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CO-EVOLUTION OF SCIENCE, TECHNOLOGY AND SOCIETY

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Chapter 1: Co-evolution of science, technology and society as an entrance point to study *Politik, Wissenschaft und Gesellschaft*

Why is co-evolution of science, technology and society an interesting entrance point to address the issues raised in the BMBF Programme on *Politik, Wissenschaft und Gesellschaft*? There is a renewed interest in evolutionary approaches, in general and for technological innovation and economic theory (see also Ziman 2000).[1] For this BMBF *Förderinitiative* which is called Science Policy Studies in translation into English, the promise of increased understanding of *de facto* and intentional modulation of co-evolution of science, technology and society is important. Such an understanding is interesting in itself, but also because it allows better modulation. This dual goal is a new challenge, and combines theoretical and practical interest. A particular question will be about "bridging of the gap" between science and technology on the one hand, and society on the other hand. New forms of technology assessment are a case in point, and will be used as a focus throughout this Expert Review.

This general argument can be laid out in terms of three reasons to choose this theme, which will then structure the analysis and presentation of the Expert Review.

One reason can be presented in an autobiographical manner. In our work on Constructive TA, we realized that we were doing more than just developing new TA tools. We were addressing the way our society handles technology (Rip, Misa and Schot 1995), and offering approaches to do better. Whether one uses the label of 'co-evolution' or not, it is clearly important to link concrete change action with larger patterns in the overall development of technology and society. For example, the mandate to technologists to work for progress without much external interference, in place since the late 19th century, has shifted and is now contested for particular technologies. TA can be seen as a way to work towards better technology, and to recover part of the mandate (while sharing it with others). As Wynne (2002, p. 459) remarked, there will remain a tension whether this is about specific consequences of proposed technological developments, or about conflicting larger visions of a good society.

Such reflections are a starting point to address basic questions of the social sciences: agency and structure, and order and change. Actor-centred approaches have to complemented by a recognition of the emergence and effect of repertoires and regimes at a more collective level. For example, ongoing processes of novelty creation in science and technology, and their selection by institutions and markets are modulated by expectations, promises, missions and sometimes explicit requirements like wealth creation or sustainability. Evolutionary terminology comes naturally here!

The overall process of co-evolution of science, technology and society has reflexive components. In fact, the emergence of technology assessment, and of R&D policy itself, are indicators of reflexivity in the co-evolution. Phrased in this way, there is

[1] The Dutch science funding agency NWO took evolutionary explanations of behaviour and institutions as one of its strategic themes for the social and behavioural sciences (the other theme chosen was governance). See Van den Bergh and Fetchenhauer (2001).

a link with the recent work (and discussions) on reflexive modernity of Anthony Giddens and Ulrich Beck (one of their claims being that legitimity of an action or a decision now requires reference to expert inputs rather than to traditional authority).

The second reason is practical. Policy initiatives and instruments depend for their success not just on the way they address a specific problem or mission, but also on how they become (or are already) part of larger processes. Their strength, as well as their successes, have to be evaluated in this way – a multi-level (and multi-actor) approach to evaluation, which is now recognized as important by professional evaluators, even if they can not always take it up in practice. In other words, when the BMBF Programme starts to support concrete policy studies, there must be a reminder that larger contexts and processes – signalled by the term co-evolution – are important.

The multi-level approach is additionally important because concrete actions and interactions, for example around biotechnology and genomics, add up to effects at more collective levels. Particularly interesting is how new roles and responsibilities are being defined, which may well imply emerging *de facto* governance arrangements.[2]

There is a third reason to use the concept of co-evolution. Theoretically, it refers to various (but converging) bodies of literature like evolutionary economics, sociology of technology, some strands in societal construction of science. I shall discuss this literature in Chapter 2. Evolution and co-evolution are also metaphors, which open up further thoughts.[3] And some of these thoughts are normative: evolution, and especially co-evolution, are "good" and one should contribute to this process. Interactive and participatory TA, hybrid forums as a carrier for *démocratie technique* (Callon et al. 2001) now appear as goals to work towards.

