

First Draft. Please do not cite or quote without permission of the author.

The Changing Governance of Public Research in Germany¹

Dorothea Jansen

<http://www.dhv-speyer.de>

Jansen@dhv-speyer.de

German University of Administrative Sciences, Speyer, Germany

1st of June, 2008

Paper to be presented at the 24th EGOS Colloquium “Upsetting Organizations”
July 10-12, 2008, University of Amsterdam, Netherlands

Sub-theme 42

The Changing Organization of Science and The Changing Sciences of Organization
Convenors: Lars Engwall and Richard Whitley

¹ I present research results from the project „Network strategy and network capacity of research groups“ which is conducted at the German Research Institute for Public Administration. Team members are Karola Franke and Andreas Wald (2003-2006) and Richard Heidler and Regina von Görtz (2006-2009). Funding by the German Research Association is gratefully acknowledged (JA 548/5-1, JA 548/5-2, JA 548/5-3).

1 Introduction

The German research system is characterized by an ever increasing scarcity of resources and increasing pressure for reforms. The most recent evidence for increasing competition and new forms of evaluation and funding is the so called Excellence Initiative run by the German Research Association and the German Science Council. This initiative addressed the German universities in a concours for earmarked public funding in three programme lines: graduate schools, excellence clusters, and finally eligible only for winners in both previous lines so called concepts for the future of excellent universities ("elite universities"). For the first time being, the level of the university as an institution was explicitly addressed by a funding programme of the German Research Association. The call for proposals even mentioned that management capacity of universities is asked for. In the next six years this programme will distribute 1.9 Billion Euros among 39 graduate schools, 37 excellence clusters and 9 "elite" universities.

Amendments to the German university laws at the federal (1998, 2002, 2004) and at the state level deeply changed the internal structures of universities (Hartmer and Detmer 2004; Trute et al.2007) in the last years. In particular, the convergence between the higher education sector in the different federal states ended as a result of several rulings by the federal constitutional court. Negotiation on the split of competences of the Länder (states) and the federal state in the first part of the reform of the federalist constitution in 2007 resulted in a constitutional change giving the "Länder" the full jurisdiction on education including Higher Education Institutions. The federal state kept its competence in research and innovation policy and the joint funding of the large extra-university public research sector. In addition several agreements between the "Länder" and the federal state on the joint funding of science policy programmes addressing the universities (see above) and the extra-university public research sector were concluded. Today, state legislators in the sixteen federal states have a broad leeway in regulating the organization of higher education institutions. Much legislator work set on with this increase of state level competencies and is still going on. Major changes concern the financing of the universities. Universities have been granted more autonomy regarding their spending (Federkeil and Ziegele 2001, Seidler 2004). Furthermore, salaries for professors can now be based on performance (Knopp and Gutheil 2003). New regulations mainly concern the performance related allocation of resources, performance related salary, the strengthening of hierarchical management by deans, rectors and presidents at the cost of academic self governance, the introduction of internal evaluation processes and profile building (Leszczensky and Orr 2004). In addition, the large umbrella organizations of science such as Max-Planck Society or the Helmholtz Association (i.e. the large research centers) have strengthened their internal competition, introduced evaluation procedures and a target oriented management of resources (program budgets, cost-performance analysis) (Arnold 2007, Gross/ Arnold 2007). Today, even Max-Planck-Institutes and Helmholtz Centers compete for third party money from the EU or the German Research Association (only in priority programs).

Thus, university reforms and reforms in the German system of extra-university research follow strands of reasoning that are common to university reforms in other European countries, too. These are (1) the transfer of the idea of New Public Management to the public research sector, (2) a quest for relevance and value for money that leads to a concentration

of resources and funding on priority programmes and so called mode 2 forms of knowledge production, (3) a transfer of concepts from the private sector such as critical mass, internationalization and networking to public sector research. In addition, increased competition for institutional as well as third party funding, new forms of evaluation of performance and evaluation agencies and a strengthening of management in universities and research institutes can be observed (Kehm/ Lanzendorf 2007, de Boer et al. 2007, Gornitzka et al. 2008).

This paper presents results from a study based on quantitative and qualitative data of 77 (2004) respective of 75 (2006/07) German research groups from three subfields – astrophysics as a field of fundamental natural science research, nanoscience as a potential mode 2 field and (micro-)economics as social science field. In a first step, a bibliometric analysis of the Science Citation Index (SCI) and ECONLIT revealed all researchers that published at least one article in the field.² Since the publication databases deal with 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 data were collected in semi structured expert interviews in 2004 and a follow-up questionnaire and telephone interview in 2006/07. Sixty percent of the original sample answered in 2006/2007, the missing forty percent were replaced by a new random sample from the original population. Panel mortality is lowest in astrophysics and highest in economics. In addition, bibliometric data on publications, citations and copublications were collected using SCI and SCOPUS databases.³ The study is part of a larger research programme that deals with the mechanisms and outcomes of the reforms in the German research system.

The rest of the paper is structured as follows. In the next chapter, I will give a short introduction to the recent changes in the governance of the German research system . Next I present data on how governance mechanisms changed looked at from the micro-perspective of research groups. In addition, some data on the effectiveness of governance and how they affected on research life will be discussed. The third chapter will deal with effects of policy programmes promoting critical mass, third party funding, and collaborative networks, in particular network ties to industry. The last chapter will present some policy implications.

2 New Forms of Governance of Research

Management reforms in the public sector and the ideas of New Public Management increasingly are applied to public sector research. In the implementation of recent reform acts to the German research system mixes of old academic governance mechanisms⁴ and

² The accordant articles were identified by a search strategy developed by a partner project at the Fraunhofer Institute for Systems- and Innovation Research (Ulrich Schmoch). Econlit was later substituted by Scopus because of its better journal coverage.

³ Bibliometric data were provided by the partner project, see reference 2.

⁴ By governance I refer to the mechanisms which usually form typical patterns that lead to a coordination of action between more or less interdependent actors. Following Williamson I distinguish between ex post (markets, scientific relevance of academic work defined by scientific community) and ex ante coordination. In addition I differentiate between mechanisms at different levels of an organizational field (single organization, field). Typical instances of ex ante coordination within organizations are hierarchical management, contrasted to academic self governance with some sort of collective action by an innovation coalition in an organization in between. Ex ante

new governance instruments developed. The core elements of the old system of academic governance used to be state regulation as a price for institutional state funding, traditional academic self-governance leading to rather weak management structures at the level of faculties as well as at the top of the universities. Actual operation of research was very much geared by the disciplinary scientific communities themselves. The new policy aimed at strengthening the top and middle management of universities and research organizations by shifting competencies from academic bodies to the management, complemented or even substituted institutional funding by the competition for third party funding, and partly replaced state regulation by new mechanisms of external guidance such as university boards or newly established intermediary agencies. While the intended role of university boards was to give industry and society (and the state) a say in strategies and profiles of universities and research organizations, the new intermediary agencies typically fulfil new tasks of sector intelligence demands that evolved with the increased competition in the quasi-market for earmarked funding and the enlarged competencies of hierarchical management.

Private sector concepts such as economies of scale and national champion reasoning (critical mass, elite universities, and widely visible “lighthouses”), internationalization and network building became buzz words for the research sector too. Another idea that gained much influence was the concept of a new mode of research, the so called mode 2, which was put forward by Gibbons et al. (1994, Nowotny et al. 2001, Hellström & Jacob 2000; critically Weingart 1997a and 1997b, Godin 1998, Shinn 1999). According to this concept, knowledge production is no longer driven by problems defined within the boundaries of academic disciplines, but driven by practical problems, defined also by non-academic stakeholders, the community of “practitioners”. Mode-2 knowledge is produced by transdisciplinary teams, which members come from a variety of institutional and disciplinary backgrounds which are connected in heterogeneous networks. Collaboration with users (industry) takes place in problem definition and research at a very early stage. The normative concept of a mode-2 of knowledge production (Weingart 1997b) institutionalized and legitimized in particular the quest for more influence of non-academic actors in research and was readily taken up by research policy.

2.1 Disciplinary governance mechanisms, governance patterns and performance profiles in 2004

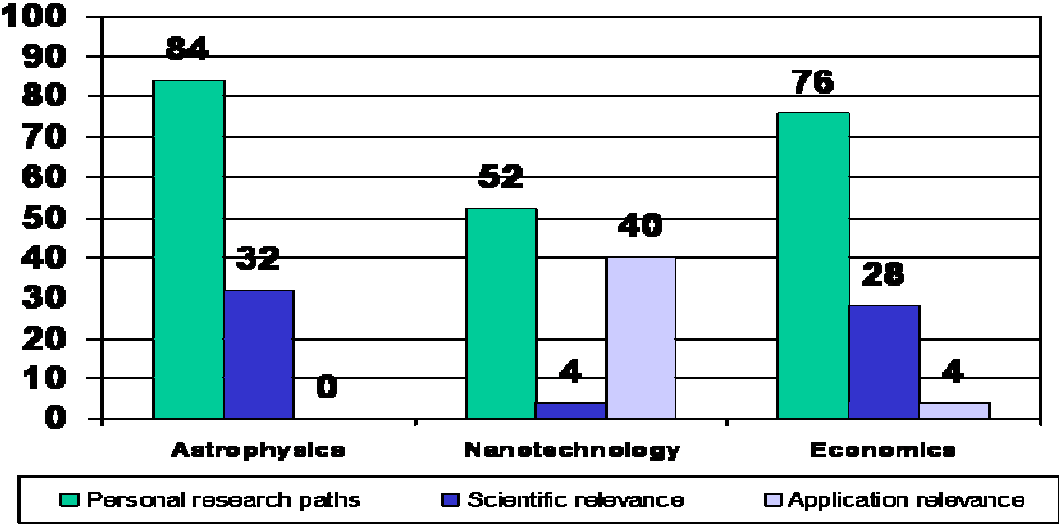
In 2004, according to semi-structured interviews with the leaders of 77 research groups personal research paths and scientific relevance of research subjects are the most often mentioned reasons for the choice of research lines. Application relevance is practically irrelevant as a motive to choose a research line except for nanoscientists. Here, 40% mention application relevance as a motive compared to 52% giving personal research paths as a relevant motive for their choices.

Effects of reforms at the micro level may be observed as an orientation of choices of project subjects and project partners according to specific criteria, e.g. scientific or application relevance or interdisciplinary or industry collaboration. Incentives for such an orientation may come from third party funders as well as from the organization’s management trying to build

coordination at the systems level is based on horizontal networks of researchers, on state regulation, or state guidance (Jansen 2007a).

up a specific profile. In 2004, acquisition of third party funding and the influence of funding criteria on the choice of research lines and network partners is the most important and visible effect of the recent reforms in the governance of the German research system. With the exception of astrophysics, the choice of project subjects seems to be more constrained than the choice of network partners. The special case of astrophysics is due to the high dependence of astrophysics on a limited number of observatories and to the dominance of EU / ESA funding schemes. All in all, the orientation towards the criteria of potential external funders is most frequent in nanoscience and least frequent in economics. Disciplinary differences also show up between the two science fields with a much higher dependence on third party funding and economics which can do quite well with little institutionally funded budgets (see tables 12 and 13).

Figure 1 Choices of research lines: personal research paths, scientific relevance and application relevance (%), 2004



The strengthening of hierarchical management in contrast has a much lower effect on research and network choices in 2004. Organizational priorities and incentives are most often mentioned by nanoscientists (24%) and least by astrophysicists (8%). New incentive schemes such as performance related pay that were established by the recent reform acts mostly were not implemented yet in 2004, in particular not in non-university institutes. Quite often interviewees did not know for sure whether such schemes existed or not and what the criteria actually were. The most common formula relates pay to third party income, other criteria being based on teaching load, number of graduates or number of doctoral degrees. The little attention paid to the new schemes is also a result of the low amount of money that was actually distributed by them (“buys me a beer”). In addition, interviewees doubted that a deviation from the established rule of equality will be possible at all. As we will see in the data for the second panel wave, these judgements changed in part with further implementation of the new schemes. Nanoscientists with a stronger orientation to organizational priorities and profiles may simply have experienced the actual implementation earlier. Nanotechnology is a new and “hype” field and gets much attention by the heads of universities and research organizations. The establishment of new faculties and profiles in

this area offered more chances to implement new tools such as target agreements and performance related pay than in the older fields of economics and astrophysics.

