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Re-thinking new knowledge production: A literature review and a research agenda

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Abstract

This paper offers a systematic reflection on the Gibbons–Nowotny notion of 'Mode 2 knowledge production'. We review its reception in scientific literature and compare it with seven alternative diagnoses of changing science systems. The 'Mode 2' diagnosis identifies a number of important trends that require further empirical efforts, but it suffers from severe conceptual problems. It is time to untie its five major constitutive claims and investigate each separately.

Keywords: Mode 2; Transdisciplinarity; Heterogeneity; Relevance

1. Introduction

Science systems are said to be in transformation. Last two decades various studies have pointed to a variety of changes, such as an increasing orientation of science systems towards strategic goals (Irvine and Martin, 1984) and the production of relevant knowledge (Böhme et al., 1983; Gibbons et al., 1994). A variety of approaches to understand, explain, and, perhaps, extrapolate such trends have emerged, but none of them is uncontested. Probably the most famous account of a transformation is the concept of 'Mode 2' knowledge production. This notion refers to a set of putative changes that are introduced in *The New Production of Knowledge* (Gibbons et al., 1994). The book sketches the emergence of a research system that is highly interactive and 'socially distributed'. The basic argument is that, while knowledge production used to be located primarily in scientific institutions and structured by scientific disciplines, its locations, practices and principles are now much more heterogeneous. Mode 2 knowledge is produced 'in the context of application' by so-called transdisciplinary collaborations. Moreover, scientists are more reflexive and they operate according to different quality criteria when compared with the traditional disciplinary mode. The new mode of knowledge production has been coined 'Mode 2', and it is not believed to replace Mode 1, but to supplement it.[1] Table 1 gives a summary of the basic claims in a well-known format.

In the decade since its launch by Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schartzman, Peter Scott and Martin Trow, the 'Mode 2' concept has gained an enormous visibility in the reflection on

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[1] 'This new mode – Mode 2 – is emerging alongside the traditional disciplinary structure of science and technology—Mode 1' (NPK, p. 14).

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Table 1
Attributes of Mode 1 and Mode 2 knowledge production

Mode 1	Mode 2
Academic context	Context of application
Disciplinary	Transdisciplinary
Homogeneity	Heterogeneity
Autonomy	Reflexivity/social accountability
Traditional quality control (peer review)	Novel quality control

contemporary scientific practice. The notion of 'Mode 2' is referred to in over 1000 scientific articles[2] and seems to have influenced science, technology and innovation policies.[3] During the same period, however, scholars have written numerous critical papers to contest the claims and the use of the Mode 2 concept, some on a theoretical basis, others supported by empirical data. We think it is time for reconsideration of the idea of a science system in transformation and we will use the claims and contestations of the Mode 2 concept as an entrance point. To what extent is this concept helpful in describing and explaining current changes in scientific practice? What does it add to other approaches? What are the most relevant questions to address when one is interested in the transformation of science systems?

We will follow two routes, one direct, and the other indirect. First, the indirect route is to compare and contrast the Mode 2 diagnosis with a number of alternative accounts of current changes in scientific practice (Section 3), such as Triple Helix (Etzkowitz and Leydesdorff, 2000), post-normal science (Funtowicz and Ravetz, 1993) and strategic research (Rip, 2004). We will address both agreements and differences between 'The New Production of Knowledge' (NPK) – the book in which the notion of Mode 2 has been coined – and the alternatives. This step will make clear about which characteristics of the science system the different diagnoses make claims and it will show to what extent the claims of NPK agree with claims made by other authors. The second, direct route is to review and evaluate the numerous reactions to 'The New Production of Knowledge'. After a discussion of its general reception (Section 4), a number of critical reactions are addressed (Section 5). The main objections that we found in the literature will be grouped under three headings: criticism regarding the empirical validity, the conceptual strength, and the political value of NPK. Consequently, the strong and weak points of the original Mode 2 claims can be determined. We will conclude with a statement about the strength and suitability of the Mode 2 concept and with a list of topics concerning the transformation of science systems that deserve further study. First, however, we will summarise the two main publications by the creators of the concept (Section 2).

2. The new production of knowledge: Mode 2

The notion of Mode 2 knowledge production is coined in *The New Production of Knowledge* (Gibbons et al., 1994). This volume constitutes the outcome of a collaborative research project conducted by six prominent scholars in the field of science (policy) studies: Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Martin Trow. The work was originally commissioned by the Swedish Council for Research and Planning, FRN, aiming to get a view on the future of universities.

The main proposition of the study is the emergence of a knowledge production system that is 'socially distributed'. While knowledge production used to be located primarily at scientific institutions (universities, government institutes and industrial research labs) and structured by scientific disciplines, its new locations, practices and principles are much more heterogeneous. To clarify this assertion the authors introduce a distinction between Mode 1 knowledge production, which has always existed, and Mode 2 knowledge production, a new mode that is emerging next to it and is becoming more and more dominant. Five main attributes of Mode 2 summarise how it differs from Mode 1 (see Table 1).

First, Mode 2 knowledge is generated in a *context of application*. Of course, Mode 1 knowledge can also result in practical applications, but these are always separated from the actual knowledge production in space and time. This gap requires a so-called knowledge transfer. In Mode 2, such a distinction does not exist. A second characteristic of Mode 2 is *transdisciplinarity*, which refers to the mobilisation of a range of theoretical perspectives and practical methodologies to solve problems. Transdisciplinarity goes beyond interdisciplinarity in the sense that the interaction of scientific disciplines is much more dynamic. Once theoretical consensus is attained, it cannot easily be reduced to disciplinary parts. In addition, research results diffuse (to problem contexts and practitioners) during the process of knowledge production. Thirdly, Mode 2 knowledge is produced in a diverse variety of organisations, resulting in a very *heterogeneous* practice. The range of poten-

[2] Scopus search on January 18, 2007.
[3] In Canada, for instance, the creation of Networks of Centre's of Excellence aimed at 'facilitating Mode 2 networks' (Fisher et al., 2001).

tial sites for knowledge generation includes not only the traditional universities, institutes and industrial labs, but also research centres, government agencies, think-tanks, high-tech spin-off companies and consultancies. These sites are linked through networks of communication and research is conducted in mutual interaction. The fourth attribute is *reflexivity*. Compared to Mode 1, Mode 2 knowledge is rather a dialogic process, and has the capacity to incorporate multiple views. This relates to researchers becoming more aware of the societal consequences of their work ('social accountability'). Sensitivity to the impact of the research is built in from the start. Novel forms of *quality control* constitute the fifth characteristic of the new production of knowledge. Traditional discipline-based peer review systems are supplemented by additional criteria of economic, political, social or cultural nature. Due to the wider set of quality criteria, it becomes more difficult to determine 'good science', since this no longer is limited to the judgement of disciplinary peers. However, this does not imply that Mode 2 research is generally of a lower standard.

In order to emphasize the width of the transformations, the authors of NPK (Gibbons et al., 1994) describe a number of developments in which they are visible such as the commercialization of knowledge, the massification of higher education and the increasing importance of collaboration and globalisation. The book also includes chapters on the case of the humanities and on the institutional changes that are involved in the rise of Mode 2 knowledge production.

In 2001, three of the authors of NPK published a second book: *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty* (Nowotny et al., 2001).[4] It can be read as a reaction to some of the criticisms that NPK has received. The authors of 'Re-thinking Science' elaborate the claims about Mode 2 in three directions.

Firstly, Nowotny, Scott and Gibbons relate their arguments to sociological literature. They discuss two accounts of social change that deal with the growth of complexity of society: the Knowledge Society and the Risk Society. They compare the two along a number of parameters and relate them to the notion of Mode 2. In addition, the authors relate their work to literature about post-modernism and co-evolution.

Secondly, 'Re-thinking Science' extends the argument of Mode 2 beyond the boundaries of the science system. Expanding its meaning, the term Mode 2, here refers to a society consisting of 'transgressive' institutions. In a post-modern fashion, the book argues that currently a de-differentiation of the various societal spheres (state, market, culture) is taking place. These are increasingly fuzzy and blurring categories that overlap and interact. According to Nowotny et al. this development constitutes the background against which the shift towards Mode 2 knowledge production takes place.

Thirdly, the authors make attempts to specify the nature of new scientific practices and discuss additional observations of contemporary scientific practice. They describe changes they perceive in various institutions involved in knowledge production: industrial and governmental research institutes, research councils and universities. In particular they introduce the concept of 'contextualised science' which basically means that 'society now "speaks back" to science' (p. 50). This refers to the demand for innovation, to new regulatory regimes, and to the multiplication of user–producer interfaces. Depending on the degree of importance, one can speak of weak, middle range, or strong contextualisation. This development affects scientific activity not only on the organisational level, but also 'in its epistemological core' (p. 94). The authors claim that Mode 2 (or contextualised) research yields 'socially robust knowledge', which has a different epistemological status than Mode 1 science. Perhaps surprisingly, the participation of a wider range of non-scientific actors in the knowledge production process enhances its reliability.

3. Mode 2 and its alternatives

The Mode 2 diagnosis is popular, visible and contested, but not unique: it appears amongst competing approaches to study changes in the science system. The first step in our reconsideration is a comparison with a set of alternatives, which we have identified in a literature study[5] (see Table 2). Each gives an account of current changes in scientific knowledge production and/or the changing relationship between science and society. We will briefly introduce each of them and discuss the agreements and disagreements with the Mode 2 diagnosis. Please note that the order of appearance is chronological and does not reflect any judgement about their relative importance. We will discuss the approaches in terms of their claims about cognitive changes, organi-

[4] In this paper we will use the definitions of Modes 1 and 2 as given in NPK and we will primarily analyse the reactions that this book has received.

[5] The bodies of literature addressed were selected based on their prominence (number of citations) and the degree of apparent similarity with NPK.

