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How does Governance change research content? On the possibility of a sociological middle-range theory linking science policy studies to the sociology of scientific knowledge*

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Abstract

Changes in the content of research are the ultimate goal of many actors involved in the governance of science. While science policy compensates for its lack of systematic knowledge about causal relationships between governance and changes in research content by tapping into the relevant experiences of elite researchers who act as stakeholders, the analysis of governance cannot rely on this approach and needs to explore the causal relationships between governance and research content. However, owing to the neglect of governance by the sociology of scientific knowledge and the neglect of research content by science policy studies, little progress has been made in the development of such knowledge. The aim of this paper is to suggest a structure and some building blocks for a middle-range theory that links variation in governance to changes in research content. It starts from the decision-making of researchers and the situation to which they respond in these decisions. Some elements of researchers' situations are 'levers' for governance because they are shaped by external actors who are thereby able to indirectly influence decisions on research. Researchers must find solutions to the decision problems emerging from expectations of their communities and governance actors. The solutions they find, and thus the impact of governance on the content of research, are modulated, among other variables by epistemic properties of fields, which is why uniform governance measures may have different consequences in different fields.

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1. The governance of science is (attempted) governance of research content

Among the effects of governance taken into account by any anticipatory or reflexive governance, changes in the content of research are the most opaque. Such changes are the ultimate goal of many actors involved in the governance of science. Current science policy wants to promote excellent research, breakthrough research, interdisciplinary research, and strategic or applied research. It also wants to promote research in certain areas such as biomedicine or nanoscience. Promoting research on specific topics is also the interest of various non-state actors ranging from industries that want research on their technologies and products to patient groups that are interested in research on cures for specific diseases. Other actors are interested in suppressing certain research, e.g. research based on experiments with animals or research using embryonic stem cells.

All these aims can only be achieved when the content of research is changed: better research means more challenging problems being solved; more nanoscience means switching from non-nano to nano, and so on. At the same time, science policy measures are suspected to have inadvertent consequences for the content of research, with changes towards mainstream, applied, short-term and safe research being the most frequently named side-effects.

But do all these policies and governance instruments change anything at all? And how are their effects moderated by the various scientific fields? Science policy does not have access to systematic knowledge about causal relationships between governance and changes in research content. It can utilise information about (future) effects of governance instruments only with the help of elite researchers who act as stakeholders. These researchers have no *systematic* knowledge about causal links between governance and research content, either. Their lobbying for or against specific governance measures is based on their experience and implicit knowledge.

While the governance of science can do well with such an approach (or so it seems), the analysis of governance cannot.[1] Analysing the impact of governance on research content requires causally attributing changes in the content of research to specific governance instruments. This means simultaneously building and drawing on a middle-range theory of how governance changes research content. Developing such a theory is difficult because its independent and dependent variables belong

[1] 'Governance' is a frequently used but rarely defined concept. According to Mayntz (2004a: 121-122) it has acquired two significantly different meanings. The wider sociological understanding of the concept is 'coping with interdependence'. This understanding includes all intentional actions aimed at an adjustment of actions of mutually interdependent actors and makes 'governance' synonymous to 'coordination'. A second understanding, which is often implied in the concept's use in political science, is limited to the political actors who are engaged in the regulation of a societal sub-system. This approach analytically distinguishes between an arena (level, actor constellation) in which decisions concerning the production of a certain good by a societal sub-system are made and the actual production of that good (in our case: scientific knowledge) in the formal organisations of that sub-system. Although there is a real danger of stretching the concept of 'governance' to an extent that its become meaningless, I prefer the more general sociological approach because it is 'scale-free' and frees us from defining a boundary between science policy and knowledge production. My paper demonstrates the necessity for studies of the governance of science to include individual and collective actors at all levels of aggregation in the analysis of governance. Following Rosenau (2004) and Whitley (2010a), I define governance of as *the construction and exercise of authority in a complex and heterogeneous set of interdependent actors* (i.e. in an actor constellation).

to fields that proceed largely independently of each other and have developed different methodological approaches, namely science policy studies and the sociology of science.

Science policy research has focused on changes in the governance of science, including funding policies (Braun 1993; Ruivo 1994; Guston 1996; van der Meulen 1998; Silvani *et al.* 2005). While political actor constellations and policies are identified as independent variables, the studies are less clear about the effects they investigate. If an impact of governance on the cognitive content of science is discussed at all, these effects are either ignored or addressed at a very general level without empirical backing (e.g. Rip 1994; Braun 1998). Mayntz and Schimank have argued that in order to understand the mechanisms that channel external expectations towards science, the "performance level of the science system" needs to be included in the analysis (Mayntz and Schimank 1998: 753). So far, this has rarely been done (notable exceptions are Van der Meulen and Leydesdorff 1991).

This disregard for changes in scientific knowledge by much work on science policy is complemented by a tendency of the constructivist sociology of science to ignore the role of institutions. The microscopic focus of laboratory studies led to the neglect of macro-structures and dominant institutions (Knorr-Cetina 1995b: 160-163; Kleinman 1998: 285-291; Mayntz and Schimank 1998: 751). The predominance of single-case studies as research design in the sociology of science further contributes to the neglect of larger social structures, whose role is much more likely to be detected if processes of knowledge production are observed comparatively across several settings. As a result, constructivist studies have discovered early that what we today understand as governance influences research content (Knorr-Cetina 1981; Callon *et al.* 1983; Callon 1986b, a; Latour and Woolgar 1986 [1979]; Fujimura 1987; Law 1994). However, neither the ways in which such influence occurs nor its consequences on the content of research have been systematically addressed.

