proportion of time spent working on projects funded by other third parties	1.2	2.3	8.1	++, ●●●
Valid cases	24	25	23	–

Significance level: Nano-Econ *** 1%, ** 5%, * 10%; Nano-Astro +++ 1%, ++ 5%, + 10%; Astro-Econ ●●● 1%, ●● 5%, ● 10%

more than 76% of their time allocated to externally funded projects, the figures being 50 and 39% in astrophysics and economics, respectively.

In all three fields most of this money comes from science foundations, the German government and the EU. Very little time is spent on research financed by industry: 5% of the time is devoted to industry-financed work in nanoscience, 0.4% in astrophysics and 4% in economics. All in all, the amount of research financed by industry is negligible. However, Table 3.10 shows that the dependency of nanoscience on third-party funding is much stronger than in the other two fields. This makes it susceptible to changes in funding policies as securing third-party funding is essential. Thus, it gives policy-makers leverage to influence the way in which research groups work in the field of nanoscience.

3.8 Effects of Mode 2 Policy: The Fostering of Science–Industry Relations as an Example

In the previous section it was shown that the establishment of science–industry relations in nanoscience is encouraged by policy-makers. In the following, the impact of such policies on academic productivity is analysed. While some authors strongly support the dissolution of boundaries between science and economy (Etzkowitz 1998; Nowotny et al. 2001), and thus favour the establishment of science–industry relations, other authors are more critical about this development (Schmoch 2003; Schimank 2008). Etzkowitz describes how the normative structure in science is changing. The commercialisation of the science system is no longer considered problematic, and the "entrepreneurial scientist" is established as the new role model. This allows scientists "to meet two goals simultaneously: the pursuit of truth and profit making" (Etzkowitz 1998: 824). Schimank (2008) in contrast sees a stable functional differentiation between the science system and the economic system as a necessary condition for an efficient operating of both. The question yet to be answered is whether research groups can pursue scientific and economic goals simultaneously or whether there is a trade-off between the proportion of science–industry relations of a research group and their scientific productivity. Empirical investigations concerning this subject have not led to clear results yet. Econometric analyses which tried to prove a trade-off between patenting activities and publication rates did not find such a trade-off (e.g. Looy et al. 2004; Goldfarb 2008). One problem of these studies is that they do not measure the effort research groups put into collaborations with industry partners since they only measure the patent rate. Yet patent rates only measure successful (in terms of technology transfer) science–industry relations. Furthermore, as Goldfarb (2008: 57) puts it, "most of these studies have focused on areas where demand on the commercialization side has been high – such as biotechnology and electrical engineering – a failure to find substitute effects in these areas may simply reflect the underlying closeness of commercializable and academic outputs in these areas". In his study, Goldfarb (2008) analyses the effect of NASA research funding on academic output and finds evidence for a trade-off between publication productivity and application-driven funding.

In the following analysis of the nanoscience subsample a bias towards successful science–industry collaborations was avoided by using the proportion of industry partners in the research networks of the research groups as the independent variable. Academic productivity was measured by the number of publications per research group member between 2004 and 2006. A Negative Binomial Regression Analysis was conducted to measure the interrelation between the two variables.[11] Instead of testing for a simple trade-off, a curvilinear relationship between scientific output and proportion of industry ties was tested for. The analysis suggests that there is indeed a curvilinear effect (Table 3.11).[12]

A small proportion of industry relations can raise productivity, but if the proportion of industry partners becomes too big, productivity declines (Fig. 3.1). The parameters indicate a curvilinear effect, although only the squared term is significant. A similar curvilinear effect for scientific productivity and the proportion of third-party funding was discovered in a previous study using data from the first panel wave (Jansen et al. 2007). Because of this, the proportion of third-party funding was included in a second model as a control variable; however, the results remained basically the same.

The results suggest that a basic openness for a small proportion of industry partners allows research groups to exploit these relationships effectively. A small number of industry partners is probably a sign for scientific openness and creativity, but if the dependency on industry partners becomes too high, the scientific productivity suffers. This effect is independent from the proportion of third-party funding, and thus not the result of an inflation of the research group through third-party funds. It shows that too many industry partners can be harmful for scientific productivity. These results correspond with the findings from the qualitative interviews in the first panel wave where nanoscientists reported several problems concerning collaborations with industry partners (for a detailed description see Wald 2007). It can be difficult for nanoscientists to find industry partners because of the lack of commercialisation possibilities of their research. Nevertheless, they are increasingly becoming dependent on money from industry partners because of the declining share of basic funding. This asymmetry of power is an incentive for industry partners to exploit their academic partners. In addition, the different objectives of industry partners (short term, commercialisation orientation) and science partners (long term,

[11] The output indicator "number of publications" is a count variable: As a count-data regression model in the first step a Poisson model was fitted and a test for overdispersion was applied. This test rejected the Poisson model on a 0% level. With the estimated overdispersion parameter of 0.445 a NegBin model was then computed. The dispersion parameter describes the heteroscedasticity of the model. If the variance does not grow proportionally to the expected value of the function, a NegBin model should be applied, otherwise the significance of the parameters could be overestimated.

[12] The negative sign of the squared term for the proportion of industry relations indicates the shape of the curvilinear relation.

Table 3.11 Poisson and NegBin models: Effect of science–industry relations on scientific productivity in nanoscience

Dependent variable: number of SCI publications of the research group per person 2004–2006

	Poisson regression			NegBin regression					
	Model 1a			Model 1b			Model 2		
	Coefficient	Standard error	$P > \|z\|$	Coefficient	Standard error	$P > \|z\|$	Coefficient	Standard error	$P > \|z\|$
Proportion of industry relations	5.86**	2.34	0.012	5.25	3.86	0.174	5.47	4.03	0.175
Proportion of industry relations^2	–18.2***	6.37	0.004	–16.00*	9.38	0.088	–16.32*	9.51	0.086
Percentage of third-party funds	–	–	–	–	–	–	0.00134	0.00714	0.851
Rest. Log-likelihood	71.578	–	–	–71.578	–	–	–71.578	–	–
Log-likelihood	–71.567	–	–	–60.382	–	–	–60.364	–	–
LR-statistic	10.56*** (2 df)	–	–	3.43 (2 df)	–	–	3.47 (3 df)	–	–
P-value (LR-stat.)	0.0051	–	–	0.1796	–	–	0.3248	–	–
Pseudo-R	0.0687	–	–	0.0276	–	–	0.0279	–	–
N	25	–	–	25	–	–	25	–	–

*** Significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

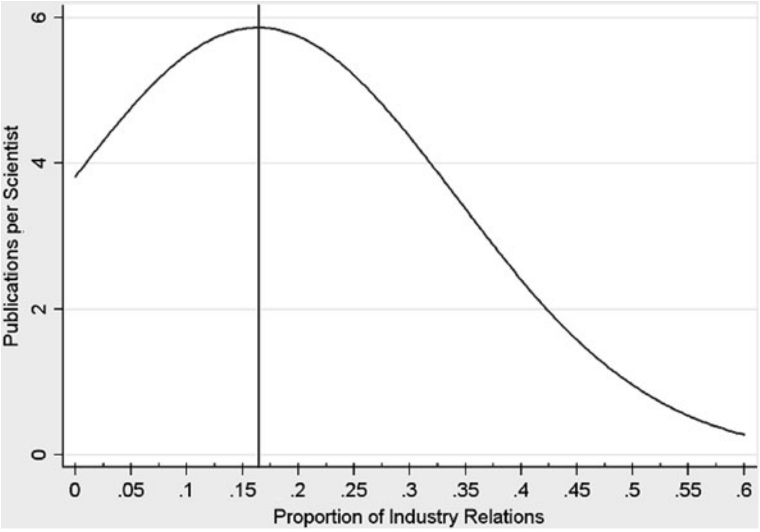

Fig. 3.1 Predicted values: Effect of science–industry relations on scientific productivity

truth orientation) make collaboration difficult. The difficulty of overcoming the cultural divide between industry and science is well known (Schmoch 2003). Especially the interest of industry partners in keeping their research findings secret in order to realise advantages in the market can lower the publication output of such collaborations. This analysis shows – exemplarily for science–industry relations – that a Mode 2-oriented policy, which treats nanoscience as a Mode 2 field of knowledge production, can have negative effects, at least in the German case.

3.9 Conclusion

This paper set out to measure empirically the main characteristics of Mode 2 knowledge production, specifically in the field of nanoscience. Evidence was found of Mode 2 characteristics in the field of nanoscience compared to the fields of astrophysics and economics where little evidence exists. Nanoscience can be seen as more application-oriented and more interdisciplinary. However, the diversity of its network partners is similar to that of astrophysics and economics. In addition, organisational structures even appear to be quite hierarchical when compared to those of astrophysics and economics. Moreover, although nanoscience is application-oriented, the main focus of the work is basic research. According to the Mode 2 thesis, the search for "truth" and "knowledge" are the antiquated, old-fashioned pursuits of science. Nevertheless, in all three fields regarded above, these traditional motives still exist. However, it can be seen that policy-makers are actively promoting Mode 2 using a variety of funding instruments; fostering inter-disciplinary, inter-organisational and international research networks. Since nanoscientists depend heavily on external funding for their research, the influence of such funding policies is high. Research proposals have to be adjusted accordingly. In the long term this development might lead to an underinvestment in basic research. Our results suggest that a considerable part of the Mode 2 characteristics of nanoscience can be explained by science policy promoting this form of knowledge production. Bonaccorsi shows that the trend towards transdisciplinarity, application orientation and science–industry relations "is not only due to societal or economic pressures" (2008: 12), while we can show that economic and social dynamics are strong enough to drive research groups into unproductive networks. It is difficult to distinguish which of the high growth rates of Mode 2 fields (Bonaccorsi and Thoma 2007) are induced by intrinsic characteristics of these new fields and which by the societal environment (e.g. funding policies). Since our sample size is small, further research has to be done to disentangle the two processes. In particular our research shows that the dominant influence in guiding and evaluating research in all fields under study rests with the scientific community even in fields that combine a reductionist and constructivist logic increasing the complexity of the systems under study by magnitude. In addition, there is evidence that policies promoting Mode 2 can be counterproductive and do not necessarily have the desired positive effect on academic output. The simple logic, maintaining that innovation is advanced by furthering links between academia and industry, does not always apply. Bonaccorsi and Thoma (2007) show that cross-fertilisation between science and industry must not necessarily occur due to direct science–industry relations. In fact, a large amount of patent inventors in nanoscience have a scientific background. The optimal degree of science–industry interaction also depends on the absorptive capacity of the industry (Jansen 1996). Collaborations require communication, mutual learning and understanding. According to our interviews this is often a problem (Wald 2007). In general, networks are probably more successful if they are allowed to develop "bottom-up".

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Chapter 4
Effects of New Governance on Research in the Humanities – The Example of Medieval History

Barbara M. Kehm and Liudvika Leiðytë

4.1 Introduction

For some years now the humanities have felt that they are in a state of crisis. It is not the first time and most probably won't be the last time (cf. for example Keisinger and Seischab 2003; Malinowski 2006). The last great debate about a crisis in the humanities took place in the mid-1980s when the humanities felt threatened by the growing primacy of the (experimental) natural sciences and by different forms of knowledge production induced by technological change. The humanities at that time saw it as their task to produce knowledge that would help to understand and accept the ongoing changes and provide support in the development of coping strategies vis-à-vis the challenges emanating from a world dominated by new technologies and innovations from the natural sciences. In Germany, the task with which the[1] humanities saw themselves confronted was to define strategies for "how to deal with..." rather than providing "a critique of..." (cf. Daxner 1986) as would have been their approach in the late 1960s and at the beginning of the 1970s.

Current debates about the crisis of have their origins in this 25-year-old feeling of threat with a few new elements added to it: recent efforts to restructure research by embedding its forms of funding into priority programmes, by strengthening competition, and by asking for proof of economic or societal relevance for the sake of innovation have led to a stronger orientation of research cultures in the humanities to those of the natural sciences (cf. Lanzendorf 2008). There is more pressure to produce short-term outputs, for example by favouring journal articles over books, there are new monitoring and audit procedures to increase efficiency and accountability vis-à-vis often non-academic and non-disciplinary stakeholder groups, there

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[1] The analysis, including the interviews, was concentrated exclusively on England, i.e. not including Wales, Scotland and Northern Ireland. Therefore, England is used throughout the text to indicate the geographical focus, while United Kingdom is used in the text to designate reforms, trends and developments that apply to the whole of the country.

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is measuring of impact factors, and there is pressure to work in inter-disciplinary units and teams. Once again the humanities feel that they are being marginalised to some extent, especially due to their lack of direct economic relevance.

This contribution is based on the results of a comparative analysis of the impacts of new forms of managerial governance on the discipline of medieval history[2] in universities of four European countries: Austria, England, Germany and the Netherlands. The subject was chosen because it represents a traditional mode or "Mode 1" of knowledge production in academia. According to Gibbons et al. (1994), Mode 1 research is characterised by orientation to basic research, by its embeddedness within a given discipline, by its use of colleagues from the same discipline as the primary reference group, and by its integration into universities as primary institutions for conducting research.

The chapter is divided into three further sections. The following (second) section will look into changes of academic staff numbers and research funding in the humanities and analyse whether this has actually been reduced or whether an increase can provide an indication that the crisis is more felt than real. The third section will analyse in some detail governance-induced changes in the forms of research in medieval history followed by conclusions.

4.2 A Comparative Analysis of Research Funding and Academic Staff in the Humanities

In order to determine whether there is a real crisis in the humanities or whether the crisis is just felt by representatives of the relevant subjects, possibly due to a decline in explanatory power or general attention, we tried to compare the development of numbers of academic staff and research funding over time. With regard to research funding we concentrated on the funding provided by national research councils and their equivalents because it can be assumed that these are the main source for funding in the humanities. Wherever possible we will provide absolute figures and figures relative to changes in staff and funding in other subject groups. The figures are not completely comparable due to the fact that for the United Kingdom no separate figures were available for England, and the statistics did not show "humanities" as a grouping but rather "education" on the one hand and "language-based studies and other arts" on the other hand. For the Netherlands the unit of analysis is based on a grouping called "language and culture", while for Germany it is "language and cultural sciences" and for Austria the subject grouping is "humanities".

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[2] The project is part of a DFG-funded larger research group established in 2003 on the international competitiveness and innovative capacities of universities and research organisations (cf. Jansen 2007) and focuses on a comparison of decision-making processes and their effects on research in managerial and collegial forms of university governance in Austria, England, Germany and the Netherlands using biotechnology and medieval history as case studies (cf. Kehm and Lanzendorf 2006; 2007; as well as Leiðytë 2007).

In Austria, the research funding for the humanities by the Austrian Science Fund (FWF) approximately doubled in absolute terms from slightly less than €10 million (€9.94 million) in 1998 to slightly more than €19 million (€19.05 million) in 2006. The amount of the annual research grants for the humanities shows a decrease between 2002 and 2004 but increased by more than €3 million between 2005 and 2006. The proportion of research grants provided for the humanities in comparison to other subject groups remained more or less the same with about 14% of the overall amount of research grants provided by the FWF but also shows some ups and downs. Between 1998 and 2006, it ranged from 12.89% in 2003 to 15.85% in 2001 and it was 13.95% in 2006. Looking at the number of full-time professors in Austrian humanities we see a slight decrease between 1998 and 2004 from 149.6 FTEs to 136.8 FTEs, a minus of about 9% (FWF 2000, 2003, 2005; Statistik Austria 1998, 2004).

The statistics about research grants provided by the German Research Foundation (DFG) for the humanities changed their subject groupings in 2002 from a group called "history and arts" to a group called "humanities". Figures on grants for "history and arts" are available until 2004, while the new grouping was introduced in 2002 and the latest figures include the year 2006. In absolute figures, the research grants from the DFG for "history and arts" increased from €32.3 million in 1996 to €52.8 million in 2004. In the category of "humanities", the DFG funding increased from €62.4 million in 2002 to €78.2 million in 2006. Compared to the natural sciences, the life sciences, and engineering sciences, the DFG funding is lowest in the humanities and social sciences, but there has been a considerable increase over time in funding as well, from €132.4 million in 1994 to €211.4 million in 2006, with a clear dip in funding between 2002 and 2003. Still the extent of increase in funding was higher in the other subject groups than it was in the humanities and social sciences. The number of full-time professors in the humanities at German universities shows a similar decline as in Austria from 5,916 in 1997 to 5,561 in 2006, a minus of approximately 6% (DFG 1998, 2002, 2006; Statistisches Bundesamt 1997, 2006).

The figures for the Netherlands look a bit different from those for Austria and Germany. We are looking here at the so-called second-stream funding provided by the Netherlands Organisation for Scientific Research (NWO). The NWO provides research grants on the basis of thematic areas in which history can be found under "cultural heritage". Figures are available for the period from 2003 until 2006. In this period NWO research grants for the subjects grouped under the name "cultural heritage" increased from €2.8 to €3.7 million in absolute terms. But while it increased strongly between 2003 and 2004, it decreased between 2004 and 2006. As a proportion of the total NWO funding it increased considerably between 2003 and 2004 from 3.5 to 6.5% and then decreased to 5.0% in 2005 and 4.5 in 2006 (NWO 2002–2006). The number of full-time professors in the subject group "language and culture" at Dutch universities increased slightly (by 8%) from 336 in 1999 to 362 in 2006 (VSNU 2008).

Finally, in the United Kingdom research funding provided by the Arts and Humanities Research Council (AHRC) increased in absolute terms from 22 million

British Pounds in 2001/02 to 45.4 million British Pounds in 2006/07, which is approximately half the funding provided to economics and social sciences (AHRB 2002; AHRC 2007). The most interesting development in the UK is the considerable increase in the number of professors in the humanities. It almost doubled from 1,072 in 1995 to 2,040 in 2006, that is an increase of 90% (HESA 1996–2007).

Thus, from a comparative perspective we find that in all four countries research funding for the humanities increased in terms of absolute figures, while it slightly decreased or remained more or less stable in terms of its proportion of the overall funding for basic research provided by the national research councils or their equivalents. Looking at the number of full-time professors, we see slight decreases in Austria and Germany, some increase in the Netherlands and a high increase in the United Kingdom. These developments do not seem to justify the interpretation that the humanities are in a serious crisis. Rather a number of other factors might explain the fact that academics in these subjects perceive a state of crisis for their subjects. Taking into account that many of the humanities subjects are part of teacher training, we also have to consider demographic changes. Without going into too much detail here, the following factors are assumed to have contributed to this feeling or perception of crisis:

- more competition for research grants leading to a decline in the proportion of successful applications;
- research councils increasingly integrate the funding available for research grants into programmes and priority areas so that applications have to be compatible to thematic priorities;
- the study of humanities subjects for the school teaching professions is facing declining job prospects as fewer teachers are recruited due to demographic changes;
- the Research Assessment Exercise in the UK as well as other forms of quality assessments have led to some concentration of research;
- the push for innovation and relevance has also led to either some concentration or integration of research units into somewhat larger inter-disciplinary research units.
- Finally, also constraints coming from the new approaches in university management should be noted, in particular the stopping of new recruitment and increasing pressures to bring in external research funding.

These factors have contributed to changes in the traditional forms and conditions for research in the humanities. And while the younger generation of researchers is socialised into these new forms and conditions from the beginning, the older generation might well perceive the changed conditions as crisis. In the following section we will have a closer look at the perceptions and practices of research in one of the typical humanities subjects, medieval history.

4.3 Medieval History: A Case Study

The analyses in this section are based on 32 interviews with mostly senior but also some post-doctoral scholars of medieval history at two universities in each of the four countries included in the study (Austria, Germany, the Netherlands and the United Kingdom). The interviews were carried out in 2004 and 2005, transcribed and coded using N-Vivo. The two basic units or departments of history that were selected for each country constituted an academically strong and a weaker unit respectively.

Traditionally, the study of the Middle Ages is a sub-disciplinary field of history that investigates a particular period which arguably covers the period from Christianisation to the Renaissance, roughly from 400 AD to 1700 AD. Medieval history investigates a broad spectrum of political, social, economic and cultural phenomena of the Middle Ages. Examples of this variety are history of monarchies, religious history, maritime history, history of arts, history of thought, history of gender relations and women, and history of law.

Medievalists use primary sources such as diaries, letters, speeches, acts and documents, objects of art, furniture and buildings. Archives are very important to them. They also study secondary sources derived from analyses of primary sources. The use of information technology becomes more important in order to preserve the archival data sources (Goetz and Jarnut 2003).

Although the study of the Middle Ages has traditionally been a lone scholar, curiosity-driven form of knowledge production, this is changing. As the idea of relevance, even utility of research becomes more prominent, medieval historians start to relate to current phenomena and can claim societal relevance for their research. For example, the study of “hoodies” in English society is related to Robin Hood and other figures from fifteenth century England (Wainwright 2005). The relevance of the Middle Ages and its studies allows researchers to satisfy the demand of historical background knowledge by scholarly treatment of topics. Moreover, with the developments of technology, internationalisation, and globalisation of societies, research on trans-national issues might gain importance (for example, comparative studies). Despite these changes, the disciplinary use of archival material remains at the centre of the field and requires a range of technical skills – bibliographic, linguistic, palaeographic and historiographic ones – rather than theories (Henkel 2000).

Despite the fact that medieval history as an academic discipline is organised somewhat differently in the four countries included in our study, quite a number of our interviewees stated that in recent times medieval history is experiencing considerably more attention and appreciation than it did previously. Medieval fairs and exhibitions are drawing large audiences, films and books with a medieval theme are seen and read by many people. Furthermore, in historic towns and villages dating back to the period in question lay groups of interested inhabitants are exploring their history and seeking the advice of experts. This has contributed to a much more diversified funding base for the subject itself and a wider spectrum of research and consultancy tasks for medieval historians to become involved in. However, the development has also led to what Meier and Schimank (2004) characterised as two potential pathways of development in the humanities in general: a specialisation and concentration either on intra-disciplinary relevance or on externally defined relevance. The latter is frequently the case for the figure of the "academic entrepreneur".

4.3.1 Perceptions of the Institutional Environment

4.3.1.1 English Cases

English medieval historians report significant changes in their institutional environment. Changes have been witnessed in research evaluation, research funding, and lines of authority and power distributions within universities. The Research Assessment Exercise (RAE) dominates most of the discussions among all British medievalists and has changed the way researchers think about their research. The researchers are well aware of the spin-off effects of the RAE in terms of management measures and external funding opportunities. They highlight the financial consequences of the RAE, the increasing need for external funding, and the growing competitiveness for such funding. Because of the lower level of funding as a result of a lower RAE score, positions of retired faculty can not be filled again. Research groups and departments experience annual internal monitoring procedures, whereby each researcher meets with the management to discuss last year's performance and outputs. They increasingly have to justify their existence and report their research outputs and externally funded projects to the management. In general, the management uses a policy of "carrots and sticks". The rewards usually include new staff appointments, promotion and research leave. In cases of underperformance, the threat is a push into teaching-only positions or early retirement, the re-organisation of a unit or department, or in extreme cases the firing of individual academics or the closing down of a unit.

4.3.1.2 Dutch Cases

Without exception the Dutch medieval historians reported significant changes in their institutional environment. Changes have been witnessed in terms of increased student numbers, restrictions in terms of hiring new PhD students, research funding, research evaluation and accountability, and new forms of managerial governance. The academics perceive the budgets of departments and institutes to be under pressure, forcing the research units to be creative in finding research grants outside the university. Research performance is being monitored and assessed, which was not the case in the past. The consequences of the outcomes of evaluations are not always clear. There is also "more management" than there used to be. At different levels, this institutional management tries to streamline or to bundle the research in the faculties and institutes. In both cases, institutional management is not per se "cursed", basically because it leaves ample room for researchers to do their own thing. Still, the increased levels of bureaucracy, partly due to "managerialism", are not appreciated at all. Competition and cooperation have also grown, although opinions slightly differ here. One of the changes in this respect concerns the "internationalisation" of research in medieval history. According to our respondents, it is clear that in the field of medieval history the pressure to perform has increased.

4.3.1.3 Austrian Cases

The reform of 2002 which made all Austrian universities legally independent bodies has led to more organisational flexibility on the one hand but also to more institutional bureaucracy on the other hand. Medieval historians report that there are increasing activities in terms of establishing particular profiles and forming university-wide, often inter-disciplinary approaches and research centres in which professors are expected to participate. By many, especially the younger professors this is seen as an opportunity, others perceive more pressure and more competition among departments for increasingly scarcer resources. A number of interviewees state that hierarchies are more pronounced and that many of the previous collegial decision-making bodies have been reduced to advisory bodies. However, organisational changes are frequently introduced in a soft manner and dependent on the style of leadership. The instrument of performance or goal agreements between university management and departments is used to establish criteria for the allocation of budgets. Some of the Austrian medievalists point out that resistance against the new reforms comes predominantly from the older generation of professors while the younger generation is practically socialised into the new forms of managerial governance. Others, however, state that the university reform has led to a demotivation of many researchers and that there is a negative trend towards maximising third-party funding without taking quality issues sufficiently into consideration. Most interviewees agree that changes have been considerable but interpretations vary in terms of their positive and negative impacts.

4.3.1.4 German Cases

What clearly stands out in the statements of German medieval historians is the performance-related internal budget allocation in which the indicator of third-party funding is very prominent. The researchers perceive high pressure in terms of writing research proposals and attracting third-party funding. In addition, both institutions in which interviews were carried out participated in the German Excellence Initiative. This led to a very close scrutiny by the central level management of areas which might have the potential to become winners in this competition. Performance-related budget allocation can provide incentives but also increases internal competition for resources. Basically, the university management formulates expectations concerning the level of third-party funding for each unit and more realistic goals are then negotiated. Budget allocations and negotiations are now based increasingly on mostly quantitative indicators and every department or faculty periodically must submit a development plan. In both institutions, smaller institutes and departments were merged and formed into larger units in order to strengthen research in inter-disciplinary teams and improve the building of networks. In preparation of the participation in the Excellence Initiative, the central level made far-reaching attempts to establish research foci in order to produce a clearer profile of the institution as a whole. Often identified strengths were then concentrated in research centres outside the faculty or department structure. Strong research areas are systematically supported with institutional resources. A typical attitude of the researchers towards the new steering models and instruments is to play the game whilst paying attention that one is not corrupted by it. New elements of the steering model are undermined in a targeted manner, while, at the same time, the researchers are showing some degree of loyalty.

