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In search of relevance: the changing contract between science and society

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This paper reflects on the relevance of academic science. Relevance plays a central role in what we define as the 'contract' between (academic) science and society. The manifestations of relevance in the daily practice of academic research can be studied using the credibility cycle. Together, the science–society contract and the credibility cycle enable a systematic analysis of relevance in scientific disciplines. This is illustrated with a case study of academic chemistry in The Netherlands. We conclude that science's search for relevance is not new, but that its meaning changes together with changing ideas about the potential benefits of scientific research.

THE RELEVANCE OF ACADEMIC research is a challenge for policy-makers and science studies. In various bodies of literature, it is claimed that the relationship between academic science and society is changing. Approaches like Post-Academic Science (Ziman, 2000), Mode 2 knowledge production (Gibbons *et al*, 1994) and the Triple Helix of university–government–industry relations (Leydesdorff and Meyer, 2006) all refer to an increasing orientation towards the production of 'relevant' knowledge (Hessels and van Lente, 2008). They observe an enhanced aspiration of academic research to contribute to the solution of societal problems and to support innovations and economic growth. This development expresses a profound change in the relationship between science, the state, the market and civil society. Some argue that the interactions between traditional institutions are intensifying (Etzkowitz and Leydesdorff, 2000), to such an extent that the boundaries have become blurred (Nowotny *et al*, 2001). Due to the limits on available resources, governments can no longer afford unconditional support for basic science (Ziman, 1994) and demand value for money, urging university scientists to demonstrate that they are effectively fulfilling their tasks. In the meanwhile, knowledge is increasingly seen as a valuable resource to ensure economic competitiveness, but global competition has forced industry to cut budgets on research with a long-term horizon (De Wit *et al*, 2007). They are now dependent on strategies like 'open innovation' (Chesbrough, 2003), in which universities are seen as a supplier of strategic knowledge.

It is a mistake to consider the stress on relevance as a completely new phenomenon (Rip, 1997). Since the emergence of modern science, expected benefits have played a role in research funding (Martin, 2003). In the course of the centuries, there have been several periods in which knowledge production was strongly connected to contexts of application (Pestre, 2003). Intimate interactions between science, invention and entrepreneurship were, for example, already important in the British industrial revolution (Freeman, 1997). Science is not an autarkic system: it has always depended on the provision of resources from the government or from other wealthy individuals or organizations so it may always have been in search of relevance. Nevertheless, the question remains when and how science can be relevant. Is research relevant when it yields knowledge about an urgent

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problem such as global warming? Is it relevant when societal stakeholders are involved? Is it relevant when industrial companies are willing to pay for it? Or is it relevant by definition, thanks to the cultural value of scientific activities? How is relevance defined and measured? When and how does the stress on relevance affect scientific practices?

Any attempt to address these questions should take into account that the notion of a 'singular science', one model of doing and organizing science, like Mode 1 knowledge production, is historically incorrect (Pickstone, 2007). The way science is conducted at universities and the way it is influenced by outside forces and how it reacts to societal developments has changed over time. In a broad-brush narrative, Mode 1 may have shown an increase — or even a 'lock-in' (Rip, 2000) — at the expense of research with Mode 2 features after World War II. The general conviction that basic research should be cherished like a 'diva' and separated from applied research and technology development, however, is specific for that time rather than a universal starting point for funding science and technology (Shapley and Roy, 1985). The issue of relevance clearly is a complicated one. It seems that no straightforward answer is possible to the above questions, and there is not even a common definition of societal relevance.

The aim of this paper is to develop a heuristic framework that can contribute to the understanding of the various meanings relevance may have and the role these play in academic research practices.[1] We will start with the basic notion that relevance refers to the expected value scientific research will have for society. What does this added value mean more precisely? We will investigate how definitions of what relevance entails have shifted and may continue to shift. In the next section we will discuss the notion that the science–society relationship can be conceived as a contract which defines the two parties, their privileges and obligations. We build on the existing literature by using the idea of a contract as a heuristic device, and enrich it by suggesting a basic composition of the contract between science and society. Next, we show how an analysis of the 'credibility cycle' (Latour and Woolgar, 1986) can help to explore the meaning and position of relevance in actual research practices. Together, our notions of the contract and the credibility cycle constitute a heuristic framework to study 'relevance' in specific disciplines. In the last section we will illustrate and substantiate the framework with a case study of chemistry in The Netherlands. Our first intention with developing and presenting this framework is to enhance the theoretical understanding of the relevance of science. Secondly, we hope to contribute to the process of gathering empirical insights into the changing relationship between academic science and society.

A contract between science and society

Academic science is not an isolated enterprise. To keep its position in society requires legitimacy. Practices in science have changed over the course of centuries, but science has always depended on societal support in the form of resources and legitimacy. In the development of the changing identities of science, different visions of science and connected legitimations can be discerned. Early modern science could be legitimatized by the claim that it was neutral, in the sense that it would not interfere with religious matters and it would not disturb the social order. In the 18th and 19th centuries, science's legitimacy became dependent on the visions of science as a 'model of rationality' and, later, as a 'reservoir of innovations' (Rip, 1982; van den Daele, 1978). The large-scale institutionalization of modern science in the 20th century has made these latter two legitimations even more important. The substantial investments that societies make in science today are only regarded as legitimate thanks to the great promises of modern science in terms of economic competitiveness, cultural enrichment or social progress. In other words, the 'relevance' of science has become crucial for its public support. Relevance can refer to practical applications of research outcomes, but also to other ways in which science may serve society, like the socio-cultural value of improved understanding of the world or the provision of a breeding ground for highly educated members of society.

Numerous writings about changing science systems and their concomitant legitimations employ the idea of a (tacit) contract. As Guston and Kenniston (1994: 5) argue the contract is a useful metaphor because:

- it 'implies two distinct parties, each with different interests, who come together to reach a formal agreement on some common goal';
- a contract is negotiated, 'arrived at through a series of exchanges in which each party tries to secure the most advantageous terms';
- a contract 'suggests the possibility of conflict – or at least disparity of interests'; and
- 'contracts can be renegotiated if conditions change for either party'.