The link between governance and research content falls into the gap between the foci of science policy studies and the sociology of science and has not yet been systematically investigated. This is unfortunate because without such a link, science policy studies will learn little about one of the central effects of governance, while the sociology of science will stay ignorant of the role institutional conditions for research play in the social construction of scientific knowledge. The aim of this paper is to suggest a structure and some building blocks for a middle-range theory that links variation in governance to changes in research content. Science studies appear to have mixed feelings concerning middle-range theories. If we take our clues from the symposium on middle-range studies, then some researchers are frustrated by their absence, others don't think they are necessary, and those who use them consider them as explanations, interpretations, sets of related concepts, or ways 'to shoot holes in essentialisms' (Wyatt and Balmer 2007: 622, see also the other contributions in the special issue introduced by Wyatt and Balmer). With this paper, I propose some building blocks for a specific middle range theory, namely a theory that aims to explain changes in research content by linking sets of conditions, social mechanisms that are triggered under specific conditions, and the outcomes of these mechanisms.[2]

[2] The idea of social mechanisms was introduced by Merton (1968) to sociological theory and by Whitley (1972) to the sociology of sciences. Interest rekindled in the 90ies (Hedström and Swedberg 1998), and many different understandings of causal mechanisms have been suggested in the literature since then. Following (Mayntz 2004b: 41), I define a social mechanism as a sequence of causally linked events that occur repeatedly in reality if certain conditions are given and link specified initial conditions to a specific outcome (Gläser and Laudel 2007: 129, for a similar but less precise definition see Merton 1968: 42-43; for many other versions see Mahoney 2003: 13-15). Mechanismic explanations are quite different from the predominant understanding of explanation as 'subsumption under a

The paper draws on a larger theoretical project on the social order of scientific communities (Gläser 2006) as well as several empirical projects that investigated institutionalised pressures towards applications and evaluation-based funding schemes in Germany and Australia. I begin by discussing the decision-making of researchers and the situation to which they respond in these decisions (2). Some elements of researchers' situations are 'levers' for governance because they are shaped by external actors who are thereby able to indirectly influence decisions on research (3). Researchers must find solutions to the decision problems emerging from expectations of their communities and governance actors (4). The solutions they find, and thus the impact of governance on the content of research, are modulated by epistemic properties of fields, which is why uniform governance measures may have different consequences in different fields (5). As a conclusion, I discuss the problem of aggregation and the methodological challenges for further research (6).

2. Decisions on research content are only made by researchers

In one of the very first laboratory studies, Knorr-Cetina (1981) demonstrated the decision-impregnatedness of research. The everyday laboratory work of researchers is impregnated with decisions on methods, the use of equipment, materials, collaborations, and other elements of the production of new knowledge. These decisions shape the conduct of research and, consequently, the content of the knowledge that is produced. Some decisions are made with explicit consideration of the consequences for the content of knowledge production, while others are made ad hoc, in order to 'make experiments work', without systematically considering all the consequences for later results.

This account of researchers' decision-making, which has been implicitly confirmed by other studies (Lynch 1985; Latour and Woolgar 1986 [1979]; Fujimura 1987) contains two observations that are important to the analysis of impacts of governance. The first observation is that all decisions on how to conduct research, i.e. all decisions that immediately influence research content, are made by the researchers themselves. From this follows that all influences on the content of knowledge are mediated by a researcher's decision. In the language of actor-network-theory we can describe the researcher as an "obligatory point of passage" (Latour 1988: 43-44) for influences on the content of research.

The second observation is that researchers are autonomous in the sense that a direct intervention in their decisions on research is a rare exception. The formulation of problems and the selection of approaches to problem-solving reside with researchers who interpret the knowledge of their community, derive problems and suitable approaches from that knowledge, and assign themselves the resulting task. Although they need to adapt this decision to their situation (see below, section 4), there is little direct intervention in the formulation of problems and selection of approaches.

The reasons for this autonomous self-assignment of tasks have been discussed by Benkler who, in his analysis of web-based knowledge production, has observed that "individuals self-identify for tasks" (Benkler 2002: 376). The "self-identification" of tasks and producers increases the likelihood that

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general law'. It is rather specific in that a satisfying explanation of a social phenomenon has been achieved only if the social mechanism by which the phenomenon was produced and the conditions that initiated and upheld the mechanism are provided. The approach is not deterministic because it acknowledges that humans can always decide otherwise. Mechanismic explanations only point to *likely* sequences of events and outcomes. They are nevertheless superior to lists of 'causal factors' that produce a phenomenon with a certain probability because these lists (which are derived from statistical analyses of quantitative data) black-box the process by which a phenomenon is produced and thus constitute a contribution to an explanation at best.

producers have tasks they are actually able to solve, a match which would be very difficult to achieve otherwise because a third actor is hardly able to adequately assess the creative abilities of a producer (ibid: 414-415).[3] Thus, only researchers themselves can define goal/approach combinations that make their being successful in their research likely.