4.3.2 Research Practices and Responses

4.3.2.1 Problem Choice

English Cases

The researchers of both English medieval history units try to find a balance between their own research agenda and the research priorities of the funding bodies, such as the Research Councils or various charities. They do so by following largely symbolic compliance strategies – maintaining their own research lines and at the same time selling their research interests according to the priorities of the external research funders. A similar strategy can be found with respect to the requests of funding bodies to establish collaborative research projects and the interest of the researchers to maintain individualised research practices. However, in the case of junior researchers in the low credibility unit, we can find evidence that they tended to compromise their problem choice and largely comply with the research priorities of the funding bodies.

To counterbalance potential negative effects of low RAE scores, researchers aim at increasing visibility and credibility in the eyes of the university management by participating in multi-disciplinary faculty themes. Also through successful participation in externally funded research projects, medieval historians could influence the faculty theme using a pro-active manipulation by proposing a medieval studies' faculty theme and in this way putting their area of research on the faculty "map".

Dutch Cases

Despite all sorts of initiatives to increase collaboration and inter-disciplinary approaches, the two Dutch research units are still a collection of individual researchers. And these individuals say that they continue to have sufficient autonomy to select their own research topics. Many admit that they have a sidelong glance at research themes and hypes promoted elsewhere in order to "sell their ideas" in the right way, but basically they decide themselves what to research and how to research it. As regards problem choice we see symbolic compliance, which means other interests are taken into account without really affecting the individual choices. With respect to the teaching-research nexus and in some instances the output preferences, however, we clearly observe strategies of compliance.

Austrian Cases

The establishment of research foci and new activities to generate a clearer institutional profile has become quite important in Austrian universities. The implementation is mostly carried out by restructuring, i.e. forming independent centres, merging departments and redefining the denominations of new professorships. Our interviewees report that it has become important for every individual professor to engage in the new research centres and try to integrate his or her own research interests into these centres. No influence is exerted on the choice of research topics, but the thematic priorities receive additional money. Basically the organisational reforms have changed the framework conditions for research but not the research itself. Individual research which is traditional for medieval history is still frequent and still possible, although long-term research interests have to be put on the backburner more frequently in favour of short-term and current topics, which are in the centre of political and public debates.

German Cases

Several of our interviewees note that research in medieval history has changed considerably due to the increasing formation of networks, cooperation in teams, and internationalisation. Although it is still up to the researchers to decide about the topics and problems of their research, it has become important to engage in cooperative projects because inter-disciplinary teams tend to have more success with applications for research funding. Medieval historians also state a growing trend towards the popularisation of research results to a wider, i.e. non-academic audience so that sometimes research topics are chosen and formulated in such a way that their relevance and the potential for the utilisation of their results is worked out more clearly. Larger research funding applications have to be frequently approved by the central university management and in one case it is reported that the application was sent back with requests to reformulate.

4.3.2.2 Relationships Between "Mainstream" and "Risky" Research

English Cases

Medievalists in both English groups stay mostly within the mainstream areas of research to ensure that they have a chance to receive funding. This is especially true for researchers who have lower credibility because they are junior staff and/or belong to a group that ranks low in the RAE. Such researchers employ compliance strategies, while researchers with high credibility use symbolic compliance strategies. Both groups mainly do long-term research, in which outputs are oriented towards the academic community, and academic inquiry is for the sake of inquiry. The trend towards short-term research projects funded by external funders is not welcomed by researchers. Short-term research for medieval historians would be 1 to 2 year projects, while to produce a PhD takes 3 to 4 years.

Dutch Cases

With respect to research, the researchers of both units conduct mainstream and risky research. In fact, medievalists report that the concept of "risky" research does not apply to their discipline. They prefer to think of their research as "curiosity-driven". The research groups report that there is pressure for relevance. This pressure comes from the external funding priorities and also from the need to contribute to the local community and region. However, the pressures for relevance are largely ignored as described by interviewees. It can be said that they continue doing the type of research they prefer to do.

Austrian Cases

On the one hand, Austrian medieval historians state that they observe a certain amount of strategic adaptation of research topics to mainstream issues and those topics for which third-party funding could be generated. However, in these cases deans and directors of centres and institutes see their task also in protecting the researchers from too much intervention into choice of topics. On the other hand, our interviewees also point out that they do not see a problem in terms of undertaking "risky" research and following unorthodox perspectives. On the contrary, unorthodox topics and approaches are frequently seen as contributing to the institutional profile and serve as an indicator for the uniqueness of the profile.

German Cases

The medieval historians emphasise that there is a willingness to formulate research proposals in such a way that the chances for getting funded are better but that this strategy does not have implications for the choice of topics according to mainstream research only. However, they also point out that unorthodox perspectives are more difficult to maintain because all applications are evaluated and refereed. Still, such unorthodox perspectives emerge as a result of the increased networking in interdisciplinary research teams. One interviewee states that his department does not need mavericks and birds of paradise but is looking for new people who fit into the existing themes and structures. Concerning the younger researchers it is deemed important to conform to some extent to the "market" that determines which topics are interesting and which not.

4.3.2.3 Output Preferences

English Cases

Both groups have less time to produce research outputs; there is hastiness in publishing papers and books which leads to an increase in the number of publications. At the same time, research results increasingly are subdivided into smaller pieces to produce more publications, thus leading to a certain amount of inflation. In terms of output preferences, both basic research units use a mix of compliance and symbolic compliance strategies. Both groups comply with the requirements for a certain type, amount and quality of research output within the framework of the RAE which is reinforced by internal management measures and the requirements of external funding bodies regarding past performance. However, in addition they comply only symbolically with the requirements to produce short-term research outputs. They divide their own long-term output preferences and long-standing research interests into short-term projects and outputs. In this way they still produce their preferred outputs, such as books, although this happens on a smaller scale.

Dutch Cases

In terms of outputs, books are still favoured by Dutch medievalists. Promotion largely depends on the number of the produced and published books. However, due to the requirements of the university management coupled with personal ambitions, funding and time constraints, "quick" outputs seem to be important as well. Therefore articles and conference contributions are gaining ground. Many Dutch medievalists fear the advent of rankings; they see a quantification of academic output which is not welcomed at all. In addition, medievalists report that publications in the English language are increasingly important, and thus they tend to publish more in English. At the same time, they try to find a balance between the local Dutch audience, popular media and the international audience.

Austrian Cases

Austrian medieval historians emphasise in particular that there is considerable pressure to bring in third-party funding. The fact that the university administration claims a part of this funding to cover overheads has led to some demotivation among researchers. Concerning the publication of research results, accountability and reporting duties have led to an increasing focus on demonstrating quick results so that publication strategies tend towards production of more journal articles. Most researchers, however, try to find a balance between producing journal articles and writing books.

German Cases

To show that the output and long-term book projects are on the backburner, research output is divided into articles more frequently than before. Medieval historians also note that there are more publications in journals with a broader and also non-academic readership. The rising popularity of films, exhibitions and books with a medieval topic has led to more demand for such kind of output.

4.3.2.4 Teaching-Research Nexus

English Cases

The increasing demands for research outputs, the need to attract external funding, and the increased number of students have led to tensions in the work of the research groups. These tensions are especially visible in the division between teaching and research responsibilities. We see that medieval historians in both English groups comply with the changing teaching-research nexus by diversifying their teaching and research staff and obtaining external funding for research leave. In this way they are “buying out” of teaching. It is common to hire short-term contract junior staff to teach in order to replace the teaching duties of researchers that are away on research leave. The senior medievalists are concerned about what this might imply for the quality of teaching in the long run.

Dutch Cases

Dutch medievalists tend to regard teaching as an important, although time-consuming activity. The Master’s programme becomes “bread and butter” for the research groups as it is a serious source of additional funding as well as a recruitment pool for future candidates of PhD studies. In terms of the teaching-research nexus the balance tips toward the teaching due to growing student numbers and the implementation of the tiered structure of Bachelor and Master degree programmes. A major concern expressed especially by the junior medievalists was the growing administrative and teaching loads at the expense of research time. There is a tendency to fill teaching-only positions and to hire research-only post-doctoral researchers funded by external grants. So there are some indications of a separation of teaching and research.

Austrian Cases

The organisational reforms in Austrian universities and new forms of governance have had so far hardly any effects on the teaching-research nexus. The practice which can be observed in other European higher education systems of buying oneself out of teaching obligations is not done in Austria; in fact, a number of interviewees state a continuous close relationship. However, it is also pointed out that the Bologna reforms have led to an increased focus on integrating practical elements into undergraduate programmes in order to secure employability. The interviewees also note that there is less time for offering seminars on research topics of individual professors because the classes prescribed in the curriculum or syllabus have to be covered through respective teaching provisions.

German Cases

In all German universities the idea of a close relationship between teaching and research continues to be strong. As a rule, the university management does not allow for teaching-only and research-only professorships with one exception. Those universities who have received extra funding in the framework of the Excellence Initiative tend to make some exceptions when recruiting new professors for research in the category "clusters of excellence". This is basically a matter of negotiation between the candidate and the central level, but regular chair holders can not buy out of teaching because they are part of faculties and departments which are responsible for the degree programmes.

4.4 Conclusions: The Effects of Managerial Governance on Research in Medieval History Compared

A comparison of the reactions of medieval historians to the new governance regimes in universities shows one notable similarity in all four countries, namely that the university as an organisation increasingly expects them to contribute with their work to the establishment of an organisational profile – and thus identify more strongly with the institution – and that the researchers comply considerably with this expectation. This has an impact on the ways in which the medieval historians build up and try to maintain their credibility (cf. Leiðytë 2007). Credibility and reputation continue to be established through research and publications, but the target group is no longer exclusively the discipline and the peers but the employing institution as well.

The new institutional governance regimes are clearly more hierarchical and have strengthened the decision-making powers of the top-level management (cf. Harley et al. 2004). The management expects more accountability, transparency, efficiency and effectiveness from the basic units (e.g. departments, centres, research groups, etc.) and in most cases it bases its budget allocations on internal performance agreements. In addition, internal as well as external evaluation of quality has increased considerably. However, the decisions and the criteria on which they are based have to be communicated by the management in such a way that the researchers find them reasonable, at least to some extent. Simple pressure from the top is being exerted here and there but often leads to avoidance, defiance or even manipulation (e.g. through undermining the implementation of policies in a targeted manner) in the basic units. Thus, institutional management has to take into account the norms and values of scholarly work when trying to establish a particular policy or implementing a decision. The most frequent reactions to demands from the central level which are regarded as being unreasonable to some extent are symbolic compliance while continuing in the old ways whenever and wherever possible. Compromises or even active defiance are strategic actions used by the basic units in cases when reporting, evaluation and accountability duties become too time-consuming or decisions are seen as unreasonable. New forms of loyalty and trust have to be established between the institutional management and the basic units in the face of the new governance regimes. This certainly requires new and different information flows and a culture of communication, negotiation, and conflict management which is new for the institutional management as well as for the basic units, especially since the traditional collegial decision-making bodies have been weakened. And this leads to the second area of similarities which can be observed in all four countries.

Performance-related budget allocations have led to a multiplication of actors with which the institutional management has to negotiate. Already for pragmatic reasons to reduce the sheer number of negotiations, measures have been taken frequently to merge smaller units into larger ones. But such mergers have followed additional logic as well. By putting more emphasis on interdisciplinarity and working in networks or teams it is hoped to support or trigger innovation. In addition, strong research groups with high reputation and a high level of third-party funding are often integrated into special centres outside the regular departmental structure. With extra funding from the institution to support visibility and high-level output, these centres are also supposed to boost the institutional profile and make the university nationally or internationally more competitive in a given field. In this context also unorthodox or “risky” research perspectives are encouraged. This has had a considerable impact on the traditional forms and ways in which research was and sometimes still is carried out in medieval history. As one German interviewee noted it has even changed the methodological approaches in the field. The traditional form of research was very much that of the lone scholar working at a desk or digging in archives who needed a well-stocked library, a computer and sufficient time to write books. Such forms of research also did not require a lot of funding, i.e. it was not very expensive.

Today there is considerable pressure:

- to find more third-party funding,
- to publish more articles in journals,
- to get involved in inter-disciplinary research and work in teams,
- to increase visibility (regional, national, international),
- to engage in regional historical events,
- to provide services and expertise for lay groups of historically interested people,
- to support the institutional profile and reputation building.

However, we can also observe a number of differences in the perceptions of changes due to impacts of new governance forms on research and in the responses to these changes by the researchers. In terms of the perceptions of medieval historians of their institutional environment, the British researchers emphasised very much the effects of the Research Assessment Exercise and its funding consequences which has led to a closer monitoring of performance by institutional management. Dutch medieval historians perceived general funding constraints and more managerialism also leading to pressures for better performance but also facing a demand for more internationalisation in their work. The medieval historians in Austria perceived a clearly increased bureaucracy and more competition for scarce resources as well as a thrust towards more inter-disciplinary approaches. In Germany, too, performance-related budget allocations have led to more competition and monitoring of performance. In addition, the medieval historian perceived more pressure towards inter-disciplinary work.

The differences become more pronounced if we take a comparative look at the effects of new forms of governance on research practices.

In terms of problem choice, medieval historians in the United Kingdom try to find a balance between their own research interests and the priorities of the funding bodies as well as between the demand for more collaborative projects and their preference for individual research. So a strategy of compromise can be observed in the British cases. Medieval historians in the Netherlands still feel a considerable degree of autonomy to select their themes and methods and follow a strategy of symbolic compliance in terms of problem choice and a strategy of adaptation or acquiescence in terms of new output preferences. The Austrian medieval historians tend to follow a dual strategy of acquiescence and avoidance by engaging in central research centres to contribute to the institutional profile building on the one hand and following individual research on the other hand. However, there is more consideration of current “hot topics” when deciding about a theme. Medieval historians in Germany perceived considerable changes due to increases in collaborative work and cooperation in (international) teams. They also tend to comply with the demand to present their results to a wider audience. And while the older generation of researchers tends to see these developments in a more sceptical manner, the younger generation is more or less smoothly socialised into the new ways of managing research.

Concerning the relationship between mainstream and “risky” or unorthodox research, British researchers mostly tend to stay in the mainstream. If at all, unorthodox research is carried out by medieval historians with high credibility. The Dutch researchers stated that they follow both mainstream and unorthodox research and basically continue with the type of research they prefer. Pressures for relevance tend to be ignored. This attitude can be interpreted as a strategy of defiance. In Austria, we see some strategic adaptation to mainstream issues and topics most likely to generate third-party funding, but unorthodox perspectives are appreciated as well due to their potential contribution to the uniqueness of the institutional profile. In Germany, mainstream topics serve to increase the chances for third-party funding. Unorthodox perspectives are more difficult to maintain but emerge through new inter-disciplinary approaches.

In terms of output preferences, we can observe similarities in the pressures with which medieval historians are confronted who namely favour short-term journal articles over long-term book projects but respond differently to such pressures. British medieval historians tend to cut up a potential book topic into smaller pieces which are then published as journal articles, but they put it together again at a later point in time in form of a book. Dutch medieval historians continue to favour books but are also aware of the importance of journal articles. They reject the trend towards quantification of outputs but comply with the demand to publish more in English. Austrian researchers of medieval history perceive an increased focus on quick results but try to find a balance between articles and books, while German researchers in the same field write more articles than before and also try to target a wider, non-academic audience. Long-term book projects are shifted to a later point in time.

With regard to the teaching-research nexus, we find the most advanced division of teaching and research responsibilities in the United Kingdom. Strong researchers try to "buy out" of teaching, weak researchers are being pushed into teaching-only positions. In the Netherlands, teaching is still considered as important, especially as it brings money into the institution at the level of Master and PhD programmes. However, there is also a trend towards a growing separation as there is an increasing number of teaching-only and research-only positions. New governance reforms have had hardly any effect on the teaching-research nexus in Austria. There is a continuous close relationship between the two. However, researchers also observed a decreasing focus on research-based teaching in favour of practice-based teaching mainly due to the employability agenda in the framework of the Bologna reforms. In Germany, the teaching-research nexus also continues to be strong, although there are erosions at the margins. In order to deal with increasing student numbers, a considerable amount of teaching-only positions have been created for younger post-doctoral scholars. In addition, there are some research-only professorships in the research clusters which won additional funding in the context of the German Excellence Initiative. Possibly with the exception of Austria we find varying degrees of an erosion of the close teaching-research nexus.

In summary, it can be concluded that the new forms of governance have affected a traditional Mode 1 humanities subject in quite a number of ways. More team work in projects, more interdisciplinarity and internationalisation, a pressure for short-term output in the form of journal articles rather than books, more competition for scarce resources and pressures to attract more third-party funding, all these elements point to deep-reaching changes against which some resistance can be observed in the form of various strategies of symbolic noncompliance or even defiance. A somewhat surprising result of this analysis has been that all teachers/researchers in all our four countries are increasingly expected to contribute to the standing and reputation of their employing institution so that the institution as a whole can be more competitive on whatever market it is competing. This might affect the flows of communication and the forms of trust building needed within the institution, in particular between the management on the one hand and the researchers on the other hand.

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Part III
New Governance of PhD Education and Effects on Performance

Chapter 5
The Performance of German Research Training Groups in Different Disciplinary Fields – An Empirical Assessment

Birgit Unger, Kerstin Pull, and Uschi Backes-Gellner

5.1 German Research Training Groups: Profile and Goals

In an attempt to offer an alternative to the traditional student–teacher relationship in doctoral studies, in the early 1990s the German Research Foundation (*DFG*) established so-called Research Training Groups (*Graduiertenkollegs*) offering a new form of structured doctoral education. A Research Training Group (RTG) constitutes a temporary programme focusing on a special research topic that covers a set of doctoral projects and is supported by a study programme at a single German university, at a small group of German universities, or at a German university cooperating with foreign partners. It is run by a group of cooperating researchers who apply for the funding at the DFG. The study programme is compulsory for the doctoral and post-doctoral students and is held to provide the RTG students with well-founded methodological skills as well as with specialised knowledge in the particular field of research. Furthermore, an early integration of the RTG students in the research activities of a collaborative research environment is appreciated as well as an international and inter-disciplinary orientation. The DFG grants fellowships to doctoral and post-doctoral students as well as funds for travel expenses and equipment for a maximum funding period of 9 years for an RTG. Until March 2003, a grant consisted of an initial funding for a period of 3 years that – in case of a successful reapplication – could be renewed twice; since April 2003, however, a grant has consisted of a funding for 4.5 years that can only be renewed once. At present, about 240 Research Training Groups are funded by the DFG (see DFG 2008).

In this paper, we study the performance of German Research Training Groups funded by the DFG by assessing their performance in two important respects: (1) the completion of *doctoral degrees* and (2) the scientific visibility of RTG students. As a measure of *scientific visibility* besides publications, we also include presentations at conferences and workshops. As Fabel et al. (2003) argue,

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presentations (at least those at refereed conferences) represent an "intermediate" indicator of research performance as they usually lead to publications at a later point in time. Hence, it would seem only fair to complement the data on publication output by the data on presentations – especially as we assess the performance of very young researchers at a very early point of time in their academic careers. However, as information on the latter is only available for a share of RTGs in our sample, we will not use the corresponding data in the Data Envelopment Analysis (DEA) performed in the last step of our analysis.

5.2 Data and Measures

Our empirical analysis is based on a data set of 86 RTGs funded by the DFG. It comprises *all* Research Training Groups belonging to the humanities, the social sciences and the natural and life sciences who are in their second funding period *and* who submitted an application for a third funding period to the DFG between October 2004 and October 2006.[1]

The data on performance measures were extracted from the detailed reports of the Research Training Groups that are part of the application for a third funding period. The RTGs in our sample hence had a strong incentive to fully document their output in order to succeed in their application. On the one hand, the reports for the second funding period are especially suitable for our analysis, because at the time of submission, the RTGs had already existed long enough to be able to report on the output of RTG students. The reports for the first funding period, on the other hand, contain only information on the years 1–2 (with hardly any performance data to be reported yet) and the ones on the third funding period presumably will only contain incomplete data as there is no incentive for full reporting when the RTGs cannot be renewed again. The inclusion of these reports in the data set would hence not seem appropriate.

While doctoral degrees and publication data are an integral part of RTG reports (with the DFG explicitly asking for the respective data), this is not the case for our intermediate indicator of research performance, presentations at conferences, and workshops. Still and even though the DFG does not require the respective figures to be included in the reports, 75 out of 86 RTGs report on this category. As a consequence, we present the descriptive data on this indicator in Section 5.3, but we do not include it in the DEA performed in Section 5.4.

Twenty-eight of the 86 RTGs in our data set belong to the humanities and social sciences, whilst 58 RTGs belong to the natural and life sciences. In order to account for the different research technologies in the different disciplines (see for example Laudel 1999; Snow 1964), we distinguish between the disciplinary field of

[1] As the RTGs reported on varying time spans (partly as a result of the varying length of funding periods), we normalized all measures on a year basis.

humanities and social sciences on the one hand and the disciplinary field of *natural and life sciences* on the other hand.

5.3 Descriptives

In the following, we present the descriptive data on the measures we use to assess the performance of the German RTGs: (1) doctoral degrees and (2) scientific visibility.[2] The descriptive statistics are partly based on Pull/Unger (2008).

5.3.1 Doctoral Degrees

Our first performance measure is rather obvious from the key goal of an RTG: It is the number of successfully completed doctoral degrees. It is measured as the share of completed doctorates per doctoral student and year. According to our data, a

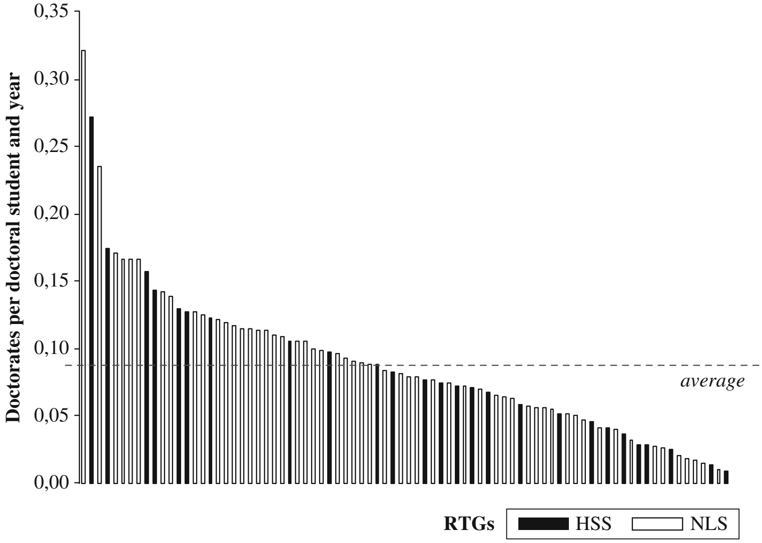

Fig. 5.1 Share of completed doctorates per doctoral student and year in the different RTGs. HSS = humanities and social sciences, NLS = natural and life sciences.
Source: Own data

[2]Besides doctorates and scientific visibility, another possible measure to assess the performance of RTGs would be the placement rate of RTG students. As we do not have any information about the career paths of former RTG students, we refer to the contribution of Schneider et al. (2010) in this monograph who investigate the placement rate of selected economics departments in an international comparison.

Table 5.1 Completed doctoral degrees per doctoral student and year on an RTG basis

			Mean		
	Min	Max	Total	Humanities and social sciences	Natural and life sciences
Completed doctoral degrees (in %)	0	32.14	8.49	7.87	8.78

Source: Own data

little less than one of ten doctoral students (8.49%) on average receives his or her doctoral degree per year. While in the most active RTG almost one third of doctoral students per year complete the degree, there are also four RTGs that do not report the completion of one single doctoral degree (see Fig. 5.1).[3]

Concerning disciplinary differences, RTGs in the natural and life sciences are quite similar to those in the humanities and social sciences as far as the completion of doctoral degrees is concerned (see Table 5.1): 7.87% of doctoral students receive their doctoral degrees in any given year in an RTG belonging to the humanities and social sciences, while the corresponding figure for the natural and life sciences is 8.78%. In absolute figures, these are on average 2.8 doctorates per year in an RTG belonging to the natural and life sciences and two doctoral degrees per year in an RTG belonging to the humanities and social sciences.

5.3.2 Scientific Visibility

As RTGs were also established in order to qualify the coming generation of researchers, we complement the indicator of doctoral degrees by indicators of the scientific visibility of the doctoral and post-doctoral students in an RTG. In order to educate a new generation of researchers, doctoral and post-doctoral students in the RTGs should be introduced to the process of scholarly publication, and they should produce a visible research output. The publication output of RTG members would then mirror the success of the RTGs in qualifying young researchers and in introducing them to scientific research; conference presentations would represent an early indicator of that same activity. When collecting the data, we distinguished between different kinds of publications and conference presentations. Then we adjusted the publication and presentation output according to the number of authors and allocated a fraction of 1/n to each author (see e.g. Egghe et al. 2000: 146).[4]

[3]While one of these RTGs reports on a time span as short as 5 months (which may well result in an underrepresentation of its performance), this is not true for the other RTGs with a doctoral completion rate of 0 who report on time spans in the range of comparable RTGs with significant doctoral degree completion rates.

[4]Whenever the number of co-authors was not specified in the research reports but the expression "et al." hinted at a joint production of publication outputs, we supplemented our data from the RTG research reports by information gathered from the internet.

5.3.2.1 Publications

Regarding the total publication output, the most active RTG reports 1.52 publications per RTG student and year while the least active RTG only reports 0.02 publications per RTG student and year (see Fig. 5.2). On average, an RTG student (doctoral and post-doctoral students) produces 0.33 publications per year: RTG students in an RTG belonging to the humanities and social sciences produce on average 0.59 publications per year and RTG students in an RTG belonging to the natural and life sciences produce on average 0.21 publications per year (see Fig. 5.2 and Table 5.2).