Baldursson (1995), Elzinga (1997), Martin (2003), Jasanoff (2005) and Rip (2007) use the notion of a contract as a heuristic for studying the changing relationship between science and society. Although the approach, scope and size of their studies differ, their diagnoses are broadly similar. They start with the 'Endless frontier' contract, which refers to Vannevar Bush's report 'Science, the endless frontier' (Bush, 1945). It holds a clear distinction between basic research, which is self-regulated and should not be disturbed by outside steering and applied research which is subject to immediate questions about relevance and external steering. This division is institutionalized by two categories of funding agencies: basic research councils headed by scientists and sectoral funding agencies mandated by different ministries. For several reasons, the 'Endless frontier' contract is currently under attack. One of the factors is science's own success in sectors like healthcare and agriculture, which prompts a wish to co-determine its directions (Baldursson, 1995). Society demands 'strategic research' (Irvine and Martin, 1984; Rip, 2004) or 'targeted research', new categories of basic research that combine internal scientific quality with external societal relevance (Elzinga, 1997). Science–industry relationships intensify, science policy becomes strategic and funding arrangements have an increasing mission orientation (Ziman, 1994; Gibbons *et al*, 1994; Etzkowitz and Leydesdorff, 2000). A new contract seems to be emerging in which science's autonomy is increasingly constrained.

Other authors use the contract notion in a more normative way. Vavakova (1998), for instance, argues that to speak of a new contract is dangerous, because it tends to reduce the societal usefulness of science to purely economic value. In her reading, arguments for a new contract conceive research in a too utilitarian way. A new contract in which science is more closely linked to the private sector would threaten the availability of knowledge as a public good. In contrast, Gibbons (1999) argues that the prevailing contract which 'was set up to sustain the production of reliable knowledge', is no longer adequate. Given the changes Gibbons observes in science and society (increasing societal complexity, convergence of university and industrial research, rise of Mode 2), a new contract is needed to ensure the production of 'socially robust knowledge' of which the validity is determined by an extended group of experts, including lay 'experts'. This knowledge is less likely to be contested than knowledge which is merely 'reliable' in an exclusively scientific way. For Gibbons, entering into the new contract involves embracing the rise of Mode 2 and contextualized knowledge production: '(...) science must leave the ivory tower and enter the agora' (Gibbons, 1999: C84).

In this paper, we follow those scholars who use the contract as a heuristic but we enrich their approach by a more specific conception of the content of the contract. We continue the route taken by Guston (2000: 62) who defines 'the social contract for science' as follows: 'The political community agrees to provide resources to the scientific community and to allow the scientific community to retain its decision-making mechanisms and in return expects forthcoming but unspecified technological benefits'. That is, science can take care of its own integrity (by self-regulation) and is able to produce benefits for society (productivity).[2]

Because the contract concerns the delegation of a particular task, principal–agent theory (Braun, 2003; Van der Meulen, 1998; Guston, 2000) will be helpful. This approach assumes that the policy-makers ask scientists to do something for them that they cannot do themselves, because they lack the capabilities or the knowledge the scientists have. In this view of relationships between policy-makers and scientists, policy-makers have four fundamental problems:

- getting scientists to do what politics want (problem of responsiveness);
- being sure that they choose the best scientists (problem of adverse selection);
- being sure that scientists do their best to solve the problems and tasks delegated to them (moral hazard); and
- knowing what to do (decision-making and priority-setting problem) (Braun, 2003).

Science policy, in all its different, often complex, forms, can be understood as attempts to solve these four problems of delegation. Indeed, the evolution of science policy in the recent few decades can be described as a sequence of different models of delegation: blind delegation, delegation by incentives, austerity, contract delegation, and delegation to networks (Braun, 2003; Potì and Reale, 2007).

Principal–agent theory starts its analysis at the principal's side and tends to overemphasize the government's power in structuring the relationship and to ignore the perspective of the agent (Morris, 2003). Yet, scientists also shape the institutions governing the task delegation. Another limitation is that principal–agent theory has difficulties with dealing with multiple principals (Shove, 2003). The framework is useful to describe the relationship between science and the government, but it cannot easily accommodate the influence of other principals such as industry or nongovernmental organizations (NGOs). In order to overcome these limitations, we will also draw from other theories, in particular the credibility cycle (Latour and Woolgar, 1986; Rip, 1988) and resource dependency theory (Pfeffer and Salancik, 1978; Oliver, 1991).

To conclude, the notion of a contract is a powerful metaphor and it can serve as a heuristic in order to enhance our understanding of relevance and of the changing science–society relationship. The existing literature offers several useful starting points, but some further elaboration is necessary.

We use the notion of a contract as a heuristic to study the changing relationship between academic science and society

A framework to examine the relationship between academic science and society

A contract expresses the positions and the mutual relationships of the actors involved. In other words, it draws on and expresses a moral universe, as in the case of the relationship between a mother and her child, where norms and values involved in care and protection are involved. Although the norms exist and exert force, they are not fully recorded. So, explicit and implicit norms together shape a moral universe which indicates how mothers and children relate to each other. In the same vein, the contract between science and society expresses implicit and explicit agreements between science and societal parties.

The contract between academic science and society deals with the delegation of a particular task. Multiple principals ask scientific agents to do a job they cannot do themselves. From the scientists' perspective, the contract can be regarded in terms of resource dependence (Pfeffer and Salancik, 1978; Oliver, 1991; Leišytė *et al*, 2008). Scientists are dependent on their societal environment for their survival, so they cannot easily break the contract with society. If their environment develops new demands, scientists can choose between several strategies. They can shift their activities towards the new societal needs, in accordance with the 'compliance strategy'. Sometimes they manage, however, to pursue a 'symbolic compliance strategy', by creating an image which corresponds well with societal demands, without changing anything in the actual work. Alternatively, they can try to negotiate with their environment about the content of the contract, according to the 'manipulation strategy' (Leišytė *et al*, 2008).

In this paper we propose to use the notion of a contract as a heuristic to study the changing relationship between academic science and society. Just like the moral universe of the example above, this contract cannot be found at a particular place. Nevertheless, its history can be told using various data sources like the written utterances of different actors, actual policy measures, funding patterns and interviews with key actors. Assuming the existence of a contract can help to organize these data into a coherent history of relevance. To this end, we assume that the contract contains three main components. In our conception it addresses three basic questions: what is the nature of the delegated task, why is it delegated and how is it arranged? In other words, the contract arranges what science should do, why it should do this, and what are the appropriate conditions for science to fulfill its delegated task (see Figure 1). The answers to these questions, of course, are the result of negotiations between at least two parties. In the case of science and society there are more: neither science nor society can be seen as a single actor. Moreover, science is a subsystem of society rather than external to it. Thus, the contract is an agreement among all actors that have a stake in academic research, including: the researchers doing the actual work, university managers, policymakers and research councils facilitating it, and companies, NGOs, authorities and any other actors who are using the knowledge developed by science. The assumption of a contract does not imply that there is no place for disagreements. Of course, the parties involved have diverse interests. However, at each point in time, there are a number of rather fundamental notions which the actors do not call into question, instead, they refer to them as a shared vision.

The identity of science

Academic science is concerned with conducting research in order to produce relevant outcomes.

