

Hybrid regimes of knowledge? Challenges for constructing scientific evidence in the context of the GMO-debate

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Abstract

Background, aim, and scope Over the last two decades, there has been a remarkable shift of attention to the scientific and political fundamentals of the precautionary principle. The application of this principle has become a main strategy of coping with the different forms and problems related to non-knowledge. Thus, societies are increasingly confronted with the challenging and hitherto unresolved problem of political and technological decision-making under conditions of diverging framings of non-knowledge. At present, there seems to be no generally accepted scientific or institutional approach. This is why the fundamental question of how different scientific actors define and construct evidence is not answered yet. Hence, this paper is based on the consideration that the conflicts in risk policy concerning genetically modified organisms (GMO) depend on the unresolved conflicts about the diverging scientific strategies and structures of evidence-making between the epistemic cultures involved. Thus, this study investigates two questions: (1) do the epistemic strategies of evidence-making differ systematically with the scientific actors involved in the GMO-debate? (2) What consequences emerge considering institutionalized procedures of decision-making?

Main features This article is based on a secondary analysis of findings and perspectives reported in the literature and on the methods of qualitative social empirical research, i.e., interviews with experts. A total number of 34 interviews

were conducted to explore the different strategies of handling non-knowledge and constructing evidence. Actors from science, administration, business and NGOs were interviewed. In this way, typical epistemic cultures can be described. An epistemic culture is the constellation of methodological strategies, theoretical assumptions and practical-experimental settings which define in every speciality the ways how we know what we know.

Results There are two main results. Firstly, it was worked out that the epistemic cultures involved in the GMO-debate use rather distinct strategies to define non-knowledge and to classify evidence. There are three types of constructing evidence, which correspond to different types of epistemic cultures. Secondly, the findings imply that the intensity of the conflicts in risk policy fields like the GMO-debate is due to a lack of knowledge politics. Usually, knowledge politics is restricted to the design of institutional procedures to compile knowledge provided by experts. The institutional setting of risk analysis and risk management is based on the premise of strict separation between knowledge and power. However, inadmissible mixing-up of knowledge and power is observable.

Discussion It seems that non-knowledge leads to an epistemic no man's land, and, hence, hybrid regimes of knowledge emerge. These regimes are hybrid with respect to the unclear and not explicitly reflected strategies of evidence-making. By lacking of knowledge politics, this situation opens up 'windows of opportunity' for actors with special interests in risk policy fields like the GMO-debate. Therefore, there is a difference between the visible institutionalized structures of risk policies and the rather invisible hybrid regimes of knowledge. Structure and scope of expertise have to be reflected and new instruments of knowledge politics have to be designed.

Conclusions Different epistemic cultures can be qualified by describing their particular strategies of evidence-making.

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To solve the conflicts between these strategies, a meta-expertise is needed. Besides the institutionalized settings of knowledge politics, the underlying hybrid regimes of knowledge have to be identified.

Recommendations and perspectives The concept of epistemic cultures and their strategies of evidence-making should be investigated more explicitly with respect to other risk policy fields. The analysis of hybrid regimes of knowledge should be deepened by looking at the complex interactions between institutional, discursive and practical rules affecting risk assessment.

Keywords Epistemic cultures · GMO · Non-knowledge · Politics of knowledge · Precautionary principle · Risk policy

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1 Background, aim, and scope

The debate about risks of GMOs (Genetically Modified Organism) is driven by many forces. First of all, there is a

multifaceted scientific debate about the different effects of such organisms in the environment. What negative side-effects could be expected with respect to a wide-range use of GMO in agriculture? These scientific debates are relevant up to now, but there is still no scientific solution for the conflicts. Moreover, a debate about the inherent scientific limitations arose under the topos of ‘non-knowledge’ (Wehling 2006a). But there is a political solution. If one looks at the far-reaching political and scientific debate about the Precautionary Principle (PP) (Levidow et al. 2005; van Asselt and Vos 2006), then one can find an answer to the question how to decide under conditions of uncertainty or non-knowledge. This debate and their institutional consequences indicate a remarkable shift in risk policy. For a long time, risk policy was based on a more or less consensual scientific knowledge about the possible side-effects of a technology. But, with debates such as the GMO-debate or the debate about BSE (Dressel 2002) the insight about inherent limitations of the risk knowledge arose. Therefore, the question got more important how to decide when legally protected rights are in jeopardy and the knowledge resources to decide are not available. The precautionary principle addresses this question and offers institutional strategies to implement a technology although the risk knowledge is limited and important side-effects are to be expected. It has been politically accepted in the meantime and has exerted a decisive influence on, e.g., the risk policy of chemicals within the new regulatory framework REACH (Registration, Evaluation and Authorization of Chemicals; Scheringer et al. 2006) or the policy of agrobiotechnology with the new EU directive 2001/18/EC on deliberate release (Boschert and Gill 2005). Depending on the structure of the various risk policy areas, the PP was set up differently.

