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In search of relevance:

The changing contract between science and society

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In search of relevance

The changing contract between science and society

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Abstract

This paper presents a framework to study the historical development of the relationship between science and society. We elaborate this relationship as a contract that specifies the mission of scientific research, the rationales for public support for science, and the conditions under which scientists work. These three structural elements will always be part of the contract, but their specific content can vary. The credibility cycle, as a model for scientific practice, helps to describe and understand the consequences of a changing contract for the work of individual scientists. A brief case study of chemistry in the Netherlands demonstrates the usefulness of the framework. We show how concepts of relevance have changed since 1975 and how this affects the practice of academic chemistry.

Keywords: relevance, contract, credibility cycle, chemistry

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1. Introduction

When is scientific research 'societally relevant'? Is research relevant when it yields knowledge about an urgent 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? The issue of relevance clearly is a complicated one. It seems that no straightforward answer is possible to the questions above, and there is not even a common definition of societal relevance.

Relevance is central in the relationship between science and society. In a basic sense, society pays for science and expects something in return, value for money (figure 1). This value can have all types of appearances. A variety of terms is used here, like 'quality', 'excellence', 'innovation', 'expertise', 'valorisation', 'dissemination' and 'relevance' to give content to it. From an analytical perspective, however, these terms can be grouped under the common heading 'relevance', pointing to the essential principle of exchange that the knowledge scientists produce should have value to society.

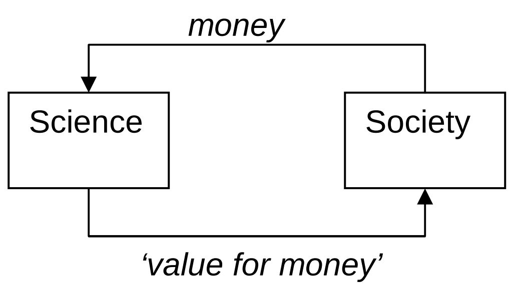

Figure 1. Very schematic picture of the relationship between science and society

The relationship between science and society is said to be changing. Various approaches have been proposed to describe the current dynamics in science systems, such as 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 these approaches refer to an increasing orientation towards the production of 'relevant' or 'applicable' knowledge (Hessels and Van Lente, 2008). They observe an enhanced aspiration of scientific research to contribute to the solution of societal problems and to support innovations to facilitate economic growth. This development is assumed to relate to profound changes in the relationship between science and the other societal spheres: the state, the market and civil society. Scholars report that 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 resources available, governments can no longer afford unconditional support for basic science (Ziman, 1994) and demand value for money, that is, relevant knowledge. In the meanwhile, knowledge becomes an increasingly valuable economic resource, and global competition has forced industry to outsource basic research (De Wit et al., 2007). In all these bodies of literature relevance plays a role, but it is not in the centre of attention.

Given its importance in the relationship between science and society we conceive that the notion of relevance deserves further elaboration. The current paper is an attempt to clarify how considerations of relevance are intertwined with scientific practice. Our second aim is to develop a framework to study the historical development of the science-society relationship.

It is mistaken to consider the stress on relevance as a new phenomenon (Rip, 1997). Since the scientific revolution in the 17th century there has always been a notion of relevance of science in place which legitimized and mediated the operation of the science system (Martin, 2003; Pestre, 2003). Intimate interactions between science, invention and entrepreneurship were, for example, already important in the British industrial revolution (Freeman, 1997). The notion of a 'singular science', one model of doing and organizing science, like Mode 1 knowledge production, is historically incorrect (Pickstone, 2007). Anyway, Mode 1 may have shown an increase - or even a 'lock-in' (Rip, 2000) - at the expense of research with Mode 2 features after WWII. In this paper we will corroborate the claim that the idea of relevance is not new, but that definitions of what relevance entails have shifted and may continue to shift. By focusing on 'relevance' we will address the actual, and in fact perennial, question how science relates to society. What does it mean for scientific activities and outcomes to be relevant? How is relevance defined and measured? When and how does the stress on relevance affect scientific practices?

Our argument will proceed as follows. In the next section we will introduce the notion that the relationship between science and society can be seen as a contract. A contract defines the relation between two parties by settling privileges and obligations. We address the usage of this notion both in political philosophy and in the sociology of science. In section 3 we elaborate the basic elements of the contract and develop a framework for studying it. The framework includes the 'credibility cycle' (Latour and Woolgar, 1979) as a model for scientific practice. Section 4 demonstrates the value of this framework in a case study of chemistry in the Netherlands. We conclude with a critical reflection (section 5).

2. A contract between science and society

It is a truism that science is not just useful for its own sake but also for society in a broad sense. 'Societal relevance' relates to expectations that society, in the end, will benefit from the outcomes of scientific research, in terms of economic competitiveness, cultural enrichment or social progress. Such expectations are a crucial condition for public support for science: why would society pay for science, if it can not expect its outcomes to be relevant? The ideas of the benefits attached to relevance have profoundly changed over the course of the last decades, or centuries, but this does not change the point that society eventually will benefit from science.

Numerous writings about the science systems and its changes employ the idea of a (tacit) contract. Baldursson (1995), Elzinga (1997), Martin (2003) and Jasanoff (2005) use the notion of a contract to discuss the changing relation between science and society in comparable ways. Although there are differences between them regarding the approach, scope and size of their studies, their diagnoses are roughly similar. They start with the 'Endless frontier' contract, which has appeared arisen right after WWII. The dominant view on science of this period is associated with Vannevar Bush's report 'Science, the Endless Frontier' (Bush, 1945). Based on the experiences with the Manhattan project, Bush advised the President to pursue a clear distinction between pure/basic and applied/technological research, according to the linear model of innovation. In this contract, basic research is self-regulated and should not be disturbed by outside steering, while applied research is socially mandated and 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, their arguments continue, this contract is currently under attack. One of the factors for this is science's own success in external contexts (Baldursson, 1995). Given the enormous impact science can have on sectors like healthcare and agriculture, society increasingly desires to co-determine its directions. Furthermore, innovation studies have shown that the linear model of innovation is inadequate and call for a systemic approach (Smits and Kuhlmann, 2004). 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. The contract authors (Baldursson, 1995; Elzinga, 1997) (Jasanoff, 2005; Martin, 2003) only sketch the contours; none of them is sure yet about the nature of this emerging contract.

Michael Gibbons (1999) deviates somewhat from the authors cited above; he uses the contract notion in a more normative way. He argues that the prevailing contract which 'was set up to sustain the production of reliable knowledge', is not adequate anymore. Given the changes Gibbons observes (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'. This is knowledge of which the validity is achieved through involving an extended group of experts, including lay 'experts'. This knowledge is valid not only inside but also outside laboratories and is less likely to be contested than knowledge which is merely 'reliable'. 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' (p. C84).