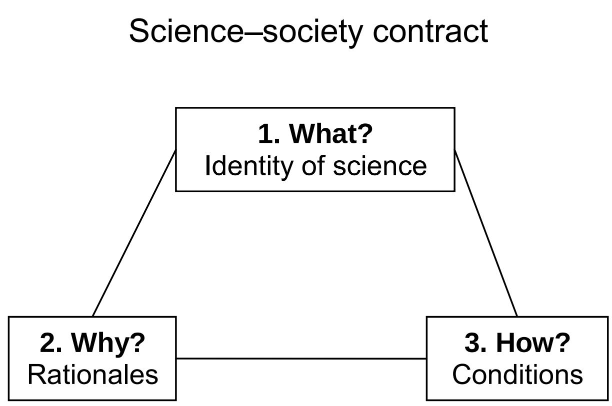

Figure 1. General composition of contract between academic science and society

Science's task is to produce knowledge and to deliver it in the form of communications (publications, presentations) or artefacts. More specifically, the contract can describe which type of research should be carried out. What is the balance between basic and applied research, or is science supposed to conduct strategic research (Irvine and Martin, 1984), or to work in Pasteur's quadrant (Stokes, 1997)? This question relates to the kind of knowledge science is expected to deliver, or in other words, what knowledge is considered 'relevant'. Societal actors may want science to offer expertise that contributes to the solution of complex policy issues, to deliver insights into metaphysical puzzles or to produce strategic knowledge which enhances its economic competitiveness. The contract can have (and, indeed, has had) various concepts of relevance and these can also be specified to varying degrees. However, one can probably assume that relevance has always had a place in the identity of science, as society will demand some sort of return for its investments.

Rationales for funding science

In the proposed conception, the contract also describes why academic science deserves support. Many different (combinations of) arguments are possible, but most relate to concepts of the societal relevance of science. The expected benefits of science can take various forms, such as 'new or improved weapons, more accurate nautical almanacs (based on improved astronomical observations), better medical care and agriculture, improved engines, new chemicals and materials, new energy sources, new electrical devices and so on' (Martin, 2003: 19). Without claiming completeness, we mention four generic rationales which are prominent in the science studies literature. One possibility is to regard science as a cultural good, if one believes that it has an intrinsic value or 'axiomatic relevance' (Spiegel-Rösing, 1980). Or academic research may be seen as inevitable to sustain a system of higher education (Martin, 2003). Third, one may fear that academic research is needed because the market will invest insufficiently in basic research (Guston and Kenniston, 1994). Finally, academic science yields knowledge of general interest (like expertise which can support governmental decision-making or strategic knowledge that may lead to medical innovations) (Gibbons, 1999; Funtowicz and Ravetz, 1993; Böhme *et al*, 1983).

Conditions

The third element of the contract we propose contains agreements about the conditions under which university researchers work. 'To create new knowledge, special procedures, norms, rewarding mechanisms, and institutionalisations are put into place characterising scientific activities and distinguishing them from other professional activities in society' (Braun, 2003: 310). Society delegates research to science by 'a set of specific grants and contracts, each with its own terms and conditions' (Guston and Kenniston, 1994: 8). For the government, the challenge is 'how to make sure that good and useful knowledge is produced, as well as how to assure that the investments in science do not go with unproductive pressures from the government to produce applicable knowledge' (Van der Meulen, 1998: 398), and the same goes for other stakeholders of science. Science's organization is attuned to its identity. A traditional feature of the way academic science is currently organized is the nested hierarchy of research groups in faculties. This may change, however, with the rise of inter-university 'centres of excellence' and other novel forms of organization (Rip, 2004). Another agreement concerns the way money is distributed to scientific researchers, in which intermediary organizations have a central role (Van der Meulen and Rip, 1998; Lepori *et al*, 2007). This is not the place for a complete description of all the agreements concerning science's organization. Here, we simply want to emphasize that, in principle, the features of the organization of science aim to facilitate the fulfilment of science's task. There can also be specific instruments ('organizational devices') which aim to enhance the quality and/or relevance of research, like earmarked funding (Potì and Reale, 2007; Benner and Sandstrom, 2000) and performance assessments (Van der Meulen and Rip, 2000; Geuna and Martin, 2003).[3]

As the descriptions of the three elements of the contract indicate, their precise contents can change and are subject to negotiation among all parties involved. We assume, however, that the general composition of the contract is of all times, as these three central questions are always at stake.

Credibility cycle

The next step in our investigation is to consider how 'relevance' manifests itself in the daily practice of academic research. Given the basic ingredients of the science–society contract (see Figure 2) it is now

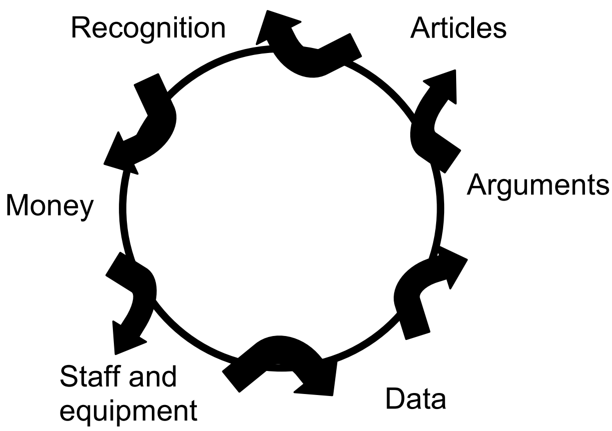

Figure 2. The credibility cycle, adapted from Latour and Woolgar (1986)

pertinent to ask how this may interfere in the way science operates. This undertaking can build on the sociology of science. A central finding in the sociology of science is that scientists are not primarily driven by financial incentives and rewards, but rather by a desire for recognition and reputation. In science, 'the need to acquire positive reputations from other scientists is a crucial factor controlling what tasks are carried out and how, and how they are evaluated' (Whitley, 2000: 25). Reputations play a central role in the organization of scientific work. Scientific activities are carried out to convince fellow researchers of the importance and significance of the results and hence to enhance one's own reputation. A scientist's reputation in his or her field is a key factor in acquiring jobs and resources. Thus, one's position within the employment organization (university) also depends on one's reputation.