Although there is an institutional solution, one all-decisive question is remaining. What is the actual evidence on which decisions about the applicability of the PP are to be taken? And which evidence is necessary to decide about different precautionary strategies? These questions are difficult to answer with respect to the debate about non-knowledge. But they have to be answered, because political decisions are always based on knowledge (Mayntz 1999). The discourse of non-knowledge focuses on the inherent limitations of the dominant framings of risk issues. The framework of risk is based on the certainty that all relevant aspects of dangers induced by scientific–technological progress could be scientifically described—if not now then in the future. Therefore, the side-effects caused by the implementation of scientific–technological innovations can also be calculated. What is there against this description? As shown by historical case-studies (Böschen 2000; EEA 2001), science and technology intervene in the (natural and social) world, but frequently are unable to anticipate the consequences and adverse effects of those interventions.

Therefore, the concept of non-knowledge emphasizes the possibility of ‘unknown unknowns’ (Grove-White 2001), things we do not know we do not know. The shift to non-knowledge or, more specifically, to what Ravetz (1990, p. 26) has termed ‘science-based ignorance’, i.e., an absence of relevant knowledge generated by science, is only understandable by looking at the great social promise connected to science. Paradoxically, it is the success of science and technology in solving social problems which generates expectations science and technology can hardly fulfill. For a long time, it seems, science and technology have been able to innovate boundlessly—and also to cope with the difficulties connected to this progress. Today, the situation is dominated by the impression that there are severe conflicts between different experts and the risk knowledge is dramatically limited. This situation has not only scientific but also political implications. The structure and dynamics of the interrelation between scientific advice and political decision-making has to be reflected. Who are the experts and why? (Collins and Evans 2007) What are the criteria to fix the scope and standards of evidence in precautionary procedures? (restricted PP: Soule 2002; open PP: Myhr 2007). And: how do we decide under conditions of diverging cognitive and social framings of knowledge and non-knowledge? Until now, no generally accepted scientific or institutional approach appears to be available in order to settle these fundamental questions about the spectrum and the hierarchy of different resources of expertise (EC 2007). Against this background, the main question can be put in a concrete form: how can one construct actual evidence against the background of diverging expertise and an orientation towards non-knowledge?

In this article, I would like to put forward two theses. Firstly, that the described pluralization of expertise has widened the field of risk analysis and supported the reorganization of institutional structures in the field of agrobiotechnology. Secondly, that this evolution also enforced a restrictive view on scientific evidence. It seems that only in the case of strong evidence about risks regulatory decisions are to be taken. This outcome must be seen as a paradoxical effect of the institutional orientation towards non-knowledge and the PP. Opening up an epistemic conflict between different forms of expertise, a kind of epistemic no man’s land arises. This is due to a lack of knowledge-policy orientation and leads to a situation which allows, in many cases, special interests to be covertly at work. To underline these two theses, the paper is based on three lines of argumentation. The *first* line of argumentation emphasizes that the conflicts of (non-) knowledge mentioned are based on the differences between the scientific disciplines involved. They do not speak the same language. In order to understand the consequences it is necessary to differentiate between diverging practices of

epistemic cultures involved or relevant in the GMO-debate (Böschen et al. 2006, 2009; Chapter 2). The *second* line of argumentation is build upon different cases of conflict in the GMO-debate. The scope includes scientific debates and conflicts about relevant concepts or the validity of expertise in the regulation of agrobiotechnology (Chapter 3). Against this background, I argue in the *third* step that, under the conditions of non-knowledge, the entanglements of knowledge and power are increasing and need to be analyzed more deeply. These entanglements will be referred to as hybrid regimes of knowledge (Chapter 4). These regimes are hybrid with respect to the diverse and confused interactions between knowledge and power in specific risk policy fields like the GMO-debate.

2 Main features

The structure and dynamics of conflicts of knowledge depend on the diverging character of the epistemic cultures involved. A lot of work has been spent on the exploration of the construction of knowledge in the so called laboratory studies (Latour and Woolgar 1986; Knorr-Cetina 1981, 1999/2002). These studies have followed an ethno-methodological approach. This approach is very useful to observe the manufacturing of things in concrete situations. The problem is that this approach takes an enormous amount of time to produce data relevant to analysis. In previous research, my colleagues and I worked out this concept for the analysis of risk debates. The conflicts of non-knowledge are based on the different practices of diverging epistemic cultures relevant in the GMO-debate (Böschen et al. 2006). This heterogeneous setting of different epistemic cultures makes it more difficult to reach a consensus on the relevant and appropriate strategies for dealing with non-knowledge. The concept of epistemic cultures was elaborated by Knorr-Cetina (1999/2002). It points out the different epistemic practices and object constructions within the sciences and analyses the ‘machineries of knowledge’, the social, technical, material, and cognitive structures which determine “how we know what we know” (Knorr-Cetina 1999/2002, p. 11). The concept was developed along two empirical case studies on high energy physics and molecular biology. Her analysis already includes some remarks concerning not only the sciences’ production of knowledge but also their relation to non-knowledge. High-energy physics is described as being engaged in the production of ‘liminal knowledge’ that specifies the limited evidential power of the produced data. In this way, epistemic strategies of high-energy physicists are to produce also knowledge about their non-knowledge, errors and limitations of knowledge. Molecular biologists on the other hand follow a strategy of “blind variation in combination with natural selection” (Knorr-Cetina 1999/2002, p. 35), which is based