Figure 2 Choices of research lines and network partners: Relevance of third party funding priorities (%), 2004

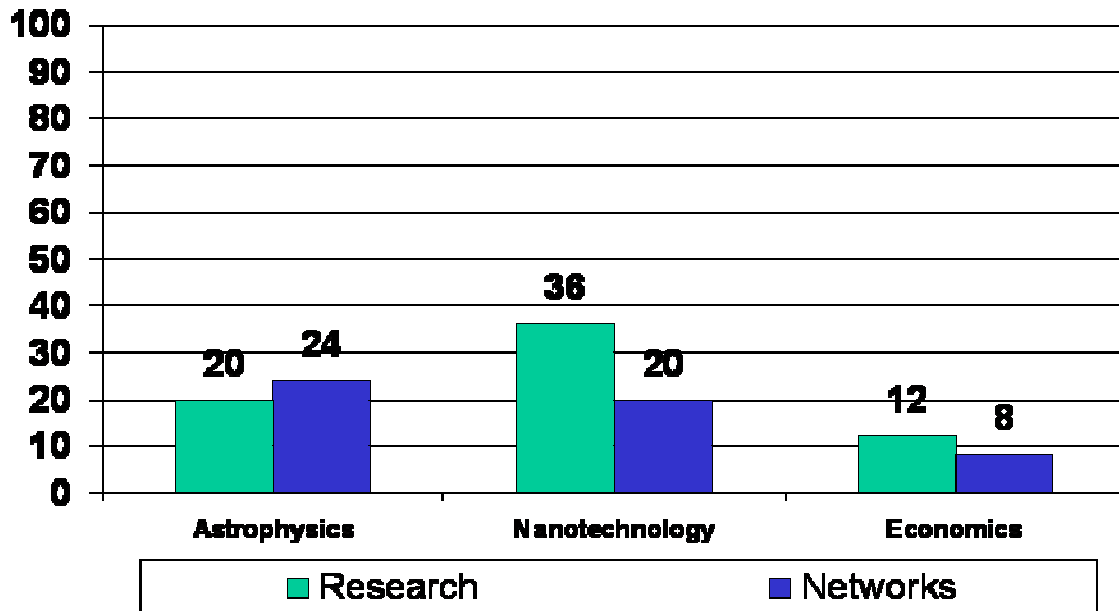
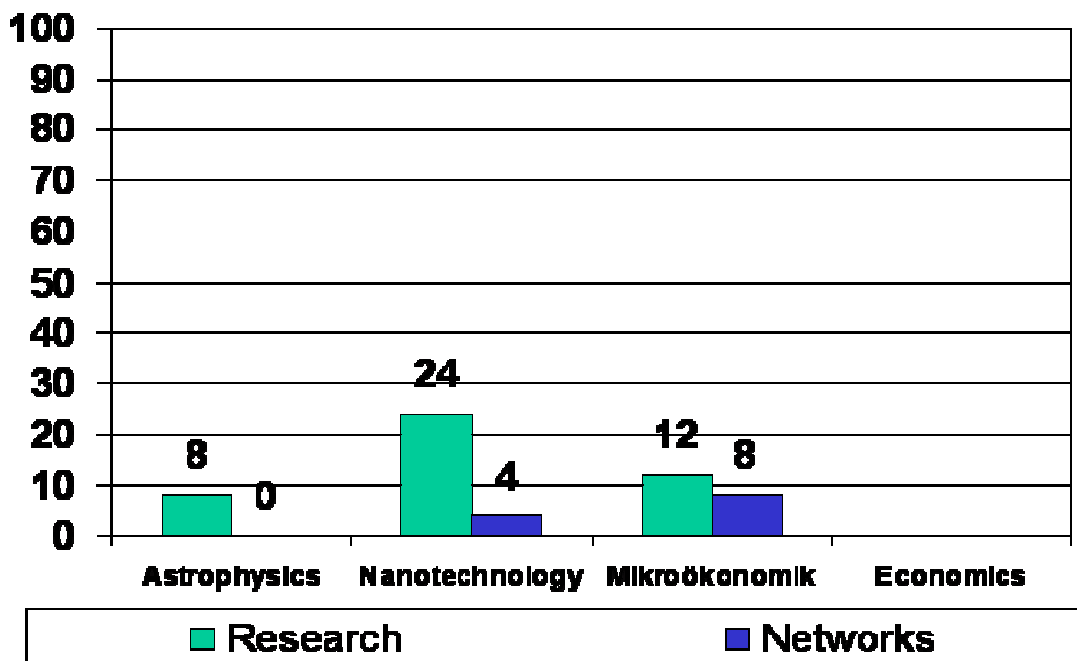
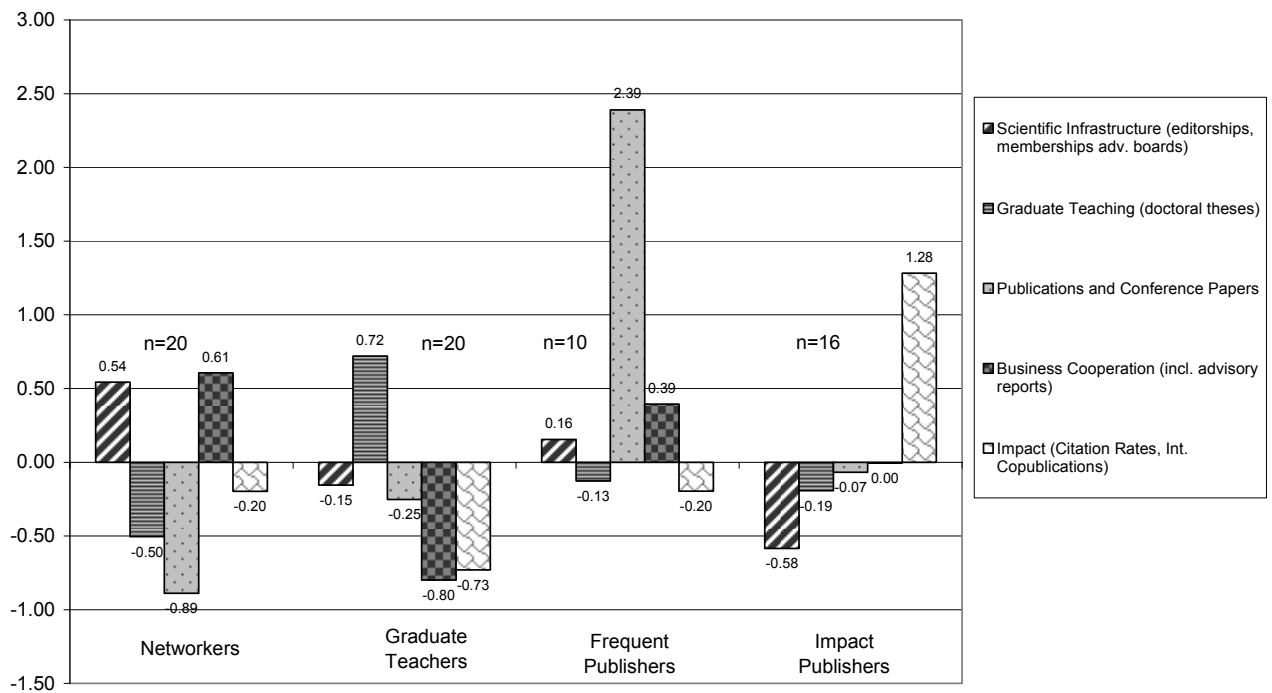


Figure 3 Choices of research lines and network partners: Relevance of organizational priorities (%), 2004



In addition to information on governance factors influencing research choices, data on research performance were collected by a short questionnaire after the interviews and by a bibliometric analysis of publications co-publications and citations covering the time period 1998 -- 2003. In the questionnaire we collected output data not covered by databases such as national journal publications and conference papers, books and editorships, dissertations and habilitations. Also we asked for membership of scientific committees, advisory boards, and other activities of scientific evaluation and consulting. These data were standardized or to control for field specific differences. A factor analysis of the bibliometric and questionnaire data on the output profiles of the research groups yielded five factors (publication, citations, sustaining scientific infrastructure, promotion of young researchers, knowledge/ technology transfer) which were used to define four output profiles by a cluster analysis (Jansen et al. 2007d). Two of them build on published outputs that can be measured by data-based bibliometry. One of the profiles is characterized by a more than average amount of journal publications (bibliometric data) and conference papers (frequent publishers, 16%), the other one is a high impact profile with an excess amount of citations and co-publications (impact publishers, 24%). The other two profiles are characterized by activities that are important for a sound research infrastructure: promotion of postgraduates and postdocs (graduate teachers, 30%) and organization of an infrastructure of journals, scientific associations and scientific committees, evaluation and advisory bodies (networkers, 30%). While the graduate teachers tend to be less than average on the impact factor and average on the publication factor, the pattern is reverse for the networkers. It could very well be that the roles of researchers change during their scientific life. This question will be followed up with an enlarged data set.

Figure 4 Performance profiles of research groups, 2004



An important result of the profiles depicted in Figure 1 is, that scientific performance is multidimensional and driven by specialization. Three profiles are characterized by the strength of just one performance dimension while the other dimensions are around average or below. There is only one profile exhibiting two strengths: the networkers are above average in work related to the functioning of scientific infrastructure and in technology transfer. Only two of the profiles (40% of the sample) can adequately be identified by bibliometric analysis. The two other profiles (networkers and graduate teachers, each about 30%) are not necessarily less productive, but show a different specialization profile. The data corroborate other studies' findings of a considerable degree of functional specialization in research and research related tasks (Laredo /Mustar 2000). This implies that normally research groups cannot reach a more than average performance in every dimension. Second this result implies that policy measures have to take into account the multidimensionality of research performance. If new policy instruments do not honor tasks such as mentoring doctoral students and postdocs, organizing conferences, editing journals and doing advisory and committee work, these tasks will loose attractiveness. In the end, this might endanger the long term capacities of the research system.

Table 1 shows the output differences between the subfields. There are three important points: nanotechnology is very high in citations which may be caused by the characteristics of a young fast moving subfield with a short time interval between publication and citation. Economics instead has a very low percentage in the highly cited cluster. Both basic fields instead have significantly more people in the doctoral teaching cluster than nanoscience. Research activists are most common in economics. All in all, economics groups seem not

only to devote more time to teaching doctoral students but also to be engaged in many research related administrative and consulting activities.

Table 1 Performance profiles by fields (%), 2004

	Astrophysics		Nanotechnology		Economics	
	Mean	Std	Mean	Std	Mean	Std
Networkers	0.23	0.429	0.27	0.456	0.41	0.503
Graduate teachers	0.41	0.503	0.14	0.351	0.36	0.492
Frequent Publishers	0.14	0.351	0.14	0.351	0.18	0.395
High impact publishers	0.23	0.429	0.45	0.510	0.05	0.213
Valid cases	22		22		22	

In the next step a cluster analysis of the governance mechanisms will be presented and connected to typical input and output variables. Since there is always more than just one governance mechanism at work, we have to search for more or less well integrated governance patterns as well. The cluster analysis includes all factors that were identified as relevant motives/ reasons given for the choice of research lines/ research projects and for the choice of network partners by a qualitative content analysis of the interviews. These ten variables⁵ were coded binary. The analysis yielded five clusters, one of which had only one member and was omitted in the further analysis. Figure 4 displays the four remaining clusters in a two dimensional space constructed by a multidimensional scaling analysis of the same governance variables. The horizontal dimension contrasts groups with a strong orientation of choices along scientific relevance ($r = -.354$) and path dependency of research careers ($r = -.426$) (left hand side) with groups with strong application orientation ($r = .554$), responsiveness to organizationally ($r = .453$) or externally defined research goals ($r = .377$) and an open choice of research partners along these strategically defined goals ($r = .769$). The vertical dimension contrasts those group which are characterized by a low responsiveness to third party funding and third party criteria for networks ($r = -.715$ and $-.562$) with groups that strongly respond to external funding criteria for research lines and research partners. The MDS explains 0.92259% of variance.