The concept of the 'credibility cycle' (Latour and Woolgar, 1986) has been introduced to explain how struggles for reputation steer the behaviour of individual scientists or research groups. Similar to Whitley's notion of reputation, credibility refers to the ability 'actually to do science' (Latour and Woolgar,1986: 198). This notion is broader than only recognition or reward for scientific achievements. It is of a more generic nature and can take various forms such as money, data or articles. Thus, scientific behaviour can be described as a cycle of conversions of different types of credibility. Scientists invest time and money to acquire data that can support arguments. These are written down in articles, which may yield recognition from colleagues. Based on this, scientists may receive new funding, from which they buy new equipment (or hire staff) which will help to gather data again etc. Conceived in this way, the research process can be depicted as a cycle in which conversions take place between money, staff and equipment, data, arguments, papers, recognition etc. (see Figure 2). In this quasi-economic model, researchers are like investors of capital who spend credibility with the intention of earning it back after a complete cycle, with interest.[4]

It is important for our purposes to note that at each point in the cycle the scientific actor meets specific institutions which facilitate or constrain the conversions that are being made – a point not well elaborated in the original version by Latour and Woolgar. The scientist cannot make the conversions independently. In each step there are formal or informal structures which influence the transformation of one form of credibility in another. For example, peer review procedures govern the conversion of arguments into articles. The criteria used by peers to assess the quality of manuscripts determine what type of arguments can be converted into publications. In the next conversion, recognition is only awarded to articles which have been accepted in prestigious journals, or – increasingly – which are cited by other scholars. In a similar fashion, all other conversions in the cycle are also governed by institutions of various kinds, such as university organizations, funding bodies and quality assessments. The institutions determine the exchange rate, so to speak, of one form of credibility into the next. For the researcher, the institutional environment is instrumental in building credibility.

Two issues deserve attention here to clarify how we understand the credibility cycle. First, although scientific researchers are the main actors in this model, it does not deal with science alone. Knorr-Cetina (1982) has warned of the danger of internalism when using quasi-economic models of science such as the credibility cycle. One should not conceive scientists as if 'they were isolated in a self-contained, quasi-independent system' (Knorr-Cetina, 1982: 109). Scientists' activities go beyond the boundaries of their specialist community. Recognition is received from peers, but also from scientific colleagues in other disciplines. As an extreme example, Nobel prizes are usually awarded to research with an impact extending towards other scientific disciplines or even towards products or solutions in society. What is more, nonscientific actors play crucial roles in the acquisition of money. The availability of funding for particular scientific projects is a product of interactions between scientists, societal actors (in industry, government, or elsewhere), and often intermediary bodies like funding agencies. However, these interactions can be described in terms of the credibility cycle, if it is not applied in a narrow sense (Leišytė, 2007; Wouters, 1999; Elzinga, 1997; Rip, 1994). We follow Leišytė in assuming that credibility is achieved not only within a researcher's specialist community, but in 'several arenas that interact with each other, such as financial backers, the scientific community, regulatory authorities, and professional and consumer marketing' (Leišytė, 2007: 48).

Secondly, we assume that the precise composition of the credibility cycle can be subject to change. We consider it a valuable model for scientific practice. Its precise composition, however, is a historical contingency rather than a necessity. What conversions are part of the cycle, which ones are most important and what are the guiding norms and values may change over time? Although Latour and Woolgar (1986) have introduced the cycle as a timeless, generic model for scientific activities, several scholars have already shown that it is useful starting point for describing changes in the science system. Guston (2000), for instance, uses the credibility cycle to explain the relationship between scientists and the government in the USA during the period of the 'social contract for science', which he positions between 1945 and 1980. Packer and Webster (1996) argue that the cycle needs to be extended in order to accommodate patenting activities, which are of increasing importance for academic scientists. Rip (1994; 1988) shows that the credibility cycle can help to understand how the role of research councils has developed over the years. His analysis indicates the rise of a pressure for relevance and related criteria in the assessment of research proposals. As a result, scientists are now also involved in struggles for relevance and for legitimity, on top of struggles for facticity and for fundability (Rip, 1988). In this paper we focus on the struggle for relevance. We use the credibility cycle in a more specific way than Rip, in a step-by-step analysis.

As a model for scientific activity, the credibility cycle can be used for studying the changing relationship between science and society. The central question, then, is: how is relevance manifested in each conversion of credibility? Are there significant changes in the composition of the cycle?

A combined model

We have already explained how both the notion of a contract and the credibility cycle can help to understand what relevance is and how it figures in academic research practices. But how do these elements relate to each other?

The credibility cycle describes the activities of university researchers as individuals or as organized in groups or research institutes. In this way, it puts one actor in central focus. The conversions of the cycle may seem primarily to be processes that are internal to science, conducted by the scientists themselves. However, the institutions governing each step are co-constructed by society (to varying degrees). For instance, the possibilities of converting recognition into money depend on the formal structures of university funding and research councils. In turn, the criteria used in the selection of research projects to fund are strongly determined by notions of relevance as expressed in the science–society contract. Similarly, the production of scientific papers is, in the first place, ruled by peer review processes. But how scientists act is also strongly influenced by university policy and national quality evaluations. If the allocation of funding is increasingly based on the number of previous publications of the applicants, because this is conceived as an indicator of quality, this will stimulate scientists to develop strategies to increase their publication output (Weingart, 2005).

In the terminology of Rip (1988), scientific activity takes place at the level of 'scientific entrepreneurs mobilizing resources', but the intermediary level 'organized field of scientific institutions' also give shape to the credibility cycle. Some of the credibility conversions are ruled by institutions at the intermediary level, such as research councils or disciplinary associations. These institutions constrain the actions and interactions of scientists, but also enable them by providing legitimacy and opportunities. The science–society contract can be located on the macro-level of the 'general social context' (Rip, 1988) in the sense that it is of a general kind and all stakeholders of science take part in it.

The science–society contract constitutes a platform for all actors in the research system which provides them with arguments, legitimacy and other resources. The particular specification of 'relevance of science' in the operative contract precipitates into the intermediary-level organizations and therefore shapes the credibility cycle. The conditions which are generally believed to be needed for science to optimally fulfill its task are translated into institutions such as university organizations and research evaluations.

The science–society contract constitutes a platform for all actors in the research system which provides them with arguments, legitimacy and other resources

From the scientist's perspective, the conversions of the credibility cycle may appear as exchanges of different currencies. All forms of credibility constitute pools of resources that can be transformed into one another. The exchange rate of these conversions, however, is determined by the contract. For instance, the criteria ruling the selection of manuscripts for publication, the selection of candidates for academic positions, or the selection of research proposals for funding depend on the content of the contract between science and society. The agreements about the conditions probably have a direct influence on credibility conversions, while the identity of science and the rationales for public support will contribute indirectly to the institutions steering the conversions of credibility.