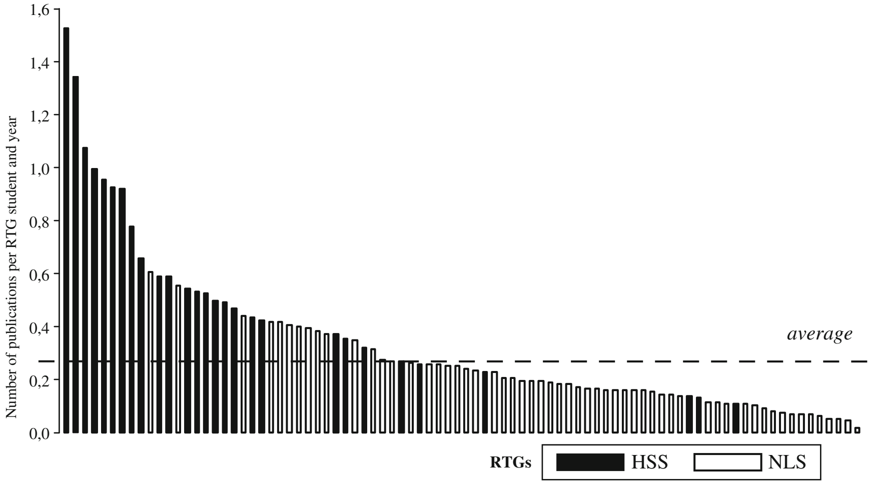

Fig. 5.2 Average number of publications per RTG student and year in the different RTGs. HSS = humanities and social sciences, NLS = natural and life sciences.
Source: Own data

Table 5.2 Publications per RTG student and year on an RTG basis

			Mean		
	Min	Max	Total	Humanities and social sciences	Natural and life sciences
Publications (in total)	0.02	1.52	0.33	0.59	0.21
Thereof:					
Monographs	0	0.14	0.02	0.04	0.01
Editorships	0	0.11	0.01	0.01	0.00
Journal articles	0	0.40	0.11	0.13	0.11
Book sections	0	0.79	0.08	0.22	0.01
Conference proceedings	0	0.59	0.05	0.07	0.03
Discussion papers	0	0.42	0.03	0.06	0.02
Published abstracts	0	0.30	0.03	0.01	0.04
Reviews	0	0.28	0.02	0.05	0.00

Source: Own data

While the reported publication figures may seem quite low at first sight, one has to bear in mind that we are discussing very young researchers here. Most of them are doctoral students who come into contact with scientific research for the first time of their academic career. As post-doctoral students could be expected to show more active publication patterns and as their shares vary related to their RTGs, it would be interesting to regard only the publication output of doctoral students when comparing the scientific visibility of RTGs. This information, however, is not easily available. In the DEA performed in Section 5.4, however, we are able to account for differing shares of post-doctoral students by analysing the different production inputs of doctoral and post-doctoral students.

Concerning the different publication outlets, these, too, differ considerably between the disciplines. Therefore, the RTG students of an RTG belonging to the natural and life sciences publish articles particularly in scientific journals with 0.11 articles per RTG student and year, whereas RTG students in an RTG belonging to the humanities and social sciences mostly publish book sections with 0.22 book sections per RTG student and year. Table 5.2 shows the different kinds of publications that can be distinguished in the data and those publications' use by RTG students.

Figure 5.3 shows the publication patterns for the RTGs belonging to the humanities and social sciences and to the natural and life sciences, respectively.

The average RTG student in an RTG belonging to the humanities and social sciences produces 0.22 book sections, 0.13 journal articles, 0.07 conference proceedings, 0.06 discussion papers, 0.05 reviews, 0.04 monographs, 0.01 editorships and 0.01 published abstracts in the course of 1 year. Except for the published abstracts, the average publication numbers in an RTG belonging to the natural and life sciences are *below* the average publication numbers in an RTG belonging to the humanities and social sciences. Even the average number of journal articles per RTG student in an RTG belonging to the natural and life sciences is – even though

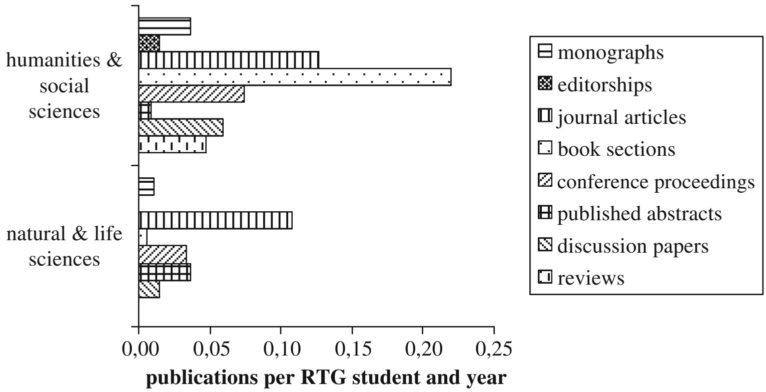

Fig. 5.3 Publication patterns by discipline.
Source: Own data

the journal is the most widely used publication outlet – lower than the corresponding number of articles displayed by an RTG student in an RTG belonging to the humanities and social sciences. This finding is, however, – at least in part – owed to the fact that the publication output was adjusted for the number of authors and that papers in the natural and life sciences typically have considerably more authors (with more than 500 authors of one single article as an extreme case in our data set). When the number of authors is ignored and each publication is fully counted for each co-author, the finding is the reverse: An RTG student in the natural and life sciences on average participates in the production of 0.47 journal articles per year while his colleague in the humanities and social sciences only participates in 0.19 journal articles. Furthermore, it has to be kept in mind that in our data set we are not able to adjust for a possibly differing quality of journals (or even articles) as there is no comprehensive journal ranking for all the different study fields under consideration. If the RTG students in the natural and life sciences systematically aimed at more reputable journals, this then would also be able to explain the observed differences in publication output.

5.3.2.2 Presentations

Presentations at conferences and workshops are an indicator that is only available for 75 out of the 86 RTGs. This indicator has to be interpreted with caution as the corresponding information is not an integral part of the reports as demanded by the DFG. RTG students from an RTG belonging to the humanities and social sciences are also more active when they are about to present their research findings (Table 5.3): They give on average 0.90 presentations per year while their colleagues from an RTG in the natural and life sciences on average give only 0.41 presentations per year. Across all 75 RTGs that report on that category the mean is 0.57 presentations per RTG student and year with the most active RTG reporting 1.82 presentations per RTG student and year, whereas the least active one reports only 0.02 presentations per RTG student and year.

Table 5.3 Presentations per RTG student and year on an RTG basis

			Mean		
	Min	Max	Total	Humanities and social sciences	Natural and life sciences
Presentations (in total)	0.02	1.82	0.57	0.90	0.41
Thereof:					
Talks	0	1.82	0.40	0.78	0.21
Posters	0	0.98	0.12	0.05	0.16

Source: Own data

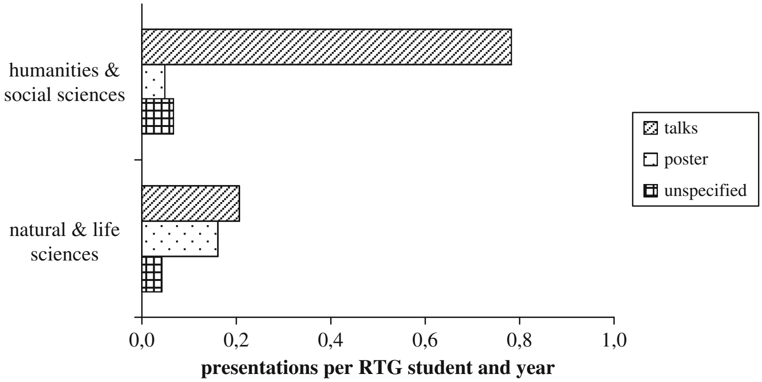

Fig. 5.4 Presentation patterns by discipline.
Source: Own data

Regarding different types of presentations, we distinguish between talks and poster presentations. The presentations we were not able to assign to one of the two categories were allocated to the category "unspecified" (see Fig. 5.4).

With regard to the different types of presentations, it can be seen that, on the one hand, an RTG student in an RTG belonging to the humanities and social sciences gives on average 0.78 talks per year, whereas a doctoral student in an RTG belonging to the natural and life sciences gives only 0.21 talks per year. On the other hand, an RTG student from an RTG belonging to the natural and life sciences gives on average three times as many poster presentations per year (0.16) as an RTG student from an RTG belonging to the humanities and social sciences (0.05). It is evident that the choice of the presentation type largely depends on the discipline: While talks are by far the most common method of presenting research results in the humanities and social sciences, researchers in the natural and life sciences introduce their research findings to a wider public either in the form of poster presentations or in the form of conference talks.

5.3.2.3 Summary

To sum up, the descriptive analysis reveals considerable disciplinary differences between the field of humanities and social sciences and the field of natural and life sciences (see Table 5.4): While the average doctoral completion rate in RTGs belonging to the humanities and social sciences is almost as high as the one in RTGs belonging to the natural and life sciences, the average publication and presentation outputs both are considerably higher in RTGs belonging to the humanities and social sciences. In light of the existing literature hinting at differences in the scientific production process between the disciplinary fields (see e.g. Laudel 1999; Snow 1964), these findings led us to analyse the efficiency of the two disciplinary fields separately in Section 5.4.

Table 5.4 RTG performance in the two different disciplinary fields

	Min	Max	Mean	Standard deviation
Completed doctorates per doctoral student and year (in %)				
... in humanities and social sciences	0	27.16	7.87	6.08
... in natural and life sciences	0	32.14	8.78	5.70
Publications per RTG student and year (in absolute numbers)				
... in humanities and social sciences	0.11	1.52	0.59	0.36
... in natural and life sciences	0.02	0.61	0.21	0.13
Presentations per RTG student and year (in absolute numbers)				
... in humanities and social sciences	0.13	1.82	0.90	0.47
... in natural and life sciences	0.02	1.65	0.41	0.32

Source: Own data

5.4 The Relative Efficiency of RTGs: The Results of a Data Envelopment Analysis

As RTGs have multiple inputs (doctoral students, post-doctoral students) and outputs (doctorates, publications, presentations) which do not only have different dimensions but may also be given different grades of importance by the individual RTGs, performing a Data Envelopment Analysis (DEA) is the measure at hand to analyse the efficiency of RTGs. As the DEA is especially useful when the lack of market prices for the outputs inhibits a coordination of supply and demand by the market mechanism, there exists a wide range of applications for a DEA in the non-profit sector (for applications in academia see e.g. Abbott and Doucouliagos 2003; Backes-Gellner and Zanders 1989; Warning 2004).

5.4.1 The DEA Model

The DEA is based on Charnes, Cooper and Rhodes (Charnes et al. 1978). It was the most suitable way for us to present the DEA intuition graphically: In the example presented in Fig. 5.5, there are six decision-making units (i.e. in our case, six RTGs) to be evaluated. Let there be only one input (e.g. doctoral students) and two outputs (e.g. doctorates and publications). The input–output ratios are plotted for each decision-making unit. The DEA uses all the other decision-making units as reference points to identify the relative efficiency of a decision-making unit. Connecting the decision-making units A, C, E and F, we can construct an efficient frontier. All units lying on this frontier line are efficient and have an efficiency index of 100% – although they display different output structures (e.g. unit A concentrates on output 2 while unit F concentrates on output 1). The units B and D, which are below the frontier, are inefficient. A linear projection of B and D to the efficient frontier shows that both units could realise higher output levels without using

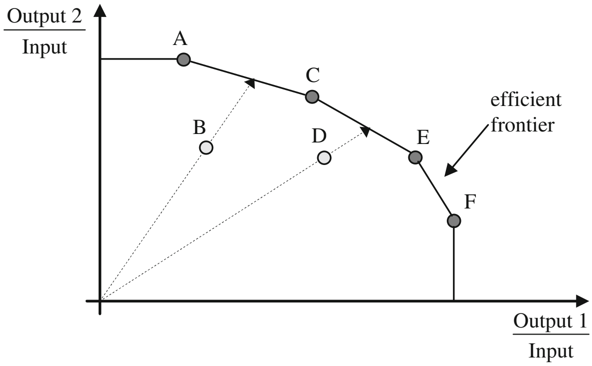

Fig. 5.5 The DEA intuition.
Source: In analogy to Cooper et al. (2006: 9)

more of the input. In fact, unit B realises only about 70% of its potential output, unit D only about 80%. This approach is called output-oriented because it emphasises the maximisation of the output that may be realised with a given amount of input. On the contrary, input-oriented DEA models emphasise the minimum input which is necessary to realise a given amount of output (see Cooper et al. 2006: 58).

Mathematically, the DEA solves the following problem (Charnes et al. 1978: 430):

$$\max h_0 \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{1}$$

h_0 = efficiency index for unit 0
y_r = amount of output r with $r = 1, \ldots s$
x_i = amount of input i with $i = 1, \ldots, m$
u_r = weight for output r
v_i = weight for input i

$$\text{s.t} \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1 \text{ for all } j = 1, \ldots n \tag{2}$$

$$u_r, v_i \geq 0 \tag{3}$$

When the index h for every decision-making unit in the sample is maximised (Equation 1), the DEA endogenously determines the optimal input and output weights from the perspective of the individual decision-making unit. The optimal weights are subject to two conditions. Firstly, the weights that are determined for every decision-making unit must not result in an efficiency index larger than 100%, neither for the decision-making unit under consideration nor for any of the other units (Equation 2). Secondly, all weights have to be non-negative (Equation 3). With the help of these two conditions, the interval for the efficiency index is restricted to a scale of 0–100. An index of 100% stands for relative efficiency and an index of less than 100% for relative inefficiency (see Charnes et al. 1978: 430).

5.4.2 The Input–Output Structure of the DEA Model

As *inputs*, we use (1) the number of fellowship months of doctoral students per year and (2) the number of fellowship months of post-doctoral students per year. Thus, we count how many months in total the DFG supported the doctoral students ("Fellowship months of doctoral students") and, respectively, the post-doctoral students ("Fellowship months of post-doctoral students") of a given RTG. Afterwards we normalise the figures on a year basis. We prefer the number of *fellowship months* as the input variable to the number of RTG *students* in any given year because the former is not susceptible to a fluctuation bias. Table 5.5 presents information on the input variables.

As *outputs*, we include (1) the share of completed doctorates per RTG and year and (2) the number of publications per RTG and year. We exclude presentations because we do not have the corresponding data for our whole set of RTGs. Furthermore, presentations correlate significantly positive with publications (r=0.6, 0.1%-level). As publication data is available for all RTGs in our sample, we include those instead of presentations in the DEA.

We use the DEA specification with the *constant-returns-to-scale technology* (see Charnes et al. 1978) because our data supports the assumption of constant returns to scale per fellowship month – at least for the case of doctoral students whose fellowship months on average account for more than 90% of the fellowship months in an RTG. We use an *output-oriented* DEA model, calculated separately for the

Table 5.5 Input variables for the DEA: descriptive statistics

			Mean		
	Min	Max	Total	Humanities and social sciences	Natural and life sciences
Fellowship months of doctoral students (per year)	73.09	395.27	178.40	172.63	181.19
Fellowship months of post-doctoral students (per year)	0	86.86	12.74	11.91	13.13

Source: Own data

two different disciplinary fields: humanities and social sciences on the one hand and natural and life sciences on the other hand.

5.4.3 DEA Results and Implications

When interpreting the results, it is important to notice that we must not compare the efficiency indices of the two disciplines. The humanities and social sciences would be favoured over the natural and life sciences because of their lower number of RTGs in the DEA leading to a generally larger share of efficient RTGs.

5.4.3.1 Humanities and Social Sciences

Figure 5.6 presents the efficiency indices of the RTGs in the humanities and social sciences. Only four of the 28 RTGs in the humanities and social sciences, reach an efficiency index of 100%; while three of these score highly on publication output (with varying success in the completion of doctoral degrees), one clearly concentrates on the completion of doctoral degrees and is characterised by a comparatively lower publication output. Regarding the average efficiency score of 59.9% and the share of RTGs that operate at a relative inefficiency, the efficiency can still be improved. However, it has to be kept in mind that maybe an RTG scores low on publication output because it concentrates on high-quality journal publications instead of going for "mass production" in lower ranked publication outlets. However, according to our DEA, the lowest performing RTG (efficiency score of 19.8%) was in fact not renewed for a third funding period by the DFG (whose referees should be in a position to evaluate the quality of publications). This hints at the plausibility of our analysis. Furthermore, the average efficiency score of those RTGs in the humanities and social sciences that were not renewed by the DFG is about 10% points below the average efficiency score of all RTGs from the respective disciplinary field in the sample. In the humanities and social sciences, the RTGs with a below average efficiency score have a significantly lower chance of being renewed than those with an efficiency score above average.

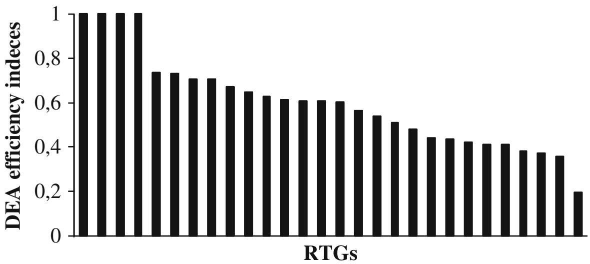

Fig. 5.6 Efficiency indices of the RTGs in the humanities and social sciences. Source: Own data

5.4.3.2 Natural and Life Sciences

Figure 5.7 presents the efficiency indices of the RTGs in the natural and life sciences. Here again, only four of the 58 RTGs in the natural and life sciences reach an efficiency index of 100%; two of these score comparatively highly on doctoral completion rates (with varying success in generating publication output), one is characterised by a comparatively low doctoral completion rate but generates a comparatively high publication output, one actually succeeds in both: doctoral completion and publication output. For the small number of RTGs that operate at a relative efficiency and average efficiency index of 61.7% considerable room for efficiency improvement is hinted at. However, the same caveat as above is still true: Without an adequate measure of publication quality an efficiency analysis of RTGs is generally incomplete and should only be interpreted with caution. However, according to our DEA again, the lowest performing RTG (with an efficiency score as low as 9.6%) was not renewed for a third funding period by the DFG, which hints at the plausibility of our analysis. As was the case in the humanities and social sciences, the average efficiency score of those RTGs in the natural and life sciences that were not renewed by the DFG is below the average efficiency score of all RTGs from the respective disciplinary field in the sample; and RTGs with a below average efficiency score have a significantly lower chance of being renewed than those with an efficiency score above average.

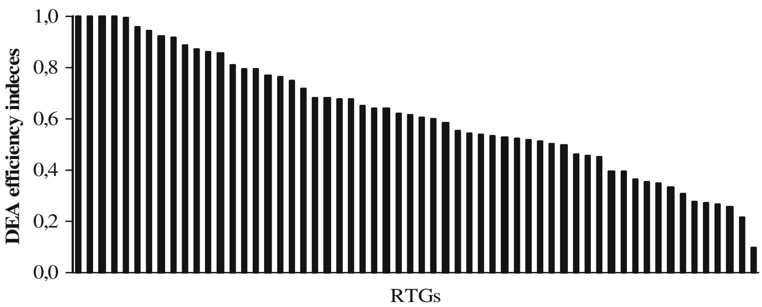

Fig. 5.7 Efficiency indices of the RTGs in the natural and life sciences.
Source: Own data

5.5 Conclusions

Even though Research Training Groups were already established in the early 1990s, their performance has not been evaluated as yet. In this paper, we undertook a first step in that direction and assessed the performance of German RTGs in two different disciplinary fields: the humanities and social sciences on the one hand and the natural and life sciences on the other hand. We did so by assessing (1) the doctoral completion rate and (2) the scientific visibility of doctoral and post-doctoral students as measured by their publication and presentation output. We are able to show that the performance of German RTGs varies considerably in and between the different disciplinary fields: While the average doctoral completion rate of the RTGs belonging to the humanities and social sciences was almost as high as the one of the RTGs belonging to the natural and life sciences, the average publication and presentation outputs both were considerably higher in the RTGs belonging to the humanities and social sciences. An additionally performed output-oriented constant returns-to-scale Data Envelopment Analysis (DEA) with doctoral degrees and publications as outputs and fellowship months of doctoral and post-doctoral RTG students as inputs reveals that there seems to be a remarkable potential for a performance improvement among RTGs in both disciplinary fields.

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Chapter 6
Success and Failure of PhD Programmes: An Empirical Study of the Interplay Between Interests, Resources and Organisation

Peter Schneider, Nicole Thaller, and Dieter Sadowski

6.1 Introduction

In the early 1990s, almost all European countries viewed their doctoral programmes as falling short of the primordial objective of doctoral education: to qualify young academics to do original research on their own. Given that diagnosis, initiatives were taken in many countries to change this dismal situation, with the structured PhD education of American research universities generally serving as a model. Although in many European countries the shifts in their doctoral education led to considerable success, the majority of all economic departments in German universities remained inert (Wissenschaftsrat 2002a; DFG 2003). This reluctance can well be illustrated by the finding of the "German Research Foundation" (DFG 2003) that in 2002 only 2% of all doctoral students in the German social sciences received some kind of structured education, although this is seen as one key element to a stronger research performance (Wissenschaftsrat 2002b). Taking research presentations at important and competitive German conferences as an indicator (Fabel/Lehmann/Warning 2003), PhD students and postgraduates deliver a great part of the scientific research in German economics departments. However, recent research grant allocations by the European Research Council (2008) indicate that the potential of young German researchers is still valued poorly against many other European researchers. It is therefore surprising that, despite political intervention to favour reforms, most German economics departments stick to the traditional master–apprenticeship model (Berning and Falk 2004: 54–55).

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Political interventions in Germany intensify the pressure on departments to reform their educational mode. This intervention occurs at different political levels. The German federal states use indicator models and "Collaborative Research Centres" (e.g. Leszczensky and Orr 2004), while the Federal Government provides incentives through the provision for funds for "Research Training Groups" by the "German Research Foundation (DFG)". Yet initiating change is not free and demands different kinds of resources for success (Thursby 2000). To improve department endowments, competition based on academic achievements for additional financial funding is the primary initiative in the current academic reform efforts in France and, with the Initiative for Excellence by the German Federal Government, even more so in Germany since January 2004. This initiative assumes a shortage of financial resources and that a strong financial foundation will enhance competitive research, leading to changes that promote academic excellence among young scientists.

Each university, or rather each department, has to face these pressures and to decide whether to enter the competition for a strong research orientation and the best young academics. In Germany, the situation may even become dramatic, as the Wissenschaftsrat (2006: 56) suggested prohibiting non-performing departments from awarding doctoral degrees in the future, thus losing a defining feature of university membership.

Success in PhD education is not evenly spread among German economics departments (Welsch and Ehrenheim 1999; Schlinghoff 2002; Mayer 2001: 19); and the correlation between financial resources, research output and PhD graduates in German economics departments is far from linear (Berghoff et al. 2002: 124).

In this paper we present a sample of 14 European economics departments to analyse organisational preconditions for a successful PhD education, which we narrowly define as placement success in universities. We relate PhD education to a set of six resources and ask how they interact with the interests of the department members. Such knowledge should guide any attempt to promote research via PhD education within the paradigm of New Public Management (Grüning 2000; Schedler and Proeller 2000; Schimank 2005). Our sample contains 14 economics departments from Germany, the Netherlands, Switzerland, Italy, France and Great Britain. They were not selected randomly, but according to two discriminating criteria to provide significant variation. According to the ranking of Combes and Linnemer (2003), the first criterion is the research intensity. The second criterion is the PhD production technology: individual master–apprenticeship relationships on the one hand and the more or less structured collective education on the other hand. Both technologies are represented in the sample.

In our data we rely on three different sources to assess organisational characteristics. The first source of information is directly drawn from semi-structured interviews with 43 academic and administrative key persons. They were conducted between May 2005 and March 2007. The second source of information consists of data from curricula vitae which were posted on the websites of the departments. The third source consists of publication records from the database "Scopus". For an extended description of the study design compare Sadowski et al. (2008).

6.2 Linking Organisational Characteristics to PhD Education

6.2.1 Goals and Interests

While the ideology of any university ascribes an unconditionally high value to doctoral education because in this kind of education the Humboldtian idea of the unity of teaching and research reveals itself unambiguously, we gained a different picture from the semi-structured interviews in our case studies. For the sake of brevity we confine ourselves to three real types of preference or goal structures. We identified the departments that are clearly geared towards "scientific excellence", where PhD education is just one part of the efforts to influence the course of science markedly as is shown by publications in highly ranked journals. The second type of department was more modest in its scientific claims and pursued "good education outcome" in order to prepare their students for the general job market. A third group of departments would not deny such aspirations, but perhaps regrettably they essentially considered their PhD students as an indispensable resource to manage the everyday routines of the department: teaching, administration and applied research projects. Table 6.1 provides an overview of the departments according to their goals and their academic placement success, a relationship to be unfolded in detail below.

Table 6.1 Goals and placement success in the sample

		Department goal		
Placement		Scientific excellence	Education outcome	Everyday routine
	Successful	D1, D10, D11, D14	D5, D9, D12, D13	–
	Unsuccessful	–	D2, D3, D4	D6, D7, D8

Note: D1–D14 = the departments of the sample

6.2.2 Resources and Organisational Conditions

The engagement of individuals and departments in PhD education is not only dependent on the preferences and net rewards they can internalise, but also on the resources available in a department. The current political initiatives focus primarily on financial funding as a key element of academic success (BMBF 2004), but recent findings for Dutch departments (Bartelse 1999), French universities (Carayol and Matt 2004, Dahan and Mangematin 2007), or Swiss universities (Osterwalder 2007) emphasise the relevance of additional organisational characteristics like the faculty size for changes in academic behaviour.

We suppose that the following conditions could have an important impact:

- Engaging in PhD education requires time. In order to improve PhD education, professors need extra *time budgets* to offer additional supervision, coursework, or administrative tasks – time that has to be withdrawn from other activities, for instance, the daily routines and duties of a chair and a department.

- A successful PhD education can only occur where a critical mass of faculty is motivated to undertake *intentional extra effort* beyond their daily routines in the "PhD production process".
- Teaching PhD students scientific skills presumably requires supervisors with *research competence*<B></B> to attract PhD students who are interested in serious research and to impart the necessary skills to them. In some economic fields the supervisor's publication record influences the PhD graduates own publications in the early stage of their academic career more than the reputation of the PhD granting institutions (Hilmer and Hilmer 2007).
- Although not all social science research requires large budgets, *financial funding* in general influences the investments in PhD education (Dillon 2005; Graham and Diamond 1997; Gumport 2005).
- The *total number of supervisors* participating in PhD education might be important for a successful PhD education. PhD programmes in Switzerland consider a minimum number of five supervisors as crucial for a successful PhD education (Osterwalder 2007). The reasons given vary. Hilmer and Hilmer (2007) pointed out that greater numbers of supervisors facilitate a successful matching between supervisors and students. Moreover, larger departments ease the switching from one supervisor to another if the relationship suffers (Lovitts 2001).
- The effect of the *total number of PhD students* enrolled in a programme is unclear. Bowen and Rudenstine (1992: 149) identify an increase in PhD completion rates in smaller cohorts, "students enrolled in smaller programs earned PhDs in appreciably higher proportions than students in larger programs". By contrast, Hansen (1991: 1061) found the opposite effect for graduate schools in economics.