Note that the authors discussed so far use the notion of a science-society contract metaphorically. In this way they escape from the duty to clarify the content of the contract. They use the 'science-society contract' as a heading for speaking about the relation between science and society, but they do not explicate how to conceive such a contract. Although the idea of a contract is indeed a metaphor for an accomplished and negotiated relationship, we think it is useful to stretch the metaphor a bit further and examine the content of the contract between science and society. So, how to describe the parties involved and how to describe their rights and obligations?

By this we continue the route taken by Guston and Kenniston (1994) who take the idea of contract bit more literal:

> 'Science and the technology that it spawns are viewed as the cornerstone of our past, the strength of our present, and the hope of our future. An unofficial contract between the scientific community and society has arisen from these beliefs. This contract confers special privileges and freedoms on scientists, in the expectation that they will deliver great benefits to society as a whole' (Representative George Brown (D-CA), 1992: p. 781, as cited by Guston and Kenniston (1994)).

They continue with a further specification of the science-society contract as follows:

1. it 'implies two distinct parties, each with different interests, who come together to reach a formal agreement on some common goal'
2. a contract is negotiated, 'arrived at through a series of exchanges in which each party tries to secure the most advantageous terms'
3. a contract 'suggests the possibility of conflict – or at least disparity of interests'
4. 'contracts can be renegotiated if conditions change for either party' (p. 5)

According to Guston and Kenniston there are two main features of the science-society contract (Guston and Kenniston, 1994). First, the scientific community provides a public good: research outcomes. The private sector, as a rule, will underinvest in research because it is difficult to appropriate the return on investment. Second, special arrangements balance the responsibilities between government and science: the government invests in a public good, but it delegates the actual conduct of the research to other institutions. The scientific community is responsible for 'producing' research, discoveries and new technologies. But the government's delegation is not a gift; its financial support is tied to specific terms and conditions[1].

Science is not an independent sub-system of society. Because its viability depends on support from other societal actors, science has the responsibility to continuously demonstrate its right to exist. In the relationship between science and society, both parties have expectations of each other. Society expects to benefit from the outcomes of scientific research. Science expects its support to be sustained and not to be tied to increasing constraints or conditions. Central in the relationship is the delegation of a task. To facilitate effective execution of research, society has appointed a particular party and made her responsible for it[2].

A small excursion to the philosophy of science can contribute to the understanding of this relationship. The basic idea of delegation and the concomitant social order was first raised by Thomas Hobbes in his work on a 'social contract'. His social contract concerns the mutual transfer of rights, which transform man's 'natural condition' into a situation with politico-juridical order. The natural condition is the disastrous situation in which humanity would be if there was no contract. Because man is intrinsically self-interested, this is a war of all against all, in which life is 'solitary, poor, nasty, brutish, and short' (Hobbes, 2003). There is no moral code at all; everyone can claim the right on anything, including someone else's body. Hobbes claims, however, that two fundamental 'laws of nature' can be rationally deduced which apply in this situation:

1. 'that every man ought to endeavour peace, as far as he has hope of obtaining it; and when he cannot obtain it, that he may seek and use all helps and advantages of war'
2. in order to secure the advantages of peace, 'that a man be willing, when others are so too… to lay down this right to all things; and be contented with so much liberty against other men as he would allow other men against himself'

So first, everyone should strive for peace as long as that seems a viable option. When this is not possible, however, everything is allowed which is needed to defend oneself. Second, however, everybody should be ready to give up his rights to a certain extent if others do the same, to the benefit of all. The second law creates the possibility of a social contract. The contract involves the voluntary transfer of rights for one's own good. In principle people transfer their rights to each other in symmetrical one-to-one transaction. In a state created by a social contract, however, numerous persons have all transferred their rights to the collective. The state is then represented by a sovereign, who is allowed

[1] Like the other authors, Guston and Kenniston argue that the social contract is undergoing change and may need to be replaced by a new one. However, they address this issue specifically in an American context and identify a different threat: decreasing public confidence in the integrity of scientists. This integrity crisis does not have our main interest. This issue is not as hot in Europe as in the USA (Jasanoff, 2005). Moreover, Guston and Kenniston regard the contract as an agreement of science with government, while we are interested in society in the broader sense.

[2] This task delegation can also be analysed using Principal-Agent Theory (Van der Meulen, B.J.R., 1998. Science policies as principal–agent games: Institutionalization and path dependency in the relation between government and science. Research policy 27, 397-414.; Braun, D., 2003. Lasting tensions in research policy-making - a delegation problem. Science and Public Policy 30 (5), 309-321.), but this asymmetrical approach to the science-society relationship tends to overemphasise the government's power in structuring the relationship, leaving limited space for scientists' power in coproducing the norms and values governing the task delegation.

by the majority to act on the people's behalves. This implies that any member (subject) of the state authorizes the sovereign's judgments and acts as if they were his own. All of this serves to keep the peace, both within the community and with the external world.

The thought experiment of Hobbes on 'contract' can be extrapolated to science.[3] A set of agreements about the rights and obligations of science can be described which aim to facilitate a productive task delegation (Braun, 2003). The agreements make up a contract, similar to the social contract as introduced by Hobbes. Like Hobbes' sovereign receives a mandate to fulfil a particular function to the benefit of all, science receives a mandate to carry out research. Similar to Hobbes' imaginary 'natural condition', one can think of a society in which everybody has the right to produce knowledge (table 1). Here, the task to conduct research or to develop expertise is not delegated to anybody in particular, so every member of the community can claim to possess truthful knowledge. This is probably an undesirable situation, everybody holding his own beliefs about nature. It may lead to unproductiveness and ineffectiveness, as there is limited consensus to build on for making decisions or developing technology. The citizens will spend a lot of time and energy on exchanging views, peacefully or violently.

In contemporary societies, however, science has a privileged position in the production of truth, comparable to the way Hobbes' sovereign has a monopoly on violence. All people have transferred their right to conduct research to science. Of course, nobody will forbid anyone else to carry out research, but only scientists have uncontested cognitive authority. Similar to Hobbes' thought experiment, we can think of an act in which all members of society transfer their rights on research to each other and subsequently appointing one institution to which this task is delegated. The task formulation of this institution (science) is what we call the contract[4]. Of course, such an event of collectively deciding that the task of conducting research can best be delegated to one particular institution - and rationally choosing what would be the most effective working procedure - has never factually occurred in history, but the idea of such an event can greatly help to clarify what science is and how it relates to society.