⁵ In addition to ones given by the figures 1-3, for the network choices we identified two further factors: Restriction of choices to a closed pool of potential partners and a strategic open choice of partners along specific demands resulting from the research task.

Figure 5 Patterns of governance 2004

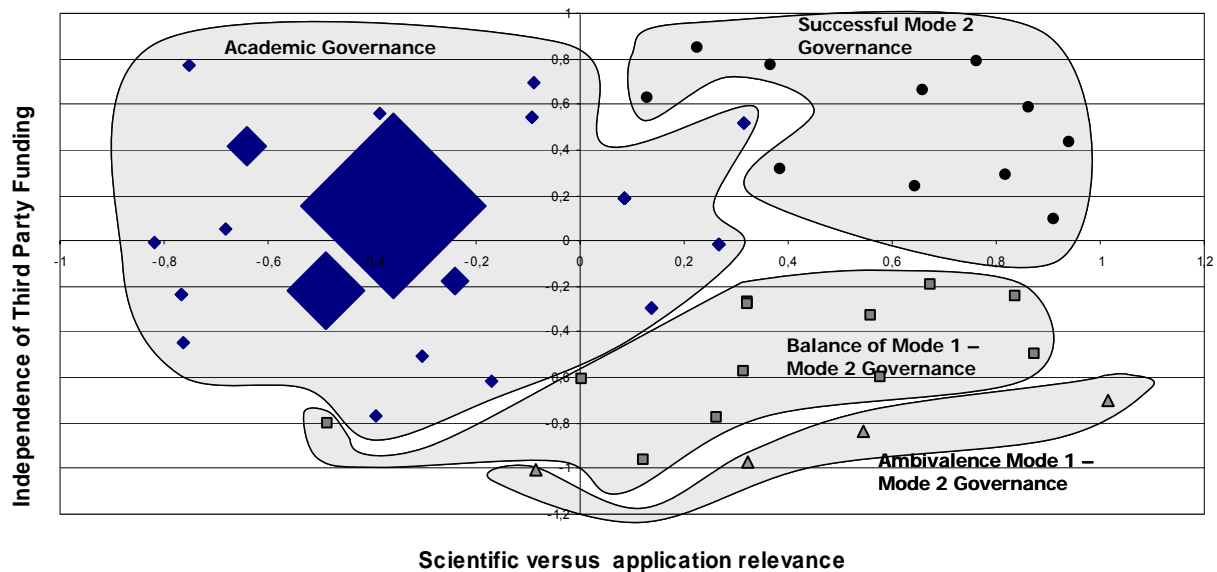


Figure 4 shows the four clusters. The largest cluster (n=47, 63% of the research groups) is called here “Academic governance”. It is situated in the upper left area of figure 4. Research groups belonging to this cluster make their choices of research lines and networks according to scientific relevance and their personal interests. 64% of the astrophysics groups and 88% of economists belong to this cluster. Groups typically are affiliated to universities (80%) or Max-Planck-Institutes (11%). Actually they are able to live up to their science orientation. 80% of their research time is allocated to basic research. The percentage of time allocated to third party funded projects (39.3%) is lowest when you standardize the figures for disciplinary differences, but the percentage of high quality funded projects (science foundations) is quite high (55.2%). Time for project acquisition is below average. Research groups are quite small (9.8 members, full time equivalents) and command small networks (8.7). The performance profile of this cluster is characterized by strong contributions in doctoral programmes (rank 2) and first rank in contribution to the infrastructure of the research systems (editorships, journals, reviews, advisory boards etc.). Publications are slightly below average (but well above the median, 18% belong to the high publication profile) while citation and co-publication profile is below average (13% belong to this profile).

The remaining three clusters are much smaller. They are all dominated by nanoscience and exhibit some characteristics of mode 2 governance. 27 research groups are attributed to these clusters, 16 nanoscience groups, eight astrophysics groups and three economics groups. All clusters display much higher application relevance for their research choices than the academic cluster. The second (n=11) and the fourth cluster (n=4) exemplify characteristics of mode-2 research and governance. The third cluster shows a balance of mode-2 / mode-1 research and governance mechanisms.

Cluster 2 is situated in the upper right side of figure 4. Seven research groups come from nanotechnology, three from astrophysics and one from economics. There is one important deviation from the ideal of NPM and mode-2 Governance – third party funding has zero relevance for the choice of research lines and almost none for the choice of partners in this cluster. Instead, the cluster is characterized by the strongest internal management and

profile building priorities, a strong application orientation without scientific relevance mentioned at all, and very strong orientation to a strategic open search of research partners. So contrary to the mode-2 concept of loose and more informally driven transient research groups and research collaboration, we find here very strong steering by organizations. This is also due to the fact that the majority of the groups come from extra-university research institutes, such as Helmholtz institutes or Leibniz institutes (but only few Max Planck institutes). These institutes typically display more hierarchical management structures than universities and enjoy quite high levels of institutional funding. The groups' size is very large (25 on average) as are the networks (13 on average). Despite the lack of a strategic orientation towards the competition for third party funding, the groups on average invest 62% of their research time in third party projects which is above average absolutely but below if you standardize for disciplinary differences. Most of the projects are funded by earmarked national and EU programmes. Industrial funding is well above average, but still small (10% of research time). Despite mentioning only application relevance as choice criteria, three quarters of overall research time are devoted to basic research. The cluster is above average in standardized numbers of publications (20% of it belong to the high publication output profile) and most successful in citations/ co-publications (50%). But it ranks only second in technology transfer activities.

The fourth cluster – albeit very small (n=4; 3 nanoscience groups) shows potential ambivalences of mode 2 governance. The cluster is situated in the lower right side of figure 4, thus combines strong orientation towards competition for third party funding (100%) and strong application orientation (50%). Again there is no interest in scientific relevance and a strong orientation towards organizational priorities (50%), too. 70% of research time is devoted to third party funded projects with the highest percentage of industry projects overall (19%). While the second cluster can rely on support by organizational management to deal with acquisition procedures this cluster lacks such support structures. Two of the groups come from universities, the other two from extra-university institutions without secure institutional funding. Time devoted to applied research is highest in this cluster (39%) as is the percentage of industry partners in networks (24%), but also the time needed for project acquisition. Complaints on a lack of transparency and highly bureaucratized funding procedures are frequent. There is another important difference to cluster 2. This cluster is not at all following path dependent research interests. This means that research paths have to adapt very quickly to changing demands and opportunities. With respect to their workload the groups are very small (8.6 on average), but have networks of quite large size (12). Contrary to cluster 2 their network strategies are oriented towards a closed pool of well-known partners. The choice of partners is driven by incentives from (industrial) funders. We may speculate that closure of research networks may be a consequence of this funding structure. There is no clear performance profile of this cluster; each of the four groups is specialized in a different function – technology transfer, teaching, high numbers publishing and high citations/ co-publications. Their performance is above average each, but the small number does not allow describing a performance profile for the cluster.

The third cluster (n=12) is characterized by a balance of mode-1 and mode-2 elements which allows these groups to combine science and application orientation. The groups mostly come from universities, one from a Max-Planck-Institute. Half of them have a disciplinary background in nanoscience, another five in astrophysics and one in economics. This cluster is situated in the middle right side of figure 4. Groups in this cluster have a very strong

orientation towards third party funding (100%). Their dual orientation is reflected in the highest percentage of third party funded research time (absolute 82% - also highest if standardized for disciplinary differences) and a balanced project portfolio. Both, projects funded by science foundations and those funded by industry are above average (Science foundation projects: 56% of third party research time (ranking first); industry projects count for about 5 % (ranking second). The groups have a moderate size (12), and can rely on networks of moderate size (9.8). But at the same time, industrial partners account for less than 2 % in their networks. Time devoted to applied research is below average (10%). This cluster is below average in publication but well above the median and well above average in citations/ co-publications (44% of 9 valid cases belong to this performance profile). But contrary to application orientation and industry funding, engagement in technology transfer is even less than in the academic cluster.

To sum up, the early effects of governance reforms mostly show up in an increased competition for third party funding to compensate for shrinking institutional budgets. Nanoscience is clearly the field which responds strongest to the new opportunity structures. Here we see an important institutional differentiation between research groups from large extra university research institutes and university groups and less well situated non-university institutes. The first ones are in the comfortable position of low dependence on third party funding, plenty of resources (size, networks) and a very supportive internal management. Instead, small university groups and groups from institutes with small institutional budgets lack resources and management support. The groups from the academic cluster and to some extent from the fourth ambivalent cluster exemplify problems that small research groups encounter in a competitive environment particularly in potential high technology fields. In order to compete they have to have access to resources for early exploration of potential research problems and solutions. These resources may be institutionally funded personnel, seed money from the institution, or it may stem from successful basic research project acquisition. The first is the case with cluster 3, the latter with cluster 2. If you lack these prerequisites you may be torn between the need for acquisition to get your staff funded and the time needed for running the research projects, getting short on chances to exploit your research results and to think about tomorrow's research.

2.2 Disciplinary governance mechanisms in 2006/2007

In the questionnaire sent out in 2006/2007 to all groups interviewed in 2004 we used a standardized questionnaire to collect data on the influence of funders, organizations and the scientific community on the choices of research lines and network partners among other subjects. For nine of the ten governance mechanisms that were identified in the content analysis of the qualitative interviews we collected data on whether this mechanism is relevant, partly relevant or not relevant.⁷ In addition we asked for changes in the strength of these effects on research. The polled questionnaire was supported by a telephone interview.

Tables 2 and 3 deal with the role of scientific versus application relevance for the choices of research lines and project development in the three fields studied. The omitted category is "applies only partially". The disciplinary pattern resembles that of 2004 except for the higher

⁶ For a more detailed analysis see Jansen 2007c and Jansen et al. 2008 (forthcoming).

⁷ The category of path dependency of research lines was omitted since it yielded very little variance.

level of scientific relevance reported in economics groups. In addition, the level of acquiescence elicited by this predefined category is higher because of its high social desirability. Orientation towards scientific relevance is what you would expect from a scientist. Again in 2006/2007 astrophysics groups are strongly oriented towards scientific relevance. They hardly look at application relevance. Nanoscience groups rank first in application relevance with significant differences to the other fields. While among astrophysicists and among economists there is to some extent the impression that the influence of scientific relevance decreased in the past two years nanoscientists don't feel such a pressure. In addition, none of them neglected the relevance of application for their research choices; contrary to a significant number of research groups in the two less applied fields astrophysics and economics.