upon an ongoing reorganization of the experimental settings until they work. Possible explanations of the initial experimental failure are not sought. With respect to the GMO-debate, three typical epistemic cultures could be differentiated with respect to their strategies defining and solving problems of non-knowledge: (1) control-oriented epistemic culture (e.g., molecular biology); (2) the complexity-oriented culture (e.g., ecology), and (3) the expertise-oriented culture (e.g., physicians). These three epistemic cultures differ clearly with respect to their strategies defining non-knowledge. The control-oriented epistemic culture focuses mainly on known unknowns or “specified ignorance” (Merton 1987). In this case, research questions and a known setting of methods allow answering easily to the problem. The complexity-oriented culture tries to reflect also the unknown unknowns due to the complexity of ecosystems. And, finally, the expertise-based cultures are searching for pragmatic views in the tension between known and unknown unknowns in a concrete situation of decision (Böschen et al. 2006, 2009). Against this background, in this paper, the question is put forward, if there are also different strategies of constructing evidence and if so, in which way they are relevant for the risk debate about GMO. Therefore, the character of this contribution is the one of an exploring investigation. Accordingly, the research is, on the one hand, based on methods of qualitative social empirical research, i.e., interviews with experts, which were conducted in the reported research project (Böschen et al. 2009). On the other hand, it is based on a secondary analysis of findings just reported in literature.

1. *Interviews with experts* are one of the most widely employed methods of qualitative sociological research. Nevertheless, the debate on the assumptions, boundary conditions, fields of application and the strategies of the tool expert interviews is still evolving (Meuser and Nagel 1991; Bogner et al. 2004; Gläser and Laudel 2006). There are some special aspects with this kind of interviews. The most important one is that the interviewer does not have the same pool of knowledge as the expert. The expert knows much more than the interviewer—in contrast to the typical interview setting, where the interviewer knows much more than the interviewee. Finally, the interview is always structured by a questionnaire. But the questionnaire is not a rigid schedule for the interview (Przyborski and Wohlrab-Sahr 2008, pp. 131). To get the chance of flexible intervention, the questionnaire consists of different modules, some are compulsory while others are optional. Therefore, the questionnaire contains the important keywords for the topics and questions which should be asked in every interview (key questions) and questions which could be asked depending on the prevailing situation. The questionnaire allows on the one hand an examination and on the other hand an open

dialogue. The first is necessary with respect to comparability, the second is necessary to get narrative elements which indicate the implicit structures of thinking and doing research. In this way, structures of relevance are to be detected and the interviewee has the chance to speak from his or her own experience.

- a. *Selection of the interviewees.* In the field of the GMO-debate many actors are involved and therefore the field is very fragmented. To get an overview, two strategies were conducted. Firstly, the field was structured with regard to the institutionalized actors. This was done by a literature study about platforms of conflicts in this debate, like the different participatory technology assessments (Böschen et al. 2003), or main topics and the actors involved. Secondly, pre-interviews ($n=6$) are carried out to get an insight about the relevant positions, epistemic cultures and stakeholders involved in the debate (2=scientists; 2=administrators; 2=stakeholders). To assemble the group of experts to be interviewed, the following criteria were set up: (a) membership of a specific institutional field (politics, economics, science and the public); (b) within the scientific field membership of specific disciplines; (c) positioning in the GMO-debate (pro, neutral, contra). An overall number of 28 interviews were realized. The first group was the one of scientific experts to get information about the structure of epistemic cultures ($n=14$; molecular biology=3; plant scientists=3; ecology=5; physicians=3). The second group of experts were stakeholders (most of them are scientifically educated) with a specific political function or position in the field (administration, non-governmental organizations, industry; $n=14$; administration=5; industry=5; NGO=4). The interviews were transcribed and analyzed with the methods of qualitative research but not statistically. Therefore, the interviews were analyzed like a text and in the paper the quotation is given by the number of the interview and the page of the transcript. This is why the sociological question underlying this paper is an explorative but not a question of hypothesis-testing. The goal here is to get hypotheses, which could be part of future research about the overall structure of epistemic cultures and the conflicts about non-knowledge emerging due to these differences.
- b. *Design of the questionnaire.* The questionnaire covers three main topics: (a) description of standard-settings of experimentation: How the standard processes of knowledge production could be described? What are the main strategies to cope with non-knowledge? What are the main goals of

the research? (b) Description of the scientific community and its structure: What are the different parts of the community? Which researchers are important in the different areas and why? In which ways the knowledge is communicated and validated? (c) positioning in the risk-debate and discussion about the importance of the PP and the different forms of expertise: what is the perceived importance of the PP in this field? What are the main topics of the risk debate? What is the role of laypeople in this debate?

2. *Secondary analysis of findings and perspectives reported in the literature.* This strategy is helpful to surround a research field when a new perspective is set up. In this way, insights from other studies can be made productive to broaden the weight of evidence for the suggested research perspective. In this case, it is the question, how the conflicts of (non-)knowledge put the construction of evidence on a new trail. What are the epistemic, conceptual, and institutional conflicts to solve the debates between the different actors and their scientific background, described by their epistemic culture? To address these questions, three fields of conflict were analyzed. The first level is portrayed in this paper by a scientific debate between actors of different epistemic cultures in the case of the monarch butterfly (Chapter 3.2 (1)). The second level is characterized by the change of meaning of the concept of substantial equivalence (Chapter 3.2 (2)). And the third level is addressed by three cases of institutional conflicts in the GMO-debate (Chapter 3.3).