Table 1. A comparison between Hobbes' social contract and the contract between science and society.

	Social contract (Hobbes)	**Contract science-society**
State of nature	War	Irrationality
Contractants	All people	All people
Aim	Peace	Truth / knowledge
Sovereign	Political ruler (dictator)	Science
Transferred right	Violence	Research / cognitive authority
Derived rights	Various (3-19)	Academic freedom, respect, education...
Resulting relationship	Total dependence	Right to object

To conclude, the notion of a contract provides a possible route to enhance our understanding of relevance and of the changing science-society relationship. However, to date no detailed account of the content of this contract is available. In the following, we will take up the challenge and develop a framework. The leading question in this undertaking is: what are the minimum ingredients of a contract between science and society? Here, we are less concerned with the specific agreements between both actors on a particular time and place than with the generic structure of the contract. What are the basic issues to settle in a contract?

3. A framework to examine the relationship between science and society

The aim of this paper is to develop a framework to study the changing relationship between science and society, in particular with regard to societal relevance of scientific research. To this end, we need three ingredients: a model of the relationship between science and society, a model of the science system itself, and an understanding of how the dynamics of both models mutually relate. The figure below (fig. 2) is a concise presentation of our framework. It contains two major concepts: the contract between science and society and the credibility cycle. As we will explain

[3] The prefix 'social' used by several scholars (Jasanoff, 2005; Elzinga, 1997; Gibbons, 1999) seems redundant. This word is inherited from the political philosophy debate, which started from questions about the conditions for the possibility of social stability. If one speaks about the contract between science and society, this aspect is not present anymore.

[4] Note that this concept of the science-society contract differs from the one of Guston and Kenniston, who consider the contract as a result of the negotiations between two existing parties: science and government. In our concept, science is the product rather than a precondition for the contract.

below (section 3.1), we use the credibility cycle as a model for the functioning of the science system, as it describes the basic sequence of activities of individual scientists. On an aggregated level, we conceive the relationship between science and society in terms of a contract (3.2). The two-directional arrow between the two shows that the dynamics of both are related. Section 3.3 will explain how.

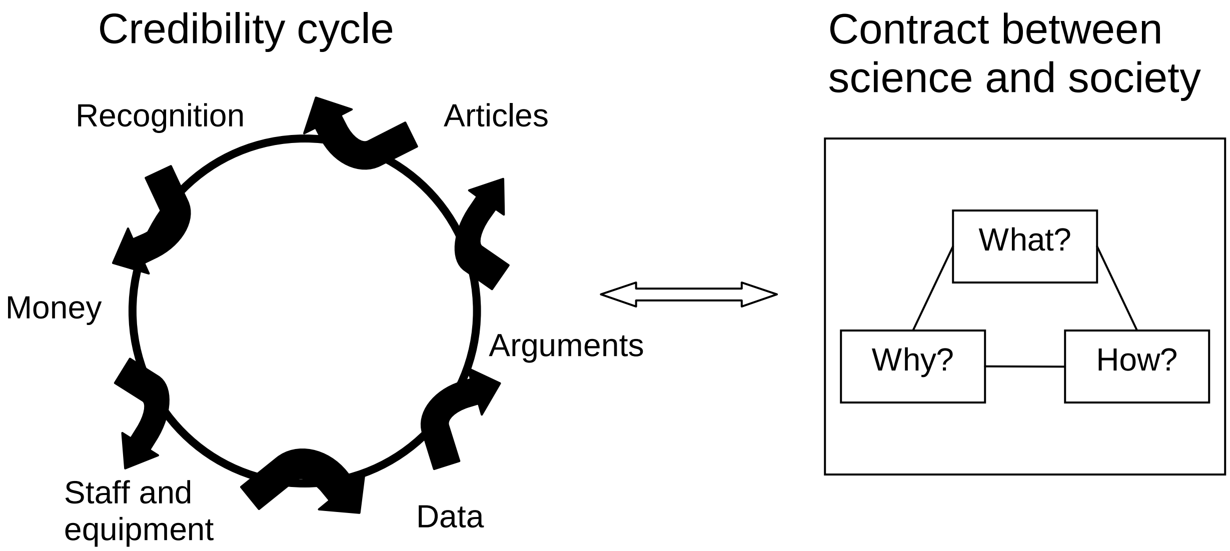

Figure 2. A framework for studying the changing relation between science and society

3.1 Credibility cycle

Sociology of science indicates 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) (p. 25). Work is organised and controlled through reputations. Scientific activities are carried out with a view to convincing fellow researchers of the importance and significance of the results and hence enhancing one's own reputations. A scientist's status in his employment organisation (university) depends on his reputation, because this is a key factor in acquiring jobs and resources.

The concept of the 'credibility cycle' (Latour and Woolgar, 1979) explains how struggles for reputation influence the behaviour of individual scientists. Similar to Whitley's notion of reputation, credibility refers to the ability 'actually to do science' (p. 198). Scientific behaviour can be described as a cycle of conversions of different types of credibility. The quest for credibility constitutes the major motivation for a scientist's actions. Scientists invest time and money expecting to acquire data that can support arguments. These are written down in articles, which may yield recognition from colleagues. Based on this, scientists hope to be able to 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, data, prestige, credentials, problem areas, argument, papers, and so on (see figure 3).

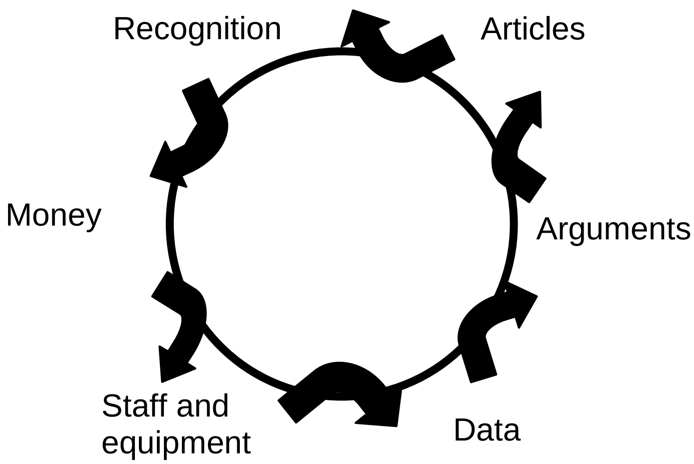

Figure 3. The credibility cycle, adapted from Latour and Woolgar (Latour and Woolgar, 1979)

The constructivist studies of science from which the credibility cycle originates are traditionally seen in opposition to Merton's sociology of science, which stresses the importance of norms in structuring scientific practice. However, these two traditions are not necessarily in contradiction as each conversion can be conceived as governed by a set of norms. Only certain types of data have enough 'validity' or 'reliability' to be converted into arguments. In turn, arguments need to have strength in order to enable conversion into a publication. 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 prescriptions and standards. The existence of norm systems facilitates the conversions which constitute the credibility cycle. In this sense the whole cycle can only exist thanks to a set of shared norms and values.