Table 2 Influence of scientific relevance on choices of research lines/ project development 2006/2007 (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	88.0	62.5	61.5	**, ●●
does not apply	4.0	4.2	3.8	
Valid cases	25	24	26	
Relevance increased in past two years	16.0	22.7	18.5	
Relevance decreased in past two years.	4.0	0.0	7.4	***, +++
Valid cases	25	22	27	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level
 Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level
 Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Table 3 Influence of application relevance on choice of research lines / project development 2006/2007 (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	8.7	25.0	19.2	
does not apply	78.3	29.2	46.2	***, ●●
Valid cases	25	24	26	
Relevance increased in the past two years.	13.0	22.7	23.1	
Relevance decreased in the past two years.	0.0	0.0	0.0	
Valid cases	25	22	27	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level
 Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level
 Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

In a second less obtrusive approach we measured the relevance of different sources of influence on research decisions by asking interviewees from where they got ideas for new research questions and projects. Three of the five response categories were designed to measure scientific versus application relevance. Influence of face to face exchange among colleagues can be understood as an indicator for the importance of horizontal ex ante network coordination within a field. By the literature, the scientific community coordinates

research behaviour ex post by differentiating the relevant from the irrelevant subjects. We can see that again there are significant differences in the relevance of the application context between astrophysics groups and the other two fields. In addition, both indicators pointing to scientific influences are lowest for nanoscience groups. There is an interesting, but not significant difference between the two more basic research oriented fields. Astrophysicist groups rely as often on ex ante coordination mechanisms as the ex post coordination of scanning the literature. For economist groups, the coordinative function of the scientific literature is much more important. This corresponds to the importance that is attributed to networks (not important: 4% vs. 15%) and the average size of networks (astrophysics 11.2, economics 7.1)

Table 4 Sources of inspiration for new research projects mentioned 2006/2007 (%)

	Astrophysics	Nanoscience	Economics	Significance
Colleagues & peers	54.5	36.8	45.0	
Literature	54.5	42.1	65.0	
Context of application, practitioners	0.0	21.1	15.0	+++ , ●●●
Valid cases	22	19	20	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Next I deal with the influence of criteria set for research lines and network partners by third party funders. In the questionnaire we asked whether research groups observe the thematic priorities of research funding programmes by national and EU funding organizations. Compared to 2004 we find the same pattern of lower responsiveness of astrophysics and economics than of nanoscience. The lower level of agreement is probably due to a social desirability bias. While choosing research subjects according to their scientific relevance is well established, it may compromise the ideal of scientific autonomy if you acknowledge an influence of external funding on your choices in research. The ambivalence of this question shows up in the large share of the omitted category “applies partially”. Between 37% (economics) and 60% (astrophysics) admit to be influenced by third party funding programmes at least partially. The influence of third party funding is felt to be increasing by about a third of respondents in the natural science fields, and a fifth in economics.

Table 5 Influence of third party funding on choices of research lines/ project development 2006/2007 (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	12.0	20.0	11.1	
does not apply	28.0	32.0	63.0	+, ●●
Valid cases	25	25	27	
Relevance increased in the past two years	32.0	36.0	19.2	
Relevance decreased in the past two years	8.0	4.0	3.8	
Valid cases	25	25	26	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

The effect of priorities of funding programmes is even stronger with respect to specific criteria for the choice of collaboration partners. The strongest effect – as in 2004 but at a higher level – is displayed by astrophysics. The smallest influence albeit almost doubled is observed for economics. All fields experience a strong increase of specific criteria applied to the choice of partners in third party funding. In particular for the natural science fields, a strong and increasing demand for international research collaboration is felt, much less but relevant in economics. Nanoscientists in addition are confronted with increasing requests for university – industry collaboration.

Table 6 Influence of third-party funding on network formation 2006/2007 (%): promoting research network ties

	Astrophysics	Nanoscience	Economics	Significance
third-party funding calling for research network ties	39.1	33.3	30.8	
third-party funding calling for research network ties has increased in the past two years	21.7	8.3	19.2	
third-party funding calling for research network ties has decreased in the past two years	0	4.2	0	***, ●●●
Valid cases	23	24	26	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Table 7 Influence of third-party funding on network formation 2006/2007: promoting science-industry ties (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	8.3	33.3	3.8	** , +++
increased in the past two years	0	25.0	3.8	***, ++, ●●●
decreased in the past two years	0	0	0	
Valid cases	24	24	26	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Table 8 Influence of third-party funding on network formation 2006/2007: promoting international ties (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	58.3	66.7	19.1	***. ●●
increased in the past two years	20.8	29.2	3.8	***, ●●
decreased in the past two years	4.2	4.2	3.8	
Valid cases	24	24	26	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

The increased relevance of third party funding regimes and the strengthening of management capacities lead to an increase of external and internal controlling efforts and an increased reporting load for the researchers. 65.7 % of the research groups are evaluated regularly, in astrophysics (81.8%) and nanoscience (71.4%) a larger percentage of the groups are covered by evaluation procedures regularly than in economics (45.8%). While in the two natural science fields evaluation is done by external evaluators, in economics it is done internally. Evaluation periods range from 1 to 10 years. The medium length for astrophysics is 4.8 years, in economics 4.7 years. Nanoscience which gets much attention by the management of research organizations and by funding programmes is under evaluation on average every 2.5 years. Evaluation bodies are in some cases scientific advisory bodies established by the institutes (e.g. Max-Planck institutes). External evaluation bodies for extra-university institutes often are established by the umbrella science associations, by the German Science Council/ German Research association or by ministries. While umbrella science associations are more prevalent in astrophysics, in nanoscience and economics (mostly university groups) procedures combining internal and external evaluation bodies, professional evaluation bodies and evaluation networks of universities or disciplines are more common.

A significant change can be seen in the role that priorities of one's own organization do have for research strategies. While in 2004 the effects of organizations were almost negligible, except for nanoscience, in 2007 interviewees stated quite a strong relevance for their choices (15 – 36% compared to 8 – 24%). Again we find that economics groups less often experience organizational profile building as relevant for their choices than the natural science fields. In all fields effects of organizational priorities on research choices increased strongly, particularly in nanoscience. University groups more often feel an increasing pressure (26.9%, n=74) while extra-university groups always experienced a higher amount of

organizational direction. Only 18 % (n=22) negate any influence here, compared to 44% (n=55) of university groups

Table 9 Influence of organizational priorities on choices of research lines / project development 2006/2007 (%)

	Astrophysics	Nanoscience	Economics	Significance
Applies	36.0	24.0	14.8	●
does not apply	32.0	20.0	55.6	**
Valid cases	25	25	27	
Relevance increased in the past two years	24.0	33.0	20.0	
Relevance decreased in the past two years	0.0	8.3	0.0	
Valid cases	25	24	25	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level

Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level

Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Another indicator for the strengthening of hierarchical competencies in research organizations is the wide participation in the excellence initiative. Applications here had to be put in by the universities as institutions. Extra-university institutes were eligible only in collaboration with university groups. 59.2 % of the groups studied participated in an excellence initiative of their institution (universities: 57.4%, extra-university institutes: 63.6%). 44.2% were successful with an application in the two first funding lines (graduate school, research cluster) but none in the final election of elite universities (first round). About half of the university groups and a quarter of the extra-university groups were among the winners and a quarter of the extra-university groups.

To sum up the effects of the reforms in the German research system are much more visible in 2006/ 2007. Research groups in all fields report a growing importance of application orientation, particularly for nanoscience and economics groups the context of application became a relevant source of inspiration for new research projects. Influence of the priorities of external funding agencies on research lines increased strongly in the two natural science fields. Contrary to the negligible effect of funders on network choices by 2006/2007 30%to 40% acknowledge such influences. Internationalization of networks is the most often mentioned request by funders, it particularly increased in the two natural science fields. For nanoscience also the demand for science-industry ties is raised more and more often. Not only did the competitive pressure in the market of third party funding increase, in addition organizational management strengthened significantly. Thus the lack of effect in 2004 is clearly due to latency. Implementation of new instruments in 2006/2007 reached not only the new field of nanoscience, but increasingly astrophysics and economics too.

3 Policy effects on research behaviour and on scientific performance

3.1 Research profiles, project portfolios and network structures 2004 and 2006/2007

Change in research profiles, i.e. the respective shares of basic, applied and developmental research (Frascati Manual), the changes of the balance of third party funding and institutional

funding, the changing structure of external funders, and the size and structure of networks are indicators that shed light on the actual effects of the reforms. Profiles and the share of third party funding and its structure were measured as shares in the total amount of research time. It does not come as a surprise that astrophysicist groups indeed spend most of their time on basic research. Their comparatively high interest in development stems from instrument building initiatives. Applied research is negligible in this field. The contrast is nanoscience with a larger percentage of applied and developmental research. Economists do applied research despite not being driven by application relevance in their research choices. This is mostly work on special policy fields such as health or agricultural economics. There is not much change to be seen by 2006/2007, the time of the replication of the study. In particular the amount of time resources going to basic research did not decline in the two natural science fields. Basic research is still the strongest type of research. But there is a decline of basic research time in the economics groups.

Table 10 Allocation of time budget to basic research, applied research and development, 2004 (%)

Research type	Astrophysics	Nanoscience	Economics	Significance
Basic	84.0	62.5	74.4	+++ , ●
Applied	2.4	20.4	25.6	+++ , ●●●
Development	13.6	17.1	0.0	*** , ●●●
Valid Cases	23	21	23	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level
 Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level
 Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Table 11 Allocation of time budget to basic research, applied research and development, 2006/2007 (%)

Research type	Astrophysics	Nanoscience	Economics
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

While research profiles did not change much, the funding structure did change. For the economics groups the percentage of research time in third party funded projects almost doubled, in particular other funders (e.g. local actors and initiatives) and industry gained in importance.⁸ Astrophysics groups became less dependent on third party funding in general (50%) while nanoscience groups became more dependent. Most of the plus goes to public funded oriented research programmes (+5%) and a bit to projects funded by science foundations. It is worth mentioning that the amount of work for industry did not increase, even decreased a bit. In particular those fields affiliated to university research (nanoscience and economics) show responsiveness to the competitive pressure stemming from the growing

⁸ Since the composition of this subsample changed significantly there may be doubts about attributing the changes to recent policy. Here we can rely also on the evidence that particularly the economics groups increasingly observe application relevance in their research choices (see table 3). Thus we may conclude that there is indeed a change in the input structure of this field too.

necessity to acquire third party funded projects. Groups from extra-university institutes enjoy larger amounts of institutional funding and therefore are less dependent on third party money.

Table 12 Share of research time spent working on projects funded by third-parties 2004 (%)

	Astrophysics	Nanoscience	Economics	Significance
Proportion of research time spent working on projects funded by third-parties in total	60.2	71.9	20.2	***, ●●●
Proportion of research time spent on research financed by industry	0.4	6.7	1.5	** , +++
Proportion of time spent on research funded by science foundations (DFG, Thyssen, VW)	35.7	38.0	14.1	***, ●●●
Proportion of time spent working on projects funded by the German government (BMBF. other ministries) and the EU	22.3	23.1	4.9	***, ●●●
Proportion of time spent working on projects funded by other third parties	1.8	4.5	0.0	***, ●●●
Valid cases	24	24	23	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level
 Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level
 Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Table 13 Share of time spent working on projects funded by third-parties 2006/2007(%)

	Astrophysics	Nanoscience	Economics	Significance
Proportion of time spent working on projects funded by third-parties in total	50.0	76.4	38.7	***, +++
Proportion of time spent on research financed by industry	0.4	5.3	3.6	***, ●●●
Proportion of time spent on research funded by science foundations (DFG, Thyssen, VW)	30.1	40.5	16.8	+, ●●
Proportion 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	

Nano-Econ *** significant at 1%-level, ** significant at 5%-level, * significant at 10%-level
 Nano-Astro +++ significant at 1%-level, ++ significant at 5%-level, + significant at 10%-level
 Astro-Econ ●●● significant at 1%-level, ●● significant at 5%-level, ● significant at 10%-level

Next I deal with the question of whether research policy aiming to intensify international collaboration and university industry cooperation had some effect on the structure of research networks in the three fields under study. Corresponding to the funding structure we observe a small increase in the proportion of industry ties in the research groups in all fields. The effect is largest for nanoscience groups. There is no relevant increase in the overall size of the networks.