3 Results

3.1 Epistemic cultures involved in the GMO-debate differ with respect to the construction of evidence

The construction of evidence is not a mainstream-topic within the Science and Technology Studies, but it gets more important (Krohn 2006). The description of epistemic cultures as evidential cultures was developed by Trevor Pinch (1981, 1986) and Harry Collins (1998) with reference to different examples from physics; therefore the analysis was focused on the differences within one single epistemic culture. Nevertheless, the concept of evidential cultures can be used to analyze the differences of construction processes of evidence between distinct epistemic cultures. Therefore, the epistemic cultures introduced can also be characterized as evidential cultures. The validation and communication of insights are shaped by the main strategies of the evidential

cultures. In the concept of Collins, two evidential cultures are brought out: open and closed evidential cultures (Collins 1998: 307). Three dimensions are important to describe the differences between the evidential cultures. (a) Evidential collectivism and evidential individualism. This dimension tackles the personal responsibility for the validity and meaning of scientific results. Individualists believe that the scientist or the research group of a laboratory have to take the responsibility. By contrast, collectivists believe that it is the job of the community to assess the results from an early stage. (b) The dimension of evidential significance. Here, the degree of abstraction is decisive. It is a difference to report on some concrete phenomena or on their interpretation aligning specific theoretical explanations. “The higher the evidential significance, i.e. the longer the chain of inference, is, the more important the findings” (Collins 1998, p. 306). The longer the chain of inference, the higher the risk of misinterpretations is. To claim a low level of significance reduces the risk of interpretation clearly. (c) The evidential threshold. The different epistemic cultures might be more or less risk averse with respect to the level of certainty demanded for publication. The evidential threshold is fuelled by problems of statistical significance and therefore statistical risk.

To put the pieces of the jigsaw together, the distinction between open and closed evidential cultures could be described as follows. Open evidential cultures are characterized by evidential collectivism, a low evidential significance and a low evidential threshold. Closed evidential cultures are characterized by evidential individualism, a high level of evidential significance and a high evidential threshold (Collins 1998, p. 308). To apply this concept to the situation of epistemic cultures involved in risk policy areas, it would be better not to refer to the distinction between open and closed evidential cultures which are fixed by the view on the communication strategies of the different research group. In the context here, it is more useful to focus more precisely on the experimental methods used to validate knowledge, the concrete “epistemic things” (Rheinberger 1997), the ways of constructing explanations and the structure of argumentation. The assumption is that epistemic cultures proceed along a set of main strategies of validation knowledge. These strategies control—like a central perspective—the evolution of evidence in the specific epistemic cultures. Against this background, the three reported epistemic cultures could be described as evidential cultures as follows:

1. *Restrictive evidential culture (e.g., molecular biology).* “I have to define my system very precisely to get answers. If I have too many variables which aren’t under my control, I usually can’t interpret the results” (Interview No. 19, p. 28). To do so, scientists of this

culture have to limit the relevant horizons of space and time. The ideal type of this reduction is the laboratory experiment with its controlled basic conditions and highly standardized epistemic settings (Rheinberger 1997). Scientific cultures oriented in this way are highly innovative due to the technological construction of laboratory settings. Non-knowledge is mostly seen as specified ignorance or as an irrelevant factor, because it could not be translated into new research questions. Against this background, the evidential culture follows the strategy of theory-based explanation and is characterized by a high level of evidential significance and high evidential threshold. Typically, proofs are given by empirically enriched and theoretically sound laws of causality. This results in very high thresholds for integrating other forms of knowledge. Therefore, only the knowledge of such epistemic cultures could be integrated, which follows the same rules of construction of evidence. Knowledge produced by epistemic cultures with this character of evidence production is very functional for policy or court decisions because the evidence will, by and large, be supported by the actors. Thus, statements fuelled from restrictive evidential cultures are not easy to disprove.

2. *Holistic evidential culture (e.g., ecology)*. “We often go out relatively unencumbered and just look: what is actually happening outside? And then we allow ourselves to be surprised by what we find: we observe this and then try to evaluate our findings without looking for a specific systematic condition that has to be achieved. (...) It is our recurrent finding that self-organized natural systems are highly resistant to our planning. This aspect of self-organization is perceived less as a disturbing factor that has to be eliminated, but rather as an actual characteristic of the systems” (Interview No. 4, p. 14). Scientists of this culture confront themselves with the whole complexity of ecosystems. Their aim is to analyze the effects of GMO on the different levels of biological organization. To outline this kind of research they have to take into account far-reaching horizons of space and time; and they have to deal with relatively broad concepts like the concept of ‘ecological risk’ (Breckling and Verhoeven 2004). Epistemologically, scientists of this culture have to combine different ways of constructing epistemic things. Laboratory testing, research with model organisms and field studies are all part of the research. Therefore, this evidential culture follows the strategy of structure-oriented local descriptions. In this case, a combination of low evidential significance and a low evidential threshold is given. In this way, indices of heterogeneous theoretical status can be combined to yield proofs. This is why holistic evidential cultures are

open to other forms of knowledge and why they can integrate the knowledge of such cultures with a relatively large epistemic distance. Moreover, the non-epistemological knowledge of stakeholders can be integrated. Holistic evidential cultures are able to handle a broad scope of knowledge resources. Therefore, this evidential culture allows for gaining information on early warnings more easily. However, the expertise provided by such epistemic cultures does not really fit the demands of the political process of decision-making which needs a more narrow focus for structuring decisions.