This description may give the impression that peer judgment is the central determinant for success in this model, but that is not necessarily the case. In the traditional understanding of science, most conversions may be governed primarily by internal scientific procedures. The model does not exclude the possibility, however, of other procedures or norm sets dominating. Although Latour and Woolgar (1979) 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. Packer and Webster (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. Arie Rip (Rip, 1994) uses the credibility cycle to analyze how the role research councils has developed over the years. Garcia and Sanz-Menéndez (Garcia and Sanz-Menéndez, 2005) use the credibility cycle to show the importance of competition for funding in contemporary science systems[5]. They argue for a performance indicator based on success in funding acquisition to complement bibliometric indicators.

The credibility cycle is a valuable analytical tool for studying scientific practice. Its precise composition, however, is a historical contingency rather than a necessity. Figure 3 can not be seen as a timeless representation of science. What conversions are part of the cycle, which ones are most important and what are the guiding norms and values are all questions for empirical investigation. For instance, Merton's original formulation of the fundamental norms (Communism, Universalism, Disinterestedness and Organized Scepticism) (Merton, 1973) is nowadays contested. Ethnographic laboratory studies have had difficulties empirically discerning these norms. Scientists turn out to be occupied with building networks and alliances of interested actors rather than being disinterested and skeptical (Latour, 1987). The production of truth seems to be more an act of creating interest for one's own propositions than of altruistic devotion to the progress of human understanding. These objections, however, do not imply that Merton was completely wrong. Politics and power-play exist in every sector of human activity. If one is interested in the distinctive characteristics of science, one has to look below the surface of politics. Being interested

[5] Garcia and Sanz-Menéndez, however, do not argue that the credibility cycle has changed in the course of time or denounce the adequacy of the model of Latour and Woolgar. They rather use the cycle to draw attention to the importance of competition for research funding for scientific reputations.

in the historical development of the contract between science and society, we regard the ethos of science as a historical contingency. Although Merton's CUDOS concept seems a highly idealized picture of reality, we would not reject its validity beforehand. It may turn out to be a convenient framework to discuss the ethos of science at some point in history, to be contrasted with more recent developments. This may be done using Ziman's alternative PLACE framework (Ziman, 2000, p. 78-79). John Ziman argues that the CUDOS concept helps to contrast academic science with industrial science (as conducted in industrial labs or governmental research institutes), which is characterized by 'PLACE' norms: '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.' In Ziman's diagnosis, the division between both spheres is currently blurring, giving rise to 'post-academic' or 'post-industrial' research.

3.2 Contract science-society

A contract defines a 'moral universe', which indicates the positions and the mutual relationships of the actors involved. If one thinks about the relation between a mother and her child, there are many norms and values involved. In contemporary western societies, some central values are probably love, development and safety. Some norms: the mother should feed her child, the child should obey its mother, and the mother should support her child and stand by its side when it happens to be in trouble. Although the norms just presented are beyond dispute, not all are recorded anywhere. Some of them are even hardly ever communicated. Still people generally expect each other to respect these rules. 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 is the whole of all implicit and explicit agreements between science and societal parties. It arranges what science should do, why it should do this, and what are the appropriate conditions (see figure 4). In the following, we will give a general description of the three main elements of the contract. We do not claim to know the precise content of the articles, as this changes in time. Our claim rather concerns the general 'structure' of the contract, which is stable. In any time, or at any place, a contract specifying the societal mandate of science has to address three central questions: what, why and how?

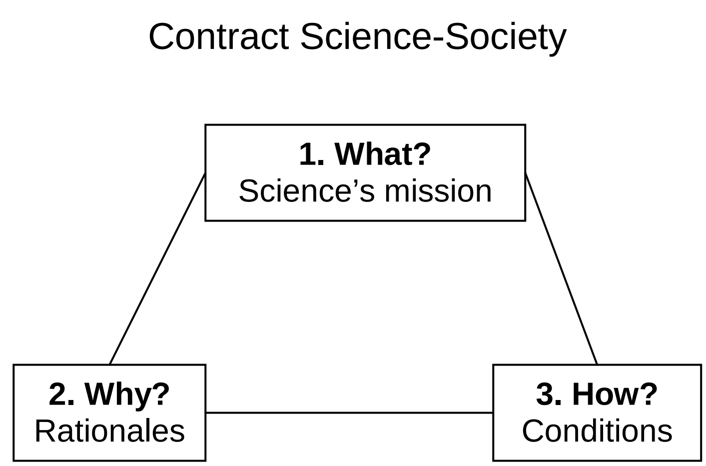

Figure 4. The general composition of the contract between science and society

1. Science's mission: producing relevant knowledge

The mission of science is to provide a public good: relevant research outcomes. Science's duty is to produce knowledge and to deliver it in the form of communication (publications, presentations) or artefacts. This task is delegated by the community. In return for these duties, science also has particular rights, such as: stability (job opportunities), autonomy (freedom for scientists to choose the best way to reach particular goals) and societal recognition of scientific expertise (room for uttering concerns in public media). Note that we do not consider quality as a separate norm here. Of course one can argue that scientists are expected to be excellent in what they are doing[6]. But in our concept, this is only instrumental in successfully fulfilling their mission of producing relevant knowledge and not a goal in itself.

2. Rationales for funding science
The contract also describes why science deserves support. Many different (combinations of) arguments are possible, but most of them relate to the concepts of societal relevance listed above. First, science is seen as a cultural good. Second, it is needed to sustain a system of higher education. Third, it is believed that the market sector will underinvest in basic research in spite of its economic importance, so a public research system is needed. Fourth, public science enables the government or consortia of various actors to demand specific knowledge which is of a general interest (like expertise which can support decision making or strategic knowledge which may lead to innovations).

3. Conditions
Third, the contract contains agreements about the conditions under which scientists work. One can assume that science's organisation is attuned to its mission. A basic feature of the way science is currently organized is the nested hierarchy of research groups in faculties in universities. Another agreement concerns the way money is distributed to scientific researchers, in which intermediary organisations have a central role. This is not the right place for a complete description of all agreements concerning science's organisation. Here, we just want to emphasise that the current contract includes specific instruments ('organizational devices') which aim to enhance the quality and / or relevance of research, like earmarked funding and performance assessments[7].