Table 14 Share of industry ties and international ties in networks 2004 (%)

	Astrophysics	Nanoscience	Economics
Proportion of international ties	61.4	38.1	39.9
Proportion of industry ties	0.0	10.7	3.2
Average size of networks	10.1	11.3	7.2
Valid cases	25	27	23

Table 15 Share of industry ties, university ties and international ties in networks 2006/2007 (%)

	Astrophysics	Nanoscience	Economics
Proportion of international ties	59.8	40.1	34.6
Proportion of industry ties	2.3	14.1	4.7
Average size of networks	11.2	10.3	7.1
Valid cases	24	25	23

3.2 Determinants and resources for the change of research lines

More than three quarters of the research groups in the three fields started a new research line in the last two years. A quarter of astrophysics and economics groups gave up old research lines. Volatility is higher in nanoscience (39.1%). Still, intra scientific developments are the most often mentioned motives for change. Albeit, there are also effects of organizational and of science policy. New profiles of institutes are quite important for the redirection of ones research lines. This is particularly true for nanoscience, but also for economics (generational change). Funding programmes are most important for astrophysics groups. Resources for the start of a new research line mostly come from a reallocation of institutional resources and the appointment of new chairs. For nanoscience groups the foundation of attached institutes or firms is another relevant finance mechanism.

Table 16 Triggers for the change of research lines in 2006/2007 (%)

	Astrophysics	Nanoscience	Economics
New opportunities, research questions	95.5	70.0	65.0
Old lines ended, no longer attractive	22.7	35.0	40.0
New profile of the institute	18.2	40.0	30.0
Attractive funding programmes	27.3	10.0	10.0
Valid cases	22	20	20

Table 17 Origin of resources for the start of new research lines in 2006/2007

	Astrophysics	Nanoscience	Economics
New appointment	14.3	15.0	25.0
Founding of attached non-university institute	0.0	20.0	5.9
Founding of a firm	4.8	10.0	5.9
Reallocation of resources	42.9	50.0	17.6
Valid cases	21	20	17

An often mentioned concern in the debate on the reforms is that the chances for “blue sky” research and high risk projects will substantially decrease. This might lead to a loss of creative ideas. The research system would be unable to tap its full potential. The demand for “value of money” and an application perspective as well as the relative increase in third party and priority funding mechanisms might redirect resources into more standardized research projects.

Table 18 Chances to get money for high-risk research project from funding agencies, 2006/ 2007

	Astrophysics	Nanoscience	Economics
No problem	29.2	25.0	21.7
Depends on funders' priorities	33.3	45.8	39.4
Difficult	37.5	29.2	32.4
Valid cases	24	24	23

As we see in tables 18 and 19, about a third of nanoscience and economics groups find it difficult to get third party funding for a high-risk project, and even 37.5% of astrophysics groups. Between 22% and 29% would not expect a problem to get funded. The remaining acknowledge as restriction that the project must fit to the funders' priorities. This is mentioned in particular by nanoscience groups (45.8%) and economists (39.4%). All in all, more than two thirds of the respondents expect to be constrained in getting funding for a high-risk project.

The chances for getting seed money are – in the opinion of the leaders of the groups – a bit better within their organization. Between 16% and 33.3% expect to be able to get money from the institution's funding pool. What is even more important, between 20% and 52% can rely on a sufficient large own budget to fund such a project. The main difference is between astrophysics and the other two fields here. Nanoscience groups and economists are mostly affiliated to universities. University professors and heads of university institutes usually have their own budget being subject to the appointment and eventually “staying” contract(s). Astrophysicists mostly come from extra-university institutes with a more hierarchical management of resources. This explains why 44% of the university groups report that they could rely on their own budget, but only 18% of extra-university groups could do so. With respect to the chances to get resources from an organizational pool this relation is contrariwise. Only 22 % of the university affiliated groups would see no problem to get additional funds from the organization, compared to 44% of the extra-university groups.

Table 19 Chances to get money for high-risk research project within organization, 2006/2007 (multiple responses)

	Astrophysics	Nanoscience	Economics
No problem	33.3	16.0	33.3
Depends on organizational priorities	33.3	16.0	33.3
Difficult	20.0	12.0	7.4
Own budget suffices	20.0	36.0	51.9.6
Valid cases	21	20	17

When we compare the degree of thematic restriction between funding within one's organization and funding by external funding agencies, we see that the leeway for high-risk

research is definitely larger in organizations. More than half of the groups in all fields would be able to start a new risky research line without a problem. For external funders, 30% and even less expect that they would be able to get funding. This probably means that these applications for high risk projects will not be written. Thus, concerns about the increasing share of third party funding in the finance model of the research system at the expense of institutional funding are quite justified.

3.3 Effects of critical mass and third party funding on scientific performance (2004)

The demand for critical mass denotes the argument that research groups or research labs can only be productive if they exceed a certain size. There are two main strands of reasoning behind this postulate that became part of the science policy in Europe (see the debate on the European Technology Institute or on elite universities in Germany). First there are some simple economies of scale reasoning. Natural science disciplines depend on expensive equipment and large instruments which can be used by many users. Social science disciplines need much smaller equipment. Thus research groups and institutes in the natural science fields tend to be larger than in social science. Second, there is a sort of visibility argument that is connected to potential deficiencies of the international competition in science. In order to be visible at the international level, a university or a research institution has to be large. Thus to compete with MIT we supposedly need a European Technology Institute.

On the other hand the effect of size needs not always be beneficial. Carayol and Matt (2004) found that among the 88 research institutes of the University of Strasbourg the large ones enjoying additional funding by INSEAD and CNRS are only mediocre in scientific performance. Institutes in the top cluster instead are not much larger than the cluster with the smallest labs covering the social science institutes. The high performing institutes were characterized by professors working on research and teaching, many doctoral students, and large share of postdocs also from abroad.

Deficiencies of scientific competition may well stem from a concentration of funding on a few large institutes. Geuna (1999) points to the problem of a concentration of markets for earmarked funding which may lead to problems to get high risk projects funded. In addition because of information deficits funders may tend to address only a few institutions. Thus large entry barriers for newcomers may be built up. A vicious circle of being large and therefore visible and getting more funds from funding agencies may be the consequence. Laudel (2005) adds to the problem, that the amount of third party funding is often used as a performance indicator itself. As Whitley observes (2003) openness of competition is the most important precondition of high performance of a science system. Strong prestige hierarchies instead tend to harm the chances to change research lines and research careers.

Obviously research groups (and labs too) are of different size in different disciplines. An important result from our study is the large difference in the size of research groups. Nanoscience groups on average have 19 researchers while economics groups have only 4.2 members. Astrophysics groups are also significantly larger (15) than economics groups. The size differences correspond to the differences in the share of third party funded research time (see table 12) and to the differences in performance indicators.⁹ An analysis of scale

⁹ Number of publications per researcher: Astrophysics 2.68, nanoscience 2.40, economics 0.16.

elasticity for the three fields yields an interesting result, although based on very small numbers. Only if elasticity is higher than 1 the additional effect of one more researcher yields a synergy effect, that would justify the personnel growth. That more researchers do publish more is obvious. For astrophysics we find an elasticity of 1.47 – that is significantly larger than 1. In nanoscience we find 1.25, not significantly different from 1. And for economics we find an elasticity of 0.29 which signifies decreasing returns. Thus while astrophysics groups may exploit further economies of scale, nanoscience groups probably reached the optimal level. Economics groups seem to have exceeded their optimal group size already. With respect to third party funding we can conclude that a further increase of the share of third party funding for those groups which are near or beyond their optimal size most likely will have negative consequences for performance. An increase in funding usually leads to a growth of a research group.

Detailed studies of the relationship of third party funding and research performance are scarce. An older study by Stolte-Heiskanen (1979) did not find a correlation between resource level and performance. A newer study by Hornbostel (1997:213f.) reports correlations in the rank order of 0.7 to 0.8 for number of publications and amount of third party funding per faculty and per professor. But we would expect that an increase in input in human capital and equipment will lead to an increase in publications. Third party funding has a double function as an input and an output factor. Additional resources will be spent on research and should yield a publication return. At the same time third party funding is a result of a review process and an output factor. This dual role of third party funding leads to the conclusion that effects of third party funding on research performance always have to be controlled for the effect of the increase in resources as such. The results by Carayol / Matt (2004, see above) and of another study by Moed et al. (1998) even shed doubt on the positive effect of third party funding at all. Moed et al report for Flemish universities a very high concentration of third party funding on a few institutions and a negative effect on level of publication. Nevertheless the amount of third party funding is very often used at all levels of the German research system as if it was a performance indicator, for instance in target agreements, in performance related formula for pay for professors, resource allocation to faculties, and base funding of universities by the federal states.

From the perspective of production economics other than positive monotonic relations between amount of third party funding and research output are well thinkable, e.g. decreasing returns could be expected. A multivariate regression analysis for the 2004 sample data is presented in table 20.¹⁰ As dependent variable we use the sum of publications in the period 1998 – 2003. The variable is a highly skewed count variable. In the first approach a Poisson model was fitted. The hypothesis of a Poisson distribution was rejected because of overdispersion, i.e. the variance is larger than for Poisson data expected (Poisson distribution parameters: variance=mean). A better model in this case is the negative binomial model which is presented here.

As independent variables we employ the share of third party funded research time. To catch a possible curvilinear effect, we include both the linear term and a quadratic term into the regression equation. Because of small numbers we were not able to split the sample for the analysis. So we had to take into account for disciplinary differences in economies of scale by another approach. This is done by multiplying the quadratic terms with three field dummies.

¹⁰ For a more detailed analysis see Jansen et al. 2007 and Schmoch et al. 2008.

The size effect of third party funding is controlled for the number of researchers. In addition we control for institutional effects of the German research system by introducing two dummies to represent the Max-Planck institutes (particularly wealthy) and the other extra-university institutes (still wealthier than universities = omitted category).

All coefficients in the model prove to be significant at the 1% level except the constant. There is a positive effect of number of researchers on publication output as we expected. Positive coefficients for the affiliation to the Max-Planck-Society (MPG) and to other extra-university institutions point to the better resource endowment and a lower level of teaching duties, i.e. more time for research. While it is quite easy to interpret the coefficients, more important is in the context of this analysis that they control for structural difference other than share of third party funding.

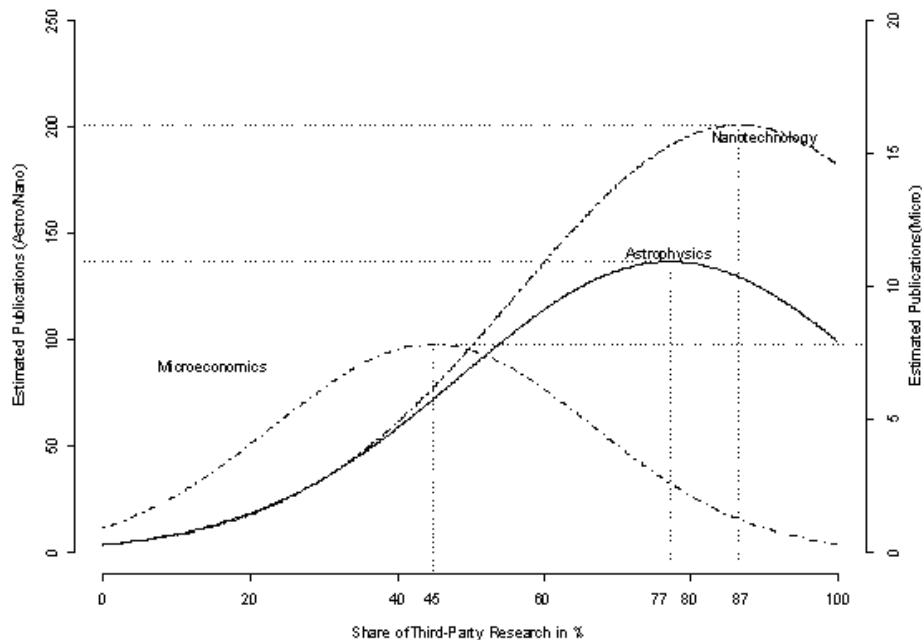
With respect to our interest in the effects of third party funding on productivity the hypotheses of a curvilinear relationship is corroborated. Despite the small numbers, the share of research time in third party funded projects has a significant positive linear effect on sum of publications. But in addition, the quadratic terms are significant and negative for all three fields. This means the acquisition of third party funding has a positive effect at the beginning but, if the share exceeds a critical threshold the effect turns and becomes negative.¹¹ This critical level is above the field specific means of share of share of third party funding. So only in few cases third party funds actually have a negative effect. Most of the groups are still on the increasing branch. Despite the small numbers we estimated the gradient of the effect for the three fields. The particular numbers are of course debatable, but illustrate the turning point is much higher for the natural science fields than for economics.