3. *Evaluative evidential cultures (e.g., environmental medicine)*. “New research questions normally arise throughout the daily professional practice. A certain vaccination is administered and no one knows how it works. And then you start thinking and you try to see what happens: is it really these specific cells? Do they accumulate? What I investigate currently in clinical research is mostly derived from this clinical approach. I notice that there is no evidence-based treatment available and if I am interested enough, I start looking for answers” (Interview No. 27, p. 11). Professionals give scientifically based advice to specific groups of clients (in the case of medicine, the patient) to solve their everyday problems of life (Stichweh 1997). Within this culture, it is decisive to connect a situation heavily influenced by uncertainty and non-knowledge with the external expectation to solve relevant problems. Scientists require a professional expertise to deal with concrete situations. They have to decide simultaneously what is appropriate with respect to the client and to vary the ‘experimental parameters’ to get new insides about relevant phenomena. In this case, the emphasis lies on the proof of function for single cases. A high level of evidential significance is combined with a low evidential threshold. Most important within this evidential culture is to get a constellation of indices situated at different levels of abstraction for generating diagnostic and therapeutic preparations. Due to this requirement, this epistemic culture systematically focuses not only on scientific but also on transdisciplinary knowledge resources to integrate and evaluate them with respect to the goals of problem-solving.

To sum up: the just-mentioned epistemic cultures differ also with respect to construction of evidence. Control-oriented epistemic cultures proceed in a restrictive–experimental way and are oriented towards an improvement of (technological) options for action. In contrast, complexity-oriented epistemic cultures structure their knowledge in a holistic–contextual way and enhance options for reflection. Finally, expertise-based epistemic cultures are marked by the combination of

diagnostic knowledge and knowledge on problem-solving. There, epistemic strategies are related towards an improvement of options for decisions. All of these cultures generate knowledge relevant for making decisions, but they do not find a balanced attention in the risk policy of the GMOs. Therefore, a selection process of the knowledge resources relevant for the conflicts occurs.

3.2 Lines of debate between different epistemic cultures

What about the debate between the different epistemic cultures? There are specific occasions of debate between the different epistemic cultures. On the one hand, there are debates on the observation and classification of concrete effects. On the other hand, there are debates on general concepts, e.g., the strategies of case-by-case or step-by-step, or models like substantial equivalence or the general question what an adverse effect is. Both can be described as discursive gateways for structuring problems of non-knowledge. Both dimensions and their interaction are significant not only for the evolution of orders of knowledge and non-knowledge, but they are also seismographs for a change of claims of non-knowledge.

1. *Risk analysis of GMO* focuses on adverse effects of GMO cultivation itself or due to gene transfer (Myhr and Traavik 2003, p. 233). With respect to potential hazards, adverse effects on non-target organisms are to be considered, too. I would like to underline this by reconsidering the case of the monarch butterfly. The entomologist Losey stated in the course of a laboratory analysis that the caterpillars of the monarch butterfly were susceptible to the Bt-toxin (Losey et al. 1999). His study was criticized by scientists of control-oriented cultures as not conforming to scientific standards. In addition, these findings were preliminary and therefore they couldn't be in accordance with the scientific standard to validate knowledge first and then publish it (Wolt and Peterson 2000, p. 42). Finally, the laboratory studies were seen as being insufficient to draw conclusions with regard to whole ecosystems. Also, scientists from complexity-oriented cultures stressed the necessity to acknowledge the realities derived from the assessment procedures, for instance in the course of field studies. In the best case, the environmental conditions, effects on biodiversity, and the susceptibility of different species should be part of a risk assessment, which should grasp a long time horizon (Obrycki et al. 2001). At the end, large-scale field- and lab studies of Bt pollen funded by EPA (United States Environmental Protection Agency) and the agricultural biotechnology industry showed that the pollen from the Bt corn do not contain enough toxin to

harm monarchs (Clarke 2001). The conflict was solved by combining elements of the holistic evidential culture with elements of the restrictive evidential culture. This is a strategy to make the knowledge of such cultures more approachable for decision processes in risk politics.

2. *The concept of substantial equivalence* was introduced in the early 1990s to compare novel kinds of food with traditional food by the OECD (Organization for Economic Cooperation and Development) and endorsed by the FAO (Food and Agriculture Organization) and the WHO (World Health Organization). This concept is based on the assumption that food can be qualified on a purely substantial basis and it allows to narrow the argumentation about effects of GMO to a restricted set of criteria (Pouteau 2002, p. 293). Therefore, it had served as basis for a rather technocratic risk assessment and safety evaluation. Within this concept, safety was measured only with respect to the genetic ingredients. Epistemic cultures with a restrictive evidential approach defined the strategies of risk management. But, at the end of the 1990s, experiences with allergenic or toxicological effects raised the question to what extent this concept oversimplifies the situation and gives a biased advice favoring GM-food. It was asked, for instance, to what extent variations in food composition might be regarded (and considered negligible) as normal or whether minimal differences might result in relevant and unforeseen differences in toxicity or allergenicity (Levidow et al. 2007, pp. 37). Surprisingly, the argumentation of substantial equivalence was promoted by molecular biologist on the basis of an analogy. A strong assumption-based argumentation was combined with no or little experimental validation (Millstone et al. 1999). As a result, within the EU the role of the concept of substantial equivalence in GMO safety assessment was markedly reduced. While it is still regarded as a relevant step it is no more the final step of the risk assessment. Rather, additional efforts such as nutritional or toxicological tests are needed (Levidow et al. 2007, p. 58). This development is contrary to the case outlined before. Due to the requirements of the precautionary principle, this concept was re-interpreted and at the same time the balance between different strategies of construction of evidence was newly adjusted. On the conceptual level, it is true that the argumentation was fuelled by restrictive evidential reasoning, but this argumentation was not supported by the corresponding experimental strategies (Traavik et al. 2007). In this case, the combination of experimental strategies supported by a more holistic interpretation of risk evaluation concepts opened a more reflexive view in risk policy.