Table 2
Alternative diagnoses studied

Concept	Aim (descriptive or prescriptive)	Format	'Main' publication	Number of citations[a]
Finalisation science	D / P	Articles	Böhme et al. (1983)	22
Strategic research/strategic science	D (P)	Diverse	Irvine and Martin (1984)	58
Post-normal science	P	Articles	Funtowicz and Ravetz (1993)	204
Innovation systems	D / P	Diverse	Edquist (1997)	298
Academic capitalism	D	Book	Slaughter and Leslie (1997)	315
Post-academic science	D	Book	Ziman (2000)	97
Triple Helix	D	Articles	Etzkowitz and Leydesdorff (2000)	175

[a] Scopus search, April 27, 2007.

sational changes and science–non-science relationships. The discussion is summarised in Table 3.

3.1. Finalisation science

The concept of 'finalisation science' (Böhme et al., 1983, 1973) describes and explains the dynamics of science and its societal function. To some extent, it also contains a prescriptive message. In the 1970s, the German research group known as the 'Starnbergers' (Rip, 1989), developed a research programme on science dynamics consisting of case studies of scientific disciplines. The programme has resulted in a number of journal articles, part of which have been published in German. Most accessible is an edited volume with contributions of the main proponents of the programme (Böhme et al., 1983). Based on the case studies, their main claim is that all disciplines follow a general development in which an explorative phase, a paradigmatic phase, and a post-paradigmatic phase can be distinguished. In the context of this paper, the last phase is most important. In this phase, 'finalisation' may occur: theoretical development that is determined by external factors. When a discipline attains theoretical maturity, it becomes open to orientation in accordance with external objectives. Its further theoretical development then proceeds along the paths that these goals indicate.

According to the 'finalists', more and more disciplines reach this phase. This implies that the relation between science and society is changing. In this relationship, society is becoming an active rather than a passive partner, and it increasingly takes a guiding role.

As Peter Weingart has indicated (Weingart, 1997), this observation is comparable to the Mode 2 thesis. Four important differences need to be mentioned, however. First, the 'finalisation'-approach has a strong empirical basis. Second, it clearly differentiates between scientific disciplines: it studies various disciplines separately. The claim that the whole science system is undergoing change arises as an inductive conclusion from the observations of different disciplines. Third, distinct from the emergence of Mode 2 knowledge production, finalisation of disciplines is related primarily to internal rather than external causes. Its driving force is the theoretical maturing development which facilitates social orientation. In contrast, in the Mode 2 thesis, global developments such as globalisation of business and the complexity of policy issues figure as causal factors. Fourth, the Starnbergers are explicitly prescriptive when they speak of 'normative finalisation'.[6] They do not merely report the increasing social orientation of science but also provide policy recommendations. In their writings, one finds a call for 'social natural science', science in which natural norms and social interests are coordinated. Given the possibility of social orientation of scientific research, they argue for setting restrictive conditions that the aims set by scientists must meet (Schäfer, 1983).

3.2. Strategic research/strategic science

The notions of strategic research and strategic science appear in a variety of sources. They are mainly used for descriptive purposes, but are often translated into policy goals in a prescriptive way. The term 'strategic research' was coined in a policy study (Irvine and Martin, 1984) and is defined as: 'basic research carried out with the expectation that it will produce a broad base of knowledge likely to form the background to the solution of recognised current or future practical problems'. A striking feature is the emphasis on basic rather than applied research. This distinguishes this diagnosis from Mode 2, in which the distinction between basic and applied science has disappeared. Strategic science, however, has internalised the pressure for relevance while maintaining the (academic) freedom to continuously move to the most promising line of research. Scientists do not operate in

[6] This element is particularly visible in the work by Schäfer (1983).

Table 3
The various diagnoses put emphasis on different characteristics of scientific knowledge production

Levels	Characteristics	NPK	Post-normal science	Triple Helix	Post-academic science	Academic Capitalism	Strategic science/research	Innovation systems	Finalisation science
Cognitive	Choice of research agenda (research content)	X	X	X	X	X	X	X	X
	Methods (teamwork, transdisciplinarity)	X	X						
	Epistemology (socially robust knowledge)	X[a]	X						
Organisational	Map of disciplines (transdisciplinarity)	X		X					
	Values/labour ethic of scientists (reflexivity)	X			X				
	Norms of quality control (extended peers)	X	X		X		X		
External relations	Interaction with other societal 'spheres' (industry, government)	X		X	X	X	X	X	X
	Incorporation of non-scientific expertise (participation)		X						

[a] NPK is unclear on this point. The follow-up book *'Re-Thinking Science'* (Nowotny et al., 2001), however, does claim that an epistemological transformation is taking place.

the 'context of application', but they do consider the relevance of their work as a legitimate condition to take into account. There remains a distance between the actual research and its eventual uptake in the form of solutions to societal problems or innovations that enhance economic growth.

Arie Rip uses the notion of 'Strategic Science' to describe an upcoming regime (Rip, 2004). This regime is characterised by a recontextualisation of science in society. Due to the importance of science for innovation and for decision-making, there is more emphasis on strategic research: producing knowledge which combines relevance[7] with scientific excellence. It replaces the regime of 'Science, the endless frontier', in which resources have been available to basic science without requiring clearly articulated promises. Rip regards the spread of 'centres for excellence and relevance' (Rip, 2004) and also the commitment of (entrepreneurial) universities to both regionalism and academic excellence (Rip, 2002a) as indicators for the new regime.

3.3. Post-normal science

'Post-normal science' is a prescriptive approach that is presented in a journal article (Funtowicz and Ravetz, 1993), but it has led to the development of a research community working on the further development of the programme. The concept originates from policy-relevant science fields and starts from an acknowledgement of the limitations of rational decision-making. Given the complexity of current issues in (environmental) policy, it argues for a reassessment of the appropriate role of scientific research. In environmental debates typically 'facts are uncertain, values in dispute, stakes high, and decisions urgent' (Funtowicz and Ravetz, 1993). According to the authors, 'normal science' in the Kuhnian sense is not an adequate mode of knowledge production in this situation, as it assumes that problems can be divided into small-scale problems that can be handled without questioning the broader framework or paradigm. There is a need for a scientific practice which can cope with uncertainty, with value plurality and with the decision-stakes of the various stakeholders of the problem at hand. In addition it must have the capacity to support policy makers taking their time constraints into account. For this purpose the term 'post-normal science' has been invented.

[7] In this context, 'relevance' refers to application possibilities in either (industrial) innovations or in (governmental) decision making.

The most striking characteristic of post-normal science is public participation. The solutions that proponents of this model offer generally boil down to engaging stakeholders in decision-making processes or in the quality assessment of scientific knowledge production. According to the post-normal science view, quality assurance of scientific input to policy processes should be performed by an 'extended peer community' (Funtowicz and Ravetz, 1993). To this end, several frameworks have been developed that enable dealing with different types of uncertainty, both on the level of model parameters and assumptions (Van der Sluijs et al., 2005) and on the level of societal perspectives (Craye and Funtowicz, 2005) and value diversity (Kloprogge and van der Sluijs, 2006).

Post-normal science shares a number of characteristics with Mode 2 knowledge production but places slightly different accents. Common features of both approaches are the increased interaction across disciplinary and organisational boundaries, additional quality criteria and a greater reflexivity. However, there is a clear difference in scope. Because post-normal science is only relevant for policy-supporting research, it does not deal with the university–industry interactions. In post-normal science, corporations play a role only in as much they are a stakeholder of the policy problem at hand, not because of their potential role as a knowledge (co)producer. For the same reason, there is no consideration of product or process innovations, but only for policy innovations or system innovations. Because of its focus on the public function of research, post-normal science has stronger similarities with the more recent book (Nowotny et al., 2001) by some of the authors of NPK. It fits the ideal of contextualised research, yielding 'socially robust' knowledge.

Compared to Mode 2, post-normal science has a more programmatic character. It does not have a descriptive content in the sense that it *reports* the emergence of a new mode of research. Rather, in a prescriptive sense, it expresses a need for new modes of knowledge production and aims to contribute to its fulfilment by developing the required tools.

3.4. Innovation systems

Systems thinking in innovation studies emphasises the importance of interactions and feedback mechanisms between all actors involved in innovation, including university researchers, industrial product developers, intermediary organisations and end-users. The concept of innovation systems is primarily applied as a heuristic framework, in order to describe and explain the complexity of innovation systems. In addition, it is used in a prescriptive sense, by arguing for a more systemic innovation policy (Smits and Kuhlmann, 2004). In accordance with the variety of approaches, a diversity of publications is available on the topic including numerous journal publications and (edited) books. The innovation systems perspective is applied on various levels of aggregation: National Innovation Systems (Freeman, 1997), Regional Innovation Systems (Cooke et al., 1997) and Technological Innovation Systems (Carlsson and Stankiewicz, 1991). However, all approaches share a consideration of the interactive nature of successful innovation processes (Edquist, 1997).

The innovation systems approaches share with NPK the emphasis on the non-linearity and heterogeneity of knowledge production. Both reject the linear model of innovation in which basic research is translated into applied research, which in turn may result in technological product development (and subsequent diffusion). In Mode 2, the distinction between basic and applied science does not exist; in innovation systems such a distinction is conceived to be ineffective. Moreover, the organisational diversity of Mode 2 corresponds to the network character of innovation systems. Collaborations between universities and industry, but in particular the role of intermediary research organisations, figure in both bodies of literature.

A distinctive feature of the systems approach in innovation studies is that it is merely a heuristic framework rather than a descriptive theory. Compared to the Mode 2 thesis, it hardly contains any descriptive claims. While NPK's authors argue that contemporary knowledge production is heterogeneous and non-linear by nature, innovation systems literature only argues it should be heterogeneous and non-linear in order to facilitate fruitful innovation processes.

3.5. Academic Capitalism

The book '*Academic Capitalism*' (Slaughter and Leslie, 1997) reports the observation of increasing market- and market-like activities at universities in a set of empirical case studies.[8] The authors aim

[8] There is a large body of literature that deals with the increasing links with industry. However, a lot of studies in this category start from a firm's perspective and mainly deal with the potential benefits and costs for industry of collaborating with university researchers (Meeus et al., 2004; Krahmer and Schmoch, 1998; Kaufmann and Todtling, 2001). In the present context, however, we are mainly interested in the consequences of this development for scientific knowledge production.

both to describe and to explain this phenomenon. With 'academic capitalism' they refer to two types of activities. First they point to the increasing (market-like) competition for external funding: grants and contracts, endowment funds, university–industry partnerships, institutional investment in spin-off companies, or student tuition and fees. Second they discern increasing market-activities: for-profit activity, patenting or subsequent royalty and licensing agreements, spin-off companies, and university–industry partnerships having a profit component.