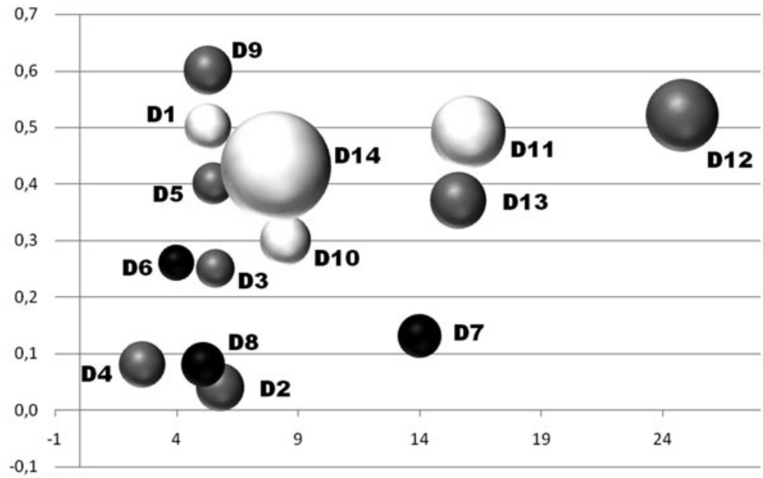

Fig. 6.1 Programme size, goals and placement success (**a**). Note: *y*-axis: placement success; *x*-axis: total amount of PhD students; goals: *black* – everyday routine, *white* – scientific excellence, *grey* – education outcome; bubble size: number of supervisors

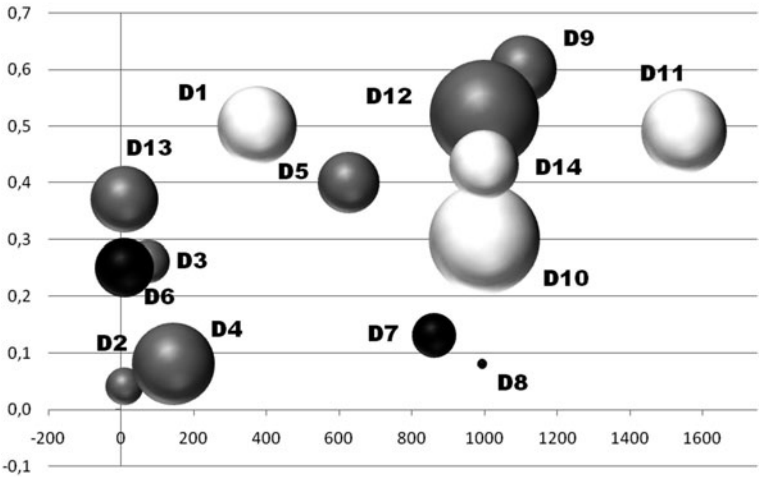

Fig. 6.2 Publication records, financial funds, goals and placement success (**b**). Note: *y*-axis: placement success; *x*-axis: third-party funding; goals: *black* – everyday routine, *white* – scientific excellence, *grey* – educational outcome; bubble size: publication records of the faculty

Two graphic representations of our case study observations show that there are no easily recognisable patterns separating more successful departments from less successful departments (the *y*-axis gives the quota of PhDs entering academia) according to their educational goals – marked by colours – and programme size (number of students: *x*-axis; number of supervisors: size of the circles in Fig. 6.1). Figure 6.2 shows the relationship between placement success and third-party money (*x*-axis) as a proxy for available financial resources, mediated by the faculty publication record (circle size) and educational goals (circle colours).

6.3 Empirical Patterns

6.3.1 The Method: Exploiting Case Study Evidence by QCA Analysis

In order to analyse qualitative and quantitative data for small-N cases, we use Qualitative Comparative Analysis (QCA), which was developed by Charles Ragin in 1987, as well as Multi-Value Qualitative Comparative Analysis (MVQCA) (Brayton and Khatri 1999; Berg-Schlosser and Cronqvist 2005; Cronqvist 2007a, b), which is an enhancement of QCA. QCA and MVQCA allow statements about minimal conditions that produce a certain outcome in a given sample. There may be one or several necessary factors or conditions that are associated with a certain outcome; there may be a condition that by itself is observed whenever the outcome is observed. In its classic version, QCA treats only dichotomous conditions and outcomes: a condition or outcome is given or not, the variable taking the value 0 or 1.

The analysis of an observed configuration then means recording the variable values that go together and identifying the minimal conditions that produce a certain outcome. While QCA only allows calculations for dichotomised input variables, MVQCA extends the procedure to multiple but still nominal characteristics in the input variables, hence allowing more differentiated configurations.

> QCA essentially looks for consistency across cases rather than looking for non-random patterns. The method asks completely different questions of the data than inference statistical approaches do. The latter ask: Is there a factor, which ceteris paribus is over-randomly associated with the (non-) occurrence of a result Y? QCA asks: Is there any factor (-combination), which is associated with the (non-) occurrence of result Y without logical contradictions? (Liebmann 2008: 93).

The logical consistency is tested with Boolean operators. It is calculated whether a case is consistently a member of a set or an intersection of factors. Starting from the cases, their characteristics are rewritten as a truth table. Both QCA and MVQCA can be conducted through the free software TOSMANA (Cronqvist 2007a, b).

6.3.2 Variables

For our study, we collected the conditions of placement success, the input variables, for the period of 2001 and 2003. We relate them to the average placement success between the years 2002 and 2006. We assume that on average PhD education takes 5 years. Both QCA and MVQCA are easy to apply to nominal data. This can be explained by the nature of a variable such as "male/female" or "blue/green/yellow". When continuous values must be transformed into nominal characteristics, clear criteria are necessary to set thresholds of the discrete conditions. In the case of continuous variables TOSMANA offers thresholds to break up the data into nominal values by clustering the data accordingly. Where necessary, in our study continuous data were transformed based on the mathematical thresholds given by the program.

6.3.2.1 Outcome Variable: PhD Placement Success

The dependent (outcome) variable in the study captures the success of PhD graduates in the academic world. In contrast to earlier studies and approaches, which either base their success measure on the publication records of young professors (Rauber and Ursprung 2006; Mayer 2001; Heining et al. 2007), the total number of graduates, or the reputation of a graduate school (Ehrenberg 2004; Burris 2004), we consider the proportion of PhD students who have been hired in a post-graduate position within a university, thus neglecting the many young doctors who entered the non-academic labour market, often by choice.

We tried to identify all PhD graduates in our sample departments for the years 2002–2006 and to follow each career path. An average ratio of 0.3 indicates that three out of ten PhD graduates had been placed in academia within the time span under consideration. In the QCA spirit of dichotomising variables, we set this threshold according to the clustering of the data in MVQCA as a mark of the difference between successful and failing PhD programmes in relation to research.

6.3.2.2 Input Variables: Organisational Conditions

The *time budget* was assessed by calculating the proportion between the academic personnel employed at a department and the number of undergraduate students. A ratio of 1:10 means that one person in the faculty has to supervise ten undergraduate students. The higher the ratio is between the scientific personnel and the undergraduate students, the lower are the time capacities for the supervisors to engage in PhD education.

The figures for the scientific personnel were drawn from the internet presentation of the sample departments and include all junior and senior researchers (e.g. teaching assistants, research assistants, lecturers and assistants, associate and full professors) associated to an economics department.[1] Since professors of economics have to teach undergraduate students enrolled not only in economics but also in business studies, the student numbers represent all undergraduate students in economic sciences at the relevant universities in the year 2001.[2]

In Germany, the average teaching load of a professor is 8–9 h per week per semester. Interview partners from the European sample mentioned far lower undergraduate teaching loads leaving them more resources to engage in alternative activities,[3] so we considered them as having large time budgets. The variable values were divided by MVQCA according to its threshold setting into three categories:

0 = more than 99 students per faculty member teacher have to be taught;
1 = between 50 and 99 students have to be taught;
2 = less than 50 students have to be taught.

To assess the motivation of a critical mass of faculty in order to invest *intentional extra effort* in PhD education, i.e. engaging in additional administration tasks, attracting extra funding, teaching post-graduate seminars, supervising several PhD students, we rely entirely on the judgments of our interview partners. We coded the variable according to the statements of our interview partners who stated whether they felt that there was sufficient faculty effort invested in the tasks involved in PhD education to keep it running or whether there was too little effort invested. The variable assumes two values:

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[1] For German departments it excludes doctoral students that do not have to teach at a department and hence do not contribute to extra time budgets by alleviating the supervisors' teaching load (e.g. PhD students in "Graduiertenkollegs" or external PhD students).

[2] Data from: http://www.wissenschaftsrat.de/texte/5455-02-2.pdf

[3] For example: A rough teaching load for German professors of 216 h per year corresponds to a teaching load of 100 h in the British department which can even be reduced according to "workload models", whereas teaching usually can not be reduced by German professors.

0 = insufficient faculty effort at improving PhD education;
1 = critical mass of faculty members invests effort to improve PhD education.

To assess *research competence*, we started with the rankings of Combes and Linnemer (2003), complemented by Kalaitzidakis et al. (1999). Yet some of our sample departments do not show any publications in these rankings, for those we refer to the data from the "Scopus" database. Scopus not only contains all relevant international refereed publications of the "Web of Science" and "Econlit", but also adds refereed national journals – as long as they have English abstracts, providing us with a more detailed picture of the publication activities and research competences in our departments.[4] Since the database for MVQCA requires data on a rather aggregated level, publications are not weighted according to the journal rank, the number of authors or published pages as this has been done by Coupé (2003) and Rauber and Ursprung (2006). The variable values were divided by MVQCA into two categories:

0 = less than 1.9 publications per supervisor between 2001 and 2003;
1 = more than 1.9 publications.

To assess *financial funding*, the yearly budget of a department would serve best, but this data is not available. We therefore rely on data of additional research funds as a rough approximation. The most recent dataset for Germany is available for the time period between 2001 and 2003 and comprises several different funding sources (Berghoff et al. 2006). The data of third-party funds for the British department is comparable to the German sample and can be drawn from the website of the Research Assessment Exercise (RAE 2008). It does not comprise exactly the same time span as the German data, but total third-party funds of our English department had continuously risen over the years (from 1995 to 2001) and lie above the third-party funds of the German departments with the highest funding.[5]

The variable was divided into three categories according to the three tier classification of third-party funding of German economics departments between 2001 and 2003 of the Centrum für Hochschulentwicklung (CHE)[6] (Berghoff et al. 2006):

[4]All the departments in our sample which score high in Scopus are also listed in the ranking by Coupé (2003: 83–84). This indicates congruence between the current sample and the analysis by Coupé although they rely on different bibliographic databases.

[5]For the departments in Italy, France and the Netherlands public data for third-party funding was not available. We therefore asked the heads of PhD programmes or deans for the amount of third-party funding in their department.

[6]The "richest" German departments in our sample belong to the seven German departments which receive in total about 52% of the entire third-party funding of Germany's economic departments (first tier); in addition, 17 departments receive the next 40% (second tier); and 21 departments receive the remaining 10% of the entire research funding of Germany's economic departments (third tier).

0 = less than €200,000 for each department per year;
1 = between €200,000 and €850,000 per year;
2 = more than €850,000 per year.

The *total number of supervisors* represents the number of people having the right to train PhD students.[7] For German departments, the faculty size was assessed relying on the list of Rauber and Ursprung (2006: 39–41) and on our own calculations from the department websites. For the non-German sample we took the figures from the official websites of the departments. The variable was divided into two categories by clustering the data through MVQCA:

0 = no more than ten supervisors at the department;
1 = more than ten supervisors at the department.

To assess *the total number of PhD students* at a department, we constructed a new dataset. We received the number of all doctoral students of the departments in the sample who had graduated between 2002 and 2006. Since the number of graduating PhD students may vary in some departments over the time frame,[8] we use the average number of graduations over the 5-year period for each department. The variable was divided by MVQCA into three categories:

0 = on average there are five or fewer PhD graduates per year;
1 = between six and 13 PhD graduates per year;
2 = more than 13 PhD graduates per year.

To classify a department according to its goal structure which distinguishes between the *goals of* "scientific excellence", "education outcome" and "everyday routine", we had to condense the characterisations given by our interview partners. Exceptionally interviewees deviated from the general department line to develop their own methods of educating PhDs. For MVQCA, the goals were coded into three categories:

0 = everyday routine;
1 = education outcome;
2 = scientific excellence.

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[7] At a German department the number of supervisors equals the number of professors at a department; in Great Britain, PhD students can also be supervised by "lecturers" not holding a PhD themselves; in France, also CNRS researchers can supervise PhD students under certain conditions.

[8] Differences in total PhD graduations within the same department over several years are very heterogeneous (e.g. between 7 and 29 or 2 and 19).

6.4 Results

6.4.1 Conditions for Placement Success

An MVQCA was then conducted with outcome = 1 (including logical remainders).[9] To preserve department anonymity, we show only the configuration table (Table 6.2). The results for successful departments are demonstrated in Table 6.3.

In our sample, successful PhD education was observed with regard to two different conditions, or to put this in bolder terms but risk exaggeration: "it can be explained by two resource patterns and three resources". The first pattern for success is given for the departments D1 and D5; a medium level of financial funds (R1 {1}) is a concomitant of a successful PhD education. The pattern for success comprises, in addition to department D5, also the departments D9, D14, D11, D12 and D13: here, a successful PhD education is a concomitant of intentional extra effort made by a critical mass of faculty (R2 {1}) in combination with enough additional time (R3 {2}).

The results indicate that in our sample only a small set of resources is necessary for a successful PhD education. Financial funds – third-party funds in our crude

Table 6.2 Configuration and multi-value truth table of resources for outcome = 1 (placement success)

Goal (G)	Funds (R1)	Effort (R2)	Time (R3)	Research (R4)	Supervisors (R5)	PhDs (R6)	Outcome (O)	Department (ID)
2	1	1	1	1	0	0	1	D1
1	0	1	0	0	1	1	0	D2
1	0	0	0	0	0	0	0	D3
1	0	1	1	1	0	0	0	D4
1	1	1	2	1	0	1	1	D5
0	0	0	0	0	0	1	0	D6
0	2	0	2	0	0	2	0	D7
0	2	0	1	0	0	1	0	D8
1	2	1	2	1	0	1	1	D9
2	2	0	2	1	1	1	0	D10
2	2	1	2	1	1	2	1	D11
1	2	1	2	1	1	2	1	D12
1	0	1	2	1	1	2	1	D13
2	2	1	2	1	0	1	1	D14

Note: G: Department goal, R1: Financial funds, R2: Intentional extra effort, R3: Time budgets, R4: Research competence, R5: Total supervisors, R6: Total PhDs, ID: D1–D14, departments in the sample, O: Outcome

[9] "Logical remainders" are non-observed configurations which could theoretically be observed. TOSMANA software uses them for its minimising algorithm as an intermediate step. When the logical remainders are included, a hypothetical matrix is constructed which contains all possible combinations given the number of conditions and the scales chosen in the sample.

Table 6.3 Formulas and factors for outcome = 1 (placement success)

Variable label	Cases
Financial funds {1} + Extra effort {1} • time budgets {2}	(D1, D5) + (D5, D9, D14, D11, D12, D13)

Note: Level of the independent variable in curly brackets. "+" means logical OR; "•" means logical AND

operationalisation – are of importance (solution 1) but not necessary. Financial funds can be traded off against intentional extra effort in PhD education (R2 {1}) in combination with sufficient time budgets (R3 {0}, solution 2). The departments D7, D8 and D10 in Table 6.2 show that a high level of funding is not sufficient for successful training; neither is a low level of funding for D13 detrimental as such. PhD education is seemingly not a routine process that develops as soon as sufficient funding is provided. In fact, the motivation of a faculty to engage in extra activities in order to improve education makes the difference when departments at least award sufficient time budgets to their professors. So neither a high level of funding nor, according to Hilmer and Hilmer (2007), research competence is sufficient for a successful PhD education. All successful departments have a faculty with a strong publication record; this is true, but so do D10 and D4 without a placement ratio beyond the success threshold. Department D10 is strong in publishing, and has a high level of funding and great time budgets, but it lacks a critical mass of faculty to exert extra effort for PhD education. Department D4 on the other hand also has a faculty with a very strong publication record and a high level of motivation to put in extra effort, but they have too little financial support (Berghoff et al. 2002, 2006) and too little time, conditions which place them among the failing PhD programmes.[10] The goal orientation confessed or conceded in interviews only partly explains successful PhD placements. In fact, the two most successful departments are the departments D9 and D12 (see Figs. 6.1 and 6.2) which do not strive explicitly for scientific excellence. For them – as well as for the departments D5 and D13 – a successful PhD placement is just a side effect of their attempt to raise the overall quality of their PhD students. Department D10, which pursues academic excellence, does not generate high placement ratios. One trend seems clear, though: The departments that regard PhD education merely as a means to manage their day-to-day routines do not achieve academic placements for their graduates.

Contrary to our conjecture, higher numbers of supervisors are not a necessary condition for successful PhD placements. In our sample, the number of supervisors in a department spanned from 6 to 70 people. Since the latter number was an outlier,

[10]Two additional MVQCAs were calculated as robustness checks with new thresholds for "research competence" where we varied the time period of the publication record. One was extended to a period of 4 years from 2002 to 2005 and the other one was extended to a period of 6 years from 2000 to 2005. The results of the two additional calculations remained the same, indicating the reliability of the thresholds for the publication measure.

we used the median of 10.5 people for a sensible split of the faculty size. To capture different size effects with the clumsy categorical coding of MVQCA, we ran four additional MVQCAs with different thresholds.[11] Each additional MVQCA yielded the same results as the original calculation.

6.4.2 Conditions for Placement Failure

In addition to identifying the conditions for a successful PhD education, MVQCA also lends itself to the analysis of the opposite outcome, namely to identifying the conditions for a low PhD placement success. We again use the raw data of Table 6.2 and concentrate now on outcome “0”. The results are shown under “formulas and factors” in Table 6.4.

The MVQCA yields two results with altogether four separate resource patterns underlying unsuccessful departments. Failing departments either have an insufficient number of faculty prepared to make an extra effort for PhD education (R2 {0}), or they do not have enough time beyond their daily routines (R3 {0}), or they have only a few graduates per year (R6 {0}), or their faculty has a low research competence, as measured by publications (R4 {0}).

Given the MVQCA of our sample departments, these four resources make up the irreducible list of factors concomitant with low placement ratios, they cannot be compensated for by factors that contribute otherwise to the success of departments. For example, department D2 exhibits a critical mass of faculty motivated to engage in PhD education (R2 {1}), but their low time capacities (R3 {1}) or research background (R4 {1}) separately inhibit success in PhD education.

Department D8 disposes of high financial funds (R1 {2}) in accordance with a medium level of time constraints (R3 {1}) and a medium level of yearly PhD graduates (R6 {1}), which at first glance seem to be sufficient for a successful PhD education. Yet the results reveal that, even with these apparently positive resource

Table 6.4 Formulas and factors for “outcome = 0” (placement failure)

Variable label	Cases
Extra effort {0} + time budgets {0} + total PhDs {0}	(D3, D6, D7, D8, D10) + (D2, D3, D6) + (D3, D4)
Extra effort {0} + research competence {2} + total PhDs {0}	(D3, D6, D7, D8, D10) + (D2, D3, D6, D7, D8) + (D3, D4)

Note: Level of the independent variable in curly brackets. “+” means logical OR

[11] One splits at less than or equal to nine supervisors since this figure represents the average size of supervisors of our German sample. A second one splits at less than or equal to 13 supervisors since this figure represents the mean level of our sample. In addition, we tested a third one for less than and equal to eight supervisors to capture smaller departments and a fourth one with less than or equal to 15 supervisors to capture the effects of large departments.

patterns, the absence of a critical mass of faculty making a joint effort for PhD education (R2 {0}) or the low publication record (R4 {0}) independently have a negative impact on the placement ratio (outcome = 0). A similar picture can be found for department D4 which has a critical mass of faculty engaging in extra activities to favour PhD education (R2 {1}), a good research background (R4 {1}), and a medium level of time capacities (R3 {1}); yet the low level of yearly PhD graduates (R6 {0}) appear to inhibit placement success.

Department D10 finally is in a similar situation where the pattern of positive resources (R1 {2}, R4 {1}, R6 {1}) initially would hint towards a successful PhD education, but the absence of a critical mass of faculty to engage actively in PhD education (R2 {0}) is the sole source for failure.

In contrast to successful departments where only two resource patterns "explain" the placement success of PhD graduates, unsuccessful departments are characterised through four single resource patterns.

One resource in particular seems to decide on success and failure: a critical mass of faculty motivated to engage in extra activities in favour of PhD education. Otherwise, not even the best financial situation guarantees success, as the results for D7, D8 and D10 demonstrate.

Furthermore, the lack of effort to engage in a structured PhD education is crucial for failing departments. Departments that are trying to alter their PhD education, but cannot draw on a crucial number of colleagues, do not succeed. But even if departments have a critical mass of faculty willing to join in, one unfavourable condition out of the decisive ones will be detrimental for a positive outcome (D2 or D4).

It is worth noting that a positive outcome effect of one variable does not automatically induce the opposite outcome effect for the opposite level of the variable. While, for example, a low publication record is sufficient to explain failure (D2, D3, D6, D7, D8), strong publishing records are a necessary (D1, D5, D9, D11, D12, D13, D14) but not a sufficient condition for successful departments (D4, D10). Accordingly, while a medium level of financial funds favours a positive outcome, neither a high nor a low financial level determines the outcome. Departments with high funds (D7, D8) also deliver low success rates, and departments with moderate financial funds can deliver successful students (D1, D5). Even a low financial budget does not necessarily prevent a department from achieving success (D13).

6.5 Conclusions

For a non-random sample of economics departments we analysed the impact of six – roughly coded – organisational conditions on the placement of their PhD graduates in academia, taking into account that departments might differ in their goal orientation.

Only a few patterns of resources are extracted as crucial for placement success, while failure is concomitant to varied organisational conditions. It is of little surprise that departments who view their PhD students essentially as means to manage their everyday tasks do not succeed in opening academic careers for them. According to our interviews, the three departments with scientific excellence as their major goal are not directly financially compensated for the number of PhD graduates. Monetary incentives for each faculty member of any of these three departments to engage in PhD education perhaps lie in their own better future career opportunities, including higher remuneration. But even disregarding individual long-term monetary motives (Prendergast 1999), the prestige gained by successfully placing PhDs within the reputational hierarchy of institutions (Burris 2004; Frey et al. 2001) has its own value in a competitive world (D11, D1). The spirit of competition can also be a part of the self-concept of supervisors (D10), creating constant comparisons with departmental colleagues and the scientific community and also between PhD students, the high pressure perhaps being one of the causes of the apparently high effort and the excellent research.

Financial or advanced academic career opportunities through PhD education are also incentives for departments pursuing improvements in economics PhD education and lead to success in PhD placements (D12, D13). Such competition is sometimes explicitly regulated through advancement in the career hierarchy within the departments.

A second group of departments pursues the goal of raising the intellectual skills of their PhD students to "only a good level". As our interview partners indicate, placement success in universities or private enterprises or public services is of equal value to supervisors and serves as a measure of success for the supervisor. This group consists of departments successfully placing PhD students in universities (e.g. D5, D9, D12, D13) and, not altogether surprisingly, along this criterion unsuccessful departments (e.g. D2, D3, D4). They all conducted some form of structured education although they were not necessarily pure graduate schools. This implies that neither the teaching technology nor the goal orientation by themselves decide on placement success.

The importance of the organisational conditions can be well illustrated by the example of department D4, whose faculty is highly motivated to reform its PhD education and has a strong research background, but faces a very heavy teaching load, preventing it from investing the minimum time necessary for changing academic and administrative elements in its department.

While only a small set of two organisational configurations enhances PhD education in our case studies, the picture for failure was more complex. Four single conditions explained an unsuccessful PhD education, which means that an improvement in one condition does not necessarily lead to an improved situation for the departments if one of the other three resources remains in a poor condition. One main element certainly is the lack of motivation of a critical mass of potential supervisors to engage in PhD education (e.g. D3, D6, D7, D8 and D10) voluntarily. But even if this focus changes, one still has to face the next challenge, like small research output (D3, D6, D7, D8), or heavy workloads (D3, D6). In sum, our case studies shed new light on the organisational conditions of the departments engaging in an academically successful PhD education. Contrary to former assumptions, neither the production system of PhD education – whether it follows a master–apprenticeship model or relies on a structured education – nor the preferential weight given in the departments to scientific excellence or the employability of graduates in the general labour market fully explain observed variations in the departments ́academic placement success. There are rather dominant configurations of motivation and resources. The motivation to engage in extra work and sufficient time are crucial factors to explain both a successful and an unsuccessful PhD education. Should policy-makers try to improve research-oriented PhD education, they have to implement incentives for departments and supervisors to focus on academically successful PhD students by tying financial funding to research output and allowing for the time to do research and a PhD education geared towards scientific progress.

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ERRATUM

Erratum to: Governance and Performance in the German Public Research Sector

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Unfortunately, the author name is printed wrongly as "**Liudvika Leiðytë**" throughout this book. The correct spelling of the author is "**Liudvika Leišytė**".

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Summary and Conclusions

Dorothea Jansen

As pointed out in the introduction, the rationale behind this volume is the evidence of huge differences among disciplinary fields with respect to their conditions and requirements for knowledge production (cf. the profiles of astrophysics, nanotechnology, biomedical technology, and economics in the appendix). It is still an open question in this context, how the changes in the governance structures of the German research system interfere with disciplinary differences. Thus, the papers set out to contribute to our knowledge on disciplinary differences for a wide array of disciplines in knowledge production (Schubert and Schmoch; Broemel et al.; Jansen et al.; Kehm and Leiðytë) and in the production of an essential intermediary product of science, junior researchers and their doctoral research (Unger et al.; Schneider et al.). As particularly Chapter 2 by Broemel et al. points out, neither disciplinary differences nor potential interactions with new governance instruments are considered in due extent by science policy yet. Therefore, one can expect that unintended consequences of science policy will be a frequent phenomenon. It is an important aim of this book to point to these problems and to contribute to an improvement of science policy alongside scientific analysis and presentation of our evidence.