These debates are instructive not only because of the conflict between scientists of diverging epistemic cultures and processes of converging between them (Kastenhofer 2007). Moreover, these conflicts are instructive with respect to the problems of evidence construction within the different epistemic cultures. For holistic evidential cultures there is the problem of the meaningfulness of the different indicators and their spectrum. What is the value of a laboratory test in comparison to field findings? Pointedly, the spectra of evidence in holistic evidential cultures are wide ranged and in the most cases not systematically structured either. Therefore, the following questions get more important: are the findings evident, are the indications sufficient, how to validate knowledge claims in this debate? And finally, how should non-scientific knowledge, e.g. farmer's knowledge, be integrated (Mauro and McLachlan 2008)? The specific challenges for restrictive evidential cultures are quite different. As seen in the debate about the concept of substantial equivalence, it is the coherent and closed structure of methodological reasoning, experimental setting and the construction of theories which generates a kind of self-evident argumentation. Such an argumentation seems to be proved without being it experimentally. It could be a proof by analogy. Therefore, it is crucial to review the construction of evidence in detail and make transparent the different epistemic strategies and their connection.

Owing to the multilayer structure of the different epistemic cultures, their conflict potential grows with the number of epistemic cultures involved. This is caused by the confrontation between diverging strategies of construction evidence proceed by the different epistemic cultures. This leads to a situation of deep uncertainty about which scientific strategies for specifying non-knowledge and validating knowledge can be found acceptable. Therefore, and since risk-debates are driven by non-knowledge, the problem of validation becomes more acute. The tacit assumptions of the respective epistemic cultures need to be made the object of an explicit discussion. Due to the insoluble character of these conflicts, a kind of epistemic no man's land could emerge. This development does not only have an epistemic aspect. Rather, new and unintended entanglements of knowledge and power become apparent.

3.3 Institutional procedures and the concrete orders of knowledge

The described conflicts about the appropriate epistemic strategies to analyze risks of GMO have not only an epistemic but also a political character. Therefore, not only orders of knowledge but also social orders become important. Orders of knowledge and social orders are intertwined; they determine each other and mutually create each other. This can be seen as a constitutive moment of

modern societies. As Steve Shapin and Simon Schaffer stated in their important study on science and politics in early modern England: "Solutions to the problem of knowledge are solutions to the problem of social order" (Shapin and Schaffer 1985, p. 332). In this context, the institutional view of the problem of co-production is decisive. "As stable repositories of knowledge and power, institutions offer ready-made instruments for putting things in their places at times of uncertainty and disorder. (...) [They are] vehicles through which the validity of new knowledge can be accredited, the safety of new technological systems acknowledged, and accepted rules of behavior written into the as-yet-unordered domains that have become accessible through knowledge-making" (Jasanoff 2004, p. 39). But institutions are only one aspect of such complex and intertwined orders of knowledge in fields of risk policies: "Civic epistemology refers to the institutionalized practices by which members of a given society test and deploy knowledge claims used as a basis for making collective choices" (Jasanoff 2005, p. 255). What can we see with respect to the GMO-case? I would like to discuss three cases of growing complexity. The first case is the safety research program of the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF), which covers a long time range since it was established in 1987. And it shows the difficulties to open the scope to different epistemic cultures. The second case is the post-release monitoring established with the EU directive 2001/18/EC. There is a general acknowledgement of non-knowledge in the civic epistemology, but some main questions remain unresolved. The third case steers the view on a global level on the conflict between the EU and the US. What are the roles of transnational actors like the WTO (World Trade Organization) and actors on the EU level like the EFSA (European Food Safety Authority), which is responsible for the enforcement of the GMO-legislation?