The authors explain this development by two factors. First increasing globalisation enhances the pressure on industry to innovate and causes corporations to turn to universities for assistance. In the same time, the flow of public moneys to universities is receding. Together these factors make universities more willing to engage in 'capitalist' activities. Notably, both identified causes are external, in the sense that they originate outside the science system.

Slaughter and Leslie complement their empirical observations with a warning for the risks of the developments they describe. In all four countries (US, UK, Australia, Canada) they have studied, governments promoted academic capitalism as a means of stimulating economic growth. Except for Canada, they all succeeded in developing promoting policies. However, there is no clear indication for the success of market-activities, as only some universities in the United States manage to make money. Opposite of the potential benefits the authors identify substantial risks for researchers, universities and their managers. Market(-like) activities can lead to 'business failure', to product responsibility, failure to meet societal expectations (with regard to economic growth and employment) and neglect of students. For this reason, Slaughter and Leslie recommend governments to create incentives for universities to spend their money in the desired ways in order to avoid a decline in academic education.

'Academic Capitalism' partly confirms the claim of rising importance of Mode 2 knowledge production. The market(-like) activities described include (at least to some extent) the attributes 'context of application', 'organisational diversity' and 'novel modes of quality control'. The authors do not pay particular attention to transdisciplinarity. A curious empirical result is the observation that researchers are ambivalent with regard to 'altruism'. They hope that their research will benefit humankind, but this does not seem to be their first priority (p. 222). From their interviews Slaughter and Leslie have got the impression of researchers being pushed in the direction of academic capitalism, but they do everything they cannot to become Mode 2 researchers. They do not show the intention of leaving university as they prefer to keep the advantages of being 'state-supported entrepreneurs' (p. 206).

3.6. Post-academic science

In Ziman's notion of post-academic science, he incorporates elements from several other diagnoses: Mode 2, Academic Capitalism and post-normal science. The notion is introduced in a single-author volume (Ziman, 2000), which elaborates on ideas published in his equally successful earlier book (Ziman, 1994). Ziman intends to describe and explain a set of developments in scientific knowledge production. To summarise, post-academic science refers to a 'radical, irreversible, worldwide transformation in the way science is organised, managed and performed' (p. 67). Post-academic science (or 'post-*industrial* science', as Ziman calls it as well) can be characterised by the following five (strongly connected) elements.

First, science has become a collective activity: researchers share instruments and co-write articles. Moreover, both the practical and fundamental problems that scientists are concerned with are transdisciplinary in nature, calling for collective effort. Second, the exponential growth of scientific activities has reached a financial ceiling. The resources available for research seem not to increase much more, creating a need for accountability and efficiency. Thirdly, but strongly related, there is a greater stress on the utility of knowledge being produced. The success of applying scientific knowledge into products or practical solutions in some fields has made industry, government and the public impatient with its diffusion rate in general. There is an increased pressure on scientists to deliver more obvious 'value for money'. Next, the emergence of science and technology policy has strengthened the competition for resources. In the resulting situation, competition for real money becomes more important than competition for scientific credibility. Research groups can be conceived as small business enterprises, their staff as 'technical consultants'. Finally, science has become 'industrialised': the links between academia and industry become closer and funding increasingly comes from contract research. This development contravenes the Mertonian norms of academic science. Due to the industrial orientation a new set of norms can be discerned, which Ziman labels as 'PLACE':

'*Proprietary*, *Local*, *Authoritarian*, *Commisioned*, and *Expert*'.[9]

Although his approach is primarily descriptive, Ziman is not neutral towards the development of post-academic science. In a recent paper (Ziman, 2003) he draws attention to the 'non-instrumental roles of science', which are threatened in the post-academic era. If science is valued primarily as a mode of wealth creation, certain functions of knowledge production are overlooked. These include the creation of critical scenarios and world pictures, the stimulation of rational attitudes, and the production of enlightened practitioners and independent experts. Ziman is convinced that post-academic science is here to stay; we cannot go back to the old academic model. However, he argues for a fuller consideration of the non-instrumental roles in the debate about the future of science.

The concept of post-academic science is quite similar to that of Mode 2 knowledge production. There are no real contradictions between the content of both notions, only some difference in emphasis. Indeed, Ziman refers to Mode 2 in a way that suggests he conceives it as a synonym of 'post-academic science' or at least for the manifestation of that which he calls 'post-industrial science' (p. 80). The most important difference between Mode 2 knowledge production and post-academic science is probably the scope of the two central notions. Whereas Mode 2 refers to a particular way of conducting and organising research that constitutes a limited but increasing part of the science system, post-academic science is a name for the whole science system in its new state. This difference results in a different relation between the traditional and the new mode of research. While NPK explicitly states that Mode 2 emerges 'next to' Mode 1 research and suggests a future in which both develop in co-evolution, Ziman speaks of post-academic science as a practice that replaces traditional academic research. 'Our exemplar is changing before our eyes into a new form—*post-academic science* (. . .)' (p. 60).

A similarity between Ziman and Gibbons et al. is the loose empirical foundation of their observations. In both cases, the authors themselves have not gathered any new data. In the same way as in NPK, Ziman only loosely refers to secondary data, although he does it a little more frequently.

3.7. Triple Helix

The Triple Helix model (Etzkowitz and Leydesdorff, 1998, 2000; Leydesdorff and Meyer, 2006) is based on the assumption that industry, university and government are increasingly interdependent. This implies that these different institutional spheres have to be studied in co-evolution. The model can be seen as a heuristic forcing researchers to systematically take into account all three spheres when studying dynamics of knowledge production and innovation. Triple Helix does not have a uniform descriptive message like NPK, but it rather constitutes a research program that has yielded a variety of descriptive claims. Its body of literature consists mainly of special issues of scientific journals dedicated to the Triple Helix conference series.

The central insight that this approach has yielded is the observation of 'an overlay of reflexive communications' between universities, industries, and governmental agencies. According to Etzkowitz and Leydesdorff (2000), in most countries there is a tendency towards a knowledge infrastructure in which these three institutional spheres (academia, state and industry) overlap. In this configuration the spheres can take each other's forms and hybrid organisations emerge at the interfaces. The linear model of utilisation of scientific knowledge is replaced by new organisational mechanisms that integrate market pull and technology push. Basic research is linked to utilisation through series of intermediate processes such as government initiated programs that facilitate university–industry interaction. The rise of this configuration is mainly due to the enhanced role of knowledge in our economy and society, and to the decreasing role of the military.

The role of universities in this configuration is often referred to as its 'third mission'.[10] Making a contribution to economic growth is becoming a central task next to teaching and research.[11] Within the Triple Helix literature, research with this mission is referred to as 'entrepreneurial science' (Etzkowitz et al., 2000b; Etzkowitz, 1998; Kleinman and Vallas, 2001).

[9] 'It produces *proprietary* knowledge that is not necessarily made public. It is focused on *local* technical problems rather than on general understanding. Industrial researchers act under managerial *authority* rather than as individual. Their research is *commissioned* to achieve practical goals, rather than undertaken in the pursuit of knowledge. They are employed as *expert* problem solvers, rather than for their personal creativity.' (Ziman, 2000, pp. 78–79).

[10] This point is elaborated in literature on the 'entrepreneurial university' (Etzkowitz, 2003; Etzkowitz et al., 2000a). Although written by one of its main founders, it is not necessarily part of the Triple Helix corpus.

[11] One can argue about the adequacy of the term 'third' mission as the authors do not seem to refer to a completely new task but to a reformulation of the second mission.

This new role of universities and its new relations with government and industry are roughly in agreement with the idea of Mode 2 science. Especially the context of application and organisational diversity are apparent. Etzkowitz and Leydesdorff also confirm transdisciplinarity with their observation that new disciplines (such as computer science or nanotechnology) arise 'through synthesis of practical and theoretical interests' (Etzkowitz and Leydesdorff, 2000, p. 117). As will be indicated in the next section, however, they disagree with the view of Mode 1 as the original format of knowledge production. Moreover, Etzkowitz and Leydesdorff prefer to speak of Mode 2 as an 'emerging' system emphasising historical dynamics. In their eyes the current knowledge infrastructure is characterised by mixes of Mode 1 and Mode 2 (p. 119).

3.8. Concluding remarks

Table 3 summarises the main findings of this section. The comparison shows that the individual elements of the Mode 2 diagnosis are not unique. All characteristics that it addresses return in one or more of the other approaches. Nearly all approaches pay attention to the changing research agenda and the increasing interaction between science and other societal actors. This suggests that these observations are correct, especially since they are supported by empirical evidence in for instance the 'Academic Capitalism' volume and the 'Triple Helix' corpus. Other claims are more distinctive, especially the ones dealing with methods, epistemology and values. The most striking result of the mutual comparison, however, is that it shows the exceptionally wide scope of the Mode 2 diagnosis. None of the alternatives deal with as many characteristics of science as NPK does. It is unclear, however, whether this is a strength or a weakness.[12]

4. The reception of Mode 2

After the comparison with alternative approaches, we will now focus directly on the strength of the Mode 2 diagnosis and study its reception in scientific literature. 'The New Production of Knowledge' (Gibbons et al., 1994) has received over 1000 citations in scientific journals[13] and Figs. 1 and 2 indicate that the number of references per year is still increasing. Table 4 presents a list of all journals in which 10 or more references were

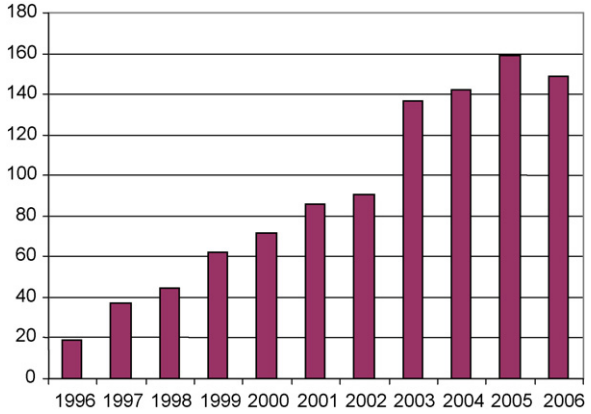

Fig. 1. Number of citations of NPK found in Scopus.