In a stable contract the three elements are strongly interlinked. Concepts of 'relevance' strongly relate to prevailing ideas about the legitimacy of funding science. Moreover, the way science is organized depends on the precise mission it should fulfill. For this reason, a history of the contract has to take into account the dynamics of all three elements. In table 2, we list the characteristics of each element that we regard as structural and variable.

Table 2. Structural and variable characteristics of the contract

element of contract	**general structure**	**variables**
What?	mission: research norms: relevance	meaning of relevance
Why?	values: science is good	specific rationales
How?	organisational devices to enhance quality and relevance	specific devices at place the norms governing the devices

3.3 Relation between contract and cycle

The contact between science and society has an enabling constraining relation with the credibility cycle. Rather than assuming a uni-directional causality, we regard the developments on both levels being in co-evolution. Both the contract between science and society and the credibility cycle deal with norms. The contract describes the ethos of science on an aggregated level; the credibility cycle describes when and how individual scientists are confronted with various norms (figure 5). Obviously both norm systems are strongly related. The generic contract ultimately is the product of interactions of individual scientists with each other and with societal actors. The norms it contains are therefore co-shaped by the norms governing at the individual level. Conversely, developments on the aggregated

[6] For example, in the general protocol for research evaluations in the Netherlands (VSNU / NWO / KNAW, 2003. Standard Evaluation Protocol 2003-2009 for Public Research Organisations. .) quality and relevance stand next to each other as two of the four central criteria, the others being viability and productivity.
[7] Most of these devices are often referred to as 'practices of quality control' (e.g. Hemlin, S., Rasmussen, S.B., 2006. The Shift in Academic Quality Control. Science, technology and human values 31 (2), 173, 126p.). But in the present context, this notion is a little confusing, because these devices do not only control quality, but also relevance.

(national) level influence the credibility cycle.

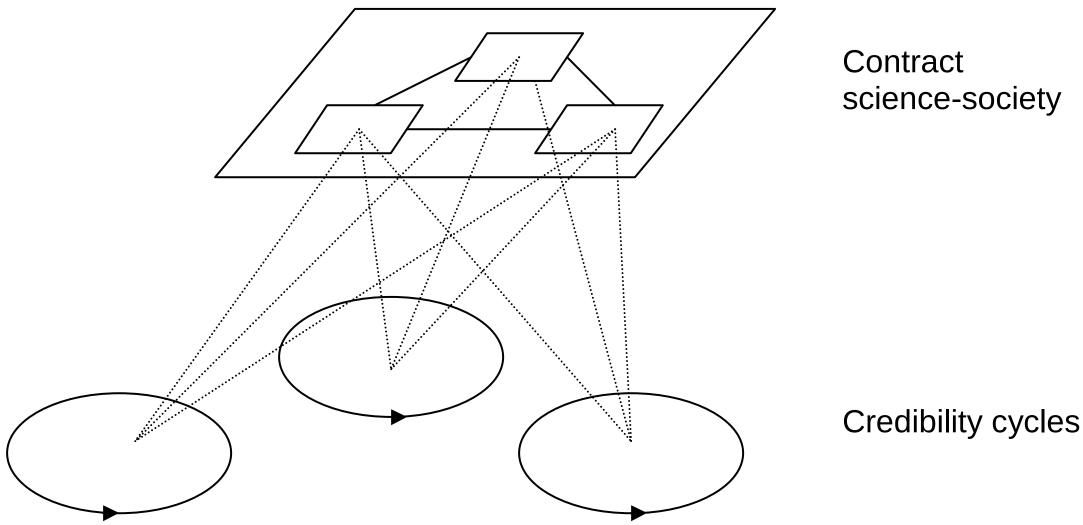

Figure 5. The collective contract of all scientists with society in relation to their individual credibility cycles.

4. Application to chemistry case

In this section we demonstrate the suitability of our approach in a concise case study on chemistry in the Netherlands[8]. Our story starts with the post-war situation, previously referred to as the 'Science, the endless frontier'-contract. First we will describe the changes in the rationales, the mission and the conditions as specified in the contract. Then we will address the changing credibility cycle.

Rationales

In the 1950s and 1960s there are two dominant rationales for funding chemical research: its necessity for the training of new R&D-workers and (less importantly) the cultural value of basic research (see table 4). Chemical industry, with which academic chemistry always had strong bonds (Homburg and Palm, 2004), has a strong interest in highly educated researchers. Industry tends to regard universities primarily as an educational system with the primary mission to supply a steady stream of highly skilled researchers (Homburg, 2003). For the government the economical importance of this sector is the reason to found SON in 1956, the foundation for chemical research in the Netherlands, which provides support to basic chemical research with the training of young scientists as its primary aim. In the 1970s an additional rationale emerges for supporting chemical research, namely the awareness of environmental problems which call for chemical expertise. The budget cuts on basic research in industry in the 1980s give rise to a new rationale for supporting academic chemistry relating to its potential contribution to technological innovations[9]. Chemical industry does not only desire 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 dominant in rationales for funding (chemical) research. This concept connects several previous rationales by combining economic growth with environmental and social development. Around the turn of the century, a new notion is added to the rationales, the innovation system. Innovation studies have shown that innovation is the product of interactions of a variety of actors who are part of the innovation system. This gives specific content to the argument to fund academic research. Maintaining a healthy

[8] This case study is based on document analysis and in-depth interviews with scientists, policy-makers and other societal stakeholders. A more elaborated analysis of this case will be published separately.

[9] The first foresight study (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 (association of chemical industry) and KNCV (professional organization of chemists) (KNCV & VCNI, 1984. Toekomstig Chemisch Onderzoek: Een uitwerking van het rapport Wagner I voor de Chemie.) that argues for increasing industrial steering of academic research and suggests a set of six 'priority fields' as a guideline in the conditional funding process.

innovation system becomes a goal as such, which implies that universities deserve support thanks to their central position in this system.