Scientific communities as collective producers of knowledge thus operate on the basis of their members' autonomous decision-making, which is based on the individual researcher's interpretation of the community's knowledge (Gläser 2006). The mutual 'fit' of members' contributions is guaranteed by the joint referent – the community's shared body of knowledge. Since this knowledge is perceived and interpreted in specific local situations by specific individuals, the fit is incomplete. For the same reason, multiple solutions to a problem are common. Nevertheless, this mode of production is superior under conditions of multiple uncertainties that frequently occur in the production of scientific knowledge. In many situations of knowledge production the following points may be unknown:

- What exactly the problem is that needs solving (how it should be formulated);

- Whether there is a solution to the problem at the current stage of knowledge;

- How the problem could be solved;

- What knowledge can be regarded valid and reliable and should therefore be used for solving the problem; and

- Who can solve the problem.

In these situations decentralised autonomous decision-making is efficient because it means that many independent attempts to formulate and solve problems as possible are undertaken simultaneously. While many (and sometimes most) of the attempts are bound to fail or to become redundant, the decentralised approach provides the highest likelihood that the problem is solved as quickly as possible.

This ideal-typical description of the formulation of individual research tasks also points to the few possible limitations of a researcher's autonomy. Only members of the same community have the ability to interfere directly with the formulation of research problems and approaches. Other researchers from the same community who have the necessary authority, e.g. because of their position in the organisational hierarchy, can force researchers to address specific problems. Their understanding of their subordinates' problem solving capability, though, is still limited. This is why in the institutes of the Academy of Sciences of the GDR, i.e. under conditions of strong double hierarchies of the state and the communist party, direct interventions into decisions on research were rare event. Researchers occupying positions in the state hierarchy knew about the functional necessity of self-identification. Other powerful actors lacked the knowledge required for a meaningful intervention (Gläser and Meske 1996; Mayntz 1998). The situation in industrial research might be different (see the accounts in Fujimura 1987) but we know too little about it. The only common situation of interference is the supervision of PhD students, who are considered as apprentices rather than autonomous researchers and therefore have a supervisor from their community (Laudel and Gläser 2008).

[3] Fujimura (1987) discusses the researcher's perspective on the ‚do-ability' of problems. Interestingly, the researchers she observed never included their own abilities in their accounts of 'do-ability' – self-identification had already taken place.

While the independence from direct interference guarantees a comparatively high base level of autonomy, researchers' decisions depend on their conditions of action. A secondary analysis of the many ethnographies of science that have been conducted during the past three decades reveals the following influences on decisions:

- The community's shared body of knowledge serves as a source from which problems and approaches are drawn. Researchers interpret their community's knowledge, identify gaps in that knowledge and formulate projects aimed at closing these gaps. Examples include the task of detecting solar neutrinos, which was derived from theoretical, methodological and empirical knowledge accumulated over several years (Pinch 1986: 55-68), the search for free quarks (Pickering 1995: 68-112) and the tackling of decade- or even century-old persistent mathematical problems (MacKenzie 1999; Heintz 2000: 157-159).

- The preferences and norms of the scientific community provide important information about acceptable contributions and contributions that would earn a researcher the highest reputation. Scientific communities tacitly or explicitly agree on the problems that must be urgently solved because the community's further progress depends on the solution. Examples include the demand for new theoretical models emerging from the discovery of new elementary particles (Pickering 1982: 127-129), the discovery of the structure of TRF (Latour and Woolgar 1986 [1979]), and the rejection of Weber's claims to have detected gravitational waves by his scientific community (Collins 2004: 23-210).

- The researcher's own research biography creates a unique combination of knowledge that has been accumulated in prior research, the frames guiding the perception and evaluation of new knowledge, and individual interests and preferences. Collins' study of Weber's attempts to detect gravitational waves provides an interesting case study (ibid.).

- The local research environment consists of experimental systems (Rheinberger 1992a, b, 1994, 2001) and other researchers, all of which trigger new ideas and can be combined in new research processes (Knorr-Cetina 1981).

The importance of both trans-local knowledge and collective preferences guiding the allocation of reputation clearly demonstrates the crucial role of scientific communities as collective producers of scientific knowledge (Gläser 2006). It is rather unfortunate that the constructivist turn in the sociology of science (or the sociology of scientific knowledge) led to both a direct rejection of the scientific community as an important social context of knowledge production (Knorr-Cetina 1981: 68-93, 1982; Callon *et al.* 1983: 191-194; Jacobs 1987; Jacobs and Mooney 1997) and an empirical neglect of the scientific communities (with Harry Collins being a notable and important exception, e.g. Collins 1981, 1998, 1999). As I will demonstrate below, the use of transepistemic criteria in decisions on research indicates a superimposition of community and external influences rather than the irrelevance of scientific communities.[4]

In addition to the conditions created by the researcher's primary work context – the scientific community – there is a second important set of conditions. All research is embedded in national societies, which maintain conditions essential for the continuation of research including access to material resources (Knorr-Cetina 1981; Fujimura 1987; Morris 2000; Laudel 2006; Gläser and Laudel 2007; Leišytė 2007; Gläser *et al.* 2010) and the legitimisation for research. While the scientific community provides researchers with one of the crucial resources – knowledge – all research requires material resources as well. In some fields, the necessary resources may include only the researcher's

[4] Interestingly enough, scientific communities both persisted and have a comeback, albeit in the disguises of 'social worlds' (Gerson 1983), 'superorganisms' (Knorr-Cetina 1995) and 'epistemic cultures' (Knorr-Cetina 1999).

salary, a basic infrastructure in the form of work space, and means for communication (a library and resources for travelling). In other fields, resources for very expensive equipment are essential for conducting research. In any case, research without these resources is impossible, and whoever controls access to them has some authority concerning the conduct of research. The same applies to actors who control the legitimisation of research, i.e. the societal acceptance of the practices of knowledge production. From the history of science we know that this legitimacy emerged at some point and is thus historically contingent.[5] We also know from specific public debates that specific research practices can easily become illegitimate (see Salter and Salter 2007 on stem cell research; Isasi and Knoppers 2006 on cloning research).