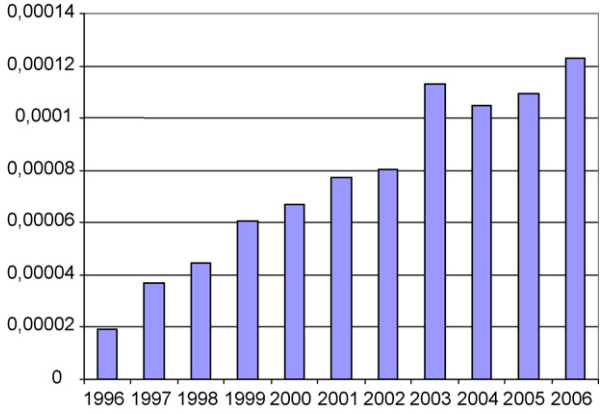

Fig. 2. Number of citations of NPK found in Scopus, as a fraction of all articles containing the letter 'A', in order to correct for the growth of the number of journals that are included in the Scopus database.

Table 4
Scientific journals in which NPK was cited at least 10 times

Journal name	Number of references
Science and Public Policy	51
Research Policy	40
Scientometrics	38
Higher Education	36
Minerva	21
Research Evaluation	20
International Journal of Technology Management	19
British Journal of Management	18
Studies in Higher Education	15
Social Science Information	15
Technology Analysis and Strategic Management	15
Science Technology and Human Values	15
Futures	13
Social Studies of Science	12
Organisation	12
Prometheus	12
R and D Management	12
Higher Education Policy	10

[12] We answer this question in the concluding section.
[13] Scopus search on January 18, 2007.

Table 5
Important reactions to NPK

Authors (year)	Title	Number of citations[a]
Godin (1998)	Writing performative history: The new new Atlantis?	21
Weingart (1997)	From "Finalisation" to "Mode 2": Old wine in new bottles?	41
Hicks and Katz (1996)	Where is science going?	35
Godin and Gingras (2000)	The place of universities in the system of knowledge production	23
Hemlin and Rasmussen (2006)	The shift in academic quality control	0
Rip (2002b)	Science for the 21st century	3
Albert (2003)	Universities and the market economy: The differential impact on knowledge production in sociology and economics	11
Shinn (2002)	The Triple Helix and new production of knowledge: Prepackaged thinking on science and technology	19
Rip (2000)	Fashions, lock-ins and the heterogeneity of knowledge production	5
Etzkowitz and Leydesdorff (2000)	The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations	175
Jansen (2002)	Mode 2 knowledge and institutional life: Taking Gibbons on a walk through a South African University	4
Jacob (2000)	'Mode 2' in context: the contract researcher, the university and the knowledge society	10
Pestre (2003)	Regimes of knowledge production in society: Towards a more political and social reading	7

[a] Scopus search, April 27, 2007.

found. As one can expect, journals in the area of science, technology and innovation studies are dominant, with a light emphasis on journals that are policy-oriented. Some exceptions in the higher rank deal with management ('British Journal of Management'), organisation studies ('Organisation'), and with policy and planning ('Futures').

A closer look at the corpus that is represented in Figs. 1 and 2 reveals that NPK's citations can be roughly divided into two sets. The first set of papers (we estimate about 80%) refers to NPK in the introduction or conclusion section, treating it as an accepted account of the current transformations. In these cases, the notion of Mode 2 serves to sketch the background for the research that is reported. It helps either to design a theoretical framework from which research questions are formulated or to discuss the implications of the findings. For example, Starkey and Madan (2001) use the Mode 2 notion as a theoretical framework to discuss current developments in management studies. Lee and Bozeman (2005) refer to the rise of Mode 2 in order to emphasize the importance of research collaborations. Lenhard et al. (2006) cite NPK to sketch the background of their discussion about the future of transdisciplinarity.[14] The content of these articles varies widely, but they have in common that they refer to NPK in an approving manner, without questioning the validity of its claims.

The second set (roughly 20%), however, does not take the legitimacy of the Mode 2 concept for granted, but puts its claims to the test. Papers belonging to this category generally dedicate more text to the issue of Mode 2. They do not cite NPK 'by accident', but use it as an essential theoretical starting point. The following section addresses a number of papers that belong to this second set.

A Scopus citation search[15] yielded a list of all scientific articles with a reference to NPK. Based on source title and article title, a subset of all papers that have been cited 20 times or more was selected for detailed study. This subset constituted the starting point of the literature study. Other papers and book chapters taken into account were all found by tracing references of this subset. In this way, the most important[16] contributions to the Mode 2 debate should be included (see Table 5).

[14] Although the authors do no criticize Gibbons et al., their discussion of transdisciplinarity in fact contradicts NPK's message. Their plea for 'late integration' rather than 'early integration' amounts to a preference for Mode 1 above Mode 2 knowledge production. The integration of disciplines early in the research project is the central characteristic of NPK's concept of transdisciplinarity.

[15] Search entry: REF(gibbons AND "new production of knowledge").

[16] In this context, two conditions for 'importance' can be distinguished: articles that give extensive reactions to NPK and that have influenced other scholars (to be measured by the number of citations). Note that our focus is on the debate directly linked to the Mode 2 concept. Literature about the changes addressed in NPK in fact is much broader, as not all research dealing with these developments necessarily cites NPK. We do not aim to cover all literature dealing with changes in contemporary science systems, but only papers explicitly reacting to the Mode 2 concept.

Table 6
Reactions to the individual attributes of Mode 2

Mode 2 attributes	Godin	Weingart	Hicks and Katz	Godin and Gingras	Hemlin and Rasmussen
Context of application	–	–	+/–		
Transdisciplinary	–	–	+		
Heterogeneity	–		+/–	+/–	
Reflexivity/social accountability		–			
Novel quality control	–	–			+

5. The main objections to the Mode 2 notion

The criticism of the claims of NPK found in scientific literature is very diverse. We have identified 7 recurring objections, which will be subsequently presented. In our evaluative discussion (Sections 5.8 and 6), we clustered them into three categories: NPK's descriptive or empirical validity (Sections 5.1–5.3), its theoretical and conceptual strength (Sections 5.4 and 5.5), and its political value (Sections 5.6 and 5.7). The first type of objection is the most common, but the other two appear regularly as well.

In the following, we will discuss the main criticisms to NPK. In some cases we regard it appropriate to comment on the validity of the objections posed. Is the objection indeed a serious problem to NPK? To our mind, this depends on correct citation of NPK, available empirical evidence and convincing arguments.

5.1. The descriptive validity of the various attributes of Mode 2

Table 6 lists the authors that comment on the five Mode 2 attributes, indicating the nature of their comments (positive or negative).

5.1.1. Context of application

The assertion that research is increasingly conducted in the context of application receives relatively little protest. Weingart (1997) argues that the 'context of application' would lack stability, which means that it will always remain dependent on disciplinary practices. However, this does not contradict the Mode 2 theory as Gibbons and his co-authors also expect Mode 1 science to remain present.

According to Gibbons et al. Mode 2 knowledge is produced in contexts of application, going beyond the distinction between basic and applied research. Godin (1998) argues, however, that this distinction (which would disappear in Mode 2) in fact has never existed. Fundamental research has always been inspired by more applied knowledge and applied research has always shown interest in fundamental understanding of the relevant phenomena. This observation, however, does not imply that basic and applied research have never been separate domains. Godin's argument does not affect NPK's claim that the interactions between basic and applied research are intensifying.

Hicks and Katz (1996) test the claim that the locus of knowledge production shifts to the context of application Their bibliometric analysis, however, does not succeed to either confirm or reject this claim.

In conclusion, the 'context of application' remains a complicated concept and there is a lack of clarity with regard to the difference with 'applied' science. A possible solution for this problem can be found in typology of research modes of Stokes (1997). He breaks open the classic dichotomy of basic and applied research resulting in a quadrant-model, which treats the quest for fundamental understanding and the considerations of use as distinct variables (see Fig. 3). In this framework, 'considerations of use' corresponds to 'context of application' and still leaves room for different degrees of being inspired by the quest for fundamental understanding.

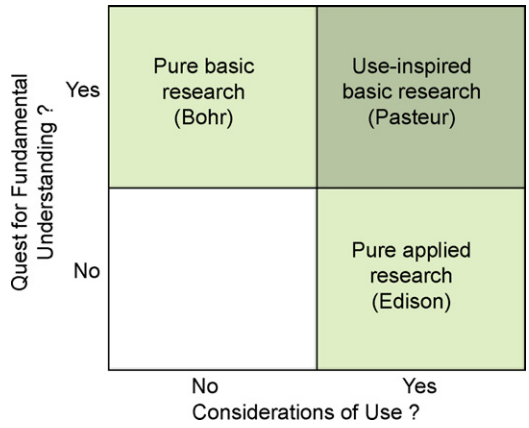

Fig. 3. Stokes' model of scientific research (Stokes, 1997).

5.1.2. Transdisciplinarity

The claim that science becomes increasingly transdisciplinary receives mixed reactions. The discussion of this topic is complicated by the lack of universal definitions of inter- and transdisciplinary research.

Godin (1998) criticises the dichotomy between disciplinary research and interdisciplinary research. According to him, the development of disciplines with specialisations and hybrid formations is typical of any scientific practice. Knowledge production never occurs in isolation; it always involves the employment of elements from other disciplines. Disciplines might acquire some degree of autonomy, but Godin assumes the same could happen to 'transdisciplinary' research. This argument would hold for interdisciplinary research. However, transdisciplinarity as proposed by Gibbons et al. implies more than only the cooperation of different disciplines. Additional conditions include the co-evolution of a common guiding framework and the diffusion of results during the research process. The assertion that this type of knowledge production is currently gaining importance is, in our mind, not sensitive to the criticism just described.

Weingart (1997) shares Godin's concern that the recombination of disciplines is not a new phenomenon. As defined in NPK, transdisciplinarity involves more than that, but according to Weingart, what the differences are 'remains vague and ambiguous' (p. 596). A more serious problem raised by Weingart is the difference between the level of program funding and the actual research. Research programs may formulate interdisciplinary or even transdisciplinary problems, but the research carried out under their headings is often of a disciplinary or multi-disciplinary kind.