In their turn, developments in scientific practice also contribute to shifts in the content of the science–society contract. As actors refer to concepts of relevance in their daily work, they reinforce the contract. In giving credit to particular research contributions or in deciding how to spend money, scientists refer to shared views on what science is and what it should or should not contribute to society. For instance, technological expectations that go together with research outcomes influence ideas about potential benefits of a particular field for society (Van Lente, 1993; Van Lente and Rip, 1998). Scientific research yields insights both in problems to be solved (e.g. climate change) and in possible solutions (e.g. metal hydrides for hydrogen storage on board vehicles) (Bakker *et al*, 2008). These promises can give rise to dedicated research programmes, schools or institutes on the meso-level that subsequently influence the negotiations about the science–society contract. Expectations about how particular science and technology can solve societal problems shape concepts of the societal relevance of science in general, too. Particular expectations may deal with specific domains, but in the end the overall view on the value of science will be affected by the expectations in all fields together.

To conclude, the contract enables and constrains scientists and others in their activities. It expresses the agreements among all actors and determines the rules and regulations of the institutions which give shape to the credibility cycle. In this way, it makes particular conversions of credibility possible, but complicates others. There is no unidirectional causality between the contract and the various credibility cycles. The contract influences academic practice, and developments in practice, in their turn, influence the agreements in the contract. Because of these interactions, we believe that a study of the relevance of science requires analyzing the contract as well as scientific practice. We will now illustrate this with an empirical case study.

Struggles for relevance in academic chemistry

We now go one step further, and investigate how concepts of relevance and the struggles around it are visible in a case study. As a unit of analysis, the scientific discipline seems appropriate. In this section we narrow down the focus from science in general to a case study of academic chemistry in The Netherlands.[5] Obviously, the empirical outcomes of this case study do not represent science in general. The meaning of relevance can be different in each field of research. An interesting aspect of chemistry is the intensity which the relationships between universities and industry traditionally have. For this reason, one can expect the relevance of chemistry to be strongly connected with industrial applications and the relationship between science and society to be relatively stable. As such it seems a 'hard case' for studying changing notions of relevance and an interesting test for our framework. Given the heterogeneity of science, this case can obviously not be taken as representative of the whole science system. In some other fields, more radical transformations may occur, especially if considerations of economic or commercial relevance are traditionally absent. Our analysis starts with the post-World War II situation, previously referred to as the era of 'Science, the endless frontier'. First we will describe the changes in the identity, the rationales and the conditions that have regulated academic chemistry research in The Netherlands. Then we will address the changing credibility cycle.

Identity

In the first postwar decades, some professors have strong ties with chemical companies, but the main task of academic chemistry is to conduct basic research not directly aiming at industrial applications. The relevance of academic research is often defined in terms of a contribution to chemical industry, but more in terms of skillful and knowledgable research and development (R&D) staff than in terms of useful knowledge. Knowledge transfer to industry takes place through the people who move to industry after their (doctoral) graduation, by consultancy services and by industrially funded research assistants (Homburg, 2003). The usefulness of academic chemistry is not called into question, given the importance of chemical industry for the Dutch economy and the linear model-based belief that basic research will ultimately lead to innovation and economic growth. In the 1970s, when 'science policy' is introduced, the government demands academic research to more effectively address societal needs.[6] The minister of science policy emphasizes that chemistry should produce knowledge which is useful not only in chemical industry, but also in domains like agriculture and healthcare. In the 1980s, when innovation emerges as a central topic for policy-making, chemistry's relevance is broadened to also include delivering applicable knowledge. The main activity remains basic research, but this is justified merely as a necessary condition for the existence of good applicable research. During the 1990s the idea of 'strategic research' emerges which blurs the boundary between basic and applied research. Chemistry's task then becomes producing 'strategic knowledge' which combines aspects of basic and applied research. Strategic knowledge can be defined as fundamental insights in domains of high relevance for the economy or society (Irvine and Martin, 1984; Rip, 2004). The domain of 'sustainability', which gains importance since its introduction in 1987, becomes a major strategic field for chemistry.[7] This notion combines the aspirations to contribute to economical growth and, at the same, to solve environmental issues. The strategic identity of academic chemistry endures in the new millennium as it is compatible with the most recent innovation concepts, in which the university is seen as a supplier of basic knowledge which can be valorized by other actors in the innovation system.

Rationales

The most dominant rationales for funding academic chemistry of the 1950s and 1960s seem to be its necessity for the training of new R&D-workers and (less importantly) the cultural value of basic research (see Table 1). The chemical industry, with which academic chemistry has always had strong bonds (Homburg and Palm, 2004), has a strong interest in highly educated researchers. Although some university researchers also provide industry with technical advice, in the post-war period, industry tends to regard universities primarily as an educational system to supply a steady stream of highly skilled researchers (Homburg, 2003). The Dutch Research Council (SON), founded in 1956, provides support to basic chemical research with the training of young

Table 1. Overview of the changing contract for academic chemistry. + signs indicate that these elements complement existing elements rather than replacing them

Time period	Summary of identity	Most dominant rationales	Most important conditions
1950s and 1960s	Basic research	Education Cultural value	Autonomy Unconditional funding SON communities
1970s	+ Useful knowledge	+ Problem solving potential	+ Social accountability
1980s	Applicable knowledge	Technological innovation	+ Conditional funding + Application-oriented funding (STW, IOP, contract research) + Foresight + Scarcity of resources Reorganization of NWO
1990s	Strategic knowledge	+ Sustainable development	Further prioritization + Performance assessments
2000+	Strategic knowledge	+ Innovation system	+ Consortia (ACTS, TTI, BSIK) + EFPs

Notes: ACTS Advanced Chemical Technologies for Sustainability Program of NWO
BSIK Besluit Subsidies Investeringen Kennisinfrastructuur Programs
IOP Innovation Oriented Program
TTIs Technological Top Institutes (funded by the Ministry of Economic Affairs)
STW Technology Foundation

scientists and the stimulation of cooperation as its primary aims. In the 1970s, when governmental science policy is born, the need for chemical research is framed in more general terms, going beyond its value for chemical industry. In justifications for its public support the potential to contribute to problem-solving in other sectors gains visibility.[8] This broadening is a response to the negative image of the chemical sector, due to the rising awareness of environmental problems. The budget cuts on basic research in industry in the 1980s increase the importance of the rationale for supporting academic chemistry relating to its potential contribution to technological innovations.[9] Chemical industry not only desires to benefit from academic research in terms of educated staff, but also in terms of applications of the knowledge produced[10] (De Wit *et al*, 2007; Van Helvoort, 2005). In the 1990s the notion of sustainable development becomes increasingly significant in rationales for funding (chemical) research.[11] This umbrella concept connects several previous rationales because it refers to growth in economic and environmental dimensions[12] (Rip, 1997; van Lente and van Til, 2008). Around the turn of the century, the funding of university research is increasingly framed as support for the national innovation system. Maintaining a ‘healthy innovation system’ becomes a central goal of economic policy, which implies that universities deserve support thanks to their central position in this system. In this perspective, however, support for university researchers is accompanied by the expectation that they actively interact with other actors in the innovation system, and contribute to the process of ‘valorization’, by writing patents or by founding spin-off companies.