Mission

In the first postwar decades, the mission of academic chemistry is to conduct excellent basic research. Good research is research which succeeds to train its executers with skills they can later use in an industrial context. Although it is quite common for industrial labs to pursue basic research as well, the academic environment is regarded to have some special characteristics that facilitate the development of scientific skills. Relevant research simply equals excellent research. Chemical research is regarded as relevant by definition, given the importance of chemical industry for the Dutch economy. In the 1970s, when governmental science policy is introduced, an additional mission of serving societal needs emerges[11]. For chemistry this implies to produce knowledge which is useful not only in chemical industry, but also in domains like agriculture and healthcare. More specifically, chemistry is expected to contribute to the solution of environmental issues. In the 1980s chemistry's relevance is rephrased as delivering applicable knowledge. There remains a place for basic research as well, but this is justified merely as a necessary condition for the existence of good applicable research. During the 1990s the boundary between basic and applied research starts blurring and chemistry's mission becomes producing 'strategic knowledge'. Strategic research combines aspects of basic and applied research. Strategic knowledge concerns fundamental insights in domains of high relevance for economy or society. The domain of 'sustainability', which gains importance since its introduction in 1987, becomes a major strategic field for chemistry[12]. The strategic mission of academic chemistry endures in the new millennium as it also fits the innovation system rationales.

Conditions

In terms of conditions, during the 1950s and 1960s chemical scientists have a high degree of autonomy. The most important types of funding (first and second money stream) are distributed without any conditions attached, based on considerations of academic quality. In the 1970s scientists are increasingly held account for their work. Although they are not yet affected by formal policy measures, chemical researchers need to put more effort in explaining to society what they are doing than before. From 1980 onwards, however, a substantial change occurs in the funding of chemical science. Faced with the need for budget cuts, the ministry of science, culture and education starts to supply part of the first money stream on a conditional base. Moreover, within the second money stream, an increasing share is dedicated to application oriented research[13]. In addition, an increasingly significant 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 second money stream continues to broaden its mission beyond basic research, which is demonstrated by its name change in 1998 from ZWO to NWO[16]. Another significant event in the 1990s is the institutionalization of performance evaluations. In 1996 the first nation-wide 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 societal relevance or applications. In practice, they turn out to generally ignore this criterion and focus strongly on traditional scientific norms[17]. After 2000 chemistry faces the

[11] In the first policy paper (1974) by minister Trip, the primary mission of science policy is defined as enhancing the agreements of research agenda's with societal demands.

[12] Foresight studies by OCV (OCV, 1995. Chemie in Perspectief: een verkenning van vraag en aanbod in het chemisch onderzoek, Overlegcommissie Verkenningen, Amsterdam) and by KNCV and VNCI (KNCV & VCNI, 1994. Toekomstig chemisch onderzoek: Universitair fundament voor industriële meerwaarde.) both pay significantly more attention to environmental issues than their predecessors from the 1980s.

[13] SON, the major chemical research council, starts a program for applied chemical research in 1980, together with the new technology foundation STW.

[14] During the 1980s, the number of temporarily paid chemical researchers funded by the 'third money stream' rises from about 70 to 350 (ACC-evaluatiecommissie, 1991. Evaluatie van de universitaire chemie in de jaren '80, ACC/KNAW, Amsterdam.).

[15] The 'Innovation Oriented Programs' (IOPs), for example 'Membranes' (1983), 'Carbohydrates' (1985) and 'Catalysis' (1989).

[16] Abbreviations for the organization for Pure Scientific Research and the Dutch organization for Scientific Research, respectively.

[17] This may change, as in the meanwhile a protocol is available (VSNU / NWO / KNAW, 2003. Standard Evaluation Protocol 2003-2009 for Public Research Organisations. .) and there are attempts to develop more holistic methods that include societal relevance (Spaapen, J., Dijstelbloem, H., Wamelink, F., 2007. Evaluating Research in Context, Second edition, COS, The Netherlands, The Hague.)

rise of consortia-based funding, large sums of governmental money supplied to collaborative programs of university scientists which are monitored by (industrial) user committees[18].

Table 4. The changing contract for chemistry. + signs indicate that these element complement rather than replace already existing elements.

	mission	**rationales**	**conditions**
50s and 60s	excellent basic research	education cultural value	autonomy unconditional funding SON communities
70s	+ serving society	+ environmental issues	+ social accountability
80s	applicable knowledge	technological innovation	+ conditional funding + application oriented funding (STW, IOP, contract research) + foresight + scarcity of resources
90s	strategic knowledge	sustainable development	further prioritization ZWO → NWO + performance assessments
2000+	strategic knowledge	sustainable development innovation system	+ consortia (ACTS, TTI, bsik)

In the course of years, the meaning of societal relevance has changed dramatically. It was initially defined in terms of education; later in terms of global inequality and environment; in the 1980s in terms of innovation; since the 1990s in terms of innovation and sustainability. Related, the emphasis in the rationales for funding chemical research have 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 and 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 regulations of emissions. The conditions specified in the contract have become increasingly complex. Chemists receive less unconditional support. Still the ministry of science provides a certain share of funding without specifying how it should be spent, but this 'basic funding' is subject to increasing interventions from university management[19]. Moreover, for a fruitful career, scientists depend on the acquisition of additional funding, from NWO, European Framework Programmes or from private companies. Each of these sources involves 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 at place in order to stimulate the production of good and relevant knowledge: performance assessments and foresight activities.

Credibility cycle

The developments just described have a strong impact on scientific practice, which can be analysed in terms of the credibility cycle. The governing set of norms of each conversion is influenced by changes in the contract. Some conversions seem solely ruled by the scientific community, but in other cases society deliberately interferes. A number of 'organizational devices' is present to enhance the relevance of scientific research. These can be connected to particular credibility conversions (figure 6). In this case study, we identified five types of these devices:

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

These devices are not developed by one party on its own, but are rather created in interaction between science and society. The way the devices modify the conversions differs, because the devices are of different nature. Generally, however, they have the potential of influencing the norms governing the conversions. This effect can be either

[18] E.g. the ACTS-program (Advanced Chemical Technologies for Sustainability) of NWO, the Technological Top Institutes funded by the ministry of Economic Affairs and the BSIK-programs (Besluit Subsidies Investeringen Kennisinfrastructuur).
[19] E.g. the current 'Focus en Massa' policy.

consolidating or opposing the existing norms.