Hicks and Katz (1996) observe a growth in 'transdisciplinary' journals (although disciplinary research still accounts for the bulk of scientific output). However, they employ this term in a different sense than Gibbons et al. According to Hicks and Katz, a journal counts as transdisciplinary when it cannot be classified as belonging to a single field or discipline. They do not take into account the epistemological and methodological dimensions of the definition of transdisciplinarity as used in NPK. As a result, the selection made by Hicks and Katz includes journals which Gibbons and his co-authors would call 'multi-disciplinary' journals. Their outcomes do prove that interactions between the various disciplines are increasing, but they cannot provide insight into the qualitative nature of these interactions and do not imply that they are 'transdisciplinary' in NPK's sense.

5.1.3. Heterogeneity

Most scholars seem to agree that the heterogeneity of knowledge production is increasing, but they disagree about the extent.

In a bibiliometrical study, Godin and Gingras (2000) show that the share of academic publications that include non-university contributions is increasing, in accordance with the Mode 2 claim of 'organisational diversity'. In spite of this diversification, however, the presence of universities in scientific papers is not diminishing at all. In Canada the share of papers including a university address has increased from 75% to 82% in the period 1980–1995. From this study it can be concluded that intersectoral collaboration is growing, but universities remain at the centre of knowledge production.

Weingart (1997), on the contrary, argues that the role of think-tanks and consulting firms is negligible in terms of manpower and budgets. This will probably vary for different disciplines; in management research, for instance, they are prominent (Huff, 2000). Weingart's remark that they remain dependent on academic research does not contradict the NPK claims.

In their bibliometric analysis, Hicks and Katz (1996) show that an increasing number of organisations house authors of journal articles. Between 1983 and 1991, the number of organisations in the UK participating in scientific publishing has increased in all sectors they studied (hospitals, industry, non-profit, universities, government and polytechnics), except for research councils.[17] However, within the various sectors, Hicks and Katz do not discern a uniform trend toward dispersion of the publication activity. Several sectors (e.g. industry, and hospital) even have become more concentrated. For this reason, their observation cannot be seen as an indicator for the increasing heterogeneity of scientific knowledge production.

5.1.4. Reflexivity/social accountability

Reflexivity and social accountability receives less attention in the criticisms of the Mode 2 concept. Weingart, for instance, regards social accountability to be mainly applicable to policy-relevant knowledge production. In these disciplines he agrees that an institutionalisation of reflexive mechanisms is discernable. Yet, in areas of knowledge lacking an immediate connection

[17] This observation may seem to contradict the findings of Godin and Gingras but does not necessarily imply a difference between Canada and the United Kingdom. The co-existence of the findings of the two studies can be explained by assuming that the share of papers with authors from several sectors has increased, or even more general, that the average number of authors on each paper has increased.

to social values and subjective risk perception ('high-energy physics, astronomy, and paleontology', p. 603), he denies that there is either a need for or a perceivable rise of reflexivity. This assertion is not supported by empirical evidence, however. The issue of reflexivity seems to deserve further investigation.

5.1.5. Quality control

The novel types of quality control probably constitute the most controversial attribute of Mode 2 knowledge production.

In agreement with NPK, for instance, Hemlin and Rasmussen (2006) argue that a shift is taking place from 'quality control' to 'quality monitoring'. Similar to Mode 1, however, the former remains important. The notion of quality monitoring shares some characteristics with Mode 2. It is subject to influences of industry and policy, it includes new 'peers' (users, consultants, lay persons) and a greater consideration of ethical and political issues. However, Hemlin and Rasmussen also add some elements that are not apparent in NPK: a shift from the assessment of individuals to organisations and a shift in time perspective from a retrospective judgment of research activities to an ongoing evaluation process during the research progression. The authors also relate the putative shift to organisational theory and argue for a further study on organisational learning in scientific institutes. However, they do not provide much empirical evidence for their claims, apart from a couple of illustrative examples.

Weingart and Godin are sceptical, however. Godin (1998) argues that the scientific criteria are still the most important. Referring to the personal experience of his readers, he states that the success of attracting research funds being dependent on extra-scientific criteria relating to social priorities, relevance and accountability 'is still a rhetoric rather than a fact' (p. 478). In our opinion this assertion does not do justice to the diversity of contemporary funding systems. Probably still a lot of funding allocation is still ruled by scientific considerations. Nevertheless, today a significant share of funding in many western countries[18] depends on societal priorities.

Similar to Godin, Weingart (1997) claims that in industrial research marketability and cost effectiveness have always been present, while in academic quality assessment they are still of minor importance. Even in policy-relevant science that is carried out in the context of application, the scientific standards assessed by 'peer review' remain the most significant measure of quality. However, in contrary to Weingart's suggestion on 'ample freedom for (. . .) researchers and long-term perspectives' (p. 603) at corporations such as IBM, multinationals today seem to be increasingly reluctant to engage in fundamental research programs. Due to globalised competition, industrial corporations have been forced to cut their budgets and have chosen to cut the costs of long-term research activities (De Wit et al., 2007).

In conclusion, the importance of additional quality criteria at universities is contested and remains a question open for empirical investigation.

5.2. Generality of Mode 2 notion

In addition to the detailed comments on the individual Mode 2 attributes, scholars point to limitations in the empirical validity of NPK's claims on a more generic level. In this respect, two major problems can be discerned: the generality of the argument *per se* and its historical perspective.

Gibbons et al. argue that the rise of Mode 2 affects the whole science system: 'Mode 2 is spreading across the entire landscape of science and technology' (NPK, p. 22). 'These changes appear in the natural and social sciences but also in the humanities' (NPK, p. 3).

Weingart (1997) contests these claims. He argues 'that the features of "Mode 2" (. . .) are limited to a fairly small sector of the entire science system' (p. 608). He claims that some Mode 2 attributes (context of application, transdisciplinarity) make sense only for science which is close to policy-making such as environmental research. The subset of academic research from which he believes Gibbons et al. draw their evidence, represents only a fraction of the entire science and technology system. Features like 'uncertainty of knowledge, complexity of subject matter, policy orientation and value-ladenness' (p. 600), which characterise the sector of technology assessment, risk research, and environmental and climate research, cannot be generalised. Therefore, Weingart sees no reason to believe Mode 2 will extend to all other areas of science.

Godin (1998) rejects the generality of NPK's approach, too. In particular, he argues that 'the social sciences, as well as the humanities, have always been of Mode 2, much more than has been the case for the natural and physical sciences' (p. 472).

Albert (2003), however, has shown that there is no observable trend towards Mode 2 in the sociology and

[18] For instance the European Framework Programmes and national innovation policy instruments. Examples in the Netherlands are 'Technologiestichting STW', 'Technologische Topinstituten' and 'Innovatiegerichte Onderzoeksprogramma's'.

economics departments of two Canadian universities. Based on interviews with scientists and a study of their publications, he states that there is no tendency towards problem-oriented research, but rather a predominance of Mode 1 knowledge production. Albert concludes that his findings demonstrate that academic research cannot be seen as a homologous unit. He argues that one should take into account the heterogeneity of scientific disciplines and of the various research 'regimes'.

Critics also mention the neglect of national contexts. Shinn (2002) claims NPK fails to 'recognise that the university, business and government all function in a national setting' (p. 610). He argues that scientific disciplines and specialties operate differently in different national institutions. In spite of current globalisation, the national component of the organisation and work of science is still apparent. Referring to the literature on national systems of innovation, Shinn states that, even in Europe, national science policies are still of great importance.

The claim of NPK of a general move to Mode 2, therefore, is denied by several authors on different and sometimes contradicting grounds. This implies in any case that the specificity of disciplinary developments needs be taken into account much stronger.

5.3. The long-term historical perspective

NPK's second generic limitation indicated in literature concerns its historical perspective. Referring to historical studies of sciences, several scholars (Rip, 2000; Etzkowitz and Leydesdorff, 2000) claim that at least some of the attributes of Mode 2 knowledge production have always been present in modern science.

Rip (2002b) rejects the view of Mode 1 as the original type of research. We should rather see it as historically located: it emerged during the course of the19th Century and became locked in during the 1950s and 1960s. Features of Mode 2 such as heterogeneity and transdisciplinarity are not new; they were already present in the 'Renaissance melting pot' (Rip, 2000) before the birth of modern science.

Etzkowitz and Leydesdorff (2000) also contest the newness of Mode 2 and use similar arguments. Referring to historical studies of science they claim that it is not Mode 1 but Mode 2 which is the original format of science, as, in the 17th Century, research focused on practical problems. 'Mode 2 represents the material base of science, how it actually operates. Mode 1 is a construct, built upon that base in order to justify autonomy for science, especially in an earlier era when it was still a fragile institution and needed all the help it could get' (p. 116).

Similarly, Pestre (2003) argues that elements of Mode 2 have always existed in modern science. Knowledge producers have never isolated themselves in an ivory tower, but have always paid attention to the interests of states and economic elites relating to science. Moreover, 'science has always directly contributed to, and has been a major resource for, changes in social ideologies' (p. 250).

5.4. The coherence of the concept

The Mode 2-authors describes Mode 2 as a stable entity, with a specified set of characteristics. This implies that the notion of Mode 2 is coherent in the sense that the various attributes mutually correlate. 'These attributes, while not present in every instance of Mode 2, do when they appear together have a coherence which gives recognisable cognitive and organisational stability to the mode of knowledge production', Gibbons et al. declare (NPK, p. 8). Critics seriously question this assumption, and the criticisms discussed above illustrate this. If the evidence for the diverse attributes of Mode 2 varies, and some receive more assent than others, one can wonder about their mutual relations. Possibly the claim of the NPK authors about the rise of Mode 2 should be divided into five different claims about five distinct trends in contemporary science.

According to Rip (2002b), the separate features that Gibbons et al. describe 'are clearly visible, but one might question their overall thesis that these add up to a new mode of knowledge production' (pp. 104–105). He doubts whether the features together have enough stability to make it appropriate to speak of a new research mode.