Conditions

During the 1950s and 1960s chemical scientists have a high degree of autonomy. The most important types of funding (university funding and SON funding) are distributed without any conditions attached, based on considerations of academic quality. Industry also pays for research assistants and consultancy services, but only to a minority of all professors (Homburg, 2003). In the 1970s scientists are increasingly held accountable for their work. Although they are not yet affected by formal policy measures, chemical researchers are under pressure to put more effort into explaining their research priorities to policy-makers and funding agencies. From 1980 onwards, however, a substantial change occurs in the funding of chemical science, due to two interrelated developments. First, faced with the need to restrict the growth of science funding (Ziman, 1994), the Ministry of Science, Culture and Education starts to supply part of the first money stream on a conditional base (Blume and Spaapen, 1988). Moreover, informed by foresight studies (Anon, 1980; 1982), an increasing share of the second money stream is dedicated to application oriented research.[13] Second, a growing part of all funding stems from industrial corporations[14] and the ministry of Economic Affairs starts to implement a number of innovation programmes in specific fields like carbohydrates and catalysis.[15] These developments continue in the 1990s. The reorganized research council (NWO) continues to broaden its mission beyond basic research and increasingly works with ‘priority programmes’ and ‘fields of attention’ that are chosen partly thanks to their societal relevance.[16] Another significant event in the 1990s is the institutionalization of performance evaluations. Governmental policy-makers, research councils and university managers who have become more selective in supporting particular activities, develop a need for transparency with regard to research outcomes. In 1996 the first nationwide quality assessment of chemical science is conducted (VSNU, 1996), the second in 2002 (VSNU, 2002). Due to the lack of a strict protocol, the evaluators can choose themselves to what extent they take into account considerations of societal relevance as for instance the economic value or technological applications of the produced knowledge (Van der Meulen, 2008). In practice, they generally ignore this type of criteria and focus strongly on traditional scientific norms.[17] After 2000 chemistry faces a further diversification of policy instruments. Thanks to their continued growth, the EFPs become a substantial source of income for academic chemists. Moreover, there is a rise of consortia-based funding, large sums of governmental money supplied to collaborative programs of university scientists which are monitored by (industrial) user committees and which explicitly aim at enhancing the interactions with industry.[18]

To summarize, there have always been bonds between academic chemistry and industry but the type of interaction has changed. The meaning of relevance has changed in the course of years. Initially education and cultural value ruled its definition; later serving society and the environment; in the 1980s innovation became dominant; since the 1990s specified in terms of sustainability. Related, the emphasis in the rationales for funding chemical research has shifted from its function to support higher education and its cultural value to the notion that basic research is needed to sustain the innovativeness of industry since global markets fail to stimulate private sector basic research. An additional rationale that has evolved over the years is the need of chemical expertise for governmental decision-making about the regulation of emissions. The conditions specified in the contract have become increasingly complex. Chemists receive less unconditional support. The Ministry of Science still provides a certain share of funding without specifying how it should be spent, but the degree of freedom in spending this 'basic funding' is also decreasing.[19] Moreover, for a fruitful career, scientists depend on the acquisition of additional funding, from NWO, EFPs or from private companies. Each of these sources has specified targets and requires from researchers to define *ex ante* the societal significance of the research they propose. Moreover, a couple of new devices are in place to stimulate the production of good and relevant knowledge: performance assessments and foresight activities.

Credibility cycle

Changes in the identity, rationale and conditions of academic chemistry will have an impact on scientific practice, which can be analysed in terms of the credibility cycle. The institutions around each conversion in the cycle are influenced by changes in the contract. Some conversions seem solely ruled by the scientific community, but in other cases external parties deliberately interfere. In our case study we followed a number of 'organizational devices' that have been designed to enhance a particular form of relevance of scientific research. In the case study, we identified five types of these devices:

- earmarked funding;
- foresight activities (e.g. Verkenningscommissies, Sectorraden);
- internal (scientific) procedures of quality control (peer review of scientific papers, selection of candidates for academic positions, citation practices);
- university management, (e.g. 'focus and mass' policy, promotion criteria); and
- performance assessments (visitations).

In the following we will discuss how these organizational devices interfere with particular credibility conversions (see Figure 3) and, thus, how 'relevance'

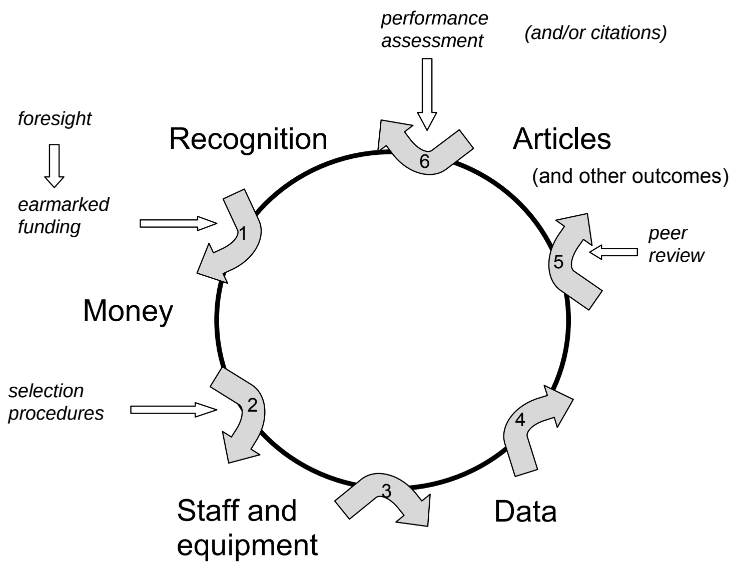

Figure 3. The credibility cycle, adapted from Latour and Woolgar (1986). Points at which organizational devices connect to the cycle are shown

has been expressed in the practices of Dutch academic chemistry research.