Table 20 Regression of percentage of time budget for third party funding projects on sum of publications (1998-2003) – Negative binomial regression model

Dependent variable: SUMPUBS				
Method: QML Negative-binomial count model				
Number of observations : 70				
Variable	Coefficient	Std. error	z-statistic	p
CONST	-0,39206	0,52290	-0,74978	0,45340
MPG	2,13833	0,62659	3,41264	0,00060
Extra-univ. institute	1,64802	0,36648	4,49689	0,00000
% TPF projects	0,09507	0,01885	5,04440	0,00000
ASTRO*%TPF^2	-0,00062	0,00017	-3,56691	0,00040
NANO*%TPF^2	-0,00055	0,00016	-3,53598	0,00040
MIKRO*%TPF^2	-0,00106	0,00023	-4,61955	0,00000
# researcher FTE	0,05463	0,01645	3,32085	0,00090
Restr. Log Likelihood	-742,01260		Log likelihood	-326,00520
LR statistic (7 df)	832,01470		LR Index (Pseudo-R2)	0,56065
p (LR Stat)	0,00000			

¹¹ One might argue against this result that publications and share of third party funding are interdependent. The simultaneity of both variables was indeed proved by a test. The introduction of a multi-equation model and 3 stage least square estimation with instrument variables lead to very similar results and is therefore not presented here.

Figure 6 Share of third party funded research projects and estimated publication number per field



To sum up, increasing shares of third party funding of research can have negative effects if they exceed a critical level. This level is field specific. There are strong incidents to assume that this effect is caused by the team growth that is often the consequence of more funding. This means that additional funding will lead to an absolute decrease in publications despite the growing number of group members. Behind this we suppose mechanisms of harshly increasing intraorganizational and intra-group transaction costs and growing costs of acquisition which more than compensate the positive effect of growing team size.

3.3 Effects of network size and science industry ties on scientific performance

As figure 2 (2004), and tables 4 and 5 (2006/2007) show, third party funding programmes quite often set incentives for collaboration between research groups, for instance for interdisciplinary collaboration, international collaboration or collaboration with industry partners. Collaboration in research is increasingly seen as a factor that positively influences performance in terms of number and impact of publications. Corroborating evidence is mostly based on studies of co-publications as an indicator of research collaboration (Adams et al. 2005, Frenken et al. 2005, Narin et al. 1990 on international co-publications, Katz/ Martin 1997 on the types of collaborations and its measurement by co-publications). The problem of this approach is that only more or less successful collaboration in networks can be analyzed. Only those collaborations that led to co-publications can be covered. Here I will deal with

research networks of research groups. Data on networks of research groups were collected using name generators and interpretators for so-called ego-networks (networks focussed around the research group) in personal interviews with the leader of the research groups.

Building on research on the evolution of social networks (Jansen 2002, 2007, Snijders 2005, 2006, Stokman/ Doreian 2001 and Doreian/ Stokman 1997), we can differentiate between two mechanisms that influence the formation and change of networks: selection and contagion. The most important selection mechanism in network building is a trend towards homophily. It was established not just for friendship networks but also for research collaborations in corporate alliances and academic collaborations along similarities with respect to industry class, scientific /technical competencies, regional affiliation, previous collaborations or common third parties (Uzzi 1996, 1997, Gulati 1995, Gulati / Gargiulo 1999, Laudel 1999, Jansen 1998, Hasse 1996). A particular form of homophily is the trend to choose partners from established collaborations for the next collaborative project. Homophily of networks lowers transaction costs and makes collaboration easy (Talmud /Mesch 1997, Ingram / Robert 2000, Hansen 1999, Ahuja 2000). But there is also evidence that an overdose of embeddedness into dense and stable networks can hamper innovation and produce too much confidence into established routines and products (Burt 1999, Anderson / Tushman 1990). These disadvantages also stem from the second important mechanism of network evolution – contagion – i.e. the infection process by which the partners within the network become more similar in their ideas and competencies, even if they were quite different in the beginning. The positive synergy from the collaboration shrinks. The search for new competencies and resources is another driving mechanism for the choice of network partners and limits the general pattern of homophile choices. Heterogeneous partners and their resources have a positive effect on scientific and technological performance (Stuart/Podolny 1999, Jansen 2000), but large differences also make communication and relations more difficult (Carley 1999, Contractor/ Grant 1999).

These ideas can be complemented by reasoning put forward by Wagner and Leydesdorff (2005) discussing their co-publication data for six research areas. They identify as an important factor for the growth of co-publication numbers the self-organization of researchers. Researchers choose partners along the lines of reputation and productivity in order to gain reputation and visibility for themselves. While Wagner and Leydesdorff argue that this mechanism of self-governance is even more important than factors such as science policy or technological opportunities, there is no doubt that in fact science policy and funding programmes promoting research collaboration support this virtuous cycle of accumulation of legitimacy. Wagner and Leydesdorff show for their data that the distribution of co-publication ties per author follows a power law – this indicates that strong networked authors more often gain further ties than less embedded authors. Similar power laws have been identified for the number of publications per author by Lotka (1926) and Price (1976). Merton (1968) described the result of this process which is driven by the search for and effects of legitimacy as the Matthew effect.

From a very different angle economists model the stability of networks and ask for their efficiency and its dependence on allocation rules in networks (Jackson 2005, Jackson/ Wolinsky 1996). Premise is here that the maintenance of ties is not without costs. The allocation of these costs and of the network benefits affect the structure and stability of the network. One of the models deals with co-publication networks and argues that the attractiveness of a co-publication partner will decrease with the number of co-publication ties

an author already commands. The argument behind this is that resources and research time are scarce and thus the initiation of an additional tie will negatively affect existing ties (negative externality). Obviously this model does not capture the mechanism of increasing returns that governs the search and establishment of legitimacy of actors within a network and motivates the search and acceptance of ties. Legitimacy is not subject to rivalry in consumption that is typical for most economic resources. On the other hand, the model warns to disregard the scarcity of at least some of the resources that flow in networks and the cost of the network links. Thus it sheds light on phenomena such as the increase of coordination and communication costs in growing networks. Thus, I postulate that network size will have a double effect on scientific performance too. First network growth yields return in the form of complementary knowledge and equipment and in the form of legitimacy and visibility. But if network size exceeds a critical threshold the effect becomes negative. The cost of the management of the large network outgrows the networks returns.

Table 21 presents the results of a regression analysis. As indicator of scientific performance we use again the sum of publications per group in the time period 1998-2003 as dependent variable. To measure the potential curvilinear effect of network size, a linear and a quadratic term are included into the equation. The quadratic term is created as a field specific term to control for the expected differences in economies of networks. As a further effect the orientation of networks choices of the group towards funders' priorities is included. Number of researchers and the affiliation to universities are further input factors to scientific performance which have to be controlled for. The omitted institutional category is all extra-university institutions. In the first step a Poisson model was fitted. The test for overdispersion of variance rejects the Poisson model at 0% level. In the next step a negative-binomial model was fitted using the overdispersion parameter alpha. The negative binomial model is significant at the 0% level.

The results partly corroborate the hypothesis of a curvilinear shape of the effect of network size. The linear term is positive and significant at the 5% level. The quadratic terms all have negative signs. The effect is significant only for the field of microeconomics at the 0.002 % level. For nanoscience the effect fails to be significant ($p = .271$). Astrophysics does not seem to be a case of negative effects at all. Further research with a larger sample will be needed to take a deeper look at productivities in nanoscience. Orientation of research groups towards funders' priorities in their network choices has a positive, albeit again not significant effect on performance ($p = .121$). The control variables have the expected effects. Number of researchers positively affects on sum of publications. University groups suffer from their worse resource endowment compared to the extra-university groups.

Table 21 Regression of network size on sum of publications 1998-2003: Poisson model and negative binomial model (2004 data)

	Poisson: Model 1 n=72		Neg. -Bin: Model 2 n=72	
Constant	3.4636	0.000	2.1124	0.002
# researchers FTE	0.0069	0.000	0.0266	0.043
University affiliation	-1.0649	0.000	-1.0152	0.007
Size of network	0.1435	0.000	0.2838	0.031
Network choices: external funding	0.2810	0.000	0.6518	0.121
(size of network)**2 * field astro	-0.0004	0.606	-0.0055	0.465
(size of network)**2 * field nano	-0.0008	0.319	-0.0069	0.271
(size of network)**2 * field micro	-0.0293	0.000	-0.0219	0.002
Alpha (overdispersion parameter)			1.343537	0.000
Log -likelihood	-2315.9672		-321.2089	
LR chi2	7312.5	df=7	60.74	df=7
Prob > chi2		0.0000		0.0000
Pseudo R2	.6122		0.0864	

In chapter 2 it was shown that the promotion of science-industry relations is particularly encouraged by research policy and funding agencies in the nanoscience field. The German Federal Ministry of Science¹⁵ as well as the EU Seventh Framework programme run well endowed programmes to promote science-industry collaboration in this area (c.f. the European Technology Platform ENIAC and the Joint Technology Initiative AENEAS). Such new types of transdisciplinary networks and the involvement of heterogeneous industrial and academic actors in research were put forward by STS researchers such as Gibbons et al. (1994) or Leydesdorff/ Etzkowitz (2000). They coined the ideas of a new mode 2 of knowledge production and of a triple helix of academic, state and industrial actors. The field of nanoscience is often described as a cardinal “Mode 2” field (Gibbons et al. 1994:16; Meyer 2001; Mehta 2002; Jotterand 2006). Wald (2007), using the interview data of the first panel wave, comes to the conclusion that nanoscience is not a mode-2 field, but rather treated so by science policy. On the other hand, we found evidence of some “Mode 2”-characteristics in the field of nanoscience compared to the fields of Astrophysics and Economics where little evidence exists.¹⁷ Nanoscience is more application-oriented. In addition research choices are more often driven by priorities of funding agencies and network building takes into account

¹⁵ Quote of German Ministry of Science: “Germany is strong in nanoscientific research but has deficiencies when it comes to applying the technology to industrial applications. The more fascinating the possibilities for Nanotechnology are, the slower local industry and manufacturers seem to be to make use of Nanoscience in the development of innovative products.” (BMBF 2004: 21, own translation)

¹⁶ Even if Gibbons et al. do not mention the terms “Nanoscience” or “Nanotechnology”, which were not yet in popular use at the time, they clearly describe this kind of research: “Instead of purifying natural substances or resorting to complex reactions to obtain those with desired properties, the required materials can now be built up atom by atom, or molecule by molecule, by design, in order to obtain a product with specified properties and possessing certain desired functions.” (Gibbons et. al 1994: 45, cf. also p. 19)

¹⁷ For a detailed analysis see Jansen et al. (2008).

the quests for internationalization and collaboration with industry most often. Albeit, although nanoscience is application-oriented, the main focus of the work still is basic research. Basic research also did not decline. 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 looked at here, these traditional motives continue to be strong.

So while it may still be debated whether mode-2 is a general phenomenon in science or restricted to a limited number of areas, or whether the concept catches the driving forces of science adequately or only catches a surface phenomenon (Weingart 1997a, Bonaccorsi/Vargas 2008, Shinn 1999) I will deal here with the question which effects the promotion of science–industry collaboration has on performance in nanoscience. Since particularly nanoscience experienced a strong and increasing promotion of industry ties the analysis is based on the data for 2006/2007.