1. *BMBF safety research.* In the context of the safety research of the BMBF it is obvious that there is a dominance of the control-oriented cultures. This is due to the fact that the BMBF is involved in a twin function which is difficult to handle. On the one hand side it is responsible for supporting the technological progress in the area of GMO-research. On the other, the BMBF has to conduct research probable inhibitive to progress: risk research. Therefore, some voices demand a separation of the safety research from the ministry (Strehlow 1988, p. 187). The argumentation of the BMBF was that the safety research would be the more profitable the more it is connected to the innovation research. The overarching goal was to derive risk policy-procedures from a restricted set of case studies by standard setting

(BMFT 1990). Could the wide spread of GMOs in the environment be described by scientific models? Are there standardized testing procedures? What are the best available strategies of containment? The answers to these questions are very much depending on the scope of investigation taking place. And these strategies were also criticized by supporters of restrictive epistemic cultures, because they take the reality of negative effects for granted which are expected by the critics. “Scientific statements are unsuitable to verify political utopias” (Sengbusch 1995, p. 160). This problem was reflected in some statements of interviewees. They gave the information that there was a selection between the line of projects with concrete risk-hypotheses which were funded and such projects offering risk-research about non-hypothesis-oriented risk research (Interview No. 2, p. 13). This is also the demarcation-line between restrictive evidential cultures and the ones with a holistic approach. The latter are to be seen as sensitive with respect to scientific non-knowledge. There were even some voices who said that safety research is more or less application oriented biotechnology research for industry (Interview No. 20, p. 3). Moreover: “Science is deeply used as plaything of interests.” (Interview No. 1, p. 38) Although there is the institutional framework to integrate different scientific views or to focus on ‘unknown unknowns’ the chance has not really been taken. This selection is due to the decision-oriented and technology-promoting approach of this ministry.

2. *Post-release monitoring.* The deliberate release of the recombinant DNA technology was subject to legal rules, at first timidly, but later more thoroughly (Levidow et al. 2005; Boschert and Gill 2005). Containment strategies were crucial and they have also been transferred to agrobiotechnology. In this framework, the two stages of field release and general release were intended to limit the unwanted spread of GMO. With the first experiments involving GMO in the free environment, the question of risk-paths dominated. These paths embodied a specified ignorance. Accordingly, the risk philosophy of step-by-step and case-by-case created a setting of a real-world experiment (Groß et al. 2005). These strategies were open to the problem of uncertainty and non-knowledge, but they are fundamentally knowledge-based (Jasanoff 2005). With the new regulatory approach, the institutional focus has been shifted to the problem of unknown unknowns. The EU regulation on deliberate release (2001/18/EC) stipulates that environmental and health effects of GMO have to be monitored after the introduction on the market, continuously. This means that it institutionally acknowledges the possibility of unknown unknowns. This post-release monitoring is not only to reassure that the original risk assessment was

correct but also to find out hazardous effects of GMO which were not predictable in the preceding risk assessment. To handle this, the distinction between two aspects of monitoring was drawn: case-specific monitoring and general surveillance. The competencies of the different epistemic cultures play a fundamental role in this context. Control-oriented epistemic cultures have been given the predominant task to test hypotheses on the as-yet-unknown, the specified ignorance (case-specific monitoring). This corresponds with their restricted evidential strategies. Epistemic cultures with a holistic approach are faced with the task to elucidate the horizon of unforeseen effects and to question the evidences hitherto constructed (general surveillance). It has to be pointed out, however, that the implementation of this monitoring is saddled with a number of unresolved conceptual and practical questions (Bardocz and Pusztai 2007). To give two examples: (a) even though a period of 10 years has been laid down to observe possibly adverse effects, there is by no means a scientific consensus about this fixing. Is the period of 10 years long enough, or not? (b) What are relevant indicators and what is a significant incident to begin more detailed research? The core question of these debates is how to engage in a search for adverse effects while nobody knows, where, at which time and by what methods they could be detected. Therefore, again, the question arises how to validate knowledge and to cope with non-knowledge with respect to the diverging strategies constructing evidence in the named epistemic cultures. These questions not only have an epistemic but also a political dimension. To what extent are the data collected by industry reliable for administrations? What are the selection criteria for expertise in this context? It is known that EFSA, the central administration for coping with these questions, follows a restrictive approach of evidence construction, which is documented in different cases (Ferretti 2006).

3. *Transnational conflicts between EU and US.* The political dimension is not restricted to the legislation within the EU. With respect to the growing economic globalization there is also an increase in global risk regulation observable (Murphy and Levidow 2006). In this context, the WTO (World Trade Organization) received one key position to mediate in international trade litigations. What are the consequences of this dynamic in the field of the GMO-debate? Confronted with an international trade litigation between the EU and a group of agro-exporting countries led by the United States, the WTO has, in the end, to decide what are the evidences in the course of risk assessment procedures. What is the scientific basis for a precautionary approach? The US model is based on a restrictive evidential

approach, so that only the proven risks—that means the observation of strong adverse effects—are reasonable arguments against the trade with a specific substance, foods, or other goods (Anderson and St. Hilaire 2004). The EU model is institutionally based on a holistic approach to fulfill the diverging demands of the freedom of choice-principle, a labeling-regime based on the traceability principle and the institutional framework of the post-release monitoring based on the precautionary principle (Seifert 2006, p. 2). Against this background, not only risks but also riskiness—that means the availability of reasonable grounds of concern not yet drawn on scientific certainty—is an acceptable argument to restrict global trade relationship. The WTO finally decided to follow the US model. It seems that the emergence of a transnational regulation of risk policy in the context of international trade disputes fuelled the tendency to a more restrictive evidential approach (Seifert 2004; Franken and Burchardi 2007). Corresponding to this development, the meaning of the Codex Alimentarius is changing. It previously defined minimum standards of food safety (WHO) which could be improved upon by single countries. Nowadays, they attained the character of maximum standards, which cannot be improved by single countries because this would be considered as a kind of trade restriction (by WTO; Pestre 2003, p. 257). But also the diverging institutional settings and traditions form the conflict. This has to be reflected with respect to the chances and limitations of a knowledge politics more sensible to precaution, respective non-knowledge (Koenig 2002).