Chapters 1 and 2 both focus on the interrelations and interactions between different levels of the research system. Their central thesis and result is that (positive) effects at one level of the system can be counteracted by consequences at another level. This problem is dealt with from a legal perspective in Chapter 2 and exemplified by an analysis of empirical and legal aspects of formula- and performance-based allocations of research resources. Under the old university acts there was neither for the states (Länder) nor for the university president a need to allocate resources to faculties and research units top-down. Universities, the large extra-university science organisations and the German Research Foundation (DFG) used to be organised along disciplinary differentiation, as a reflection of disciplinary differences in conditions of knowledge production and standards of research performance. Those had to be taken into account in negotiations on the appointment of academics or the evaluation of research proposals. The new flexibility gained

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with the global budgets and the establishment of performance-based allocations of resources by the amendments of university acts at the level of university–Länder relationships and within universities for the first time created a need for university executives to allocate resources to faculties and individual academics in a strategic and incentive-compatible way. While discipline-specific indicators and / or weightings are largely absent at the state level of the system, roughly half of the universities use weightings for formula-based models and at the faculty-professor level most models acknowledge the peculiarities of disciplines and their standards of performance and outputs.

However, as Broemel et al. discuss in more detail, these differences across the interacting levels generate strong tensions in the research system. From a management point of view, one could only expect the top level of the university to pass down the criteria underlying the state allocation of resources to the university, to the faculties and other university units. This does not only absolve them from responsibility for the allocation, but also passes gains and losses to those units which contributed to them. Albeit, this will result in distortions and disadvantages for departments and disciplines which for example do not need many research resources and are low in third-party-funds, for those that cannot publish in peer reviewed journals, since this is not a standard journal format, or for those whose publications are not covered by the large bibliometric databases (e.g. monographs, edited volumes, editions of historical documents, etc.). This can put strong centrifugal power on universities which may even dissolve into a system of more or less independent stratified schools of varying status and wealth. Exemplifications of such problems can be observed in the debate on the so-called small disciplines which are neither attractive in third-party income nor in student numbers for universities and may end up on the list for closure. Thus, even if the authors observe empirically that, the lower the level is, the more disciplinary specifics are acknowledged, this does not really solve the problem in the long run. Of course universities might develop discipline-sensitive models and this will contribute to compliance with and legitimacy of the newly introduced procedures. But in the long run, as Broemel et al. suggest, the only actor capable of providing public goods is the state. Universities competing for formula-based allocated resources within a Land cannot be expected to refrain from passing down the incentive structure that has been put on them and, thus, to neglect their own interests. As the German Federal Court has pointed out, the conformity of performance-based allocations of research resources with the constitutionally guaranteed freedom of science depends on the establishment of academically adequate procedures. This implies taking the disciplines' intrinsic rationalities and production logics into account. In addition, the Court states that appropriate involvement of representatives of academia in the setting up of the procedures is essential. Thus, the often used unilateral approach of the Länder (e.g. Rhineland-Palatinate, North Rhine-Westphalia) is in conflict with the basic law. The Länder are called on to engage in an open dialogue on a reasonable indicator system not only with the universities but also with representatives of academia and the academic professions. These calls for the involvement of academia and consideration of discipline-specific rationalities and production processes also extend to the models within universities. Given the complexity of the subject and the danger of mismanagement, Broemel et al. call in addition for an evaluation of the newly introduced instruments with respect to their effects on research performance and on institutions.

Chapter 1 presents additional evidence on the risks of intervening into complex multi-level systems from the perspective of social sciences. Schubert and Schmoch analyse the effects of various instruments from the New Public Management (NPM) context that are introduced to establish "more autonomy, more hierarchy and more competition" within the German university sector. They start from three theoretically derived performance patterns, i.e. the transfer-oriented scheme, the graduate-teaching oriented scheme and the publication-oriented scheme; and they pose the question as to how these three missions attributed to universities nowadays are affected by an increase in autonomy, hierarchy and competition. An important finding underlining the problems of steering complex systems is that by and large the transfer-oriented scheme is affected most by the new internal steering instruments but much less by competition. Thus, internal steering seems to be focused on establishing the "Third Mission" within universities. For all performance profiles the effect of percentage of third-party funded research has a curvilinear shape. While performance first increases with the quota of third-party funded research, it decreases after a specific threshold. This result confirms evidence from former studies based on a smaller sample and raises questions on the rationality of further decreasing basic state funds for universities. The introduction of additional accounting schemes (cost-performance accounting) definitely seems to be a burden rather than a gain for all types of performance profiles. More autonomy (flexible personnel) is an advantage for the old academic mission schemes such as graduate-teaching and publishing but not for transfer. The performance in the publishing profile is the only one positively affected by regular evaluation procedures.

In the second part of Chapter 1, the authors align their results with reasoning about the mechanisms shaping scientific production. They conceptualise the scientific production system as a partly self-dependent system which produces its own input such as junior researchers and infrastructures for communication, publication and technology transfer. These intermediary and infrastructural products tend to be public goods. Postdocs usually leave the faculty that trained them and journal editors are not paid much. Thus, the appropriation of benefits from this work is much more difficult than from publications and citations. One can assume that researchers who are quite autonomous in the choice of their tasks will engage in tasks that are honoured in an adequate way. In addition, a trend towards specialisation along one's strengths and resources can be expected to take place and to increase the efficiency of the system. However, if formula-based performance-related allocation models do not take into account the value of intermediate products, researchers will opt out of them and focus on those tasks that are valued adequately. The expected pattern of specialisation is indeed confirmed by a factor analysis and an additional cluster analysis. Next to the three expected performance schemes, a large cluster without specialisation is found which is below average in all performance dimensions. From their reasoning and the empirical evidence presented, Schubert and Schmoch deduce a model system that aims to take adequately into account publication-related outputs, transfer- and infrastructure-related outputs and graduate-teaching related outputs. They recommend using this list as a starting point for the construction of a broad indicator system. Additionally, this system must be watchful of disciplinary differences. Thus, empirical evidence allowing improvement of established formula-based models which may look suitable in the short run is at hand. However, science policy may not run into the pitfall of neglecting the complexity of the science system. Schubert and Schmoch thoroughly argue that science policy must not consider research groups as "lonesome riders" but has to take into account their dependence on each other in a differentiated system. If NPM instruments fail to consider these interdependencies they may still enhance individual research performance but disturb the functional balance of the system. The system will then focus only on valued outputs (e.g. publications or industry cooperation) at the cost of a loss in specialisation, the lack of well-trained junior researchers, and adequate infrastructure for mutual exchange and distribution of knowledge.

The papers from Part II explore the interactions between the level of universities and research organisations and the microlevel of doing research in more detail. In their paper on the effects of new forms of governance on the humanities presented in Chapter 4, Kehm and Leiðytë present a case study on medieval history traditionally seen as a typical Mode 1 field, characterised by knowledge production in long-term research, based on curiosity-driven individual scholarship. Jansen et al. (Chapter 3) instead focus on the concept of Mode 2 of knowledge production. They provokingly raise the question whether the new Mode 2 of knowledge production is actually fact or fiction. In particular the Mode 2 concept claiming that complex tasks are best performed in trans-disciplinary transient networks including industry and other stakeholders finds strong resonance in science policy. It complements the managerial turn of science policy which readily took up discourses in science and technology studies arguing for a new mission and increased accountability of science. In contrast to researchers pursuing the "truth", stakeholders were seen in the role of defining demand-driven criteria of functionality. Jansen et al. suspect that science policy adopted this model and increasingly shaped their policies after it – thereby turning the Mode 2 concept into a self-fulfilling prophecy.

To corroborate this thesis, the paper presents evidence from a detailed comparison of strategies and resources of research groups from three fields exemplifying a typical Mode 2 field (nanotechnology), a Mode 1 field characterised by research processes driven by scientific relevance and curiosity (astrophysics), and, as a contrast to these two natural science fields, economics as a social science. Looking into five characteristic criteria for the Mode 2 of knowledge production, they find that nanotechnology chooses subjects of application relevance more often than the two other fields and that the research teams more often come from different disciplines. However, the application context is much less relevant than either own ideas or scientific relevance. Research networks are more heterogeneous with respect to disciplines, while the differences in percentage of research partners from a different discipline are not significant. Research networks are not more heterogeneous in their institutional mix nor are the teams less hierarchical than in the other fields. Both, nanotechnologists and astrophysicists show a strategic choice of research partners more often than economists. In line with the Mode 2 idea of transient networks, nanotechnologists also choose their research partners more often from an open pool of colleagues, while astrophysicists rely on a closed pool of potential collaborators.[1] In addition, the cooperation with industry partners in research networks is significantly higher than in astrophysics (but not economics).

However, scientific relevance and truth-seeking still play a strong and increasing role in research choices of nanotechnologists. Research devoted to basic science amounts to two thirds of research-time budgets, while application-oriented research amounts to roughly a fifth. Thus, the authors conclude that a clear-cut differentiation between Mode 1 and Mode 2 cannot be established given the empirical data. They rather find a continuum between Mode 1 and Mode 2 with a high relevance of basic research and scientific quality in all fields under study. Referring to the differences in growth, dynamics, and interdisciplinarity of outputs (cf. Appendix A and B) and in the network structures and strategies between nanoscience and astrophysics, the authors conclude that intrinsic disciplinary differences in knowledge production and dynamics are relevant mechanisms behind the observed differences in the three fields. Albeit, complementing this argument of Bonaccorsi (2008), the importance of heterarchical transient networks and science–industry relationships in nanoscience is also due to science policy given the huge amounts of funding of a Mode 2 type of nanotechnology research.

These policy pressures are reflected in the data on the influence of third-party funding on network formation and in the proportion of research time that is spent on working on projects funded by third parties. For nanoscientists, the dependence on third-party funding and its effect on research lines are significantly higher than in other fields. In addition, nanoscientists report significantly more often on third-party funding asking for the choice of industry partners. This trend has even increased in the past 2 years. As the paper shows, this pressure from science policy is even strong enough to drive research groups into unproductive networks. While up to some small proportion of industry ties industry collaboration can enhance research performance, the research performance decreases beyond a specific threshold. Thus, the policies promoting a Mode 2 type of research may well be counterproductive and harm scientific output. The logic behind this policy – fostering science–industry ties will lead to innovations – is a too simple one. Other factors such as the openness of industry for science, and its responsiveness to disciplinary conditions of knowledge production have to be added if collaboration shall be successful. After all, successful collaborations tend to develop bottom-up and, next to mutual respect and understanding, build on heterogeneous competencies and resources of the different partners.

In their paper on the effects of new governance on the humanities, Kehm and Leiðytë discuss a case of a classical Mode 1 type of knowledge production, medieval history. While the discourse on the crisis of the humanities, which is seen to

[1] However, these are actually strategies which fit quite well to the differences in the production logics of the two fields as is shown by the authors elsewhere (Jansen et al. 2010).

be losing ground in the competition with more "useful" disciplinary fields goes back to the early 1970s, the empirical evidence presented by the authors shows an astonishingly healthy and strong picture in all four countries under study. The percentage of overall funding for the humanities by the research foundations was more or less stable in Germany and Austria with a considerable absolute growth of funds, while in the Netherlands and particularly in the UK both the proportion of funding and the absolute amount increased. Thus, the authors come to the conclusion that the crisis of the humanities is largely "talk" and a reflection of governance changes that some researchers perceive as a threat to their field, while for others it is simply a modernisation and complementation of traditional forms of doing research in the humanities. This diagnosis is corroborated by the findings of the authors' in-depth studies of two research groups from each country, a stronger and a weaker one respectively. Medieval history studies a broad spectrum of political, social, cultural and economic phenomena in the Middle Ages. Archives assembling primary sources such as diaries, acts, documents and artefacts are important for them, but are increasingly complemented by virtual archives and the use of information technology. Maybe as a result of the many sub-disciplinary facets of research interests, a partial change from the traditional "lone scholar" model type of research towards larger and inter-disciplinary research groups can be observed. However, inter-disciplinary collaboration and integration of research into larger centres has become an important criterion of allocations of funds, too. Thus, it is difficult to discern cause from effect here. In all countries considered, the field has successfully raised public interest in the relevance of understanding of the historic footing of globalisation and technological developments in the Middle Ages. By now, successful academic entrepreneurs concentrate their research on externally defined relevance and manage to diversify their funding sources.

While the pressure for relevance and short-term results seems to be the highest for medieval historians in England and results in mainstreaming of research, the academics in the other countries under study manage to get along with strategic compliance in selected issues such as redressing one's research interest according to the funders' priority or publishing chapters from a planned book as journal articles in advance. Dutch faculties are still a collection of individual researchers and individual research is still frequent in Austria. Austrian directors of research centres and deans even seem to see it as their duty to prevent too much intervention from above into the choices of research topics. However, Kehm and Leiðytë observe changes in research culture for the younger academics, particularly for Germany. They think it to be important to conform to some extent to the new "market" of research topics in demand. Thus, the authors conclude that the new forms of governance have brought about a considerable change in the traditional Mode 1 field. There is more collaborative and inter-disciplinary work in projects, more internationalisation and more collaboration at the regional level. Researchers partly respond to the pressure for relevance, short-term projects and outputs from the competition for scarce third-party money. Most astonishingly, the researchers in all countries under study are increasingly expected to contribute to the standing and reputation of the employing institution. Thus, medieval history research and other "paradise birds" from the humanities may contribute to a new profile of an institution. This may even allow for the acquirement of those alliances, protection of research chances and resources that are needed to secure the future of the so-called "small" disciplines.

Part III of the book presents two papers on the factors which affect the governance and performance of PhD education. While Schneider et al. compare PhD programmes of economics faculties initially looking for differences between traditional master–apprenticeship models of doctoral education and more structured PhD education programmes, Unger et al. focus on the performance of the so-called "Research Training Groups" (RTGs) established by the DFG in the early 1990s. In this context, third-party funding is made conditional on criteria such as an international and/or inter-disciplinary orientation of the study programme. This programme is made compulsory for doctoral students and postdocs funded by the DFG. RTGs were initially funded for 3-year periods and could extend their funding duration up to 9 years. Since 2003, the initial funding duration was increased to 4.5 years with only one renewal of funding possible. RTGs have to report their outcomes, in particular the completion of doctoral degrees and the scientific visibility of the students measured by publication to the DFG. The study covers all 86 RTGs from the humanities, the social sciences and the natural and life sciences which are in their second funding period and submitted an application for a third funding period between 2004 and 2006. The collection of data on performance and structural data on the RTGs is based on the second reports. While Unger et al. do not find differences in completion rates of RTGs from humanities and social sciences compared to natural and life sciences, there is considerable difference in the publication patterns between these disciplinary groups. In general, doctoral students from the natural and life sciences publish less. This is even true for journal articles, which is the most preferred outlet in the natural and life sciences, while it comes only second in the humanities and social sciences. An important factor abating the number of publications more strongly in the natural and life sciences than in the humanities and social sciences is of course the tendency towards multiple co-authorships. If the correction for the number of authors is reversed, students from natural and life sciences outperform the humanities and social sciences in the number of journal publications. For an additional indicator of inclusion into research discourses, namely the number of conference presentations available for 75 of the 86 RTGs, the picture is the other way round: Students from the humanities and social sciences give talks at conferences three times more often than those from the natural and life sciences. Albeit, a student from the natural or life sciences gives on average three times as many poster sessions than a student from the humanities and social sciences. In order to take due account of these large disciplinary differences in performance patterns the authors chose a non-parametric statistical approach, the data envelopment analysis (DEA), to analyse the two disciplinary groups with respect to relative efficiency given their input levels. The DEA allows comparing units giving due credit to their different output patterns. One may concentrate on the completion of the thesis, while another one may concentrate on the visibility of the students by publications. Units producing the same types of outputs under the same input and throughput conditions, i.e. from similar disciplines can be compared by this approach. However, since a separate analysis of the RTGs from the two disciplinary groups is necessary, a direct comparison of the RTGs from the humanities and social sciences to those from the natural and life sciences is not possible here. For both groups, the average efficiency levels of some 60% show that there is much room for improvement of efficiency rates. Thus, additional research into the factors that contribute to the differences in efficiency rates in PhD education has to be put on the agenda. In each field, only four RTGs reach a 100% efficiency level – with different combinations of outputs. In the natural and life sciences, the efficiency level drops stronger from the top to the lower level – although this may be an effect of the greater number of RTGs in the natural and life sciences.

Some of the questions raised by the results of Unger et al. are touched upon in the second paper by Schneider et al. (Chapter 6) in this part of the book. The qualitative analysis of economics departments from Germany, the Netherlands, Switzerland, Great Britain, France and Italy initially set out to corroborate an advantage of structured programmes but did not find one. Instead, a pattern of governance mechanisms at the level of the faculties, the universities and the funders explain success or failure of a PhD programme. Success is measured here more ambitiously as success of placement of PhD students in the academic system. It does not come as a surprise that all departments characterised by the primary goal to use PhD students as an indispensable resource to manage teaching, administration and applied short-term research projects did not succeed. On the other hand, the departments striving for scientific excellence succeeded in all cases. Among the eight successful cases there were also four departments which had less ambitious goals aspiring for modest scientific performance but at least good education outcomes; however, three other cases with this aspiration failed. As the most important factors discriminating between the successful departments and those that failed the authors describe the necessary and sufficient conditions of having either a medium level of additional funds or a combination of the willingness of a sufficient number of faculty members to invest extra effort into a PhD programme beyond the daily routines and the availability of some slack time for doing this beyond daily routines. In the latter factor Schneider et al. find striking national differences with Germany at the upper level of the departments' teaching load. On the other hand, if either the willingness to make an extra effort by a sufficient number of faculty members or the availability of some slack time or some critical number of PhD students or a certain level of research competence and performance is missing, the department will not be able to place its doctoral students in the academic system. Any of the conditions is sufficient for failure independently of a change in the other ones. From a policy point of view this means that allowing for slack time to do good research and to invest into PhD programmes is the factor with the most likely positive effect on PhD programmes. However, streamlining organisations and an emphasis on monetary incentives may destroy the intellectual breathing rooms and the intrinsic motivation necessarily connected to doing good research.

Summarising the results, we see a rather mixed picture. Some of the newly introduced instruments of the reform seem to work, while others have negative effects. Some instruments fit to one specialisation type but not to others. The same is of course true for the fit to different disciplines and fields. Causes and consequences are interrelated in a tricky way as can be seen from the joint occurrence of positive and negative effects at different levels of the system or from the curvilinear shape of effects that are positive at low levels of intensity but negative at the higher end of intensity. The conclusions presented in the final paragraphs try to sum up what science policy makers can and should learn from our research.

As Braun (2007) pointed out, the risk for such unintended effects of new policy instruments increases under three conditions:

The higher the complexity of the system to be steered is, the larger is the risk of a failure of steering. The science system is undoubtedly a highly complex, multi-layered system exhibiting vertical and horizontal types of interdependence. In particular, interdependencies between researchers in a subject field and between disciplinary fields have to be considered as well as different layers in the organisational set-up of the system such as national science policy, universities and the large research organisations, faculties, departments and institutes, and the level of individual researchers and research teams conducting research projects.

Unintended effects caused by the unobservability of deviations and failure occur if implicit assumptions guiding the steering actor do not come true or if mismatches between intended and unintended results of steering are hidden by the strategic action of the agents.

Unintended effects caused by biased perception and wishful thinking of steering actors may finally prevent them from actually exploring and evaluating the evident effects of a new policy.

The papers in this volume contribute to potential solutions of the aforementioned problems of governing the research system. We not only hope to reduce the chances to escape from reality by presenting clear evidence on the effects of reforms but also address science policy here by presenting valuable insights into the complexity of the science system and its vertical and horizontal interdependencies. These have to be taken into account by a balanced system of incentives preserving autonomy and heterogeneity in disciplinary research and an adequate weighting of the role of different disciplines in the concert of academia. In addition, the interdependencies that amplify or abate intended and unintended effects between the various levels of the system need more attention and scrutinised evaluation.

Chapters 1 and 2 can be read as lectures in the issue of steering deficits due to the complexity of the science system. However, the papers do not stop at this insight but give valuable advice as on how to prevent unintended consequences and governance failures. Broemel et al. advise policy-makers on the procedural requirements of constructing systems of performance-based budgeting and allocation of funds from a legal perspective. Schubert and Schmoch suggest a model of indicators taking duly into account the heterogeneity of outputs resulting from the specialisation of research groups and the differentiation of the science system. Chapters 3, 4, 5 and 6 look in greater detail into the interactions between the modes of knowledge production and the effects of new governance patterns on research lines, research performance and the success of PhD programmes. Thereby they point at unintended effects caused by a lack of observability of consequences or by abating factors resulting from strategic action that hides mismatches between intended and effective consequences of the reforms.

In Chapter 3, Jansen et al. scrutinise the ready adoption of the concept of a new Mode 2 of knowledge production by science policy as a model mode of tasks addressed to science by state and societal actors. Making the funding of research conditional on characteristics and outputs presumed by this concept, Mode 2 turns into a self-fulfilling prophecy. Albeit, neither the question whether there is actually a change of knowledge production nor the question whether new funding concepts enhance research productivity are evaluated by science policy. Thus, the mismatch between funding instruments building on the model of Mode 2 and actual characteristics of application-oriented research cannot be detected. On the contrary, the collaboration with industry and at the regional level has become a criterion of funding programmes even in social sciences and the humanities (Kehm and Leiðytë, in this volume). The pressure to acquire large amounts of third-party funding even drives research groups into unproductive short-term industry projects. Yet the empirical evidence shows that both, the percentage of third-party funding (Schubert and Schmoch, in this volume) and the percentage of industry ties in networks have a curvilinear, inverted u-shaped effect on research performance. Kehm and Leiðytë (Chapter 4) observe similar governance failures in the case of medieval history. Researchers are forced to find a balance between their own more long-term research agenda and the priorities of funding bodies. They do this largely by resorting to symbolic compliance strategies. The requirement of collaboration in research and of integration into larger centres contradicts the established forms of individual research and provokes more or less decoupling of talk from action. Thus, strategic compliance substitutes for real effects, but is hard to detect for science policy because of the alleged asymmetries of information between state and academia (Broemel et al., in this volume). However, these buffering mechanisms at the microlevel are actually in the best interest of the science system as a whole. It can well be questioned whether contributions to medieval history will profit if researchers refrain from publishing larger books building on long-term work. On the contrary, the response to new and often discipline-insensitive evaluation standards only leads to the subdivision of publications into smaller pieces resulting in an inflation of publication numbers and a waste of paper and attention of the academic system. The pressure for relevance in some cases (England) enforced by making funding conditional on compliance even prevents researchers from entering into risky and more long-term projects.

In their paper on the conditions of placement success of PhD programmes in economics (Chapter 5), Schneider et al. (2010) systematic effect of the production systems of PhD education – whether it follows a master–apprenticeship model or relies on a structured education – nor of the level and type of aspiration of PhD education – either for scientific excellence or employability. This observation of mixed results of structured PhD-education programmes is corroborated by the paper of Unger et al. (Chapter 5) who find improvable efficiency levels of roughly 60% on average for both disciplinary groups under study – humanities and social sciences, and natural and life sciences. In their research project, for the first time after the introduction of research training groups by the DFG in the early 1990s, the programme has been subjected to an external evaluation study. Instead of an initially expected positive effect of structured programmes, Schneider et al. observe important problems leading to placement failures that are connected to an efficiency myth. Failing faculties either do not have enough time beyond their daily routine work to invest extra effort into PhD education or they lack the critical mass of faculty members prepared to invest time voluntarily in an extra effort in PhD education (not driven by extrinsic incentives). As the analysis of conditions of success shows, both factors combined make for success and can even compensate for low funding from third-party programmes. Thus, it may be not so wise to streamline organisations for maximal output in a way that leaves no slack time for "fun" tasks. Nor are monetary incentives the magic bullet towards increased performance. The negative effect of replacing intrinsic by extrinsic motivation is well-known in motivational psychology (Deci 1980; Frey 1997; Osterloh and Weibel 2008). This is still truer in the academic system that is driven by non-economic motivations such as curiosity, freedom of choice of tasks, and the "taste for science" (Merton 1973; Osterloh and Frey 2008). Competition among researchers is competition for reputation, for good research, and good research students. Thus, Schneider et al. advise policy-makers that, in order to improve research-oriented PhD education, they have to implement incentives for departments and supervisors to focus on academically oriented PhD students by allowing for enough time to do research and a PhD education geared towards scientific progress.

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Appendix
Disciplinary Differences in Four Research Fields: The Cases of Astrophysics, Nanoscience and Nanotechnology, Medical Biotechnology, and Economics

Introduction

Regina von Görtz and Richard Heidler

In the following sections, four scientific research fields are presented and described. Previous chapters in this volume address specific research questions by comparing different disciplines (cf. Pull and Backes-Gellner; Jansen, von Görtz and Heidler) or by combining data from different disciplines (cf. Schmoch and Schubert). This chapter, however, follows a broader approach and aims to portray both the main characteristics of and key differences between different scientific fields. The fields examined were chosen along two axes: the natural science/social science divide and the division between basic vs. application-oriented research. Economics was chosen as a social science, while astrophysics, nanoscience and nanotechnology (nano S&T) and medical biotechnology represent the natural sciences. Nano S&T and medical biotechnology are thought to be application-oriented, whereas astrophysics is considered a basic science.

Our analysis of the four fields focuses on the characteristics of the fields in Germany and their international integration and embeddedness. The productivity of researchers, the importance of different institutions and the relevant funding schemes are identified and described. In addition, the main research questions, methodologies and future challenges of the fields are highlighted. In the fields of astrophysics and economics we also present figures of the international collaborations of German researchers. Scientific productivity was measured using the publication output of researchers; for the application-oriented fields nano S&T and medical biotechnology patent data were also gathered. For all fields, publication data were collated via the "Web of Science" which includes the Science Citation Index (SCI) for publications in the natural sciences and the Social Sciences Citation Index (SSCI) for publications in economics. The "Web of Science" only covers the most important scientific journals, thus some measurements can be distorted, depending on the coverage of the field. According to Moed (2005: 138), who distinguishes between an excellent, a good and a moderate coverage, the coverage in astrophysics and medical biotechnology is excellent, whilst the coverage in nanoscience lies between good and excellent. In economics the coverage is not as good as in the

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other fields, but still "good". A bias towards English-language journals must be taken into account when interpreting the data. The fields were identified with the help of a keyword-based search strategy developed by the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI); which provided most of the data analysed here. A keyword-based search strategy provides a more precise insight than an identification-based strategy on subject categories for journals, as for example in the "Web of Science" (Moed 2005: 187), because articles are directly assigned to a discipline rather than indirectly with respect to the type of journal they are published in.