3. Levers for governance

Since researchers are obligatory points of passage for all influences on the content of research, any attempts to change research content by governance must be based on influencing decisions of researchers. Societal actors who want their expectations concerning research content fulfilled must communicate these expectations and find ways to make researchers fulfil them. Owing to the researchers' autonomy and monopoly on the knowledge that is necessary for the definition of tasks, direct negotiations about research goals are rare. This leaves modifications of conditions of research as the only usable 'governance levers' for influencing the content of research. From the previous section follows that a variety of conditions can be used to influence researchers:

a) Knowledge

Since researchers derive problems and approaches form their community's shared body of knowledge, modifying that knowledge influences decisions on research content. Influencing researchers through scientific information seems difficult for external actors, and the results are unlikely to be predictable. However, this 'governance by knowledge production' can be empirically observed. Rare disease patient groups have begun "using their collective lay experiences, knowledge about living with disease x, as a unique, legitimate, and valuable source of research data" (Polich 2011: 1 see also Aymé et al. 2008).

The governance by knowledge production must be distinguished from situations in which knowledge-producing actors inadvertently change the content of others' research. This happens when actors mobilise resources and invest them in research on a specific topic (for the application of this strategy in the fields of rare diseases see Terry et al. 2007). All industrial research and quite a few publicly funded research activities belong to that category. While such an investment in the production of specific knowledge certainly changes a community's knowledge and thus influences the research of other community members, this is a by-product rather than the goal. The major purpose of such investments is to obtain specific knowledge. The utilisation of intellectual property rights to exclude researchers from using specific knowledge or research materials is a similar case (Eisenberg 2001). While the exclusion of researchers from using specific knowledge is a powerful way of influencing them, the resulting changes are not usually intended by the owner of the intellectual property rights.

b) Legitimacy

[5] In the 16th and 17th Centuries, scientific research was often likened to hunting in order to make a connection between scholarly activities and the self-image of the courts, and in order to increase the status of these activities (Rossi 1970: 42, Eamon 1991). Motives for research such as curiosity or wonder became 'honorable' motives only in the 15th to 17th Centuries. Prior to that, curiosity was considered a sin, while wonder was only seen as indicating ignorance (Eamon 1991: 33-34; Daston 1995: 392-399, 2000: 24-25, 2001: 77-97).

Governance by providing knowledge does occur but seems to be limited to special cases. A more common channel for influencing research content is the control of legitimacy of research. Control of legitimacy partly overlaps with granting access to resources (see below, c) because actors can grant resources only for what they consider legitimate research. However, there are separate areas as well.

The most extreme case of controlling legitimacy is making the use of objects, methods, or equipment legal or illegal. Examples of such regulation include nuclear research (Gläser *et al.* 1994) or human cloning (Isasi and Knoppers 2006). Another example would be granting access to empirical objects or data in order to enable or encourage specific research, as has been the case for Germany's participation in educational attainment studies (Husén 1996: 213). Again, the exclusion of researchers from the use of patented research materials (by making it illegal) is different because the resulting changes in research content are usually unintended by-products rather than the purpose of patenting.

Weaker forms of controlling legitimacy include the discourse about societal expectations concerning useful research, which makes researchers attempt to legitimise their research by pointing out usefulness. In this discourse, both state and non-state actors are involved. An example of civic interest groups attempting to control the legitimacy of a specific kind of research is the lobbying by animal rights groups against research based on experimentation with animals (Enserink 2008).

c) Resources

The most common channel for influencing research content – the only one reaching all research, albeit to varying extents – is the control of resources (including positions for researchers). Actors who provide resources for research can tie the allocation of resources to expectations concerning the content of research being met. Such expectations can also become institutionalised in permanent resource allocation systems, as is the case with 'performance-based funding' (Whitley and Gläser 2007).

Among these expectations, those concerning research topics are the most common. They are usually linked to an assumed societal usefulness of research on specific topics. Recent and current examples include research on nanotechnology (which is expected to contribute to industrial innovations, e.g. Johnson 2004), renewable energy technologies (preventing climate change, e.g. Dalpé and Anderson 1995), and health research (cures for diseases, e.g. Cooksey 2006). Expectations of usefulness can also be less specific and be framed as a demand across all fields (e.g. Pavitt 2001).

Expectations concerning approaches often stem from concerns about the safety or ethical aspects of research. External actors can communicate expectations of certain safety or ethical standards being met by the research or certain approaches not being used (see the discussion of legitimacy above).

Other expectations concern the way in which research is done (Braun 1998: 810). The most prominent current example is interdisciplinarity, which is regarded as leading to intellectual innovations and often contributing to the solution of societal problems. As a result, some resources are allocated to interdisciplinary research without any further specification of content or approaches (Weingart 2000).