Godin (1998) confirms two of those claims, but he rejects the other three. He agrees that the heterogeneity of the science system has increased and that researchers are more socially accountable. But in his view both the 'context of application' and 'transdisciplinarity' has always existed, while novel criteria of quality control are not yet apparent. Similarly, Weingart (1997) considers all attributes to be present in policy-relevant science, except for novel quality criteria.

5.5. Theoretical underpinning

Shinn (2002) discusses a second conceptual problem. He is concerned about the lack of theoretical underpinning of NPK's sociological framework. In Shinn's reading, 'anti-differentiationism' is the central feature

of NPK's approach, as it blurs the boundaries between academic, technical, industrial, political and sociological institutions. However, this central idea 'is never buttressed with sociological theory, concepts or models' but it 'stands as a free-floating, unintegrated component' (p. 604). NPK does not account for 'how differentiations have operated in the past, how and why they would have eroded, and what their putative demise implies for sociological theory' (p. 611).

This criticism is not completely fair. The fact that NPK does not talk about the past indeed is a severe limitation that calls for further study. However, although its treatment of the mechanisms may not be sociologically sound, it does provide an account of the why and how of the erosion of differentiations. It refers to causal forces in the supply and in the need of knowledge and it offers an explanation of the putatively increasing interactions across disciplinary and institutional boundaries. Explicit relations with sociological theory are indeed absent in NPK, but these receive some attention in the follow-up book *Re-thinking Science*.

5.6. Mode 2: wishful thinking?

Several authors complain about the uncritical blend of descriptive and normative content in NPK. According to Godin (1998), the talk of Mode 2 is more a political ideology than a descriptive theory. He associates the message with a 'polarized rhetoric', which 'denounces many of the characteristics of contemporary research and training in the name of social and political *desiderata* which are themselves in exact opposition to characteristics of traditional academic research' (p. 479). The lack of empirical foundations makes this a dangerous situation from a policy standpoint as it can easily raise the impression that the current research system *needs* to be replaced. Godin warns that some readers of NPK may conclude that the old system and the old academics are wrong and that a new type of research would be better than traditional academic research.

The comments made by Shinn (2002) are similar: 'Instead of theory or data, the New Production of Knowledge – both book and concept – seems tinged with political commitment' (p. 604). Shinn perceives the authors as being in favour of a new cognitive and social order. In his reading, they aim to support Mode 2 by persuading others to believe in its importance and desirability.

This relates to what Weingart (1997) calls 'performative discourse'. He also has the impression that the idea of Mode 2 is part of a normative program rather than an empirical analysis (p. 608), but in this remark he mistakenly fails to distinguish between Mode 2 and post-normal science. In fact, the latter indeed contains strong normative elements, but – as we have argued in Section 4 – this is exactly the main difference from the former.

Some commentators have indeed treated NPK as a prescriptive rather than a descriptive theory. For instance, the criticism uttered by Jansen (2002) and Jacob (2000) is more concerned with the problems of bringing Mode 2 into practice than with the question whether the change is actually taking place. In contrast to the previous critics, however, these do not contest the fact that NPK may bear a normative dimension, but question the validity of the normative content itself.

5.7. Lack of future outlook

A minor comment to be mentioned here is expressed by Weingart (1997), who accuses Gibbons et al. of not being clear with regard to the persistence of Mode 1 knowledge production (p. 593). NPK indeed is somewhat ambivalent in its future outlook. On the one hand, the authors acknowledge that the disciplinary forms of cognitive and social organisation continue to be prerequisite of identity, as happens during education and training. On the other hand, they expect that eventually 'Mode 1 will become incorporated within the larger system which we have called Mode 2' (p. 154), but this statement does not receive any explication. What Gibbons et al. exactly expect to remain of Mode 1 research, therefore, remains vague.

5.8. Concluding remarks

Clearly, the empirical validity of the Mode 2 claims is limited. On a generic level, critics convincingly indicate two major problems. First, the NPK authors disregard the diversity of science and second, their historical view is mistaken. Moreover, some of the Mode 2 attributes are heavily disputed. In particular empirical evidence to show the rise of reflexivity, transdisciplinarity, and new modes of quality control is lacking.

Concerning NPK's conceptual strength, one can argue that more links to sociological theory are required. We consider the problem of a lack of coherence more serious. Given the fact that the different attributes of Mode 2 receive assent to varying degrees, there seems no compelling reason to tie them together under a common heading. Whether Mode 2 has 'recognisable cognitive and organisational stability' is highly questionable.

In our opinion, the comments regarding the normative message of NPK do some injustice the content of

the book.[19] A careful reading reveals that the authors do not have explicit normative intentions. On the first page, Gibbons et al. already mention that their intentions are descriptive rather than normative: 'No judgement is made as to the value of these trends – that is, whether they are good and to be encouraged, or bad and resisted . . .'. The remainder of this sentence, however, can explain some of the confusion: '. . . – but it does appear that they occur most frequently in those areas which currently define the frontier and among those who are regarded as leaders in their various fields.' Strictly speaking, this sentence does not qualify Mode 2 as better than Mode 1, but it does hint in this direction. So there is some rhetoric, and as rhetorics about science can lead to social reality (Van Lente and Rip, 1998), the critics have right to complain. This means, thus, that the NPK authors could have been a bit more careful in distancing themselves from normative claims, that is, if that was their intention.[20] In addition, more clarity with regard to the future of Mode 1 knowledge production is desirable.

6. Towards a research agenda

Our comparison with alternative diagnoses of the dynamics of contemporary science systems shows the particularly wide scope of the concept of Mode 2 knowledge production. The diagnosis expressed in NPK (Gibbons et al., 1994) includes statements about changes on the cognitive, organisational and the societal level. Whatever one may think of the adequacy of its analysis, this must be regarded as an accomplishment. Thanks to its breadth, NPK has created a forum to discuss a wide range of putative trends.

There are certainly big differences in aims and scope between the various diagnoses that we have addressed in Section 4. An important difference is their balance between descriptive and normative content. While the 'post-normal' science literature shows a clear normative orientation, others primarily limit themselves to reporting observations. Another difference is between heterogeneous research programmes (such as Triple Helix and innovation systems) and well-defined analyses (such as NPK and Academic Capitalism).

However, as displayed in Table 3, the content of the various accounts show strong similarities. The claim that the content of scientific research agenda is currently changing recurs in all diagnoses: all address a turn towards more relevant research, research that (sooner or later) may lead to applications in the form of innovations or policy. Furthermore, all approaches point to more interactive relationships between science, industry and government. In conclusion, at least two characteristics of knowledge production that NPK claims to be undergoing change find strong resonance in the alternative diagnoses. In other words, there is some degree of consensus on these points.

The other characteristics that are addressed in the Mode 2 diagnosis are much more contested. The conviction that the shift towards more relevant knowledge production also involves a change in the research methods is hardly shared by other diagnoses. The same holds for the claims that the disciplinary map is undergoing profound changes and that there is a rise of novel modes of quality control. To conclude from this comparison then, that these three claims are wrong, would be too quick. It does point, however, to the need for empirical evidence for the putative changes.

The Mode 2 claims have received mixed reactions: hundreds of papers cite NPK affirmatively and policy makers use the arguments, but there is also serious criticism. An analysis of the receptions of NPK in the literature has yielded a list of seven objections, which we divided into three categories: the empirical validity, the conceptual strength, and the political value of NPK.

Empirical validity

1. There is a lack of empirical evidence for the rising importance of the attributes of Mode 2 (Godin, 1998; Weingart, 1997; Hicks and Katz, 1996).
2. The long-term historical perspective is incorrect: the view of Mode 1 as the original type of knowledge production is contested (Etzkowitz and Leydesdorff, 2000; Rip, 2000; Pestre, 2003).
3. The universality of the claims is not justified: in contrast with the generality of NPK, scholars expect the dynamics to be different in different national contexts and in different scientific disciplines (Tuunainen, 2005; Albert, 2003; Shinn, 2002).

Conceptual strength

4. The necessary coherence of the concept is questionable: there might be a lot of multi-disciplinary, application-oriented research that does not show organisational diversity or novel types of quality control (Rip, 2002b).

[19] Neither Godin, Shinn nor Weingart support their objections with citations from the book.

[20] Note, however, that even when the authors did not have any normative ambitions, the notion of Mode 2 could be taken up by others as a direction to follow. Texts have a life on their own, beyond the reach of authors, and may lead to self-propelling dynamics.

5. The claims lack a theoretical underpinning and references to sociological theory (Shinn, 2002).

Political value

6. The authors seem to implicitly support the observed trends (Shinn, 2002; Godin, 1998; Weingart, 1997).
7. The book lacks a proper future outlook (Weingart, 1997).

These seven objections point to problems with the content as well as to problems with the form of NPK. The last three accusations, for instance, merely deal with the form that NPK's authors have chosen to present their message. In fact, they indicate that NPK does not always meet the standards that a scientific reader expects. Although many critics have treated it as a scientific theory, we rather suggest conceiving it as a manifesto,[21] in which the authors are more concerned with getting the message across than with building sociological theories or with carefully distinguishing their observations from their opinions.

However, this observation does not necessarily affect the validity of the descriptive and conceptual content of NPK. Even the most carelessly written manifesto can still point in the right direction. And, in the case of NPK, even if both complaints about its political value were correct, the concept of Mode 2 can still be useful: they affect the appreciation of NPK as a book, but not necessarily as a descriptive project. The same holds for objection 5. Yes, the lack of theoretical underpinning definitely constitutes a limitation of NPK. Nevertheless, it does not automatically have implications for the accuracy of its diagnosis. The fact that the Mode 2 concept was introduced without references to sociological theory does not imply that it cannot be related to theory. For the concept to be viable, however, it would be required to make these references later to avoid it becoming a theoretical 'island'.