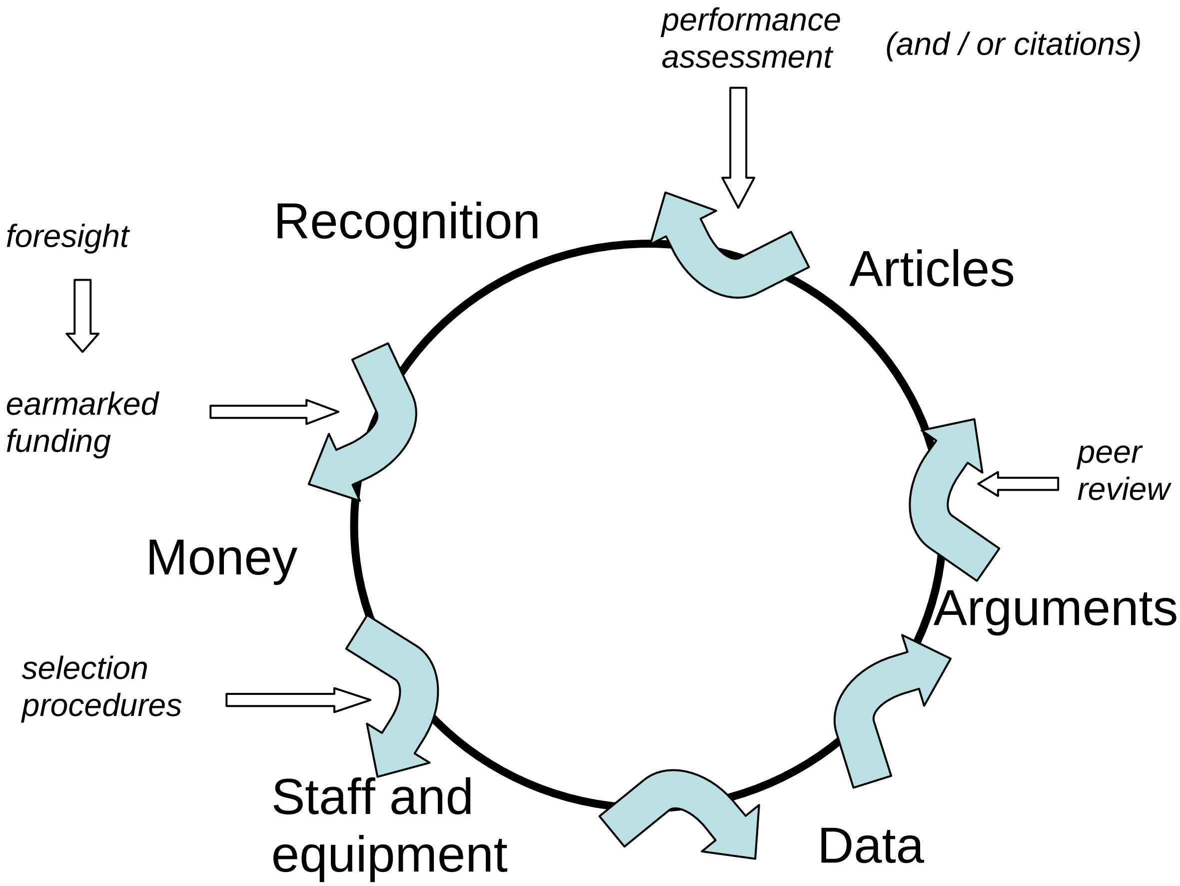

Figure 6. The credibility cycle, adapted from Latour and Woolgar (Latour and Woolgar, 1979). We have indicated at what points organisational devices connect to the cycle.

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. Also the ability to promise practical applications is increasingly valued in this conversion. Moreover, this conversion is indirectly influenced by foresight activities. The foresight studies on chemistry (1980; 1995) in the Netherlands have had a significant influence on the available funding for particular sub-fields[20].

The procedures for selecting candidates for academic positions influence the conversion of money into staff (and equipment). In these procedures normally a combination of various norms is taken into account. Recently, the publication and citation records have gained importance here. The most recent trend is that a candidate's proven abilities in funding acquisition are rewarded. Obviously, these developments co-determine how money can be transformed into staff.

The conversion of staff and equipment into data takes place inside laboratories and other research locations. Governing norms seem to be primarily of 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 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.

[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).

Proponents of post-normal science (Funtowicz and Ravetz, 1993) claim this to change, the public becoming increasingly involved in quality assessments of scientific results in fields of social importance, but we have not observed this in our case study.

The conversion of arguments into articles is strongly ruled by an instrument, but this is of scientific nature: peer review. All scientific journals employ such practices 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. This causes a potential delay in publications, due to the scientists' contractual duty to give their industrial partners some time to explore the patentability of their findings.

Obtaining recognition based on one's articles traditionally depends on peer judgment. Scientists informally acknowledge each other for the innovativeness of their articles and the degree to which they inspire others. However, in the 1980s and 1990s governments have installed performance assessments that formalise the attribution of recognition. 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 play a dominant role yet, 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.

Performance assessments, including bibliometric analyses, have increased the 'publish or perish' norm. Although they were started to enhance the societal accountability of scientists, 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, publications have become an end in itself.

The new mosaic of funding options, partly influenced by foresight activities, cause that only a happy few manage to get money without promising applications. 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. A side effect of the increasing complexity of funding options is that funding acquisition today consumes a major share of senior scientists' time. In the Netherlands most seniors have a guaranteed income for themselves, but to make scientific progress they are dependent on junior researchers who are paid mostly from project-based sources. 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 rewarded, too. Together the changed conditions under which scientists work have strengthened the mutual competition. The pressure to publish and to be cited has intensified[22]. Altogether, the new credibility cycle has an asymmetrical appearance. At the conversion from recognition to money societal relevance is very important, but at most other conversions this criterion hardly plays a role. The result is that the norms at different positions in the cycle are conflicting. This works out well in some subfields, like catalysis, in which the applicability of basic research is easily demonstrable. But in other fields, like biochemistry, there is a tension between research which is excellent according to scientific peers and research which is considered useful by societal actors.

5. Conclusion

To conclude, the idea of a contract to understand the relation between society and science appears to be helpful. One can regard the relationship as a negotiated set of rights and obligations for both parties. However, in most writings the idea of 'contract' tends to remain a metaphor. While this is correct – it is a metaphor, after all - it ignores the possibilities to be more specific about the set of rights and obligations, which would enable being more specific about changes in the science system. In this paper we intended to attain this higher degree of specificity, by discussing the general content of a science-society contract.

This undertaking enriches the understanding of how scientific practice is influenced by external pressures and how internal developments influence science's relation with society. We have built on dominant approaches in the sociology of science like Actor Network Theory that provide a fundamental understanding of scientific practice, but less of its changing relationship with society. Our framework facilitates an empirical analysis of such changes, as demonstrated in a reflection on the case of chemistry. Moreover, an enhanced understanding of these developments is crucial for making sound policy in the field of science and innovation. This is often based on primitive and

[21] Important indicators are past acquisitions and networking capacities.
[22] This is confirmed in our interviews with chemical researchers.

unarticulated notions of societal relevance, without a clear understanding of what these entail. Finally, the need to re-think the relationships between the traditional societal spheres is also apparent from a perspective of reflexive modernization (Grin, 2006). Along this line, an enhanced understanding of the science-society relationship can support system innovations.