These expectations are tied to resources in different ways. Within organisations, hierarchical decision making about organisational investments in certain topics can make these investments conditional on the promise of certain outcomes of the research. Some expectations can also be turned into a condition of employment if they are formulated during a recruitment process and turned into selection criteria. This begins with the definition of positions and continues with the selection of researchers, the extension of fixed-term contracts, and criteria for promotion. The most frequent way of using resources is making project funding conditional on properties of the proposed research and using the

selection processes (peer reviews or others) for selecting those projects that best match the expectations.

All three governance levers – knowledge, control of legitimacy, and control of resources – have in common that their use by external actors is constrained by these actors' insufficient knowledge about the relationships between conditions (including the abilities of researchers) and content of research. This is why expectations voiced by actors outside the scientific communities often remain vague (e.g. 'research on nanotechnology', 'interdisciplinary research'). The more specific the expectations concerning the content of research are to be formulated, the more collaboration with researchers from the 'target community' is necessary for such expectations to be implemented and researchers' compliance to be controlled. Peers from the same field are required to translate external expectations and to check compliance (Van den Daele *et al*. 1977; Braun 1998). The 'translated' expectations are not exclusively external anymore because they communicate community preferences as well.

Only when secondary indicators of research quality such as numbers of publications or the amount of external funding are used, external actors can formulate more specific demands (e.g. for academics to publish 2.3 peer-reviewed journal articles each year). However, this is pseudo-accuracy because the relationship between the indicator and the actual property of research (quality) is unclear. The formulation of expectations concerning research by actors external to a scientific community appears to be constrained by a specific 'uncertainty principle': The closer expectations are to the research content, the less precise can they be formulated.

Nevertheless, external actors can exercise some authority over research content even though they usually must collaborate with members of the researcher's scientific community and thus share their authority with them. While their positive influence is limited, external actors can veto most research by not hiring researchers with certain specialisations, not providing resources for research on certain topics or just forbidding researchers to work on certain topics. Although such a veto is 'blind' because its implementation faces the difficulties mentioned above and its consequences for the progress of research cannot be taken into account, it can have a powerful impact on research.

Based on the understanding of the governance of science as the construction and exercise of authority (see above, note 1), we can distinguish two levels of governance. At a more general system level, governance shapes the authority of actors concerning research content by assigning them legitimate control over careers and resources through higher education reforms, the institutionalisation of funding councils and funding programmes, the definition of legal conditions for research and other policy measures. As a result of these overlapping and partly independent developments, a large set of heterogeneous actors share opportunities to influence the conditions under which researchers formulate problems and select approaches. Consequently, these actors share authority over research content, and the system-level governance shapes the authority relations in the public sciences (Whitley 2010b).

At a second, more specific level, authority is exercised through the use of governance tools. At this organisational and policy-level of governance, external actors and members of a researcher's scientific community jointly exercise their authority over research content by using behavioural expectations in their decisions on careers, allocation of resources, and use of resources.

4. Shaping research content: researchers' responses to their situations

When deciding on research, researchers face the above-described complex situation which consists of resources and expectations from both their scientific communities and external actors, who share with them authority over their research. The overriding concern of most researchers, which explains many responses to influences mediated by governance, is to continue research. This concern is rooted in a researcher's identity as member of a community producing knowledge, an identity which is based on working with and contributing to the community's knowledge. Not doing research questions a researcher's identity (Henkel 2000, 2005). The strong interest in continuous research is also rooted in the nature of the relationship between the individual and the collective knowledge production. Being able to contribute new knowledge requires both precise and current information on the state of the art and a local head start in at least one aspect of the research. These local capabilities are continuously updated in the research process itself, which is why any break creates the danger of becoming 'locked out' from one's community's progress and of having later to invest significant work in catching up. This is why researchers are forced to strike compromises between their own interests in research and expectations of other actors at all. There is no 'waiting for better conditions'.[6]

Continuously doing research means continuously producing contributions that are accepted as such by one's community. Thus, the first set of criteria that must be met by decisions on research is a set of epistemic criteria and community preferences that define acceptable and 'technically do-able' contributions. Since these criteria relate to the relevant knowledge that is used to formulate problems and approaches, they can be influenced via 'governance by knowledge'. A second set of criteria derives from the necessity to legitimately control the time and resources necessary for the production of contributions. These criteria can be influenced by external expectations, which are either communicated ad hoc by external actors or institutionalised in regulation and resource allocation systems. To the extent to which resource allocation processes are laced with behavioural expectations of external actors, the epistemic criteria derived from these preferences must be met, too – at least to the extent that guarantees access to the necessary resources. In order to arrive at a problem that is not only technically but also practically doable, the researcher must align technical and other concerns (Fujimura 1987).

Depending on the epistemic distance between the two sets of criteria, researchers may not face a dilemma at all, face varying discrepancies that force them to compromise, or just face scarcity that threatens to make research impossible. The first case is a *match between external expectations and the intended research*. It includes all situations in which researchers meet the criteria derived from externally shaped aspects of their situations by just following their interests. This situation occurs for researchers in fields that are of political importance and therefore often provide easier access to resources as well as obvious compliance with political and organisational expectations.

A match between community-oriented criteria and external expectations may also arise in applied fields. The general political trend towards the expectation of 'useful' research has created situations in which researchers who work on applied topics both have easy access to resources and meet expectations of science policy and their organisations.

[6] There are exceptions. The more the formulation of research problems depends on the individual perspective of the researcher (the less codified the knowledge is), the lower is the danger of being locked out. In some fields of the social sciences and humanities breaks appear to be easier to handle because methodological progress is slow and individual perspectives don't become obsolete. However, even under those conditions it is important for researchers to continuously engage in research activities.