Growth rates for scientific publications follow specific patterns that can be linked to the state of a field. De Solla Price (1963) distinguishes between three periods of scientific growth. When a new field evolves, its growth is linear. If the field becomes successful, growth becomes exponential for a while until it reaches a point of saturation.[2] Although the patterns of publication productivity in different fields are more complex in real life, de Solla Price's ideal-type descriptions can help to interpret the data. In our data, the growth rates of the four fields have differed significantly over the past 10 years. The worldwide growth of economics, astrophysics and medical biotechnology is generally linear with some periods of stagnation. Only nano S&T displays the exponential growth pattern that would be expected of a dynamic new science.[3] Except in nano S&T, the German growth rate is higher than the worldwide growth rate. In nano S&T, Germany lags behind the rest of the world. However, the patent output of nano S&T in Germany shows a similar exponential growth to the rest of the world. The patent output of medical biotechnology shows a high volatility for Germany as well as for the rest of the world; this is probably due to the crisis in the "new-economy" and the accompanying market uncertainty.

In the SCI, the proportion of all German publications is 7.3%. Out of the four fields, only astrophysics is above this average. German astrophysicists provide 16% of all astrophysical publications in the SCI, making Germany the second most productive country for astrophysics worldwide. In all fields, the USA dominate the publication outputs.[4] However, the dominance is clearer in the established sciences such as economics and astrophysics, whilst the patterns in the application-oriented fields are ambiguous. In the fields that promise high economic revenues in the future, nano S&T and medical biotechnology, the Asian countries China, Japan, South Korea and India together have a much higher share in the publication rates than the USA; in nano S&T China is already the second most productive country.

[2]De Solla Price calls these stages "little science", "big science" and "new science", respectively. Today, however, the term "new science" is used to describe new academic fields such as materials science, life science and computer science (cf. Bonaccorsi 2008).

[3]In the terminology of de Solla Price, such a field would be called "big science". In the terminology of Bonaccorsi, new sciences differ from established big sciences such as high-energy physics; they are less dependent on investments and use a larger variety of instrumentation.

[4]The dominance of the USA is also partly due to the bias of the SCI/SSCI on American- and English-language journals.

Asian countries are investing in these technology-oriented fields to try to advance the competitiveness of their respective economies.

The composition of institutions publishing articles in the four fields in Germany is rather diverse; it reflects the traditional division of the German science system into university research and extra-university research. In nano S&T and astrophysics, the most productive institutions are extra-university research institutes, especially the Max Planck Institutes. The field of economics, however, is dominated by universities. In the field of medical biotechnology, the concentration of publications to one type of institution is lower than in the other fields; here many institutions are involved. Extra-university research institutes play an important role in this field, but their dominance is not as strong as in the cases of nano S&T and astrophysics. What is striking here is that a private pharmaceutical company is amongst the group of institutions that publish the most.

The field descriptions conclude with a summary of the size and type of governmental financial support of the four fields. A direct comparison is difficult in this area because of the different resource intensities of the fields. The financial resources that are available to fund economics would be wholly insufficient for astrophysics. Thus, a comparison of financial endowments in purely monetary terms is difficult to assess. Also, in the various fields funding is provided through many different channels (e.g. the EU, the DFG, federal and regional ministries, the institutional funding of universities and extra-university institutes, private funding, etc.) making a direct comparison even more challenging.

The text proceeds as follows: the case of astrophysics is discussed, followed by the cases of nano S&T, medical biotechnology, and economics in Appendices B, C and D respectively.

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Appendix A
The Research Field of Astrophysics

Richard Heidler, Regina von Görtz, and Karola Barnekow

A.1 Definition of the Research Field and Important Characteristics

Astrophysics and astronomy investigate the origin and development of the universe, the objects in it, and the physical laws determining the behaviour of these objects (DFG 2003). The terms " astrophysics" and "astronomy" are mostly used synonymously. The numerous scientific breakthroughs in the past years and the changes in the astrophysical research paradigm can mainly be explained by the technical progress in the building of telescopes and the increased calculating capacity of computers. Future research questions and priorities are basically determined by those scientific breakthroughs. In the following, the most important developments and research subjects will be summarised.

In 1998, the observation of supernovae led to the finding that the expansion of the universe is not, as older models suggested, constant or decreasing, but accelerating. Since then, the results were corroborated with different astrophysical research methods. This led to the development of the Lambda-Cold-Dark Matter model (Lambda-CDM model), which attempts to explain observations of the accelerating expansion of the universe, the cosmic microwave background and the large-scale structure of the universe. The model assumes that 95% of the energy of the universe consists of dark matter and dark energy. Because of the hypothetical character of the knowledge about their influence on the development of the universe, the exploration and explanation of the role of dark matter and dark energy are research questions that gain increasing importance in astrophysics. A better understanding of dark matter and dark energy could eventually lead to a reformulation of the physical laws of the universe (DFG 2003).

Another paradigm change can be observed in regard to the phenomenon of black holes. For a long time, black holes were seen as theoretical concepts or exotic constructs. Since they do not radiate any light, they could not be observed directly. In

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the meantime, there are indications that they exist, because objects that probably are black holes could be observed indirectly with the help of the gravitational lensing effect.[5] Another research breakthrough happened in the search of planets outside our solar system. Up to now, there have been observed more than 300 extra-solar planets. They were mostly observed with indirect methods because their faint light is outshined by their parent stars. Telescopes with better resolution could support evidence for extra-solar planets by direct visual observation. This research could also advance the search for earthlike extra-solar planets.

The most important research topics in future will deal consequently with the origin and evolution of the universe, of galaxies and of black holes, as well as with the origin of stars and planetary systems. These topics include a multitude of problems which could be solved in the next years, such as the geometry of the universe, the nature of dark energy and dark matter, evidences for gravitational waves, black holes and early galaxies and stars (DFG 2003: 12).

The answers to the upcoming astrophysical questions are strongly bound to technological development, especially to the development and accessibility of new telescopes.[6] The interaction between theoretical modelling and observation is a major element in the progress of astrophysics. With the increasing power of computers, numerical simulations of astrophysical processes have gained increasing importance and can enhance the link between theory and observation.[7] Scientists specialising in numerical astrophysics try to simulate the development of complex non-linear astrophysical processes to predict observations or to describe non-observable processes in the universe.

To enhance the connection between observation and theory, numerical astrophysics is especially dependent on the access to high-performance computer centres. Realistic simulations include many variables and are computationally intensive. Therefore observational data, on which these simulations can be built, need a high spatial and temporal resolution. The use of simulations with high-performance computers for the interpretation of detailed observational data has become a widespread method in astrophysics.

Modern observational astronomy is and will also be in the future bound to the use of telescopes for all wavelengths, because the properties of many objects can only be revealed if they can be observed within a broad wavelength range. To ensure international competitiveness, German astrophysicists need access to the best telescopes.[8] The trend that becomes apparent in some areas in the next years is the construction of global telescopes. This can only be realised through international collaborations

[5] The effect appears when light from a distant and bright source is "bent" around a massive object.

[6] The building of new telescopes has a twofold effect. Not only are technologically superb new telescopes available, but there is also a weaker pressure on older telescopes. This leads to the possibility of long-time observations that otherwise could not be done. All this can lead to major research breakthroughs. A prominent example for this is the discovery of pulsars.

[7] An impressive example for the capabilities of numerical simulations in astrophysics is the visualised simulation of the collision of two galaxies.

[8] This regards earthbound as well as space telescopes.

(DFG 2003:140). Large Projects like ALMA or LISA are only two examples.[9] But also European cooperative projects like E-ELT will still play an important role in the future.[10] It is necessary to establish successfully critical shares of such projects and institutions to secure the competitiveness of German astrophysicists. At this juncture, the German attendance at the ESA (European Space Agency) and the ESO (European Southern Observatory) as operators of such large-scale telescopes is of major importance (DFG 2003: 140).

The building and operating of instruments for national and international observatories can lead to a decisive advantage in scientific competition. This ensures early exploitation of the gained observation data and a faster access to observation time. However, the development and design of instruments are very expensive and most such projects are manageable only for international consortia. In Germany, mainly extra-university research institutes (e.g. Max Planck Institutes, Leibniz Institutes) who possess long-term stable funding are capable of competing internationally in the announcement of the building of telescopes, whilst the small university institutes can only participate to a much smaller degree (e.g. as minor partners) in such announcements.

A.2 Publication Analysis

Publications can be seen as a typical output indicator for scientific performance in the field of astrophysics.[11] There are indeed some technological contributions from astrophysics in the fields of optics, measurement engineering, data processing and communication technology, but they are so unsystematic and subordinate, that a patent-data analysis would be inappropriate.[12] As expected, nearly all publications identified with the key-word based search strategy are assigned to the category "astronomy and astrophysics" (Fig. A.1). On the one hand, there is a significant overlap of astrophysical publications to "physics, particles & fields" and "multidisciplinary physics", which reflects the importance of (basic) physical science for astrophysics (and vice versa).[13] On the other hand, there is a significant overlap

[9]The ALMA (Atacama Large Millimetre Array) will be at work from 2010 in Chile. It is mainly financed by the ESO and North-American Science funding agencies. Another American–European partner project is LISA (Laser Interferometer in Space), a joint NASA and ESA Project for a space telescope, that is able to detect gravitational waves.

[10]ESO has planed the 40-m "European Extremely Large Telescope" as the next generation of European ground-based telescopes. The plans for a 100-m Telescope called "Overwhelmingly Large Telescope" were cancelled because of the high costs.

[11]We thank the Frauenhofer Institute for Systems and Innovation Research for providing the publication data for the field of astrophysics.

[12]Journals can be assigned to more than one category in the SCI. This topic is addressed in further detail in Glänzel et al. (1999).

[13]In modern astrophysics and in physics, the connection of micro-physical phenomena (particle physics) with macro-physical cosmology is seen as a major development (DFG 2003).

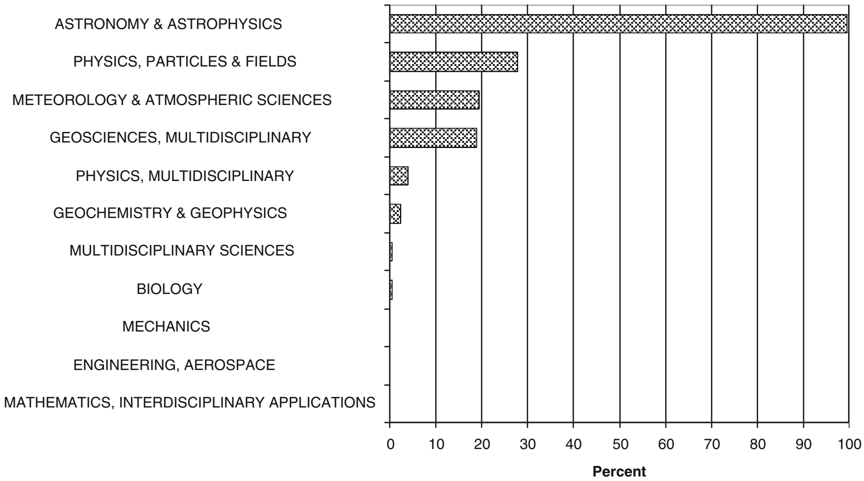

Fig. A.1 Classification of publications in astrophysics based on the SCI subject categories, 2007. Source: SCISEARCH (STN), computation by Fraunhofer ISI

to some geological sciences such as “multi-disciplinary geosciences”, “geochemistry and geophysics” and “meteorology and atmospheric sciences”. This reflects the interest of astrophysics in the geological and meteorological aspects of planets and other objects in space.

The temporal analysis of the growth of astrophysics from 1995 to 2007 shows an almost constant growth of the field which reaches 91% for Germany in 2007 (Fig. A.2). The worldwide growth rate is smaller than the German and reaches a total growth of 53% by 2007.[14]

The strong growth of German astrophysics leads to a share of 16% (Fig. A.3) of the worldwide publications in astrophysics in 2007 for Germany. A comparison to the proportion of German publications for the whole SCI (7.45%)[15] shows that astrophysics is a field where Germany is comparatively strongly represented.

Regarding the attendance of different countries to the worldwide production of astrophysical publications, the USA is, as expected, the leading country. Germany ranks second, followed by England, France, Italy and Japan (Fig. A.3). The strong position of England is partially produced by the bias of the SCI towards Anglophone publications.

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[14]The growth rate must be handled with caution, because it is partially explained by the integration of new journals in the SCI.

[15]Own computation.

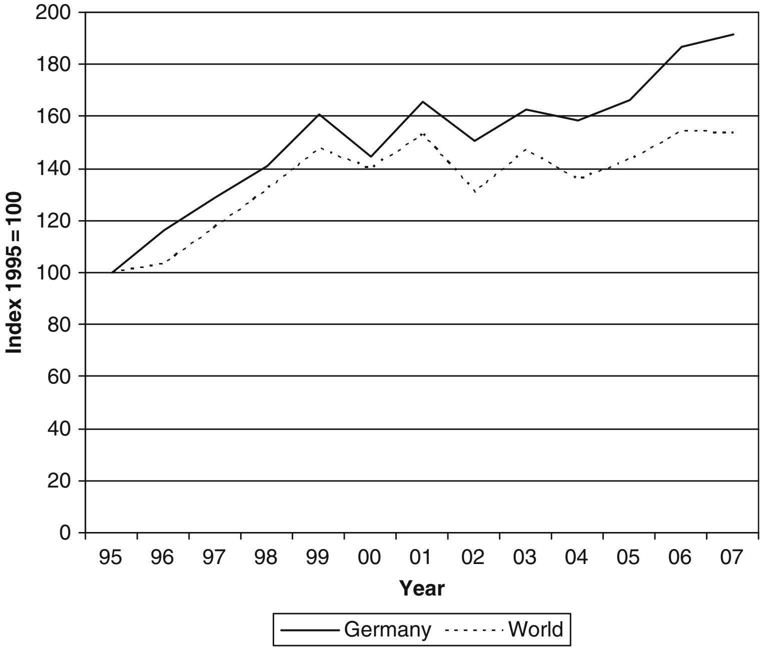

Fig. A.2 Timeline of astrophysical SCI publications in Germany and worldwide. Source: SCISEARCH (STN), computation by Fraunhofer ISI

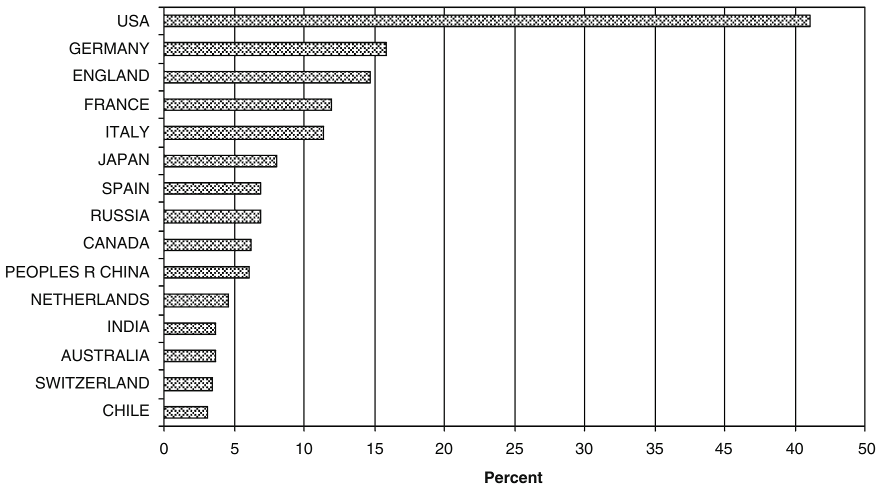

Fig. A.3 National origins of SCI publications in astrophysics, 2007. Source: SCISEARCH (STN), computation by Fraunhofer ISI

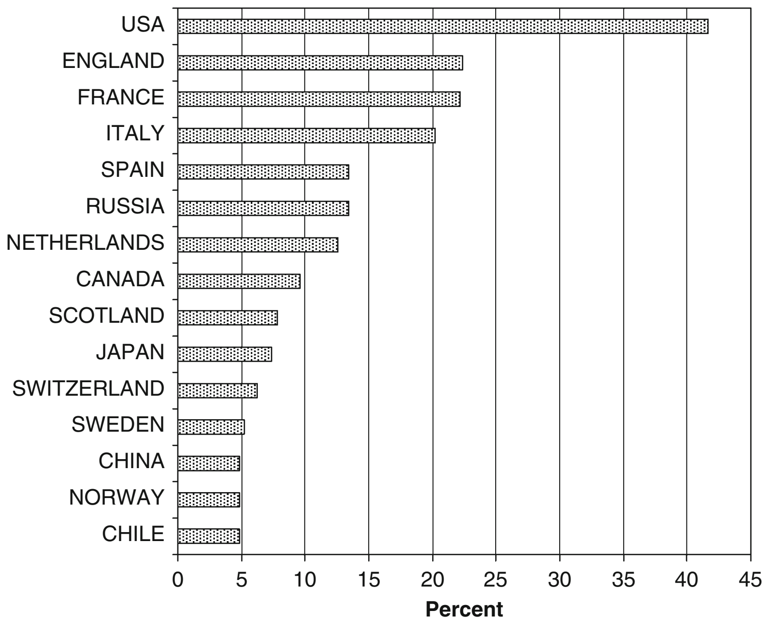

Fig. A.4 National origins of co-authors in German SCI publications in astrophysics, 2007. Source: SCISEARCH (STN), computation by Fraunhofer ISI

A strong tendency towards international collaboration is characteristic of the field of astrophysics. Astrophysics is highly based on division of labour[16] and research projects often cross national borders. The proportion of internationally co-authored papers for astrophysical publications from Germany is with 82.3%[17] much higher than the average for the whole Science Citation Indexwith 41.4% (Frietsch 2004). The most important research partner for German astrophysicists is clearly the USA (Fig. A.4). Even if the most worldwide publications are produced by American astrophysicists (Fig. A.3), the proportion of American research partners for German Astrophysics is relatively low. If one takes into account the country distribution in Fig. A.3, the data show disproportionately high preference for European research partners such as England, France, Italy and Spain (Fig. A.4).

Looking at the German institutions contributing the most astrophysical publications, the Max Planck Institutes (Max Planck Institute for Astronomy, Max Planck Institute for Extraterrestrial Physics and Max Planck Institute for Radio Astronomy)

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[16]The number of authors per paper in astrophysics is continuously growing. Fernandez (1998) gives five main reasons for this process: professionalisation, pressure on young scientists to produce papers, a value shift towards team work, better means of communication and increasingly complex devices and problems.

[17]Own computation.

Table A.1 Number of SCI publications in astrophysics in important German institutions, 2007

Number of publications	Facility	Place
211	Max Planck Institute for Astronomy	69117 Heidelberg
179	Astrophysical Institute of Potsdam	14482 Potsdam
179	Max Planck Institute for Extraterrestrial Physics	85748 Garching
101	European Southern Observatory	85748 Garching
82	Max Planck Institute for Radio Astronomy	53121 Bonn
82	Universität Dortmund, Institut für Physik	44221 Dortmund
82	Universität Heidelberg, Institut für Physik	69120 Heidelberg
82	Universität Karlsruhe, Institut für experimentelle Kernphysik	76021 Karlsruhe
82	Universität Rostock	18051 Rostock
55	Technische Universität Dresden, Institut für Kern- und Teilchenphysik	01062 Dresden

Source: SCISEARCH (Stn), computation by Fraunhofer ISI.

rank first, whilst universities follow on lower ranks (Table A.1). This reflects the good working conditions and the lack of teaching duties for scientists at Max Planck Institutes, although the table can not be interpreted as a ranking of productivity because the data is not relativised to the number of scientists who participate in the respective publications.

The Astrophysical Institute of Potsdam (AIP) which was once a part of the Academy of Sciences of the GDR and is now a member of the Leibniz Association, operates and develops its own telescopes, supports the development of telescopes for the ESO and is affiliated to international research projects.

The ESO is a European inter-governmental science and technology organisation with 14 partner members.[18] It produces the fourth largest amount of astrophysical papers. The ESO is especially important for German and European astrophysics because it is specialised on the design, construction and operation of powerful ground-based telescopes. The data show that it also produces a noticeable amount of publications.

A.3 Institutional Structure and Funding Promotion

According to a 2003 study by the German Research Foundation (DFG) into the status and perspectives of astronomy in Germany, German astrophysical research has an internationally leading position in the following research fields (DFG 2003: 178):

[18]The Czech Republic and Austria became members recently (2007 and 2008), other members are Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

- Observatory and theoretical Stellar astrophysics
- Astronomy and Stellar statistics
- Black holes and galaxy cores, the formation of galaxies
- Numerical astrophysics
- The formation of stars, the inter-stellar medium and astrochemistry
- Observation and theory of the development of cosmic structure
- Gravitational lenses and research into gravitational waves
- Solar neutrinos

These areas of expertise were identified by collecting and analysing data on publications, citations, conference presentations, international collaborations and the amount of research funding and observation time. Table A.2 gives an overview of high impact publications by German astrophysicists by research area between 1985 and 2003.[19]

In 2003, German astrophysical research was conducted in 23 university institutes, five institutes of the Max Planck Society (MPG), two of the Leibniz Association, three institutes operated by the federal states and in three other extra-university institutes in which astrophysics is among the key research areas (DFG 2003: 180). These institutes employed 524 scientists, had 624 doctorate and diploma students and 405 engineers and technicians (DFG 2003: 180, 229). It can therefore be seen that German research in astrophysics is not only conducted across all types of science institutes of the German system but it is also conducted throughout the country as a whole. There are however some regional clusters, the most influential being in

Table A.2 Publication output of German astrophysicists, 1985–2003[a]

Research topics	Number of high impact publications[b]
The universe as a whole (overall structure and history)	25
Galaxies and supermassive black holes	31
Material flow systems	29
Star and planet formation, extra-solar planets	17
Other	8
Total	110

[a]Analysis of 19,000-refereed (co-)publications involving authors from research institutes in Germany
[b]Publications with more than 100 citations
Source: Astrophysical Data System, DFG (2003: 177)

[19]Some of the most influential "high impact" journals in astrophysics charge authors a publishing fee of $100–$150 per page. When discussing the publication output of astrophysicists, it has to be taken into account that some universities struggle to pay these page charges and because of this choose to publish in journals in which publications are free of charge. However, these journals are not as widely read and therefore generally have lower impact factors (Dunn et al. 2007).

Munich/Garching which has developed around the headquarters of the ESO and two of the Max Planck Institutes (Habing 2007: 15).

The funding for astrophysics in Germany comes from several different bodies: the DFG, the MPG, the German Federal Ministry of Education and Research (BMBF), the various Science Ministries of the federal states and the German Aerospace Center (DLR). National funding alone, however, is not sufficient to maintain the infrastructure needed for research in astrophysics. This has reached such a scale that it has long become necessary to operate and finance it through international organisations and consortia. The two most important European organisations are the ESA and the ESO. Germany is affiliated as a major partner to both these organisations; to the European ESA programmes for example, the German government contributes the fixed quota of 70% of its yearly budget for space research (€544.8 million in 2005, BMBF 2006: 223).

Concerning space exploration, three types of funding schemes have been established: the German involvement in the European programme of ESA, the National Space Program and the space exploration activities by the DLR. In 2005, the national space flight programme had a budget of €149.0 million; with this, it is supposed to realise projects that are of national interest. The funding within the national space flight programme has in the past been split, with 60% of funding going to private industry and 40% to universities and research institutes (BMBF 2004: 231; BMBF 2006: 223). In total, the DLR was awarded €3.27 billion in government funding between 2005 and 2008.

The DFG is the main sponsor of research in astrophysics in universities, and awarded a total of €2.2 billion in 2007 to fund research.[20] However, the DFG is responsible for funding research across all academic disciplines, including for example philosophy, nanoscience and zoology, and has to award its grants accordingly. This, in conjunction with the higher basic funding of extra-university institutes compared to universities overall, means that the extra-university institutes are able to conduct more extensive, more cost intensive and as a result often more influential research in astrophysics. The financial imbalance between universities and extra-university institutes due to the structure of German funding of research in astrophysics creates an uneven playing field. As a consequence, the research situation for universities is becoming increasingly difficult.[21] The majority of German universities that conduct research in astrophysics are underfunded. There are only 46 university professorships in astrophysics out of 1,303 professorships in physics overall, that is a proportion of 3.5% (the proportion increases to 7% when including professors at extra-university institutes). In comparison, the proportion of astrophysicists amongst physicists in the UK has increased from 21% in 1994 to almost 30% in 2001 (DFG 2003: 179).

[20]Deutsche Forschungsgemeinschaft (2007): http://www.dfg.de/jahresbericht/koordinierte_sfb_0_index.htm (01.09.2008)

[21]Rat Deutscher Sternwarten (2003): http://www.rat-deutscher-sternwarten.de/denkrds.html (01.09.2008).

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Appendix B
The Research Field of Nanoscience & Nanotechnology

Thomas Heinze

B.1 Introduction

Science and technology based on the unified concepts of matter at the nanoscale provide a new foundation for knowledge creation, technology development and innovation. Nanoscience and nanotechnology (nano S&T) is widely considered one of the key drivers of technology-based business and economic growth.[22] Like in other high-tech fields such as biotechnology, economic opportunities abound with progress in scientific research which is conducted in both public and private laboratories.

This chapter provides basic data about this emerging research field focusing on established nano S&T indicators such as scientific publications, patent applications and funding data. In Section B.2, the recent development of the nano S&T field and the key application areas are described. In Section B.3, publications and patent applications are analysed. In Section B.4, institutions of relevance to German public research and to private business are identified.

B.2 Definition of the Research Field

B.2.1 Definition of Nano S&T

Nano S&T describes the research into and the manipulation of structures in the nano-scale field. The discovery of opportunities to access the individual modules of matter and the subsequent understanding of these modules' behaviour has involved a multi-disciplinary field of research and technology over the past two decades. The prefix "nano" (Greek for "dwarf") denotes a dimension a thousandfold smaller than that of current modules in the micrometre area. One nanometre corresponds to the

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[22]The author is grateful to Ulrich Schmoch and Torben Schubert (Fraunhofer Institute for Systems and Innovation Research) for assistance in data retrieval.

millionth part of a millimetre. The nano-scale domain is attained by the use of new physical tools and processes reducing currently existing microsystems, but also by the use of blueprints of animate and inanimate nature for matters ́self-assembly.