The framework presented enables to relate changes in the contract between science and society to changes in actual scientific practice. We do not presuppose single-directional causality in this relationship. The contract may influence the credibility cycle and vice versa. The main merit of our approach is that the dynamics of both are taken into account.

The 'relation between science and society' and 'scientific practice' both are vague concepts trying to grasp complex pieces of reality. The idea of our approach is to develop 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. Although many norms are at stake in the science-society interaction, we present a condensed framework that captures the most central characteristics. Similarly, the credibility cycle does not give a complete overview of all activities involved in scientific research. It does, however, 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. This does not imply structure-determinism. The cycle is not a result of only the contract. It should rather be seen as a description of the processes taking place, which are the product of social interactions both within science and between science and society. The credibility cycle is no 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, 1979)(p. 205).

We believe to have demonstrated the usefulness of our framework in a brief case study of chemistry in the Netherlands. The framework helped us to identify the ways in which changing concepts of relevance influence scientific practice. In our case we have distinguished various 'organisational devices', which aim to enhance the relevance of scientific research, the most influential ones being earmarked funding and performance assessments. A next step is to elaborate this case and to extend the approach to different scientific disciplines and to other national contexts. The changing science-society contract can be described based on funding data, foresight studies, advisory reports and policy papers, supplemented by interviews. For a thorough study of the credibility cycle in-depth interviews with scientists seem the most appropriate data source.

It is often assumed that the pressure for relevance has increased over the years. However, relevance has also got different meanings. A certain stress on relevance is of all times but the meaning of this notion changes because of changing ideas about the potential benefits of scientific research. Here we have introduced a framework that enables a systematic study of changing concepts of relevance as products of the interaction between science and society. This enables us to disentangle the two parallel developments around relevance, resulting in an enhanced understanding of the relationship between science and society.

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Literature

1980. Chemie, nu en straks: een verkenning van het door de overheid gefinancierde chemisch onderzoek in Nederland, Staatsuitgeverij, Den Haag.

ACC-evaluatiecommissie, 1991. Evaluatie van de universitaire chemie in de jaren '80, ACC/KNAW, Amsterdam.

Baldursson, E., 1995. The Elusive Frontier: On the emergence and change of a science-society contract, PhD-thesis, Göteborg University, Göteborg.

Braun, D., 2003. Lasting tensions in research policy-making - a delegation problem. Science and Public Policy 30 (5), 309-321.

Bush, V., 1945. Science - The Endless Frontier, July 1945.

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

Elzinga, A., 1997. The science-society contract in historical transformation: with special reference to "epistemic drift". Social Science Information 36 (3), 411-445.

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.

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.

Garcia, C.E., Sanz-Menéndez, L., 2005. Competition for funding as an indicator of research competitiveness. Scientometrics 64 (3), 271-300.

Gibbons, M., 1999. Science's new social contract with society. Nature 402, c81-c84.

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.

Grin, J., 2006. Reflexive modernisation as a governance issue, or: designing and shaping *re*-structuration, in: Voss, J.-P., Bauknecht, D.,Kemp, R. (Eds), Reflexive Governance for Sustainable Development. Edward Elgar, Cheltenham, UK, pp. 57-81.

Guston, D.H., Kenniston, K., 1994. Introduction: the social contract for science, in: Guston, D.H.,Kenniston, K. (Eds), The Fragile Contract: University Science and the Federal Government. MIT Press, Cambridge, Massachusetts, pp. 1-41.

Hemlin, S., Rasmussen, S.B., 2006. The Shift in Academic Quality Control. Science, technology and human values 31 (2), 173, 126p.

Hessels, L.K., Van Lente, H., 2008. Re-thinking new knowledge production: A literature review and a research agenda. Research policy (forthcoming).

Hobbes, T., 2003. Leviathan, Thoemmes Continuum, Bristol.

Homburg, E., 2003. Speuren op de tast: Een historische kijk op industriële en universitaire research, Universiteit Maastricht, Maastricht.

Homburg, E., Palm, L. (Eds), 2004. De Geschiedenis van de Scheikunde in Nederland 3, Delft University Press, Delft.

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

Jasanoff, S., 2005. Designs on Nature: Science and Democracy in Europe and the United States, Princeton University Press, Princeton.

KNCV & VCNI, 1984. Toekomstig Chemisch Onderzoek: Een uitwerking van het rapport Wagner I voor de Chemie.

KNCV & VCNI, 1994. Toekomstig chemisch onderzoek: Universitair fundament voor industriële meerwaarde.

Latour, B., Woolgar, S., 1979. Laboratory Life, Sage, London.

Leydesdorff, L., Meyer, M., 2006. Triple Helix indicators of knowledge-based innovation systems: Introduction to the special issue. Research policy 35 (in press).

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

Merton, R.K., 1973. The Sociology of Science: Theoretical and Empirical Investigations, University of Chicago Press, Chicago.

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

OCV, 1995. Chemie in Perspectief: een verkenning van vraag en aanbod in het chemisch onderzoek, Overlegcommissie Verkenningen, Amsterdam

Overlegcommissie Verkenningen, 1995. Chemie in Perspectief: Een verkenning van vraag en aanbod in het chemisch onderzoek, KNAW.
Packer, K., Webster, A., 1996. Patenting culture in science: reinventing the scientific wheel of credibility. Science, Technology & Human Values 21 (4), 427-453.
Pestre, D., 2003. Regimes of knowledge production in society: towards a more political and social reading. Minerva 41, 245-261.
Pickstone, J.V., 2007. Working knowledge before and after circa 1800. Isis 98, 489-516.
Rip, A., 1994. The republic of science in the 1990s. Higher Education 28, 3-23.
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., 2004. Strategic research, post-modern universities and research training. Higher Education Policy 17 (2), 153-166.
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., Dijstelbloem, H., Wamelink, F., 2007. Evaluating Research in Context, Second edition, COS, The Netherlands, The Hague.
Van der Meulen, B.J.R., 1998. Science policies as principal–agent games: Institutionalization and path dependency in the relation between government and science. Research policy 27, 397-414.
Van Helvoort, T., 2005. De KNAW tussen wetenschap en politiek: De positie van de scheikunde in de Akademie in naoorlogs Nederland, KNAW, Amsterdam.
VSNU, 1996. Quality Assessment of Research: Chemistry: past performances and future perspectives.
VSNU, 2002. Assessment of Research Quality: Chemistry and Chemical Engeneering.
VSNU / NWO / KNAW, 2003. Standard Evaluation Protocol 2003-2009 for Public Research Organisations. .
Whitley, R., 2000. The Intellectual and Social Organization of the Sciences, second edition, Oxford University Press, Oxford.
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.