The political demand for and support of 'research excellence' creates the third situation in which researchers don't have to compromise. Elite researchers have access to the resources they need – often because all external expectations concerning research topics are suspended in their case. They also can create favourable conditions for themselves within their research organisation because of their exceptional contribution to the organisation's reputation. The 'head hunting' in the context of the British RAE is probably the best known example of the elite's opportunities to shape their own research conditions (Johnston and Farrar 2003). Another example is the position of ERC grantees within their organisations (Laudel and Gläser 2011).

If the community-oriented criteria for acceptable research do not sufficiently overlap with those derived from external expectations concerning topics, usefulness, or excellence, researchers have to balance their decisions in order to ensure the continuation of research. This means they have to find research problems and approaches that simultaneously

- define meaningful tasks for themselves (i.e. relevant and solvable problems in the context of their research biography);
- define meaningful tasks in their scientific community (promise relevant new knowledge and meet the methodological standards of the community); and
- meet the external expectations that must be fulfilled if the research is to be continued.

This decision situation has been described as that of an epistemic decision (on the content and directions of knowledge production) that uses epistemic and transepistemic criteria (Knorr-Cetina 1981). I suggest a further distinction. Those criteria that directly concern the 'do-ability' of research problems and approaches can be thought of as *quasi-epistemic* criteria. Quasi-epistemic criteria are those that are derived from transepistemic elements of a situation but are translated into the framework of 'technical doability'. The most prominent example of those criteria is certainly 'fundability', which nowadays is used by researchers as a property of a research project that excludes it from further consideration in very much the same sense as the missing 'technical doability' (Laudel 2006; Gläser *et al.* 2010; Leišytė *et al.* 2010). This definition reserves the term transepistemic criteria for those that concern other properties of research projects, such as their potential to further career progress. While these criteria do not concern the 'do-ability' of the research, they might nevertheless be of utmost importance to researchers.

To most researchers, the quasi-epistemic criteria enter as constraints on their research agenda and the necessity to compromise. However, similar to their 'true' epistemic counterparts, such criteria provide opportunities as well. Moving to different topics or engaging in new collaborations because of funding needs may fertilise research and trigger new ideas (see e.g. the scientist quoted by Morris 2000: 434). The mechanism underlying these exogenous fertilisations is the recombination of knowledge that occurs whenever a researcher combines his personal knowledge base with new knowledge 'brought' to him by external expectations.

In both 'fertilisation' and 'constraint' cases, compromises between epistemic and quasi-epistemic criteria must be found because of the necessity for researchers to conduct research continuously. Since researchers feel it necessary to continuously maintain research, we can discuss their responses to perceived constraints by quasi-epistemic criteria on the basis of an analogy to organisations. Researchers and organisations have in common their interest to maintain and protect a specific 'core technology' by interacting with their environment and responding to changes in this environment. We can therefore use the knowledge about organisational strategies for systematizing researchers' responses.

Contributions to the discussion of organisational responses to their environments have been made from several perspectives. Of particular interest for our problem are

- Thompson's (1967) account of organisations' strategies to protect their core technology from the impact of changes in the environment;

- resource dependence theory (Pfeffer and Salancik 1978) and its discussion of how organisations manage their dependency on resources provided by the environment; and

- Oliver's (1991) combination of resource dependence theory and institutional theory in her discussion of strategic responses to institutional processes.

From these perspectives we can derive a set of organisational responses to environmental change that is applicable to researchers' responses to their conditions of research, and in particular to conditions shaped by governance. These responses change the environment, the conditions of research, or the content of research in order to achieve a match between the situation and the necessity to continue research. Although the responses are described as strategic, the observable behaviour of researchers is not necessarily strategic but very often just a 'muddling through':

- *Smoothing* means actively changing the environment with the aim of reducing fluctuations. Researchers try to proactively shape the supply of funding by initiating funding programmes matching their research interest. This strategy has been discussed by Leišytė (2007) as 'manipulation'. It is only available to relatively few elite researchers who are involved in political decision processes.

- *Buffering* means the creation of reserves of inputs or outputs that can be used if supply or demand change. In research, this practice only refers to inputs (resources). It has been first described by Hackett as 'bootlegging' (Hackett 1987: 143; see also Laudel 2006). This practice is very important because resources are increasingly earmarked for specific research processes (mostly the projects researchers applied for), which means that preparatory work for starting new lines of research or work on suddenly occurring new ideas is increasingly difficult to fund.

- Organisations and researchers can also *anticipate and adapt to environmental change*. These responses are the most common both in the literature and in our own empirical findings (Gläser and Laudel 2007; Gläser *et al.* 2010). They include window dressing (or 'symbolic compliance', Leišytė 2007) and the 'management of research portfolios'. The concept 'research portfolio' indicates that researchers follow more than one line of research simultaneously or construct potential lines of research which could be followed if need be. This was indeed the case with many of the researchers in Australia and Germany (Gläser *et al.* 2010). Researchers who work on more than one line of research can respond to differences between external expectations and their own interests in three ways. They can drop 'unfundable' lines of research and continuing with the others, start 'fundable' lines of research, or change existing lines of research according to external expectations ('compliance', Leišytė 2007). These responses include elements of buffering and rationing because researchers try to fulfil external expectations with part of their time and resources in order to follow their interests with the other parts.