The first 4 objections are more severe threats, especially the noted lack of coherence. Probably least threatening is the mistaken historical perspective, as this weakness can be corrected. In this respect, NPK is simply wrong, as it gives a too linear account of the historical dynamics of scientific practice. The suggestion that a traditional disciplinary mode of research is gradually giving way to a more interactive mode is not historically correct. For example, intimate interactions between science, invention and entrepreneurship were already important in the British industrial revolution (Freeman, 1997). Another example is the well-known steep increase in prestige of and available funding for basic research in disciplines such as chemistry and physics just after WWII provides another illustration. Inspired by the presidential advice by Bush (1945), western economies devoted large amounts of money to basic research, as conducted in universities.[22] This points to a strong increase – or even stronger: a 'lock-in' (Rip, 2000) – of Mode 1 at the expense of research with Mode 2 characteristics. We should not regard the changing modes of research as a one-dimensional development. Yes, it is conceivable that currently Mode 2 knowledge production is gaining importance in comparison with Mode 1. But to view of Mode 1 as the 'traditional' mode, and Mode 2 as the mode which introduces radically new characteristics to scientific practice, is incorrect. As has been suggested by Martin (2003), it may be more appropriate to speak of '*shifts in the balance* of Mode 1 and Mode 2 over time'. Research is needed, then, to specify the historical contingencies in the Mode 2 concept.

Problem 1 indicates a serious weakness of NPK: its lack of empirical evidence. We concluded that some claims are readily shared amongst alternative approaches. Of the five attributes of Mode 2, the 'context of application' and 'heterogeneity' receive assent both in the alternative diagnoses and in the direct reactions to NPK in scientific literature. For the other three (transdisciplinarity, reflexivity, and novel modes of quality control), however, neither confirming nor falsifying evidence is available. Further empirical research is required to decide whether NPK's claims about these points are appropriate.

The idea of transdisciplinarity is contested. In their reactions to NPK, several authors have addressed the issue of interdisciplinarity with theoretical comments (Godin, 1998) or empirical investigation (Hicks and Katz, 1996). However, the question of NPK's concept of transdisciplinarity is still open, because this includes additional features when compared to the concept of interdisciplinary research. Is the integration of disciplinary research elements as dynamic as Gibbons et al. argue? Numerous publications are available on the issue of transdisciplinarity (Pohl, 2005; Lenhard et al., 2006; Després et al., 2004), but these do not demonstrate the

[21] Note that the volume was originally written for an audience of policy makers rather than scientists.

[22] Ironically, the original report did emphasize the importance of interconnections between basic research and other parts of innovation processes, too. However, the report has generally been interpreted as a propaganda document advertising the importance of funding basic research and viewing applied research as 'second rate' (Shapley and Roy, 1985).

actual diffusion of this mode of research.[23] A question to address in an empirical study is how often the research outcomes are indeed communicated *during* the process of knowledge production.

The claim of NPK that reflexivity and social accountability tend to increase also merits more research. Slaughter and Leslie (1997), for instance, report that the ambition to enhance human welfare does not seem to be a first priority for scientific researchers. It remains to be seen to what extent the (potential) relevance of their work influences the choices researchers make about problem choice, research design and methods. This raises questions about the reflexivity reported by Gibbons et al. Can one discern an increased awareness of possible societal effects on the actual laboratory floor or is it only visible during interactions of researchers with their societal 'stakeholders'? Following Weingart's criticism (Weingart, 1997), one can wonder whether the trend of increased reflexivity is limited to policy-relevant sciences. There are many other fields that appear to have a stronger orientation towards commercial applications, but it is uncertain whether this makes the scientists involved more reflexive.

About the possible new modes of quality control the evidence is mixed. Some studies confirm the change (Hemlin and Rasmussen, 2006) but others (Godin, 1998; Weingart, 1997) reject it. In Swedish funding agencies for technical research, applicability has become an important criterion (Benner and Sandstrom, 2000), but the impact of this change is still uncertain.[24] After a comparison of funding practices in Sweden, the UK, Norway, Canada and the USA, Benner and Sandstrom conclude that, although new criteria such as utility and demands from 'customers' have been added, research councils preserve their core orientation: the collegial control and evaluation of research (Benner and Sandstrom, 2000). In the Netherlands, societal relevance is a structural element of the evaluation procedure of research group performances (VSNU/NWO/KNAW, 2003). However, it is unclear how important this specific criterion is and how it should be measured. Recently a number assessment tools have been developed and tested which address criteria for societal relevance. Examples are the 'societal quality research profile' (SQRP) in health research (Spaapen, 1995) and the 'research embedment and performance profile' (REPP) of agricultural sciences (Wamelink and Spaapen, 1999) and pharmaceutical research (Dijstelbloem et al., 2002). Novel modes of quality control also figure prominently in post-normal science literature. In this context, scholars have developed novel assessment systems which contain additional criteria in which non-academics have an important place (Van der Sluijs et al., 2005). It is unclear, however, on what scale this type of evaluations has been adopted to date. Quality control is a broad phenomenon that comprises diverse practices. In the NPK definition, quality control is the set of procedures and criteria that constitute the 'selection mechanism of problems, methods, people and results' (p. 32). This implies that it includes the assessment of research proposals applying for funding, manuscripts for publication in scientific journals, applications for conference contributions, applications for academic positions, and performances of research groups, programmes and projects. The question, then, is to what extent the novel criteria count in all these practices. It is conceivable that relevance or applicability is of more decisive importance as a criterion for attributing funding than it is for assessing candidates for academic positions. To put it simply, the issue at stake is: What rewards do researchers receive for conducting relevant research?

The disregard of the diversity of scientific practice constitutes another weakness in the Mode 2 diagnosis. NPK raises the impression of a dichotomy of two research modes. Contemporary philosophy and sociology of science, however, emphasise the heterogeneity of scientific practices (Stengers, 1997). Scientific research is carried out in an endless variety of ways. Modern science is a 'patchwork of very different activities, joined together under an umbrella label, SCIENCE' (Rip, 1997). It is improbable that they can all be classified as either Mode 1 or Mode 2 knowledge production. Probably it is much more valid to speak of Mode 1 and Mode 2 as the extremes of a continuum than of them as two mutually exclusive categories. In this way Mode 1 and Mode 2 are ideal types, rather than really existing phenomena[25] and this raises the possibility to position

[23] It must be noted that various definitions of transdisciplinarity are available, some in disagreement with NPK (Lawrence and Després, 2004). For some (Regeer and Bunders, 2003), the distinctive characteristic of transdisciplinary research is the inclusion of knowledge of non-scientists. Strictly speaking, however, this feature is more related to what Gibbons et al. call 'heterogeneity' than to their concept of transdisciplinarity.

[24] The new criteria employed by the funding agencies have aroused a debate including public letters signed by hundreds of university professors (Benner and Sandstrom, 2000).

[25] Muller 2000 as cited in Tuunainen (2005, p. 282): NPK overdichotomizes the evolution of science 'presenting it as two discrete ideal types that probably never exist in their pure form in the real world'.

existing practices of knowledge production on the continuum. It seems, however, that currently the knowledge is lacking for systematically positioning the different disciplines and subfields. Although several scholars argue against the generality of NPK, they only offer rough estimations of the differences between the disciplines.

An important lesson of our review is that in investigating changes in contemporary science systems, one should take into account the diversity of science. Due to the heterogeneity of scientific practice, the emergence of new modes of knowledge production will not have the same impact in the whole science system. Its importance may vary in national contexts (Shinn, 2002) and in scientific disciplines (Albert, 2003). Disciplinary characteristics that influence the shifts in balance between different modes of knowledge production need not be limited to the content of their inquiries but include features of social organisation (Whitley, 1984) too. Further research must show how visible the various Mode 2 attributes are in different disciplines and in different countries.

The problem of the lack of coherence is probably the largest threat to the Mode 2 concept. The disagreement about the five attributes of Mode 2 and their relative importance shows, in the end, that there is no compelling reason why they should operate together.[26] It seems more appropriate to regard the individual attributes as separate trends than as characteristics of a general development. Literature suggests that there may be a lot of research with one or more of the features, but that the amount of work assembling all five is marginal. For this reason, we propose to untie the wrapping around the Mode 2 concept. The individual trends that it addresses definitely deserve further research, but this should be conducted separately, ignoring the common heading of Mode 2.

6.1. To conclude

NPK has been successful as a manifesto. With its broad scope and evocative claims it has raised considerable attention in the area of science policy. It identifies a number of trends which still deserve further consideration. A review of alternative accounts and criticisms shows that the Mode 2 diagnosis of contemporary dynamics of scientific practice contains some adequate claims, and that some claims seem doubtful (the rise of transdisciplinarity, reflexivity and novel modes of quality control). Moreover, the generality of the arguments, the linear historical perspective and the necessary coherence of the original Mode 2 arguments are all problematical. The next step we suggest in re-thinking new knowledge production is addressing the following three empirical questions:

1. Do transdisciplinary research activities, with a dynamic integration of theoretical and practical components from various disciplines, constitute a substantial part of contemporary science systems?
2. Are university scientists in general increasingly reflexive, in the sense that they are aware of the potential societal effects of their research and take these into account in their choice of research objects, methods and approaches?
3. Do new criteria, relating to the societal relevance of research results, currently count significantly in all types of scientific quality control, not only in funding allocation, but also in retrospective evaluations of individuals, projects or organisations?

To scholars addressing these three questions we strongly recommend taking into account the heterogeneity of science, paying attention to the differences between scientific fields and national contexts.

The conclusion of this paper is that the viability of an aggregate Mode 2 claim that is constituted by five attributes is limited. Our review shows that it is time to disconnect the five major constitutive claims and to investigate them separately.

[26] This problem is also mentioned by Yearley (2005, p. 108).

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References

Albert, M., 2003. Universities and the market economy: the differential impact on knowledge production in sociology and economics. Higher Education 45 (2), 147–182.

Benner, M., Sandstrom, U., 2000. Institutionalizing the triple helix: research funding and norms in the academic system. Research Policy 29 (2), 291–301.

Böhme, G., Van den Daele, W., Hohlfeld, R., Krohn, W., Schäfer, W., 1983. Finalization in Science: The Social Orientation of Scientific Progress. Riedel, Dordrecht.

Böhme, G., Van den Daele, W., Krohn, W., 1973. Die Finalisierung der Wissenschaft. Zeitschrift für Soziologie 2 (2), 128–144.

Bush, V., 1945. Science—The Endless Frontier.

Carlsson, B., Stankiewicz, R., 1991. On the nature, function and composition of technological systems. Evolutionary Economics 1, 92–118.