The nano S&T field developed from a number of fundamental breakthroughs in diverse research fields. One such breakthrough in applied physics was a new type of spectroscopy based on quantum mechanics. Both the Scanning Tunneling Microscope (STM) and the Atomic Force Microscope (AFM) (Binnig and Rohrer 1982; Binnig et al. 1986) attain extremely high-resolution at the atomic level either in conductive materials (STM) or non-conductive materials (AFM). Further fundamental breakthroughs were achieved in the field of inorganic chemistry through the synthesis of two new carbon materials: carbon nanoballs (Heath et al. 1985; Kroto et al. 1985) and carbon nanotubes (Iijima 1991; Iijima et al. 1992). These carbon structures show interesting chemical and physical properties related to conductivity and stiffness. Recent developments building on these new materials are nanotube transistors at room temperature (Tans et al. 1998) and nanotube-based circuits (Collier et al. 1999).

It is not always easy to separate the nano S&T domain from other fields of research and technology, since there is a myriad of adjacent areas in neurosciences, computer sciences and life sciences. The term "converging technologies" is generally used for this phenomenon today (Roco and Bainbridge 2007; Nordmann 2004). Despite several problems of delineation, three criteria are considered relevant for the definition of "nano S&T":

1. Research and technology development in the length scale of approximately 1–100 nm;
2. Structures, devices and systems that have novel properties and functions because of this size range;
3. The technical ability to control or manipulate matter on the atomic scale (Wolf 2007; Bushan 2006).

B.2.2 Application Areas

Although the exploration of nano-scale phenomena and structures is an emerging field, there are a considerable number of commercial applications based on nano-scale research. These include (cf. Luther and Malanowski 2004):

- *Automotive industry*: optimisation of catalytic converters; paintwork, reflection and corrosion protection (e.g. lamination of windscreens and rear screens with nano particles; lamination of particularly sensitive body elements); new functional ceramic elements (e.g. substitution of heavy metal parts and/or brittle ceramic parts); lightweight construction (e.g. foams, polymers); nano particles as filling materials (e.g. nanometre-sized soot particles in car tyres).
- *Energy sector/aerospace industry*: energy storage (e.g. improved fuel cells by hydrogen storage in nano carbon tubes); energy recovery by solar cells (e.g. improved photovoltaics through light-sensitive nano particles); structural

materials (e.g. weight and energy saving through the use of lightweight, high-strength materials based on nanotechnology); sensor technology (e.g. improved medical surveillance of astronauts based on sensor elements containing nanomaterials).

- *Construction industry*: plasters and lacquers containing nanoparticles (dirt-repellent and/or water-repellent); additives for injection and high-performance concrete (e.g. silicon dioxide nanoparticles in synthetic silica); corrosion protection in the use of carbon and stainless steel (e.g. ultra-thin functional multi-layer coatings); air conditioning (e.g. titanium oxide nanoparticles as additives in varnishes to protect from natural light); refinement of tiles and shower walls (e.g. scratch- and abrasion-proof synthetic materials through nano-particle coating).
- *Biomedical and chemical-pharmaceutical industry*: substrate material and capsules (e.g. for the precisely dosed and localised administration of medicine); artificial skin (e.g. tissue engineering); bio sensors and implants in the body (e.g. against diabetes, for the administration of medicine); diagnostics (e.g. X-ray contrast agents, biochips): gene therapy to repair genetic faults (e.g. introduction of DNA segments, transport of genes through nanoparticles); search and release of active ingredients, in-vivo body monitoring systems and/or assistants for organ regulation; protection of sensitive medicines (e.g. coating with nanotensides); overcoming the blood–brain barrier (e.g. nanoparticles combined with proteins).
- *Environmental sector/consumer goods industry*: wastewater treatment (e.g. by actively reacting nanoparticles); environmental monitoring (e.g. biochips to control foodstuffs and environmental influences); cosmetics and sunscreens (e.g. sun lotions containing zinc and/or titanium oxide to protect the skin); functional textiles (e.g. to accumulate heat and transport moisture away from the body).
- *Optical industry/tools industry*: polish correction processes; photonics (e.g. aspherical lenses with a complicated curving to replace composed systems of lenses and mirrors, photonic crystals as optical circuits); wave conductors; layer structure for luminous diodes and diode lasers; multi-layer staple laser; optical items for X-raying; ultra-precision treatment of surfaces for functional optical items.
- *Semi-conductor industry/information and communication industry*: data storage and treatment (e.g. giant magnetic resistance for writing and reading heads of hard drives; single flow quanta logics; single electron transistors); molecular electronics (carbon nanotubes, organic macromolecules, DNA computing); flat screens (e.g. field emission displays using carbon nanotubes); fault-detection methods in the production of information technology products (e.g. STM as a nano-analytical tool); electronic paper, quality control and function tests of manufactured structures.

B.2.3 Analysis of Publications and Patent Applications

Publications and patent applications are typical outputs in the area of research and technology described above. In this section, we will therefore show results produced on the basis of both research and technology indicators. Publications are retrieved from the Science Citation Index (SCI), the most comprehensive multi-disciplinary data bank for publications in natural sciences. As far as patent applications are concerned, we refer to applications made to the European Patent Office in Munich. Patent data are retrieved from the Derwent World Patents Index (DWPI). To identify relevant publications and patent applications, search strategies with combined key words have been developed by the Fraunhofer Institute for Systems and Innovation Research in cooperation with the University of Leiden's Centre for Science and Technology Studies. These search strategies have been documented by Noyons et al. (2003) and Heinze (2006). More recent bibliometric papers on nano S&T include, for instance, Hullmann and Meyer (2003); Heinze (2004); Kostoff et al. (2006); Zucker et al. (2007); and Youtie et al. (2008).

B.2.3.1 Results of the Publication Analysis

From 1995 to 2007, the number of scientific publications rose tremendously both in Germany and on a global level. While the volume of papers published worldwide more than quintupled in this period, a growth factor of merely about four can be established for German publications. Compared to the international development, the growth of the inter-disciplinary research field in Germany therefore proceeded in a less dynamic manner – especially since the beginning of the new millennium (Fig. B.1).

When comparing countries concerning global scientific publications, it is most striking that the People's Republic of China has speedily caught up with the leading industrialised nations over the past decade (Zhou and Leydesdorff 2006). In the field of nano S&T publications, China ranks second behind the USA in 2007 and is thus

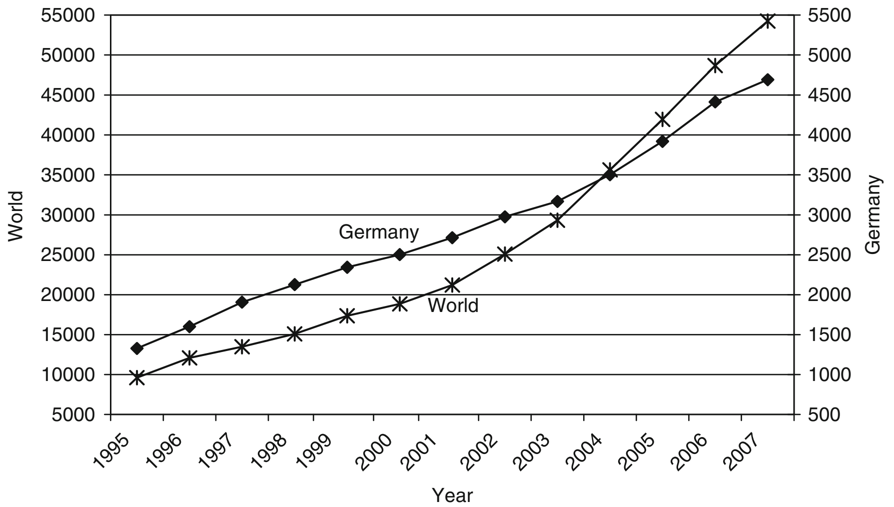

Fig. B.1 Scientific publications in nano S&T, 1995–2007. Source: SCI (Host: STN)

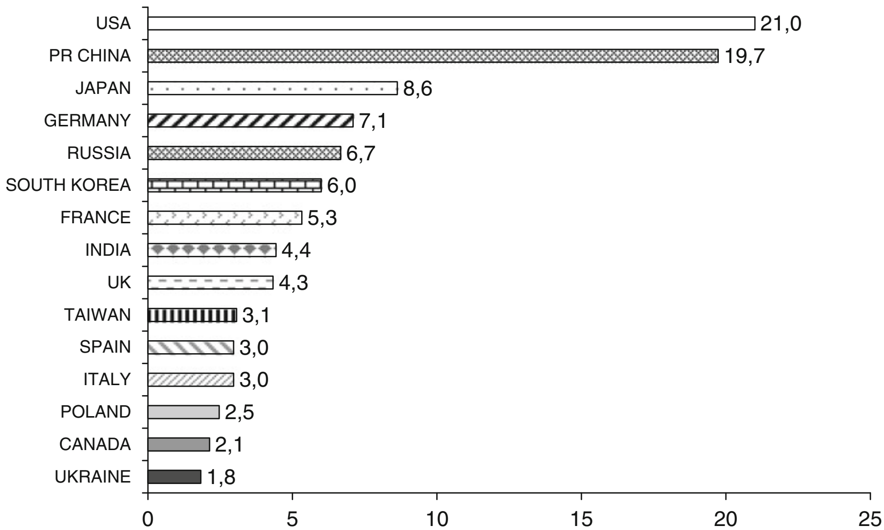

Fig. B.2 Scientific publications in nano S&T by country, 2007. Source: SCI (Host: STN)

clearly ahead of Japan, Germany and Russia. In Europe, Germany boasts the highest amount of publications, followed by France, the UK and Italy (Fig. B.2).

In Germany, the institutions featuring the highest amount of publications comprise several universities, but also a large number of institutes from the extra-university research sector. These include mainly institutes of the Max Planck Society, but also institutes of the Leibniz Association and the Helmholtz Association of German Research Centres. In contrast, the Fraunhofer Institutes have a relatively low publication output and are therefore not listed among the institutions with a large publication output (Table B.1). The names of the institutes show that subareas from physics, chemistry and material sciences are represented most frequently, while we find no institution from the life science sector.

When analysing the publications with regard to the SCI's system of disciplines, the multi-disciplinary character of the research field of nano S&T becomes most obvious. Applied physics, material science, physical chemistry, physics of condensed matter and general chemistry are among the most important subdisciplines. In the course of time, the importance of material science, applied physics, physics of condensed matter and general chemistry has increased, while subareas in life sciences and pharmacology have lost in significance (Fig. B.3).

B.2.4 Results of the Patent Analysis

The publication volume and the invention activity have increased substantially over the past 15 years. While, however, in the period under review (1995–2005) the amount of patented inventions increased every year by a factor of eight worldwide,

Table B.1 Major German research institutes in nano S&T, 2007

Number of publications	Institute
>350	Max Planck Institute for Solid State Research, Stuttgart
>150	Max Planck Institute for Polymer Research, Mainz
>100	Institute for Solid State Physics, Technical University of Berlin
>100	Institute of Nanotechnology, Research Center Karlsruhe
>80	Leibniz Institute for Solid State and Materials Research Dresden
>60	Max Planck Institute for Metal Research, Stuttgart
>60	Institute for Physical Chemistry, Technical University Karlsruhe
>50	Fritz Haber Institute, Berlin
>50	Walter Schottky Institute, Technical University Munich
>50	Institute of Physics, Rostock University
>40	Max Planck Institute of Microstructure Physics, Halle
>40	Institute of Organic Chemistry, University Erlangen-Nuremberg
>30	Institute of Theoretical Physics, Freie Universität Berlin
>30	Institute of Materials Science, Darmstadt University of Technology
>30	Institute of Theoretical Physics, Technical University of Berlin
>30	Institute for Physics, University Augsburg
>30	Institute for Chemistry, Humboldt-Universität zu Berlin

Source: SCI (Host: STN)

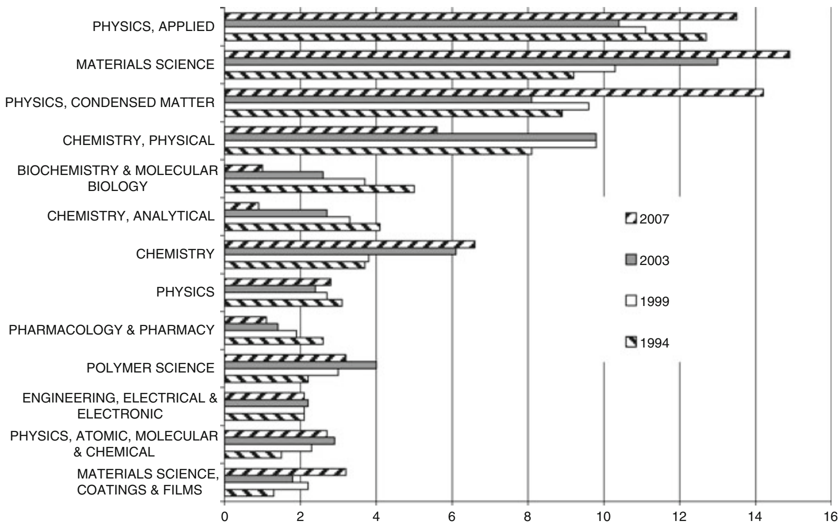

Fig. B.3 Publications in nano S&T by scientific discipline in %. Source: SCI (Host: STN)

a growth factor of merely around six can be established for German patent applications (Fig. B.4). After a phase of stagnation between 2000 and 2003, the growth of German applications has gained momentum again since 2004 and is thus following the international trend again.

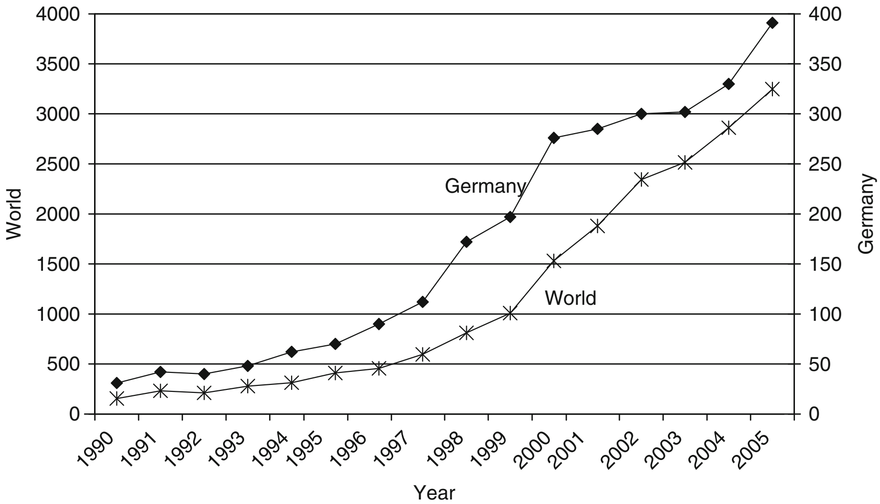

Fig. B.4 Patent applications in nano S&T, 1990–2005. Source: WPI (Host: STN)

The majority of German patent applications come from large companies such as BASF, Siemens or Degussa. It is certainly true that the number of small and medium-sized enterprises (SMEs) in the field of nanotechnology has increased over the past years. Nevertheless, these enterprises still apply for considerably fewer patents. German SMEs include for example Nanogate Technologies GmbH, Nano_X GmbH, ItN-Nanovation, NanoSolutions, Capsulution Nano Science AG, NaWoTec GmbH, ION-TOF Technologies GmbH, S.I.S. Surface Imaging Systems GmbH or nanotools GmbH. Furthermore, universities and non-university research institutions meanwhile emerge as patentees to a substantial degree. The Fraunhofer-Gesellschaft has the highest patent output; the Max Planck Society ranks second. The Saarbrücken-based Institute for New Materials, which is part of the Leibniz Association, and the Research Centre in Karlsruhe have a particularly large patent output. Both of them are pioneers in the German nano S&T sector (Table B.2).

B.3 Institutional Structure and Research Promotion

The emergence of the nano S&T field builds on the availability of substantial public and private research and development resources (R&D resources). STM and AFM facilities, but also micro-electro-mechanical systems (MEMs) and nanolithography systems are very expensive. Therefore, several countries launched nano S&T funding programmes in the late 1990s and early 2000s to meet these investment needs and to ensure the international competitiveness of their research institutions. The

Table B.2 German institutions with large patent output in nano S&T, 2005

Number of patent applications	Applicants
>50	BASF
>40	Siemens
>40	Fraunhofer-Gesellschaft
>30	Infineon Technologies
>25	Degussa
>20	Philips
>20	Max Planck Society
>15	Merck
>15	Leibniz Institute for New Materials
>10	Ciba
>10	Sony
>10	Blue Membranes
>10	Bosch
>10	Technische Universität Dresden
>10	Research Center Karlsruhe

Source: WPI (Host: STN)

total annual public funding in 2004 has been estimated for the following countries (European Commission 2005):

- United States: €1.243 million;
- Japan: €750 million;
- European Commission: €370 million;
- Germany: €293 million;
- France: €224 million;
- United Kingdom: €133 million;
- China: €83 million.

In Germany, the nano S&T field is sponsored through R&D projects (project funding) and the direct funding of institutes (institutional funding). The overwhelming share of project funding is provided by the Federal Ministry of Education and Research (BMBF) and the German Research Foundation (DFG). The Federal Ministry of Economics and Technology (BMWi) contributes a further, smaller part of the funding.

The largest share of the BMBF's funding goes to collaboration projects between companies and research institutions. Since 1998, further funds have been made available for cross-linking so-called "competence centres" in order to advance inter-organisational networking in the focal areas of nanotechnology. This strategy aims at activating self-sustaining economic dynamics in the medium and long term. Moreover, the BMBF promotes so-called "guiding innovation projects", which are meant to foster innovations. In addition to this, the BMBF launched a competition for junior scientists in the field of nanotechnology. This competition was launched

Table B.3 Nano S&T funding in the German public research sector, € millions

	2001	2002	2003	2004	2005
Project funding (federal level)					
Federal Ministry of Economics and Technology	8.0	21.1	24.5	24.5	23.7
German Research Foundation (DFG)	27	60	60	60	60
Institutional support (federal level)					
Max Planck Society (MPG)	14.3	14.8	14.8	14.8	14.8
Fraunhofer-Gesellschaft (FhG)	8.5	4.6	5.4	5.2	4.9
Leibniz Association (WGL)	25.4	23.7	23.6	23.4	23.5
Helmholtz Association (HGF)	31.8	38.2	37.1	37.4	37.8
Others	5.7	1.8	3.3	4	4.4
Total	217.3	238.1	256.9	293.1	298.3

Source: BMBF

in order to create up to 20 junior teams at university or non-university research institutions. Along with project funding, non-university research institutions in the German academic system are supported in institutional terms (Table B.3).

B.4 Further Information

There are several websites with up-to-date information on the nano S&T field. Some examples of public web resources in Germany, Europe and the United States are stated below:

www.techportal.de (operated by the German Engineering Association, VDI)
www.nano-map.de (operated by the German Engineering Association, VDI)
www.bmbf.de/de/nanotechnologie.php (operated by BMBF)
www.observatory-nano.eu (operated by a consultancy consortium)
www.nanoforum.org (operated by a consultancy consortium)
cordis.europa.eu/nanotechnology/ (operated by the European Commission)
www.nnin.org (operated by the US National Nanotech Infrastructure Network)
www.nano.gov (operated by the Federal Government of the United States).

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Appendix C
The Research Field of Medical Biotechnology

Jürgen Enders and Ulrich Schmoch

C.1 Definition of the Research Field

Biotechnology is defined in different ways, which reflects the wide breadth of the field and the constantly advancing dynamics therein. The European Federation of Biotechnology speaks of the "integrated application of natural sciences and engineering sciences with the goal to utilise cells or component parts thereof". (European Federation of Biotechnology 1989). In their "Convention on Biological Diversity", the United Nations presented the following definition: "Biotechnology is any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use". (http://www.wordiq.com/definition/Biotechnology). At the moment the definition of the OECD is also very common: "The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services". (OECD 2005: 9) These definitions point clearly to the application orientation, which is assuredly of great significance. Biotechnology, however, has also developed into many new, research-oriented fields, which is why the BMBF prefers the following, more broadly based definition: "Biotechnology can be described quite generally as dealing with biological systems and biological information in research and application". (BMBF 2001: 10).

In the literature, biotechnology is presented as a relatively young research field cutting across scientific disciplines, which has experienced a veritable boom in the last three decades. Biology and chemistry doubtless belong to the core disciplines of the research field, but informatics, medicine, physics material science and engineering can equally be named. Typical biotechnology research fields encompass for instance genome research – which again can be divided into human genome research, genome research into microorganisms as well as plant genome research – structural molecular biology, bioinformatics, nanobiotechnology, neuroscience, tissue engineering and bio-friendly environmental procedures. Thanks to the advances

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made in bioinformatics, laboratory experiments and research in these and other areas are no longer conducted only in vitro (in a test tube), in vivo (on living organisms), but also in silico (in data sets and simulation models).

With a view to the areas and potential application fields of research, this is divided into the three sectors “green”, “white” and “red biotechnology” (medical biotechnology). Whereas “green biotechnology” mainly addresses plant organisms and their application in the field of agriculture, “white biotechnology” is oriented towards improving industrial production, for example by transferring approaches developed in nature to solve technical problems. “Red biotechnology” deals with animal and human organisms and is regarded as a driving force for innovation in medicine and pharmacy. The divisions between “green”, “white” and “red biotechnology” are not always clear, as many and diverse common research questions, overlaps and mutual inspiration in research can be observed. Thus, for instance, the improved production of pharmaceutical active ingredients is a central topic in “white biotechnology”.

Doubtlessly, the pharmaceutical industry and medicine, agriculture, the chemical industry and the environmental sector could be named as areas for which biotechnology exhibits typical characteristics of a strategic key technology. Here aspects of research and utilisation can be closely joined together. Biotechnology has become the working sphere of a growing number of companies also in Germany. Regarding the numbers, Germany overtook Great Britain in 2000, which had been the leading biotechnology nation in Europe for many years. However, most biotech companies in Germany are still very young, and the number of employees per company still lies beneath the European average (BMBF 2001).[23]

C.2 Publication and Patent Analysis

Biotechnology has been one of the most dynamic science fields in recent years. In medical biotechnology, the subsector investigated here, the number of publications in the Science Citation Index (SCI) grew worldwide from 71,500 to 115,300 between 1995 and 2007. The corresponding development trends for Germany and the world as a whole are presented in Fig. C.1. According to this figure, German scientists were able to keep pace with the international dynamics in the period mentioned above, whereby the growth of German publications lay slightly above the world average from 1995 to 1999. The share of German publications within the world-wide publications in medical biotechnology was 8.6% in 2007, thus clearly above the average share of all German publications in the SCI of 7.3%. Thus, the specialisation of German scientists in medical biotechnology is very strong.

Differentiated according to the SCI technical categories, around 19% of all worldwide publications of medical biotechnology are classified in the field “Biotechnology and applied microbiology” in Fig. C.2. Further general biological

[23]This thesis is based on data from Ernst & Young, which are, however, disputed.

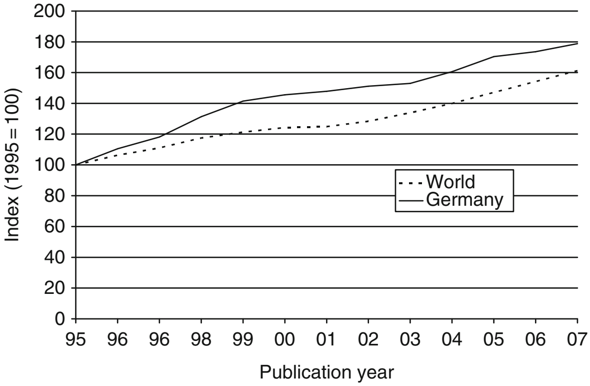

Fig. C.1 Trend in publications of medical biotechnology in the Science Citation Index. Sources: SCISEARCH (STN), calculations of Fraunhofer ISI

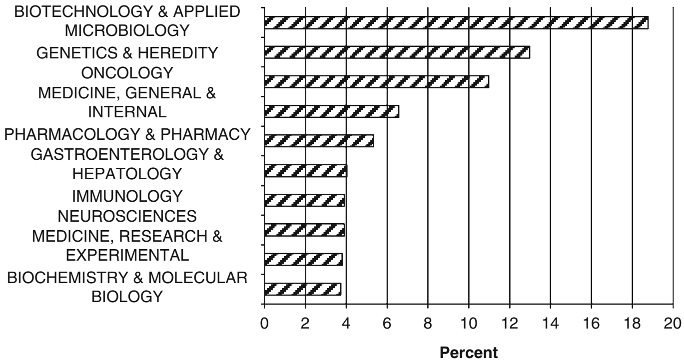

Fig. C.2 Classification of the worldwide publications of medical biotechnology into categories of the Science Citation Index, 2007. Sources: SCISEARCH (STN), calculations of Fraunhofer ISI

fields can be found among the following categories, such as "Genetics and heredity" or "Biochemistry and molecular biology", but also categories with a clearly medical relevance like "Oncology", "Pharmacology and pharmacy", or "Medicine, general and internal". Overall, if compared with the publications about biology in general, the medical application areas dominate.

An analysis of the national origins of the publications shows, as expected, the dominance of the United States, followed by Japan, France and the Peoples' Republic of China; Germany lies in fifth place. In this country table, the relatively strong positions of the Peoples' Republic of China, Brazil, South Korea and India are remarkable as they are threshold countries that have obviously committed themselves strongly to medical biotechnology (Fig. C.3).