1. First, the rise of earmarked funding interferes with the conversion from recognition to money. The criteria connected to particular funds determine the possibilities for scientists to obtain money. In this way they co-shape the prevailing norms that govern this specific conversion. The availability of a number of strategic programmes for chemical research in The Netherlands implies that scientists who are recognized experts in particular fields (like catalysis or nano-science) have an advantage in acquiring money. The ability to promise practical applications is also increasingly valued in this conversion. Moreover, earmarked funding is indirectly influenced by foresight activities. From a principal–agent perspective, foresight studies can be seen as an attempt by a principal to overcome delegation problems, since the studies seek to make the world of the agents more transparent to the principal (Van der Meulen, 1992). The foresight studies on chemistry (Anon., 1980; OVC, 1995) in The Netherlands have had a significant influence on the available funding for particular sub-fields.[20]
2. The procedures for selecting candidates for academic positions influence the conversion of money into staff (and equipment). In these procedures a combination of various criteria is usually taken into account. Interviews with scientists indicate that recently, the publication and citation records have gained importance here. The most recent trend is that a candidate's proven abilities to aquire funding are rewarded. Obviously, these developments co-determine how money can be transformed into staff.
3. The conversion of staff and equipment into data takes place relatively autonomously inside laboratories and other research locations. Governing norms seem to be primarily of a scientific nature. However, the choice of what data to produce can strongly depend on agreements with funding sources and, less explicitly, on societal issues calling for particular scientific knowledge. The frequency of interaction with potential users during the research process varies across funding sources, from about two to six times a year. However, in interviews academic researchers speak about attuning their activities to user needs as a boundary condition rather than a primary goal.
4. The conversion of data into arguments depends on norms about the characteristics data should possess before they can support arguments: reliability, validity. Traditionally, there is little societal interference here. Proponents of post-normal science (Funtowicz and Ravetz, 1993) claim that this is changing, that the public is becoming increasingly involved in quality assessments of scientific results in fields of social importance, but we have not observed this in our case study. Some interviewees, however, indicate that sponsoring organizations sometimes attempt to influence the formulation of arguments because they have a strong interest in particular outcomes, for example regarding the safety of chemicals.
5. The conversion of arguments into articles is strongly ruled by peer review. All scientific journals employ this practice of quality control. Peers judge the quality of papers in academic terms, without considering their content's societal relevance. A significant modification of this conversion concerns the rising interest of research sponsors, particularly in industrial fields like catalysis, to patent research outcomes. For this reason industrial funding often implies a delay of 1–3 months for publications, due to the scientists' contractual obligation to give their industrial partners some time to explore the patentability of their findings. We also found that chemical researchers are actively involved in writing patents, especially in the field of catalysis.
6. Obtaining recognition based on one's articles and patents traditionally depends on peer judgment of innovativeness and contribution. However, in the 1980s and 1990s the government and the union of universities have installed performance assessments that formalize the attribution of recognition (Van der Meulen, 2008). Bibliometric analyses combined with qualitative judgments from peers (and sometimes also of 'knowledge-users') yield scores for the performance of research groups, programmes and individuals. Interview data suggest that these scores increasingly contribute to an individual's scientific recognition. Although they do not yet play a dominant role, the intended involvement of 'users' and including the 'societal relevance' as a significant criterion in these assessments (Spaapen *et al*, 2007) may considerably modify the conversion of articles into recognition.

Note, however, the paradox here. Performance assessments, including bibliometric analyses, have increased the 'publish or perish' norm (Weingart, 2005; Wouters, 1999). Although they were started to enhance the societal accountability of scientists (Van der Meulen and Rip, 2000), they have increased the need for peer recognition rather than the need for societal justification. The development of bibliometric evaluation tools has added a quantitative dimension to the conversion from articles to recognition. Originally a means of communication, publication has become an end in itself.

The new mosaic of funding options, partly influenced by foresight activities, mean that only a happy few manage to obtain money without promising some sort of practical application. In the contract of the 1950s and 1960s, scientists had many options for acquiring resources based solely on considerations of originality or scientific relevance, but this has become a rarity nowadays. One effect of the increasing complexity of funding options is that acquisition activities today consume a major share of senior scientists' time. This development has also influenced the procedures for selecting candidates for academic positions. Scientific publication records still seem to be the major criterion here, but increasingly the candidate's estimated fundraising abilities[21] are also rewarded. Together the changed conditions under which scientists work have strengthened the mutual competition. The pressure to publish and to be cited has intensified.[22]

Conclusion

The framework we have developed in this paper enriches the understanding of how scientific practice relates to external pressures and how internal developments influence science's relationship with society. Today, relevance is at the core of the relationship between academic science and society. The legitimacy of public support for university research depends on its perceived potential benefits, ranging from contributions to culture or education to specific insights or products with economic value. The idea of a contract as a negotiated set of rights and obligations to understand this relationship turns out to be helpful. After making assumptions about the composition of this contract it can serve as a heuristic. Continuing on the route taken by Guston (2000), in this paper we have attained this higher degree of specificity, by conceptualizing the general content of a science–society contract in terms of 'identity', 'rationales' and 'conditions'. Moreover, we have created a link with the credibility cycle (Latour and Woolgar, 1986), turning it into a tool to study the role and position of relevance in academic practices.

The 'relation between science and society' and 'scientific practice' are both vague concepts trying to grasp complex pieces of reality. The strength of our approach is that we have developed a model in which both are reduced to something that does justice to reality and at the same time allows for systematic analysis. Our notion of the contract clearly articulates the relation between science and society in terms of a limited number of variables. Similarly, the credibility cycle may not give an exhaustive overview of all activities involved in scientific research but it does describe the general pattern in which all activities have a position. Assuming that all scientists' actions aim to contribute to the conversion of credibility, the form of this cycle becomes a crucial factor determining scientific practice. Our framework does not imply any form of determinism. The cycle is not a result of only the contract, but of social interactions within and outside science. In the same way, the credibility cycle is not a dictating norm system, but rather a particular pattern of activities that are necessary for each researcher to produce credible information. 'Norms, the socialisation process, deviance, and reward are the consequences of social activities rather than its causes' (Latour and Woolgar, 1986: 205).

We consider that we have demonstrated the usefulness of our framework in a case study of academic chemistry in The Netherlands. The framework helped us to identify the ways in which concepts of relevance change and how they influence scientific practice. In particular, we have distinguished various 'organizational devices', which aim to enhance the relevance of scientific research, the most influential ones being earmarked funding and performance assessments. An important finding in our case study is that the effects of the changes in the credibility cycle are partially in contradiction, creating a paradox around relevance. The pressure for strategic knowledge is most visible at the conversion from recognition to money, but at most other conversions it is of little importance. On the contrary, in the other conversions, the importance of academic criteria of success has increased further due to the rise of bibliometric quality criteria. In some sub-fields of chemistry this creates a tension between different parts of the cycle. This tension is absent in catalysis, where the applicability of basic research is easily demonstrable. But in other fields, like biochemistry, there is a difference between research which is excellent according to scientific peers and research which is considered useful by societal actors. This implies that the criteria guiding the selection of research proposals contradict the criteria guiding the selection of manuscripts for publication or the attribution of recognition. Scientists are then rewarded for making beautiful promises about the (possible) relevance of their research, but not for realizing these promises.