4 Discussion

1. *The orthodox view and its gaps.* Despite the institutionalized opening towards a multifaceted debate on knowledge and non-knowledge, civic epistemology is still driven by the idea that the best argument wins and that the authorities would have to decide, accordingly. But, this orthodox view of science in political decision-making (Millstone and van Zwanenberg 2003), which is based on the idea of science as disinterested provider of objective knowledge even when it is intimately involved in policy processes, is too simple for three reasons: (a) The belief in just determining which argument wins does not take into account the normative prerequisites for any argumentation in risk policy. Also, experts are part of a political controversy and their scientific frameworks are more or less corresponding to the strategies of political actors in the field of risk
2. *Orders of knowledge and hybrid regimes of knowledge.* Looking at the evolution of institutional structures and the problems of ordering the different evidential cultures within such a framework, the problem of the connection of orders of knowledge with social orders needs to be analyzed more thoroughly than on the level of established institutional rules (Bonneuil et al. 2008). Against this background, an analysis of hybrid regimes of knowledge seems to be helpful. Hybrid regimes of knowledge feature a decoupling of institutional, discursive, and practical elements in the arenas of risk policy. Thereby, a new strategic scope arises for actors who have special discursive or economic power in the field of knowledge policy. Their influence increases with the lacking of transparent legal and administrative rules to structure the different ways of evidence-making. This means that the framework conditions for the construction of evidences have to be made part of the political processes. Due to the fact that there is no overarching strategy for combining the different epistemic offers to a coherent picture, strategies of knowledge politics have to provide not only an institutional framework (even if it is innovative as shown in the case of post-release monitoring). Rather, such strategies have to address the problem of the fundamental conflicts between the epistemic cultures involved by structuring the strategies for constructing evidence and by making a choice of order and importance. Knowledge politics has to find an answer to the problem of emerging epistemic no man's land, where heterogeneous actors offer their arguments. Arguments are not only arguments but also strategies to frame the scope of conflicts. Behind the arguments, there is a complex setting of

discursive, institutional, and practical assumptions. Therefore, these aspects have to be reflected and made explicit for a decision process (Stirling 2007). To put it into a nutshell: civic epistemologies are the visible side of invisible hybrid regimes of knowledge. The investigation of such hybrid regimes of knowledge opens up the chance for a critique of existing civic epistemologies and for giving advice to improve solutions of conflicts about non-knowledge.

5 Conclusions

There are two points with special relevance for a further discussion:

1. Different epistemic cultures have developed different strategies to specify non-knowledge and to cope with the expected unknowable. These could be named as control-oriented epistemic cultures (e.g., molecular biology), complexity-oriented epistemic cultures (e.g., ecology) and expertise-based epistemic cultures (e.g., environmental medicine). As shown, there are also remarkable differences between these epistemic cultures and their strategies to construct evidences. Therefore, it is important to qualify them by describing epistemic cultures as evidential cultures. In this case, three different types of evidential cultures were differentiated. The restrictive evidential culture follows the strategy of theory-based explanation. Holistic evidential cultures follow the strategy of structure-oriented local descriptions. Finally, evaluative evidential cultures focus on the proof of function for single cases. These strategies are typically assigned to specific epistemic cultures. However, their combination is possible and open up new strategic resources. But to solve the conflicts between these different strategies, a meta-expertise with meta-criteria for judging the manufactured expertises is needed (Collins and Evans 2007, pp. 45).
2. Despite wide-ranging institutional reforms which have increased the chances for a policy of non-knowledge, the problem of serious influence of organized interests remains. Hence, it is not sufficient to analyze institutionalized civic epistemologies. Rather, the underlying hybrid regimes of knowledge are to be detected to find out about the imbalances between power and knowledge and between knowledge and non-knowledge. But proposals like these would not have any effects, if the political problems were not taken seriously that ‘civic epistemologies’ reflect the structure of power, inevitably. Thus, those rules have to be developed to diminish imbalances of power and to ensure a public participa-

tion in the different stages of the complex decision processes, adequately.

6 Recommendations and perspectives

For further research with respect to an analysis of processes of evidence-making, the following recommendations are given:

1. Based on the exploratory research represented in this paper, there should be quantitative investigations undertaken to proof the broad applicability of the concept of evidential cultures in risk research areas. Thereby, the concept of evidential cultures should be explored more explicitly with respect to epistemic cultures involved in other risk policy fields. But this analysis must not be restricted to those epistemic cultures involved in risk policies. It would be advisable to analyze evidential cultures on a spectrum between pure and applied research.
2. Strategies of knowledge politics under conditions of non-knowledge should be designed, systematically. As a first important step, different epistemic cultures have to be acknowledged and plurality has to be ascertained. This would also require reducing the present extreme imbalances, e.g., those caused by the industry controlling the resources. This could be done politically by a targeted funding of presently underestimated epistemic cultures, especially ecology. Moreover, the concept of hybrid regimes of knowledge should be deepened by looking at the complex interactions between institutional, discursive, and practical rules important for the determination of risks. This should lead to a more accurate description and analysis of knowledge politics.

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