Researchers who follow only one line of research at a time don't have these options. If their research does not match external expectations, they have only the choice between making it match by changing its content or – if this is impossible or if they don't want it – to cope with the consequences, mostly scarcity of resources or time.

- *Rationing* - limiting resources spent on research - is applied if all other strategies or practices fail. In Thompson's discussion, rationing refers to limiting the amount of scarce resources spent on certain tasks, i.e. to a decision made by the organisation not to spend some of its resources. Researchers experience 'exogeneous rationing' of their activities when they cannot acquire the resources necessary

for their tasks – when they did not apply for grants because they saw no chances of success, when grant applications were not successful, when grants were awarded but cut significantly, when grants were too small, or when there was no time for research because of competing tasks (teaching or administration). Responses include the use of student projects (whose funding is guaranteed from other sources), 'jobbing' (sell services to commercial customers and using the income to fund research, see also Laudel 2006), 'retarding' research (dropping the research if there is no time or funding, and taking it up again when conditions improve), and reducing the empirical basis of research (choosing cheap objects or methods, or reducing the number of experiments or observations) (Gläser *et al.* 2010).

The sequence in which these responses are presented represents a hierarchy. Researchers will try to smooth their environment in order to maintain favourable conditions for their research. If this is impossible or fails, they are likely to try buffering in order to protect their research form external influences. If buffering is impossible, they will adapt their research or reduce it. Governance can thus change research content by tying external expectations to conditions for the continuation of research, by being resilient to researchers' smoothing attempts and by reducing researchers' opportunities to buffer. The inevitable risk of these governance approaches is that some researchers will resort to rationing by limiting their research efforts, and that others will be forced to ration their research by reducing its quality.

5. Field-specific epistemic conditions of action and variations of effects

In the previous sections, we have established that governance may change research content by overcoming the 'defences' available to researchers for 'protecting' their research content and forcing them to make their research meet external expectations. This very general model needs to be specified by linking the occurrence and outcomes of the general mechanisms to specific conditions. In other words, we must identify important sources of variation and the specific of conditions that may trigger, prevent, facilitate or hinder the operation of the general mechanisms. This is of course not doable in an article, not the least because it requires the integration of a large body of literature and a substantial additional research program. However, it seems at least possible to demonstrate the principle by discussing one known important source of variation, namely field-specific epistemic conditions of research.[7]

Since researcher who adapt their research to signals sent by governance at all have to find a compromise between epistemic and quasi-epistemic criteria, their responses to governance are also field specific. Governance instruments are usually applied uniformly across fields, and are rarely modified to accommodate field-specific conditions of research. In the decisions on research, the quasi-epistemic criteria derived from them are combined with the epistemic criteria derived from field-specific practices of knowledge production. The emerging decision is field-specific, as are the consequences for research content produced by that decision.

[7] Two other groups of factors shall be mentioned here but cannot be discussed: *Attributes of researchers* are likely to be among the most important sources of variation. Researchers' interests and preferences including career aspirations, their research biographies, performance levels, age, professional age, gender and race are likely to (and partly known to) influence the way in which their situation is shaped by governance, the way in which they construct their situations, and the way in which they respond. The *wider societal context* is also likely to modify the ways in which governance changes research context. National cultures are known to be a source of variation of attitudes and practices within fields (see e.g. Traweek 1988: 86-90 for High Energy Physics).

The field-specificity of impacts of governance has not yet been systematically investigated due to several conceptual, methodological and logistic problems. The major conceptual problem is that after more than fifty years of science studies a comparative framework for the description of field-specific epistemic practices and field-specific epistemic properties of knowledge is still missing. First attempts have been too coarse in that they were based on binary distinctions such as 'hard' versus 'soft' sciences (Storer 1967; Solla Price 1970; Biglan 1973), 'basic' versus 'applied' research (Vollmer 1972), or 'hierarchical' versus 'concenated' theories (Nagi and Corwin 1972). Other authors used just one variable such as the degree of 'restrictedness' (Whitley 1977; Rip 1982) or a field's paradigmatic state (Masterman 1970; Martins 1972; Lammers 1974; Beyer 1978; Böhme et al. 1983). These binary distinctions and their fashionable revivals ('mode 1 – mode 2', Gibbons *et al.* 1994; 'old' and 'new', Bonaccorsi 2008) do not provide enough specific information to enable causal analyses of field-specific changes. The most advanced proposal by Whitley (2000 [1984]) uses two dimensions too describe fields (task uncertainty and mutual interdependence). Unfortunately, it shares a methodological problem with the less sophisticated approaches: None of the comparative schemes has ever been operationalised, i.e. linked to a protocol for empirical identification of the relevant properties. This also applies to Knorr-Cetina's (1999) comparison of "epistemic cultures", whose dimensions are derived *ex post* and *ad hoc* from properties of the fields compared, and therefore seems difficult to extend to other fields.

Owing to these problems we still don't have an empirical approach to measuring epistemic properties of fields. This lacuna is also linked to a logistic problem of science studies. The method of choice for an exploratory study of epistemic properties of fields would be ethnographic observation. However, the study would also need to be comparative. It would thus be a multi-sited ethnography (one person, different sites, Hines 2007) but would most likely also require a comparative observation of sites in different fields by several researchers. The large collaborative science studies project that could include such comparative ethnographic studies is at odds with the current epistemic practices of science studies, which favour ethnographic studies of one process by one person (sociology of science) or interview-based studies that do not take into account research content (science policy studies).