When German institutions which are most actively engaged in publications are examined, many non-university institutes take top places, but they are not as dominant as in the case of astrophysics, for example (Table C.1). In this type of

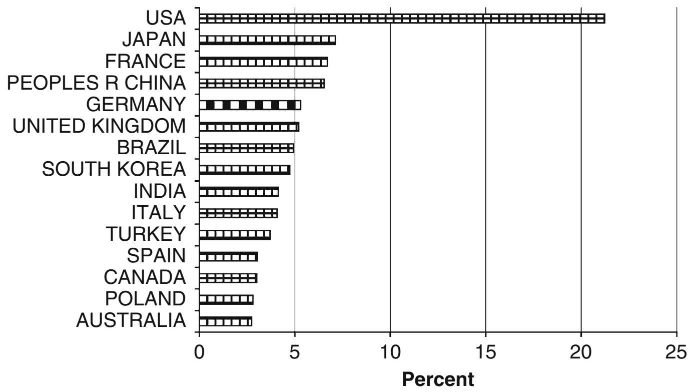

Fig. C.3 National origins of SCI publications of medical biotechnology, 2007. Sources: SCISEARCH (STN), calculations of Fraunhofer ISI

Table C.1 German institutions with the most SCI publications of medical biotechnology, 2007

Share (%)[a]	Institution
2.6	Max Planck Inst. Mol. Genet., Berlin
1.6	Univ. Heidelberg
1.4	Univ. Erlangen Nuremberg
1.0	Bernhard Nocht. Inst. Trop. Med.
0.8	Helmholtz Ctr. Infect. Res., Braunschweig
0.8	Johannes Gutenberg-Univ. Mainz
0.8	Phys. Techn. Bundesanstalt
0.8	Sygnis Biosci, Heidelberg
0.8	Techn. Univ. Berlin
0.8	Univ. Fribourg
0.8	Univ. Hosp. Erlangen
0.6	Max Planck Inst. Chem. Ecol., Jena
0.6	Univ. Erlangen Nuremberg
0.6	Aachen Uni Hospital

[a]Share of all German publications in medical biotechnology.
Sources: SCISEARCH (STN), calculations Fraunhofer ISI

assessment one must remember that the number of publications rather reflects the size of an institution and only conditionally reflects the quality. Above all, it is interesting that a pharmaceutical concern – Sygnis – can be found in the list of the institutions with the most publications. In all publications of German origin the share of individual institutions is really low in each case, as a great number of institutions are actively engaged in medical biotechnology in the meantime.

The situation for patent applications is similar to the situation for publications: up to the year 2000, considerable growth dynamic can be observed, whereby German patent applicants keep pace with the international trend (Fig. C.4). From 1998 the number of applications from Germany grows more rapidly than the statistics worldwide, although this must be interpreted as a move to catch up from a weak starting

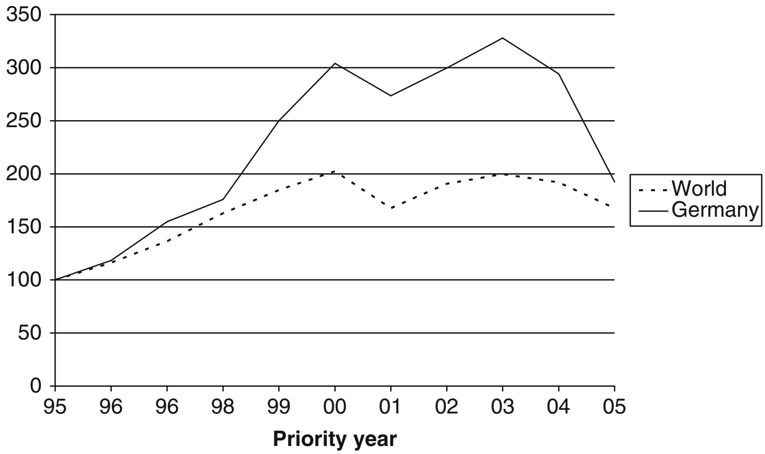

Fig. C.4 Trend of German and international patent applications in medical biotechnology (1995=100). Sources: EPPATENT (Questel-Orbit), WOPATENT (Questel-Orbit), calculations of Fraunhofer ISI

position in terms of absolute numbers. In Fig. C.4 the strong decline in application figures after the year 2000 is striking, which has to be seen in the context of the general economic crisis in the high-tech sector. Since 2002, a renewed growth can be observed in German patent applications, since 2003 once again a big decline. This lapse reflects a general uncertainty in the market. In this connection, it is remarkable that publication growth continues even if it is less strong. This corresponds to a general development in other branches showing that scientific activities react less sensitively to cyclical fluctuations in the economy.

By far the most patent applications are made by the United States, whilst Japan and Germany, Great Britain and France follow in places 2–5. As for the threshold countries, at least South Korea and China are represented in place 14 and 15, respectively. In the knowledge-intensive areas the publication indicators lie ahead of the patent applications, so in a few years a higher incidence of applications can be reckoned with from South Korea and China.

From a substantive perspective, medical preparations are the main focus for patent applications in medical biotechnology, that is, medicines with biotechnological active ingredients. Many patent applications are classified in general categories like “microorganisms, enzymes” or “biotechnological procedures”. The application category “analysis of biological substances” which refers to the biotechnological analysis of blood and other body fluids for medical purposes should be especially pointed out.

Companies dominate in filing patent applications. The participation of scientific institutions in technical inventions is visible only to a certain extent, as university employees often appear as inventors, but not as applicants. If the participation of science is researched with more sophisticated methods, a quota of ca. 40% emerges for Germany, which is a maximum value within the knowledge-based technology

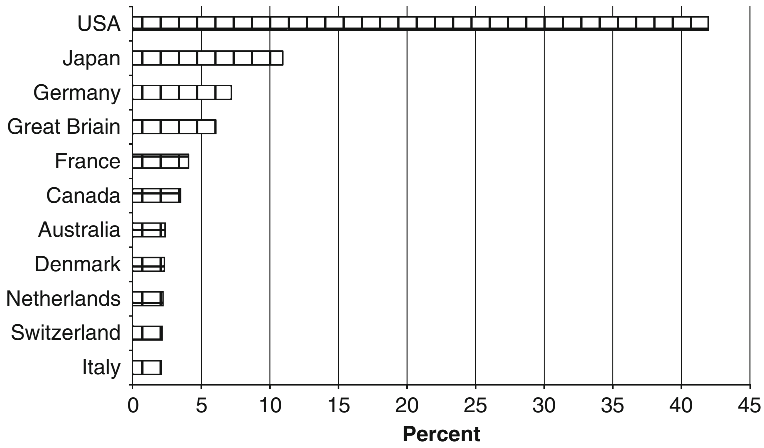

Fig. C.5 Most active countries as to international patent applications in medical biotechnology, share with reference to all applications in 2005. Sources: EPPATENT (Questel-Orbit), WOPATENT (Questel-Orbit), calculations of Fraunhofer ISI

fields. In the field of organic chemistry, this quota amounts to 20%, in metrology to 12% and for an average of all technology fields to 7% (Schmoch 2004: 717–731) (Fig. C.5).

On the whole, medical biotechnology proves to be an area with a close connection between science and technical application and therefore with scientific institutions contributing themselves to a considerable extent to the technological output.

C.3 Institutional Structures and Research Promotion

Nowadays, bioscience research is conducted in over 250 university institutes and chairs as well as in ca. 80 non-university institutions of the Max Planck Society, the Leibniz Association, the Helmholtz Association of German Research Centres, the Fraunhofer-Gesellschaft and some research facilities of the German Federal Government and the federal states. The number of scientists working in bioscience research in the public domain is estimated at approx. 13,000. Traditional strengths of German basic research are seen in areas such as cell biology, neuroscience and developmental biology. In areas like molecular biology and molecular genetics research Germany was able to catch up with international developments only by means of a corresponding priority-setting in its promotional and infrastructural policy.

In the meantime, the big research promotion organisations, the German Research Foundation (DFG) and the Max Planck Society, spend about a third of their research budgets on bioscience and biomedical research. The Federal Government annually spends around €0.79 billion to promote research and technology in the life sciences. Around €0.65 billion of these funds come from the BMBF budget, whereby the funds for the HGF centres and the WGL institutes are included in this figure. For project promotion in the area of biotechnology, the BMBF merely provides ca. €177 million annually (BMBF 2006). "The most important measures of this promotional area encompass building up basic innovations and platform technologies in genome and proteom research for the development of new products, structural measures, among others to support young biotechnology research enterprises, as well as promoting young researchers" (BMBF 2004: 284). In this context, the BMBF has been promoting many and various programmes up to now, such as the German Human Genome Project, the National Genome Research Network, the Genome Analysis of the Plant Biological System (GABI), the Genome Research on Microorganisms (GenoMik), as well as methods for functional proteome analysis, a promotion initiative for bioinformatics, or support programmes for systems biology as well as nanobiotechnology. In addition, the research mission of the European Molecular Biology Laboratory (EMBL), having its headquarters in Heidelberg, is sponsored by Germany with a share in excess of €10.2 million annually. Commonly, the programmes mentioned above should combat the fragmentation in research and should contribute to the creation of regional and inter-disciplinary focuses. Finally, at the European level, a focus on biotechnology research was created in particular by the 6th Research Framework Programme. Thus, the emphasis of the first thematic priority "lifesciences, genomics and biotechnology for health", which was sponsored to the tune of €2.26 billion, was placed on genomics and its application in medicine, with only a few exceptions (BMBF 2002).

Publications and patent analyses indicate that German research has clearly caught up with the international competition in the area of medical biotechnology. In absolute figures, the USA with approx. 37% of all publications worldwide, Japan with 10% and Germany and England with 8% respectively are the countries with the largest volume of publications. With a view to the strongly growing number of patents, Germany also takes the third place, behind the USA and Japan.

A report on biotechnology performance in Europe (European Commission 2003),[24] which works with an extended set of relatively weighted indicators, shows a more differentiated picture. In this study, a number of European countries were classified into four groups with a view to technological capability in the two areas "knowledge base" and "commercialisation" in the field of biotechnology. According to this classification, the performance of six countries in both areas lies above the European average. Among these are the Scandinavian countries, the Netherlands and Great Britain. Six countries exhibit a below-average performance for both areas. Among these are France, Greece, Italy and Portugal. Only Germany and Austria dont´ belong to any of these clusters. A below-average performance in the area "knowledge base" and an above-average one in the area "commercialisation" was

[24]The report deals with the situation of biotechnology in Europe on the whole, i.e. the public and private area, and shows no special data for biomedtech.

ascertained for Germany. Conversely, a below-average performance in the areas "commercialisation" and an above-average one in the area "knowledge base" was determined for Austria. In a final ranking of these two areas the Scandinavian countries are in front, followed by the group of the "second best performers", which besides Germany comprises also the Netherlands and Great Britain.

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Appendix D
The Research Field of Economics

Torben Schubert

D.1 Definition of the Research Field

Technically the economic sciences can be subdivided into business economics and what is usually, somewhat loosely, just called economics. It is difficult to differentiate between the two. However, when staying at a rather abstract level, it can be noted that business economics deals with practical questions which are relevant for leading or managing companies, while the term economics stands for a broader area of economics.

Commonly, the seminal work "An Inquiry into the Nature and Causes of the Wealth of Nations" by Adam Smith (1776) is regarded as the hour of birth of economics, although there are certainly predecessors in mercantilism and physiocratism (especially Francois Quesnay). In classical economics, which has been founded by Adam Smith and others, many of the theoretical concepts like Smiths ́ "invisible hand" have been worked out and are still important today. A second important step in the development of economics was the neoclassical movement, which enriched the formerly only verbal or philosophical classical economics by a mathematical model-theoretic framework. Especially Cournot (1838) made major contributions to the theory of monopoly, which are still today an integral part of undergraduate teaching in economics.

Although neoclassical economics soon was split into at least three schools, the resulting differences, seen from today's perspective, are small, which certainly is also due to the acceptance of the laissez-faire paradigm common to all neoclassical economists. The superiority of the inactive government implied by laissez-faire was later challenged by the economist John Maynard Keynes (1936). Keynes developed a completely novel macro-economic theory which was popularised from scratch by the economist Sir John Richard Hicks. Central to Keynesian economics is the rejection of Say's law, an idea of the French businessman and economist Jean-Baptiste Say saying that any supply will eventually create its demand.

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In contrast, Keynes believed that predominantly a deficit in the purchasing power of private economic actors causes macro-economic disequilibria in consumer and factor markets in the short term which leads to short-term unemployment. Keynes deduced a leading role of the government in preserving and securing macro-economic stability from his theory. This school of thought displaced the formerly dominating neoclassical body of thought for at least the following 25 years in science and lives on in policy debates still today. In any case, neoclassical ideas or, strictly speaking, their ideological offspring, experienced a revival in the early 1970s because the empirical evidence resulting from 30 years of Keynesianism was very dissatisfactory: Instead of having advanced an increasing employment, the economically "active" governments (i.e. deficit spending and active monetary policy by the central banks) rather caused increasing public debts and inflation. This was called "stagflation".

Apart from the distinction of the historic ideas, economics can be divided into the subfields microeconomics, macroeconomics, econometrics, and game theory. Those subfields are not mutually exclusive because the first two terms denote the topic of analysis, whereas the latter two rather denote the methodology used. Microeconomics deals with the foundation of economic decisions of individuals (e.g. individual persons, households, or more generally societal actors). Contrarily, macroeconomics develops models to understand macro-level phenomena like international trade, unemployment, or central bank policy. In contrast to early macro-economic research, the attempt to introduce a micro-economic foundation is usually made. Econometrics entails both the development of statistical methods for the empirical validation of theoretical results as well as the application of these methods. Therefore, the applied econometrics can, depending on the research question, either be classified as micro- or macro-economic research, while theoretical econometrics is a distinct research field. Game theory provides theoretical instruments that help to understand the behaviour of individual economic actors. Though game theory is regarded primarily as a micro-economic subdiscipline, its concepts are frequently used also in macroeconomics, inasmuch as the latter has a microfoundation.

It must be taken into account, however, that the borders between these four subdisciplines are often blurred especially because there are several other disciplines which are partially subsumed under them. For example, experimental economics, striving for the antetype of research in natural sciences, tries to conduct behavioural experiments with real persons to understand economic behaviour better. Economic policy research as well as evolutionary and innovation economics, the latter two often being attributed to the economist Joseph A. Schumpeter, are also worth mentioning.

Because of the complex character of the topics, economics as a science can hardly be characterised in a clear manner. Especially game theory (having developed the Nash-equilibrium) contributed to making societal phenomena accessible to economic methodology, which would not even have been regarded as economic topics. Thus, it seems to be better to view modern economics as a general behavioural science which tries to develop model-based theories and to test them by means of empirical methods. This is certainly a more encompassing view than the view of it as a science which deals with economic questions, where "economic" would be defined in a narrower sense.

D.2 Publication Analysis

Similarly to the natural sciences, a major output indicator in economics will be the number of publications in refereed journals. In the last decades, the importance of international publications, i.e. especially English publications, has risen considerably, while the importance of purely domestic journals has steadily declined. A common objection is that the SSCI is heavily biased towards English or American journals. This is certainly true, but it is of minor relevance in the case of economics, because the research considered to be competitive is almost always published in international journals or, at the very least, published in English. Casually mentioned, many traditional German journals have now English titles[25] and publish the papers either only or at least also in English.[26] Therefore it seems to be acceptable to use the Social Sciences Citation Index (SSCI) as a source to measure German publication-related activities in the field of economics.

The identification will be done by the SSCI-classification "Economics". Two possible biases are worth mentioning. Firstly, also publications that are rather related to business economics will be considered. Secondly, many of the peripheral subdisciplines of economics will be dropped. This will hold true especially for economic statistics. Anyhow, the author believes that these biases will not be overwhelmingly large: Business economics in Germany is, like economics several years ago, still a discipline where the domestic orientation of the community is predominant. The relevant journals of German origin are, save for some notable exceptions (e.g., Zeitschrift für Betriebswirtschaftliche Forschung und Praxis), not listed in the SSCI, though. Not considering the economically driven contributions in applied mathematics, with great emphasis on statistics, will certainly bias the results to some extent. Yet it seems hard to distinguish economic statistics from purely mathematical contributions, as the relevant journals are frequented by both kinds of scientists. Further, many of the "economic statisticians" are in fact mathematicians who only have an economic affiliation. With respect to importance, this effect should be negligible.

Turning to the evolution of the number of scientific contributions in the SSCI related to the time period from 1997 to 2007 (Fig. D.1), it can be seen that Germany lies considerably above the world trend. Between 1997 and 2007, Germany more

[25]For example, the former "Zeitschrift für die gesamte Staatswissenschaft" is today called *Journal of Institutional and Theoretical Economics*.

[26]Besides it shall be noted, that many of the German journals are now listed in the SSCI (e.g. Finanzarchiv, *Journal of Economics and Statistics*, CESIFO Studies, *Journal of Economics – Zeitschrift für Nationalökonomie*, *German Economic Review* and the previously mentioned *Journal of Institutional and Theoretical Economics*).

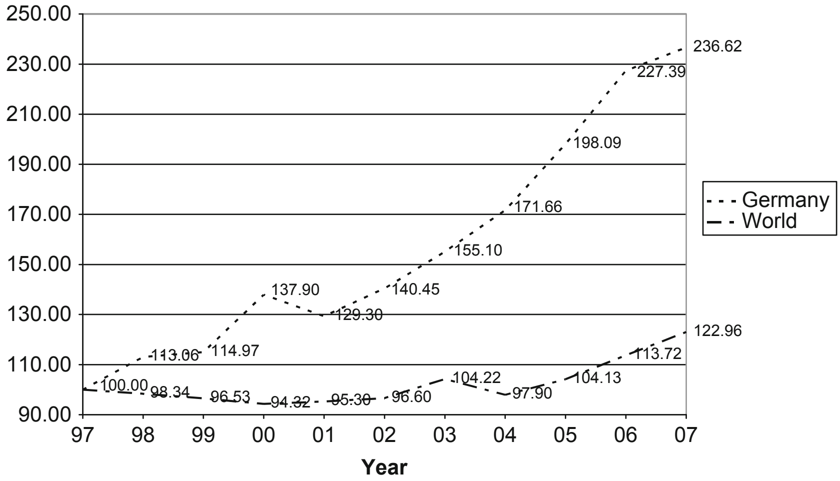

Fig. D.1 Number of publications (1997 = 100). Source: Web of Science (SSCI), calculations by Fraunhofer ISI

than doubled its scientific output, while the world experienced an increase of only about 22%.[27] This can partly be explained by the fact that the German economic community is still in an ongoing process of internationalisation which means that many articles, which would have been published in German journals before, are now rather submitted to international ones. This internationalisation is fostered by the change of generations induced by the wave of retirements in the German science sector between 2003 and 2006.

Nonetheless, turning to the question of the origin of scientific publications, the dominance of authors from the USA becomes obvious, as they hold a share of almost 45% of all publications worldwide (Fig. D.2). Germany‘s share adds up to 6.2%, ranking third behind the UK (15.4%). This also highlights that the impressive evolution of Germany‘s publication counts must also be seen against the fact that Germany started from a rather low level (3.2% in 1997). Thus, the ongoing process is one of catching up to the Anglo-American world rather than one of leaving it behind.

Also in economics, the share of international co-publications (publications with at least one author with non-German affiliation) is by now considerable. 346 of the 743 German publications, i.e. almost one half, had co-authors. Here as well the US-American partners dominate the scene (31.0%). The countries at second and third place are the UK (27.2%) and the Netherlands (11.3%). Also the two other German-speaking countries Switzerland and Austria are important partners, as their shares sum up to 16%. This can, on the one hand, be seen as a result of the linguistic and geographical proximity, but, on the other hand, also as a result of the structure of

[27] The index values correspond to about 12,000 publications in total, of which 750 are written by German authors.

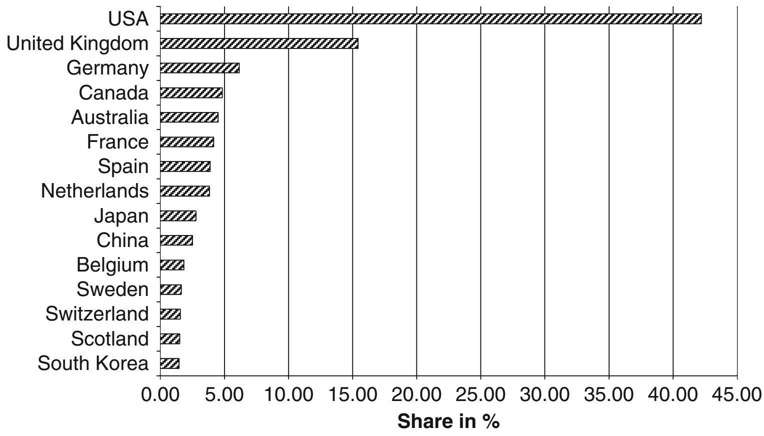

Fig. D.2 Publications by origin (2007). Source: Web of Science (SSCI), calculations by Fraunhofer ISI

the scientific societies. The largest economic society is the "Verein für Socialpolitik" which does not only address economists of German origin, but considers itself as a society of German-speaking economists. Thus, Austria and Switzerland are very important for this society. Anyhow, also the non-German-speaking neighbours of Germany are important. As mentioned above, the Netherlands is with 11.3% the third most important partner of Germany (Fig. D.3).

The universities don't dominate the field of natural sciences but of economics, at least in terms of scientific publications. Despite the fact that the extra-university unit Institute for the Study of Labour (IZA) leads the list of the most important

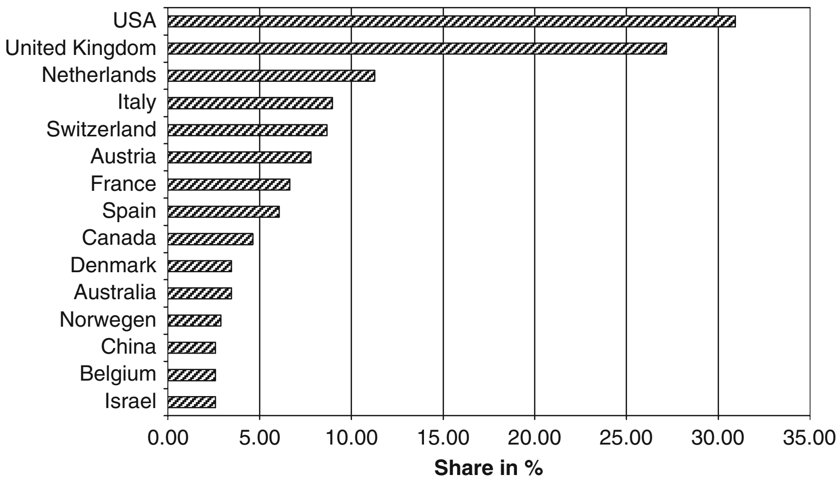

Fig. D.3 Important cooperation partners of Germany (2007). Source: Web of Science (SSCI), calculations by Fraunhofer ISI

Table D.1 Most important German publishers (2007)

Unit	Number of publications	Share in %
Forschungsinstitut zur Zukunft der Arbeit Bonn	59	7.94
University Munich (LMU)	42	5.65
University Bonn	39	5.25
CESIFO Munich	36	4.85
Max-Planck-Institut für Ökonomik Jena	30	4.04
University Mannheim	28	3.77
Free University Berlin	27	3.63
University Frankfurt	27	3.63
Humboldt University Berlin	27	3.63
University Hamburg	22	2.96

Source: Web of Science (SSCI), calculations by Fraunhofer ISI

publishers (it holds a share of about 7.9% of all German publications), only two other non-university institutes are in this top-ten list, where the other seven are universities. The University of Munich (LMU) ranks second with a share of 5.7%, the University of Bonn ranks third with a share of 5.3%. The remaining two extra-university institutes are the Institute for Economic Research (CESIFO) in Munich (4.9%) and the Max Planck Institute of Economics in Jena (4.0%) (Table D.1).

Summing up, the German economic community has gained an internationally visible position. However, it should not be overlooked that economic research is still dominated by US-American and British authors. This is highlighted also by the fact, that only one German economist has ever received the Noble prize.[28]

D.3 Structures and Research Promotion in Germany

Unlike natural sciences, economics in Germany is shaped by university research groups. According to the database Vademecum, there are over 400 of them in 2008. This can be explained partly by the lack of a dependence on expensive equipment, which makes work in large teams often unnecessary. Nonetheless, the importance of third-party funds has increased also in economics. Accordingly, in 2005 there were €17,000 of third-party funds per scientific employee in law, economics and social science. Still below the average of €34,000, this has constituted an increase of 35% since the year 2000 (Statistisches Bundesamt 2005).[29] In Germany, a major supplier of third-party funds is the German Research Foundation (DFG), both by the diverse regular funding instruments like Collaborative Research Centres, Research Centres, Graduate Schools, project funding, and by the Excellence Initiative. Only a minority of the DFG funding is directed towards social sciences, economics and humanities, which received in sum about 14% (€200 million) of the DFG budget in 2006.

[28]Reinhard Selten received the Noble prize in 1992 for his game-theoretic contributions together with John Harsanyi (USA) and John Nash (USA). See also Struve and Unterreiner (2007).

[29]Figures for economics alone are not available.

Table D.2 Project funding by the DFG (May 2008)

Discipline	Number of projects (total)	Number of projects (since 2000)
Total	34,077	16,784
Economic Sciences	493	241
Social Sciences	793	423

Source: GEPRIS-Funding-Database (DFG)

Additionally, Table D.2 shows that economic sciences received less from the DFG budget than social sciences. While the DFG funded only 493 economic projects, it funded almost 800 projects in the social sciences. In total, 34,000 projects were funded.

Besides the university chairs, there are many extra-university research institutes primarily working on questions which are related to economic policy. Among these are the Halle Institute for Economic Research, the Kiel Institute for the World Economy, the German Institute for Economic Research in Berlin, the CESIFO in Munich and the Rheinisch-Westfälisches Institut für Wirtschaftsforschung in Essen (RWI Essen), who jointly publish a report on the current economic development in Germany (Jahresgutachten des Sachverständigenrates zur Begutachtung der gesamtwirtschaftlichen Entwicklung). Besides these institutes mentioned above, there are several other research institutes like the Institut der deutschen Wirtschaft Köln, the Centre for European Economic Research (ZEW) in Mannheim and the Max Planck Institute of Economics in Jena. The institutes are funded in significantly different ways. Some of them receive only little basic funding, whereas others receive so much basic funding that they are able to finance much of their research with it. The amount of basic funding is also reflected by the thematic profile of these institutes. The Max Planck Institute of Economics, having a relatively large basis of unconditional funds, certainly is oriented heavily towards basic research, while the Institut der deutschen Wirtschaft Köln primarily works for private actors, leading to a rather applied and policy-oriented profile.

With respect to academic self-governance, there are several economic societies. The largest one is the Verein für Socialpolitik (see above). Besides, there are others like the German Statistical Society (DStatG), even if the DStatG can be regarded only partly as an economic association. Even though they are not relevant for the self-governance in the national context, for economists it is also common to participate in supranational societies, such as the European Economic Association, or other national organisations, such as the Royal Economic Society or the American Economic Association.

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