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 (Agrawal and Henderson 2002; Ranga et al. 2003; Azoulay et al. 2004; Looy et al. 2004; Markiewicz and DiMinin 2005; Breschi et al. 2006 and Goldfarb et al. 2006). 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 commercialisation 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 economic and academic outputs in this area”. 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 analysis presented in table 22 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. Scientific performance was measured by the number of publications per research group member between 2004 and 2006. First a Poisson model was fitted and a test for overdispersion was applied. This test rejected the Poisson model at a 0% level. With the estimated overdispersion parameter of 0,445 a negative binomial Model was fitted. Table 22 shows both models. 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.¹⁸ A small proportion of industry relations can raise productivity, but if the proportion of industry partners becomes too big, productivity declines. The parameters indicate a curvilinear effect, although only the squared term is significant. An calculation of the gradient of number of publication depending on share of industry ties – albeit based on very small numbers – shows that the turning point is located at 16,4%. More important than the detailed location is the fact that there are reasonable indicators for the existence of such a threshold.

¹⁸ The negative sign of the squared term for the proportion of industry relations indicates the shape of the curvilinear relation.

Table 22 Regression of percentage of science-industry ties in networks on number of SCI publications per person of nanoscience groups 2004-2006 (2006/2007 data): Poisson model and negative binomial model

Dependent Variable: Number of SCI Publication of the Research group per Person 2004-2006									
	Poisson Regression			Neg-Bin Regression					
	Model 1a			Model 1b			Model 2		
	Coef.	Std. Err.	P> z	Coef.	Std. Err.	P> z	Coef.	Std. Err.	P> z
Proportion of Ind. Relations	5.86**	2.34	0.012	5.25	3.86	0.174	5.47	4.03	0.175
Proportion of Ind. relations ²	-18.2***	6.37	0.004	-16.00*	9.38	0.088	-16.32*	9.51	0.086
Third-Party-Funds							0.0013 4	0.0071 4	0.851
Rest. Log-likelihood	71.578287			-71.578287			-71.578287		
Log-likelihood	-71.5666			-60.3819			-60.3643		
LR-Statistic	10.56 (2 df)***			3.43 (2 df)			3.47 (3df)		
P-Value (LR-Statistic)	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

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/ Franke 2006 and 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 commercialization-oriented) and science partners (long-term truth-oriented) makes 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 realize advantages in the market can lower the publication output of such collaborations. This analysis shows – exemplary 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.

4 Summary and conclusion

There is considerable evidence of a change in the governance of the German research system. In 2004 the most visible effect is an increased pressure to compete for external

funding in order to compensate for decreasing institutional funding. By 2006/2007 this pressure increased particularly for the natural science fields which much more depend on third party funding than for instance economics. In all fields, the dependence on third party funding increased significantly. In particular university affiliated research groups are negatively affected by the shift of the university finance system towards external competitive funding. Instead, extra-university research groups still can rely on an affluent institutional endowment with resources.

Criteria of funders more and more became part of the decision processes on research subjects and collaboration partners. Not only did the governance pattern of 2004 – a majority of groups still being in the academic cluster – shift towards an increased dependence on third party funding. There is also a shift towards increased relevance of the application context for research choices, particularly for nanoscience and economics (both largely university based fields). There is reasonable evidence that the governance pattern by now shifted towards the side of the clusters characterized by some of the mode-2 elements of governance and that this pattern will diffuse further in the technology related natural science fields. The results from the analysis of the three mode-2 related clusters in 2004 suggest, that to compete successfully in the new regime groups must be able to rely on strong and supportive organizations. The governance analysis for 2006/2007 shows such a trend toward a strengthening of organizational management and priority setting. This is a particular strength of large extra-university institutes and groups.

The trend toward increased shares of third party funding in the research portfolio of all groups needs to be closely watched. The analysis in section 3.3 clearly reveals that there are discipline specific thresholds for the optimal balance of third party and institutional funding. If these thresholds are surpassed, further increase of third party money (and growth of the team) will result in an absolute decline of scientific performance. Thus the use of third party money as a proxy for performance by funders, organizational management and science policy is highly problematic. It promotes a further concentration of third party funding on a few large institutions and increases the deficiencies of the market for research money. Science policy, funding agencies and the leadership of universities and research institutes must become aware of the negative effects of this vicious cycle that they keep running. Instead, the chances for smaller and less visible actors to enter the research market should not be compromised by such policy concepts as “critical mass” or “elite university”. More is not necessarily better and large is not necessarily productive. Economies of scale and the pattern of performance dimensions strongly vary with disciplinary differences. These must be better observed by science policy. For all input factors analyzed in this paper, size of group, size of networks, third party funding and share of industry ties in networks, we established evidence for an inverted u-shaped effect on scientific performance.

The analysis of chances to start a high risk new project revealed the beneficial role of institutional funding, be it in extra-university institutes – here the internal seed money pool is important – or in universities. Such pools still are small in universities but a recourse on one’s own research budget guarantees some leeway for new ideas. From this point of view a further shift in the funding structure toward more third party funding seems even more questionable.

While the field of nanoscience studied here is the forerunner in reforms (size, size of networks, share of third party money, share of industry ties), this turns out to be a debatable

advantage. Nanoscience is quite endangered by policy pressure to overdo critical mass or science-industry collaboration. In addition, there is considerable doubt about the adequacy of the mode-2 thesis of an unproblematic dissolution of the boundaries between science and economy. Etzkowitz (1998) argues that the normative structure in science is changing. The commercialisation of the science system in his view is no longer considered problematic and the “entrepreneurial scientist” is established as the new role model (cf. Heidbrink 2005). This allows scientists “to meet two goals simultaneously: the pursuit of truth and profit making” (Etzkowitz 1998: 824). The negative effects of more than optimal growth in size and third party funding, and the problems of dedifferentiation triggered by a large share of industry ties make a different point. Competition in the research system is not competition for return on investment but competition for best scientific output. Thus, only a stable functional differentiation between the science system and the economic system allows both to operate efficiently and to collaborate.

The problem of a shift of governance and research output profiles towards the mode-2 related clusters becomes even more obvious if we consider the distribution of performance profiles in the clusters. Graduate teaching and contribution to the infrastructure of the research system are the dominant outputs of the academic cluster. These tasks are not fulfilled by the other three clusters. Over-promoting mode-2 type of research thus implies the danger that research groups which are not really fit for this task try to compete here at the expense of supporting doctoral students or engaging in editorships, conference organization or advisory committees. Again dedifferentiation is not productive and would lead to a loss of potentials in the research system.

References

- Adams, J. D., G. C. Black, J. R. Clemmons, and P. E. Stephan [2005], "Scientific teams and institutional collaborations: Evidence from U.S. universities, 1981-1999," *Research Policy*, 34, 259-285.
- Agrawal, A. / R. Henderson, 2002: Putting patents in context: exploring knowledge transfer from MIT, in: *Management Science* 48(1), 44-60.
- Ahuja, Gautam, 2000: Collaboration Networks, Structural Holes, and Innovation. A Longitudinal Study. *Administrative Science Quarterly* 45, 425-455.
- Anderson, P./M.L. Tushman 1990: Technological Discontinuities and Dominant Designs. A cyclical Model of Technological Change. In: *Administrative Science Quarterly* 1990, 35. Special Issue edited by Tushman and Nelson, 603-633.
- Arnold, Natalie 2007 The Application of the Concept of Governance to the Structures of German Extra-University Research Organizations from a Legal Perspective. In: Jansen, Dorothea (Ed.): *New Forms of Governance in Research Organizations. Disciplinary Approaches, Interfaces and Integration*. Dordrecht: Springer, 177-185.
- Azoulay, P. / W.W. Ding / T.E. Stuart, 2004: The effect of academic patenting on the rate, quality and direction of (public) research output, NBER Working Paper 11917.
- Bonaccorsi, Andrea / Jaun Sebastian Vargas, 2008: Proliferation dynamics in emerging sciences. (<http://www.oecd.org/dataoecd/25/42/40050880.pdf>)
- Breschi, S. / F. Dissoni / F. Montobbio, 2006: University patenting and scientific productivity. A quantitative study of Italian academic inventors, unpublished manuscript.
- Burt, Ronald S., 1999: Entrepreneurs, Distrust, and Third Parties: A Strategic Look at the Dark Side of Dense Networks. S. 213-243 in: Leigh L. Thompson/ John M. Levine/ David M. Messick (eds.) 1999: *Shared cognition in Organizations. The Management of Knowledge*. Mahwah, NJ: Lawrence Earlbaum.
- Bundesministerium für Bildung und Forschung, 2004: Nanotechnologie erobert Märkte. Deutsche Zukunftsoffensive für Nanotechnologie, Bonn / Berlin.
- Carley, Kathleen M., 1999: On the Evolution of Social and Organizational Networks, in: Steven B. Andrews und David Knoke (Hrsg.), *Networks in and Around Organizations. Research in the Sociology of Organizations*, Vol. 16. Stamford, CO: JAI Press, S. 3-30.
- Contractor, Noshir/Susan S. Grant, 1996: The Emergence of Shared Interpretations in Organizations, in: James Watt/Arthur C. VanLear (ed.), *Dynamic Patterns in Communications Processes*. Thousand Oaks: Sage, S. 215-230.
- de Boer, H./ Enders, J./ Schimank, Uwe 2007: On the Way towards New Public Management? The Governance of University Systems in England, the Netherlands, Austria, and Germany. In: Jansen, Dorothea (Ed.): *New Forms of Governance in Research Organizations. Disciplinary Approaches, Interfaces and Integration*. Dordrecht: Springer, 137-152.
- Doreian, Patrick/ Frans N. Stokman (Hrsg.) 1997a: *Evolution of social networks*. Amsterdam: Gordon and Breach Publishers.
- Etzkowitz, Henry, 1998: The norms of entrepreneurial science: cognitive effects of the new university-industry linkages, in: *Research Policy* 27, 823-833.
- Etzkowitz, Henry / Loet Leydesdorff, 2000: The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university-industry-government relations, in: *Research Policy* 29, 109-123.
- Federkeil, Gero and Frank Ziegler 2001, *Globalhaushalte an Hochschulen in Deutschland. Entwicklungsstand und Empfehlungen. Gutachten im Auftrag der CDU-Fraktion des Sächsischen Landtags*. Gütersloh: Centrum für Hochschulentwicklung.
- Franke, K. / A. Wald, / K. Bartl, 2006: Die Wirkung von Reformen im deutschen Forschungssystem. Eine Studie in den Feldern Astrophysik, Nanotechnologie und Mikroökonomie, *Speyer Forschungsberichte*, Nr. 245, Speyer.