Cooke, P., Gomez Uranga, M., Etxebarria, G., 1997. Regional innovation systems: institutional and organisational dimensions. Research Policy 26 (4/5), 475–491.

Craye, M., Funtowicz, S., 2005. A reflexive approach to dealing with uncertainties in environmental health risk science and policy. International Journal of Risk Assessment and Management 5 (2/3/4), 216–236.

De Wit, J., Dankbaar, B., Vissers, G., 2007. Open Innovation: the new way of knowledge transfer? Journal of Business Chemistry 4 (1), 11–19.

Després, C., Brais, N., Avellan, S., 2004. Collaborative planning for retrofitting suburbs: transdisciplinarity and intersubjectivity in action. Futures 36, 471–486.

Dijstelbloem, H., Spaapen, J., Wamelink, F., 2002. Knocking at the gatekeepers door: the distribution of accountability in pharmaceutical research. In: Society for Social Studies of Science (4S) Conference, 26th annual meeting Milwaukee, USA.

Edquist, C., 1997. Systems of Innovation: Technologies. Institutions and Organisations, Pinter publishers, New York/London.

Etzkowitz, H., 1998. The norms of entrepreneurial science: cognitive effects of the new university–industry linkages. Research Policy 27, 823–833.

Etzkowitz, H., 2003. Research groups as 'quasi-firms': the invention of the entrepreneurial university. Research Policy 32, 109–121.

Etzkowitz, H., Leydesdorff, L., 1998. The endless transition: A "triple helix" of university–industry–government relations. Minerva 36, 203–208.

Etzkowitz, H., Leydesdorff, L., 2000. The dynamics of innovation: from National Systems and "Mode 2" to a Triple Helix of university–industry–government relations. Research Policy 29 (2), 109–123.

Etzkowitz, H., Schuler Jnr, E., Gulbrandsen, M., 2000a. The evolution of the entrepreneurial university. In: Jacob, M., Hellström, T. (Eds.), The Future of Knowledge Production in the Academy. SRHE and Open University Press, Buckingham, pp. 40–60.

Etzkowitz, H., Webster, A., Gebhardt, C., Terra, B.R.C., 2000b. The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. Research Policy 29 (2), 313–330.

Fisher, D., Atkinson-Grosjean, J., House, D., 2001. Changes in academy/industry/state relations in Canada: the creation and development of the Networks of Excellence. Minerva 39 (3), 299–325.

Freeman, C., 1997. The diversity of national research systems. In: Barre, R.e.a. (Ed.), Science in Tommorow's Europe. Economica International, Paris, pp. 5–32.

Funtowicz, S., Ravetz, J., 1993. Science for the post-normal age. Futures 25, 735–755.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M., 1994. The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. SAGE, London.

Godin, B., 1998. Writing performative history: the new *new Atlantis*? Social Studies of Science 28 (3), 465–483.

Godin, B., Gingras, Y., 2000. The place of universities in the system of knowledge production. Research Policy 29 (2), 273–278.

Hemlin, S., Rasmussen, S.B., 2006. The shift in academic quality control. Science Technology and Human Values 31 (2), 173–198.

Hicks, D.M., Katz, J.S., 1996. Where is science going? Science Technology and Human Values 21 (4), 379–406.

Huff, A.S., 2000. Changes in organizational knowledge production. Academy of Management Review 25 (2), 288–293.

Irvine, J., Martin, B.R., 1984. Foresight in Science: Picking the Winners. Frances Pinter, London.

Jacob, M., 2000. 'Mode 2' in context: the contract researcher, the university and the knowledge society. In: Jacob, M., Hellström, T. (Eds.), The Future of Knowledge Production in the Academy. SRHE and Open University Press, Buckingham, pp. 11–27.

Jansen, J.D., 2002. Mode 2 knowledge and institutional life: Taking Gibbons on a walk through a South African University. Higher Education 43 (4), 507–521.

Kaufmann, A., Todtling, F., 2001. Science-industry interaction in the process of innovation: the importance of boundary-crossing between systems. Research Policy 30 (5), 791–804.

Kleinman, D.L., Vallas, S.P., 2001. Science, capitalism, and the rise of the "knowledge worker": The changing structure of knowledge production in the United States. Theory and Society 30 (4), 451–492.

Kloprogge, P., van der Sluijs, J.P., 2006. The inclusion of stakeholder knowledge and perspectives in integrated assessment of climate change. Climate Change 75, 359–389.

Lawrence, R.J., Després, C., 2004. Futures of transdisciplinarity. Futures 36, 397–405.

Lee, S., Bozeman, B., 2005. The impact of research collaboration on scientific productivity. Social Studies of Science 35 (5), 673–702.

Lenhard, J., Lücking, H., Schwechheimer, H., 2006. Expert knowledge, Mode-2 and scientific disciplines: two contrasting views. Science and Public Policy 33 (5), 341–350.

Leydesdorff, L., Meyer, M., 2006. Triple Helix indicators of knowledge-based innovation systems: introduction to the special issue. Research Policy 35 (10), 1441–1449.

Martin, B.R., 2003. The changing social contract for science and the evolution of the university. In: Guena, A., Salter, A., Steinmueller, W.E. (Eds.), Science and Innovation: Rethinking the Rationales for Funding and Governance. Edward Elgar, Cheltenham, pp. 7–29.

Meeus, M., Oerlemans, L.A.G., Hage, J., 2004. Industry-public knowledge infrastructure interaction: intra- and inter-organizational explanations of interactive learning. Industry and Innovation 11 (4), 327–352.

Meyer-Krahmer, F., Schmoch, U., 1998. Science-based technologies: university–industry interactions in four fields. Research Policy 27 (8), 835–851.

Nowotny, H., Scott, P., Gibbons, M., 2001. Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty. Polity Press, Cambridge.

Pestre, D., 2003. Regimes of knowledge production in society: towards a more political and social reading. Minerva 41, 245–261.

Pohl, C., 2005. Transdisciplinary collaboration in environmental research. Futures 37, 1159–1178.

Regeer, B.J., Bunders, J.F.G., 2003. The epistemology of transdisciplinary research: from knowledge integration to communities of practice. Interdisciplinary Environmental Review 5 (2), 98–118.

Rip, A., 1989. In: Korthals, M. (Ed.), Sturing en Stuurbaarheid van de Wetenschappen. Het Model van de Starnbergers. Boom/Open Universiteit, Meppel/Heerlen, Wetenschapsleer, pp. 187–206.

Rip, A., 1997. A cognitive approach to relevance of science. Social Science Information 36 (4), 615–640.

Rip, A., 2000. Fashions, lock-ins and the heterogeneity of knowledge production. In: Jacob, M., Hellström, T. (Eds.), The Future of Knowledge Production in the Academy. SRHE and Open University Press, Buckingham, pp. 28–39.

Rip, A., 2002a. Regional innovation systems and the advent of strategic science. Journal of Technology Transfer 27, 123–131.

Rip, A., 2002b. Science for the 21st century. In: Tindemans, P., Verrijn-Stuart, A., Visser, R. (Eds.), The Future of Science and the Humanities. Amsterdam University Press, Amsterdam, pp. 99–148.

Rip, A., 2004. Strategic research, post-modern universities and research training. Higher Education Policy 17 (2), 153–166.

Schäfer, W., 1983. Normative finalization. In: Böhme, G., Van den Daele, W., Hohlfeld, R., Krohn, W., Schäfer, W. (Eds.), Finalization in Science. D. Reidel, Dordrecht, pp. 207–231.

Shapley, D., Roy, R., 1985. Lost at the Frontier. ISI Press, Philadelphia.

Shinn, T., 2002. The triple helix and new production of knowledge: prepackaged thinking on science and technology. Social Studies of Science 32 (4), 599–614.

Slaughter, S., Leslie, L.L., 1997. Academic Capitalism: Politics, Policies, and the Entrepreneurial University. The John Hopkins University Press, Baltimore.

Smits, R., Kuhlmann, S., 2004. The rise of systemic instruments in innovation policy. International Journal of Foresight and Innovation Policy 1 (1/2), 4–32.

Spaapen, J., 1995. Research for Society: Towards a Method for the Assessment of Research in a Policy Context. University of Amsterdam, Amsterdam.

Starkey, K., Madan, P., 2001. Bridging the relevance gap: aligning stakeholders in the future of management research. British Journal of Management 12 (s1), s3–s26.

Stengers, I., 1997. Power and Invention: Situating Science. University of Minnesota Press, Minneapolis.

Stokes, D.E., 1997. Pasteur's Quadrant: Basic Science and Technological Innovation. Brookings Institution Press.

Tuunainen, J., 2005. Hybrid practices? Contributions to the debate on the mutation of science and university. Higher Education 50 (2), 275–298.

Van der Sluijs, J.P., Craye, M., Funtowicz, S., Kloprogge, P., Ravetz, J., Risbey, J., 2005. Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: the NUSAP system. Risk Analysis 25 (2), 481–492.

Van Lente, H., Rip, A., 1998. The rise of membrane technology: from rhetorics to social reality. Social Studies of Science 28 (2), 221–254.

VSNU/NWO/KNAW, 2003. Standard Evaluation Protocol 2003–2009 for Public Research Organisations.

Wamelink, F., Spaapen, J., 1999. De evaluatie van Universitair Onderzoek: Methodiek voor het Incorporeren van de Maatschappelijke waarde van Onderzoek (No. NRLO 99/12). Nationale Raad voor Landbouwkundig Onderzoek, Den Haag.

Weingart, P., 1997. From "Finalization" to "Mode 2": Old wine in new bottles? Social Science Information 36 (4), 591–613.

Whitley, R., 1984. The Intellectual and Social Organization of the Sciences. Clarendon Press, Oxford.

Yearley, S., 2005. Making Sense of Science: Understanding the Social Study of Science. Sage, London.

Ziman, J., 1994. Prometheus Bound: Science in a Dynamic Steady State. Cambridge University Press, Cambridge.

Ziman, J., 2000. Real Science: What it is, and What it Means. Cambridge University Press, Cambridge.

Ziman, J., 2003. Non-instrumental roles of science. Science and Engineering Ethics 9 (1), 17–27.