Our own findings on field-specific effects of governance are based on in-depth interviews with researchers (Gläser and Laudel 2007: 132-135; Laudel and Gläser 2007; Gläser and Laudel 2009) from six fields including biochemistry, physics, geology, mathematics, political science, and history. An exploratory analysis turned up the following epistemic properties that affected the responses of researchers described in the previous section:

- resource dependency (researchers in fields with low resource dependency did not adapt to governance),

- competitiveness (high performers in highly competitive fields would end lines of research rather than putting them on hold because of insufficient funding),

- dependency on uninterrupted research time (researchers dependent on uninterrupted research time would put research on hold until such time was available or apply for grants for the sole purpose to 'buy themselves out of teaching), and

- diversity of research portfolios (researchers with diverse research portfolios were better able to buffer their research interests from external expectations) (Gläser et al. 2010).

This brief exploration should demonstrate that field-specific epistemic properties are important intervening variables in studies of the impact of governance on research content. By implication, this means that anticipatory/reflective governance needs to consider field-specific effects. For example,

there is no point in trying to influence a field whose resource-dependency is low with instruments based on resource allocation.

6. Conclusions

With this paper, I propose some building blocks for a specific middle range theory, namely a theory that aims to explain changes in research content by linking sets of conditions, social mechanisms that are triggered under specific conditions, and the outcomes of these mechanisms. The theory links knowledge about mechanisms of governance and conditions triggering them (from science policy studies) to knowledge about mechanisms of knowledge production and conditions triggering them (from the sociology of science). Much of this knowledge has yet to be produced. The building blocks I suggest indicate a 'list of ingredients' rather than providing the ingredients with the necessary consistency and completeness:

- Macro-level conditions include the governance systems that define authority relations concerning research content, the governance instruments used to exercise this authority, and epistemic properties of fields that modify the impact of governance.

- A first set of mechanisms includes those that co-produce the situation of researchers who decide on research content, e.g. the mechanisms at work when research organisations enact their environments and respond to these environments (e.g. mechanisms operating in the allocation of research funding).

- The conditions created by organisational mechanisms, conditions created by national-level mechanisms (e.g. external funding), the researcher's research biography, local work environment, collaboration and communication networks and epistemic practices shape the researcher's situation, i.e. the micro-level conditions for decisions on research.

- In the decisions of researchers operates a second set of mechanisms, namely those producing a certain course of knowledge production by either protecting the research content from governance or modifying it through a 'self-identification' (Benkler) that takes into account the conditions for the continuation of research. The categorisation of mechanisms based on ideas from organisational sociology indicates how these mechanisms could look like.

- The outcomes of the course of research chosen (and constantly adapted as the situation evolves) is research content that is modified by governance in intended and unintended, foreseen and unforeseen ways.

- These changes in individual knowledge production processes are aggregated by yet another set of mechanisms into field-level changes of knowledge. I have not discussed these mechanisms because we know least about them. While we know at least something about micro-level changes in knowledge production caused by governance, we cannot even empirically identify macro-level changes, let alone causally attribute them.

In my discussion of the various building blocks, I have also mentioned several methodological challenges. Contributing to a middle range theory poses challenges to conceptual approaches, research design, and empirical methodology. The major conceptual challenge is to 'rewrite' part of the analysis of governance as an analysis of the creation, modification and exercise of authority over research content. Instead of investigating a governance instrument in isolation and looking for its effects, the overlap and interaction of governance instruments needs to be analysed according to the opportunities they provide for specific actors to shape the conditions of researchers, and through these conditions the content of their research. This requires a leap in the complexity of analyses.

The research building such a theory would be theory-driven and use empirical data to constantly challenge and develop the theory. It would thus be similar to the construction of 'grounded theory' (Glaser and Strauss 1967) but would stretch over many research processes that are linked through their contributions to the same middle-range theory. This approach is quite different from the current practice of studying single cases and then retelling them in the language of one of the 'grand theories' of STS or general sociology.

Finally, I already mentioned that developing such a theory requires new empirical approaches (and possibly even new ways of organising research). Contributing to a theory that is based on 'mechanismic' explanations requires comparative case studies, and studying epistemic conditions of research requires ethnographies, which at least for some science fields could usefully integrate bibliometric analyses of knowledge structures. Unfortunately, such an approach necessitates a collaborative approach which appears to be difficult to achieve in science studies.

A middle-range theory about relationships between sets of conditions and changes in the content of research might actually be useful in the sense of providing background knowledge on possible impacts of governance instruments or guiding the investigation of such impacts. If we accept the rough distinction between authority-exercising and authority-changing governance, it becomes clear that the current stakeholder practices of anticipating or estimating the impact of governance on research content is differentially effective for the two. Experienced scientists are able to assess the impact of funding programmes or of changing career patterns on the research in their field. The fact that they are the only actors in a governance system that hold such knowledge might be considered as problematic but at least the impact of governance instruments can be anticipated in some way. However, it seems close to impossible for any actor engaged in the governance of the public sciences to anticipate, say, the impact of a higher education reform that strengthens the executive power of deans on the content of university research. The causal chain is too long and too complex (it is actually a causal web) for anybody to anticipate effects on the production of scientific knowledge. A middle-range theory might help here by providing knowledge about some of the strands in the causal web that are difficult to assess based on personal experience alone.

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