- Frenken, K., W. Hölzl, and F. de Vor, 2005, The citation impact of research collaborations: the case of European biotechnology and applied microbiology (1988-2002),” *Journal of Engineering and Technology Management*, 22, 9-30.
- Gibbons, Michael / Camille Limoges / Helga Nowotny / Simon Schwartzmann / Peter Scott / Martin Trow, 1994: *The new production of knowledge. The dynamics of science and research in contemporary societies*, London, Sage.
- Godin, Benoît, 1998: *Writing Performative History: The New New Atlantis?*, in: *Social Studies of Science* 28(3), 465-483.
- Goldfarb, B. / G. Marschke / A. Smith, 2006: *Scholarship and inventive activity in the university: complements or substitutes?*, Paper Presented at the Workshop on Technology Transfer from Universities: A Critical Appraisal of Patents, Spin-offs and Human Mobility Ecole Polytechnique Federale de Lausanne, September 29–30.
- Gornitzka, Åse/Kogan, Maurice/Amaral, Alberto (Eds.) 2007: *Reform and Change in Higher Education. Analysing Policy Implementation*. Dordrecht: Springer.
- Groß, Thomas/ Arnold, Natalie 2007: *Regelungsstrukturen der außeruniversitären Forschung. Organisation und Finanzierung der Forschungseinrichtungen in Deutschland*. Baden-Baden: Nomos.
- Gulati, Ranjav, 1995: *Social Structure and Alliance Formation: a Longitudinal Analysis*. *Administrative Science Quarterly* 40, 619-652.
- Gulati, Ranjav/ Martin Gargiulo, 1999: *Where Do Interorganizational Networks Come From?* *American Journal of Sociology* 104, 1439-1493.
- Hansen, Morten T., 1999: *The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits*. *Administrative Science Quarterly* 44: 82-111.
- Hartmer, Michael and Hubert Detmer (Eds.) 2004, *Hochschulrecht. Ein Handbuch für die Praxis*. Heidelberg: C.F. Müller.
- Hasse, Raimund, 1996: *Organisierte Forschung. Arbeitsteilung, Wettbewerb und Networking in Wissenschaft und Technik*. Berlin: Edition Sigma.
- Heidbrink, Ludger, 2005: *Die Zukunft der Geisteswissenschaften. Ein Plädoyer für die unternehmerische Wissenschaft*, in: *Jahrbuch des Kulturwissenschaftlichen Instituts 2004*, Bielefeld, transcript Verlag, 249-252.
- Hellström, Thomas / Merle Jacob, 2000: *Scientification of politics or politization of science? Traditionalist science-policy discourse and its quarrels with Mode 2 epistemology* in: *Social Epistemology* 14(1), 69-77.
- Ingram, Paul and Peter W. Roberts, 2000: *Friendships among competitors in the Sydney hotel industry*. *American Journal of Sociology* 106, 387-423.
- Jackson, Matthew O. 2005: *A survey of network formation models: stability and efficiency*. In: *Group Formation in Economics*. Cambridge: Cambridge University Press, S. 11-57.
- Jackson, Matthew O./Asher Wolinsky 1996: *A strategic model of social economic networks*. *Journal of economic theory*. 71(1), 44-74.
- Jansen, Dorothea, 1996: *Nationale Innovationssysteme, soziales Kapital und Innovationsstrategien von Unternehmen*, in: *Soziale Welt* 45 (4), 411-434.
- Jansen, Dorothea, 1998: *Hochtemperatursupraleitung – Herausforderung für Forschung, Wirtschaft und Politik. Ein Vergleich Bundesrepublik Deutschland – Großbritannien*. Baden-Baden: Nomos.
- Jansen, Dorothea, 2000: *Netzwerke und soziales Kapital. Methoden zur Analyse struktureller Einbettung*. S. 35-62 in: Johannes Weyer (Hrsg.), *Soziale Netzwerke. Konzepte und Methoden der sozialwissenschaftlichen Netzwerkforschung*. München: Oldenbourg.
- Jansen, Dorothea, 2002: *Netzwerkansätze in der Organisationsforschung*. S. 88-118 in: *Organisationssoziologie. Sonderband 42 der Kölner Zeitschrift für Soziologie und Sozialpsychologie*, hrsg. von Jutta Allmendinger und Thomas Hinz.

- Jansen, Dorothea 2007a: Summary and Conclusion. In: Jansen, Dorothea (Ed.): *New Forms of Governance in Research Organizations. Disciplinary Approaches, Interfaces and Integration*. Dordrecht: Springer, 233-240.
- Jansen, Dorothea 2007b, *Theoriekonzepte in der Analyse sozialer Netzwerke. Entstehung und Wirkungen, Funktionen und Gestaltung sozialer Einbettung*. FÖV Discussion Paper 39, Speyer: Deutsches Forschungsinstitut für öffentliche Verwaltung.
- Jansen, Dorothea, 2007c: *Effekte des Drittmittelwettbewerbs auf Forschungsstrategien, Netzwerkstrategien und Performanz von Forschungsgruppen*. Villa Vigoni Workshop gefördert vom Stifterverband für die Deutsche Wissenschaft. Loveno di Menaggio, Italien. July 16-18, 2007.
- Jansen, Dorothea/ Andreas Wald/ Karola Franke/ Ulrich Schmoch/ Torben Schubert, 2007d: *Drittmittel als Performanzindikator der wissenschaftlichen Forschung. Zum Einfluss von Rahmenbedingungen auf Forschungsleistung*. In: *Kölner Zeitschrift für Soziologie und Sozialpsychologie* 59 (1).
- Jansen, Dorothea, Regina von Görtz and Richard Heidler, 2008: *Is nanoscience a mode-2 field? Disciplinary differences in modes of knowledge production* In: Jansen, Dorothea (ed.) *Disciplinary differences, governance and performance in universities and research organizations*. Forthcoming.
- Jotterand, Fabrice, 2006: *The Politicization of Science and Technology: Its Implications for Nanotechnology*, in: *The Journal of Law, Medicine and Ethics* 34(4), 658-666.
- Katz, S.J. and B.R. Martin 1997, *What is research collaboration?* In: *Research Policy* 26(1), 1-18.
- Kehm, Barbara/ Lanzendorf, Ute 2006 *Reforming University Governance. Changing Conditions for Research in Europe*. Bonn: Lemmens.
- Knopp, L. and U. Gutheil 2003, *Neues Hochschulrahmengesetz (HRG) und Professorenbesoldungsreformgesetz (ProfBesReformG)*. Wiesbaden: Kommunal- und Schul-Verlag.
- Larédo, Philippe, und Philippe Mustar, 2000: *Laboratory activity profiles: An exploratory approach*. *Scientometrics* 47: 515-539.
- Laudel, G.. 1999: *Interdisziplinäre Forschungsk Kooperation. Erfolgsbedingungen der Institution „Sonderforschungsbereich“*. Berlin: Edition Sigma.
- Leszczensky, Michael/ Orr, Dominic 2004: *Staatliche Hochschulfinanzierung durch indikatorgestützte Mittelverteilung - Dokumentation und Analyse der Verfahren in 11 Bundesländern*. Bundesministerium für Bildung und Forschung. Hochschule Information System (HIS) A2-2004. Hannover: Bundesministerium für Bildung und Forschung.
- Leydesdorff, Loet / Henry Etzkowitz, 1996: *Emergence of a triple helix of university-industry-government relations*, in: *Science and Public Policy* 23, 279-286.
- Leydesdorff, Loet, 2000: *The triple helix: An evolutionary model of innovation*, in: *Research Policy* 29, 243-255.
- Lin, Nan/ Karen S. Cook/ Ronald S. Burt (Hrsg.) 2001: *Social capital. Theory and research*. New York: de Gruyter.
- Looy, B.V. / M. Ranga / J. Callaert / K. Debackere / E. Zimmermann, 2004: *Combining entrepreneurial and scientific performance in academia: towards a compounded and reciprocal Matthew-effect*, in: *Research Policy* 33(3), 425-441.
- Lotka, A. J., 1926, *The frequency distribution of scientific productivity*, *Journal of the Washington Academy of Science*, 16, 317-232.
- Markiewicz, K. / A. DiMinin, 2005: *Commercializing the laboratory: the relationship between faculty patenting and publishing*, Working Paper, University of California at Berkeley.
- Mehta, Michael D., 2002: *Nanoscience and Nanotechnology: Assessing the nature of Innovation in these fields*, in: *Bulletin of science, Technology and Society* 22(4), 269-273.
- Merton, Robert K., 1968: *The Matthew Effect in Science*, in: *Science* 57, 68-72.

- Meyer, Martin, 2001: The emergence of developer communities in a novel field of technology: A case of Mode 2 knowledge production?, in: Bender, Gerd (ed.): *Neue Formen der Wissenserzeugung*, Frankfurt / New York, Campus, 147-162.
- Narin, Francis / E.S. Whitlow, 1990: Measurement of scientific cooperation and co-authorship in EC-related areas of Science. EC-Report EUR 12900. Luxembourg.
- Nowotny, Helga / Peter Scott / Michael Gibbons, 2001: *Rethinking science: knowledge in an age of uncertainty*, Cambridge, Polity.
- Price, D. J. de Solla [1976], "A general theory of bibliometric and other cumulative advantage processes," *Journal of the American Society for Information Science*, 27, 292-306.
- Ranga, L.M. / K. Debackere / N. von Tunzelman, 2003: Entrepreneurial universities and the dynamics of academic knowledge production, in: *Scientometrics* 58(2), 301–320.
- Schimank, U. 2007: *Ökonomisierung der Hochschulen – eine Makro-Meso-Mikro-Perspektive*. Unpublished manuscript.
- Schmoch, U., 2003: *Akademische Forschung und industrielle Forschung. Perspektiven der Interaktion*, Frankfurt / New York, Campus.
- Schmoch, Ulrich/ Torben Schubert/ Dorothea Jansen / Regina von Görtz and Richard Heidler, 2008: *Suitability of Indicators for Measuring Scientific Performance*. Working paper. Karlsruhe and Speyer.
- Seidler, Hanns H. 2004: Hochschulfinanzierung. Evaluation und Mittelvergabe. In: Hartmer, Michael and Hubert Detmer (Eds.) 2004, *Hochschulrecht. Ein Handbuch für die Praxis*. Heidelberg: C.F. Müller, 478-510
- Shinn, Terry, 1999: Change or mutation? Reflections on the foundations of contemporary science, in: *Social Science Information/Information sur les sciences sociales* 39, 149-176.
- Snijders, Tom A. B. et al., 2006: *Manual for SIENA version 3*. Groningen: ICS.
- Snijders, Tom A. B., 2005: Models for Longitudinal Network Data. Chapter 11 in P. Carrington/J. Scott/S. Wasserman (eds.), *Models and Methods in Social Network Analysis*. New York: Cambridge University Press, 215-247.
- Stokman, Frans N./ Patrick Doreian, 1997: Evolution of social networks: Processes and principles. S. 233-250 in: Doreian/ Stokman 1997a.
- Stokman, Franz N./Patrick Doreian (Hrsg.), 2001: *Evolution of Social Networks Part II. Sonderband 25 (1) des Journal of Mathematical Sociology*.
- Stuart, Toby E./ Joel M. Podolny, 1999: Positional Consequences of Strategic Alliances in the Semiconductor Industry. S. 161-182 in: Andrews/ Knoke 1999.
- Talmud, Ian/ Gustavos S. Mesch, 1997: Market embeddedness and corporate instability: the ecology of inter-industrial networks. *Social Science Research* 26, 419-441.
- Tute, Hans-Heimrich/ Wolfgang Denkhäus/ Bärbel Bastian/ Kendra Hoffmann, 2007: Governance modes in university reforms in Germany – from the perspective of law. In: Jansen, Dorothea (Ed.): *New Forms of Governance in Research Organizations. Disciplinary Approaches, Interfaces and Integration*. Dordrecht: Springer, 155-173.
- Uzzi, Brian, 1996: The Sources And Consequences of Embeddedness for the Economic Performance of Organizations: The Network Effect. *American Sociological Review* 61, 674-698.
- Uzzi, Brian, 1997: Social Structure and Competition in Interfirm networks: The Paradox of Embeddedness. *Administrative Science Quarterly* 42, 35-67.
- Wagner, Caroline/Loet Leydesdorff, 2005: Network Structure, Self-Organization and the Growth of International Research Collaboration in Science, in: *Research Policy* 34(10), 1608-1618.
- Wald, Andreas / Karola Franke, 2006: Mode 2 Policy Effects on the Research Process. The Case of Publicly Funded German Nanotechnology. Paper Presented at Session 2: Standardization of Science Policies?, XVI ISA World Congress of Sociology, Durban, South Africa, 23-26 July 2006.

- Wald, Andreas, 2007: The Effect of 'Mode 2'-Related Policy on the Research Process: The Case of Publicly Funded German Nanotechnology, in: *Science Studies – an interdisciplinary journal of science and technology studies* 20(1).
- Weingart, Peter, 1997a: From "Finalization" to "Mode 2": old wine in new bottles? in: *Social Science Information* 36(4), 591-613.
- Weingart, Peter, 1997b: Neue Formen der Wissensproduktion: Fakt, Fiktion und Mode, IWT Paper: 15, [URL]: <http://www.uni-bielefeld.de/iwt/publikationen/iwtpapers/paper15.pdf>