Possible next steps are to elaborate this case and to extend the approach to different scientific disciplines and to other national contexts. The way our framework helped us to observe changes in the relationship between academic chemistry and society suggests that it will also work for other cases. Most other disciplines do not traditionally have such a strong relationship with one industrial sector, so they may show even stronger developments.

It is often assumed that the pressure for relevance has increased during the past few decades. However, it seems more fruitful to conclude that relevance can be expressed and expected in various meanings and forms. These forms can also be mutually contradictory, as our case study has shown. The meaning of relevance changes together with changing ideas about the potential benefits of scientific research. Here we have introduced a framework that facilitates a systematic empirical study of changing concepts of relevance as products of the interaction between science and society.

At least two implications for public policy follow from this paper. First, an enhanced understanding of the changing societal position of university research is crucial for making sound policy in the field of science and innovation. This is often based on popular and unarticulated notions of societal relevance, without a clear understanding of what these entail.

This paper shows that it is important to be careful with the term ‘relevance’, as its meaning is variable in time and place. Sometimes the notion is even an empty shell, which the actors use to their own advantage. Second, our brief case study of academic chemistry indicates that the effect of public policy is limited when it only intervenes at one position in the credibility cycle. Policy aiming to enhance the correspondence between academic research agendas and societal needs would be more effective if a more systemic approach is taken which includes a combination of instruments directed at various conversions of credibility.

Notes

1. This paper deals only with academic science, so research that is conducted at universities, not at public research institutes or in industrial laboratories. For the sake of readability we will not consistently use the predicate ‘academic’ throughout the paper. Everything we claim about science, scientists, research or researchers, however, is limited to university science and university scientists.
2. For the sake of clarity, let us indicate two differences between Guston’s approach and ours. First, in our view science has a contract with society in the broader sense rather than with the government alone. Guston is mainly concerned with the government as a stakeholder in science. In his work on the ‘social contract for science’ he analyzes the changing ways in which the US government deals with scientific research. However, we aspire to capture the societal environment in a broader sense, taking into account all the actors that have an interest in academic research. Besides governmental authorities, these are all other organizations and individuals that give financial support to academic research and all that can be expected to benefit from its outcomes. In fact, one may argue that all actors in society have a stake in science, but to varying degrees.

   A second difference concerns the durability of the contract. In Guston’s work, ‘the social contract for science’ is a label for a specific historical period, roughly 1945–1980. Guston uses the notion of the contract to describe and explain the particular relationship that existed between science and the government in the USA in those years, and to contrast it with the configurations before and afterwards. In our approach, however, the meaning of the contract is not limited to a specific point in time. We argue that the idea of a contract can always be applied to the science–society relationship, regardless of the historical setting. Of course, the specific content of the contract can change, but its general structure will remain the same.
3. These devices are often referred to as ‘practices of quality control’ (Hemlin and Rasmussen, 2006). But in the present context, this notion is a little confusing, because these devices control not only quality, but also relevance.
4. This does not imply that the goal of scientists is only gaining credibility and not gaining knowledge. Rather, in order to take part in the research process (to gain knowledge) it is necessary to earn, retain and convert credibility.
5. This 10-month case study is based on document analysis and in-depth interviews with scientists, policy-makers and other societal stakeholders. Here we summarize our findings, which requires simplifying a complex history involving various actors with different stakes and interests. A more elaborated analysis of this case will be published separately.
6. In the first policy paper (1974) by the first Dutch Minister of Science Policy, F H P Trip, the primary mission of science policy is defined as enhancing the agreements of research agenda’s with societal demands.
7. Foresight studies by OCV (1995) and by KNCV (Professional Organization of Chemists) and VNCI (Association of Chemical Industry) (1994) both pay significantly more attention to environmental issues than their predecessors from the 1980s.
8. E.g. Nota Wetenschapsbeleid 1974.
9. The first foresight study (Anon., 1980) of chemistry, commissioned by the minister of science policy concludes that academic chemistry should define its research goals more sharply and that the contacts with industry deserve intensification.
10. The interest of chemical industry in academic research is also visible in an advisory report by VNCI and KNCV (1984) which argues for increasing industrial steering of academic research and suggests a set of six ‘priority fields’ as a guideline in the conditional funding process.
11. ‘For all new scientific and industrial activities on the field of chemistry the *strives for sustainability and the minimalisation of environmental pressure* have become important boundary conditions.’ (original emphasis) (OCV, 1995: 2). NWO’s Strategy Note on Chemistry for 2002–2005 is even titled: ‘Chemistry, Sustainable and Interwoven’ (NWO CW, 2001).
12. The 1995 foresight study on academic chemistry, for example, writes about sustainability: ‘Much of the research on resources (...) is not only motivated by economic considerations but serves at the same time important ecological goals’ (OVC, 1995: 38–39).
13. SON, the main Dutch Chemical Research Council, starts a program for applied chemical research in 1980, together with the STW. Moreover, SON’s parent organization, ZWO (Organization for Pure Scientific Research), is reorganized in 1988 into NWO (Dutch Organization for Scientific Research), in which there is more room for funding application-oriented research.
14. During the 1980s, the number of temporarily paid chemical researchers funded by the ‘third money stream’ rises from about 70 to 350 (ACC/KNAW, 1991).
15. The IOPs, for example ‘Membranes’ (1983), ‘Carbohydrates’ (1985) and ‘Catalysis’ (1989).
16. SON Jaarverslag, 1991, 1993, 1995.
17. This may change, as since then a protocol has become available (VSNU/NOW/KNAW, 2003) and there are attempts to develop more holistic methods that include societal relevance (Spaapen *et al*, 2007).
18. E.g. the ACTS-programs of NWO, the TTIs funded by the Ministry of Economic Affairs and the BSIK-programs.
19. Due to university management like the current ‘Focus en Massa’ policy (Universiteit Utrecht, 2005) and due the requirement of ‘matching’ externally funded research projects with block-grant support (AWT, 2004).
20. For example, SON’s decision to start funding application-oriented research is partly based on the outcomes of the 1980 foresight study (SON Jaarverslag, 1980; Anon., 1980).
21. Important indicators for the assessment of a candidate’s fund-raising ability are his/her past funding acquisitions and networking skills (evidence from interviews with scientists).
22. This is confirmed in our interviews with chemical researchers: ‘Without it I do not survive’ (full professor in biochemistry) and ‘I think it is the only way to show what you have done. And I think that if something is not publishable in a scientific journal, it is not worth much’ (PhD student in biochemistry).

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