We have some experience in interactions between scientists and technology assessors and/or ethicists (for example in biotechnology, genetics and genomics) where the use of the concept of co-evolution made participants realize that they were part of a larger process – which then opened windows for constructive interaction. Bridging a gap, one could say, between technology promotors and society, here represented by social scientists and ethicists. Why there would be such a gap is a topic for research by itself (see section 2.3 for a brief discussion); here, the point is that actors want to bridge the gap, even if only for legitimatory purposes.

The concept of co-evolution further supports (and underpins theoretically) the recent and increasingly visible move from top-down steering and hierarchical forms of governance to interactive processes, policy networks and what could be called 'modulation' of ongoing processes. Co-evolution of science, technology and society cannot be steered in a simplistic interventionist way – other than for short periods of time

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[2] An EU-funded project, PARADYS, coordinated by Bohra (University of Bielefeld) and in which we participate, is tracing how citizenship is redefined in the debates on biotechnology and human genetics.

[3] Ziman (2000, p. 11) talks about "the realm of thought that opens up behind the evolutionary for technological innovation" and asks "What do we hope to gain by exploring it further?" One answer (though for a different metaphor) is given by Michael Ruse: The military metaphors favoured by Edward Wilson in his sociobiological studies (and generalizations) of ants could be removed, but they make the studies comprehensible and increase predictive fertility. (I quote from a brief review, by Doris Schroeder in *New Genetics and Society* 19(3) (2000) 393, of his book *Mystery of Mysteries – Is evolution a social construct?* Harvard University Press, 1999.)

and/or in special circumstances. ‘Modulation’, however, is always possible, and is often the preferred approach. To ‘modulate’ productively, however, requires understanding of the nature and dynamics of the processes, including the own position and role in them.

This Expert Review focuses on TA (as a form of anticipatory intelligence) and interactions between heterogeneous actors (including new stakeholders) as instances of reflexive co-evolution.

Three kinds of research themes can be derived from such a discussion:

a) improved understanding the nature of reflexive co-evolution of science, technology and society with the help of such cases;
b) improving concrete activities of anticipation, feedback and learning by seeing them as instances of (desirable) co-evolution.
c) further questions thrown up by a) or b), for example, how industrial structures and networks emerge as part of co-evolution in a sector, or more often, across sectors.

The Expert Review offers substantial analysis, in three parts, but with a view to identify research themes.

- First, a brief review of the literature on co-evolution is used as a starting point to develop a productive perspective on modulation of the interactions of science and technology with society. The co-evolutionary perspective allows me to position test labs, and probing & learning strategies in marketing as ways to anticipate on selection. Intermediary actors and interaction with new stakeholders may become similar *nexusses* between variation and selection. Such an analysis is predicated on a historical division between technology developers and the uptake of technology, which itself creates dilemmas for productive handling of technology in society. Various strategies to overcome the dilemma have emerged. Their institutionalization cannot be definitive, because science and technology continue to introduce novel challenges.
- Second, I present a case of emerging interactions: TA components in big (and sometimes small) funding programmes for genomics. Scientists and science promotors increase the viability of their ventures, say in genomics or nano-technology, by including TA. In particular, in the Human Genome Initiative since the late 1980s, an ELSI (Ethical, Legal and Social Issues) component was added as a sub-programme. All recent genomics stimulation programmes now have an ELSI or ELSA (Ethical, Legal and Social Aspects) component. The fact of their occurrence is as important as their content: prudent scientists are encountering the public interest, not just through the promises they put forward, but also by responding to possible public concerns. The nano-technologists have learned from genomics, and are taking up TA at a very early stage – and use the acronym ELSA for it. While one can position these initiatives as enlightened self-interest, their general acceptance suggests that this type of link between variation and selection is becoming institutionalized.
- Third, the co-evolutionary perspective, and in particular the idea of patterns in co-evolution deriving from emerging irreversibilities, is applied to open up new directions in TA and reflexive interaction about technology. The present repertoire of TA tools and exercises was optimized for different decision contexts; it can be evaluated in terms of how far it bridges the gap between promotion and control.

> Emerging irreversibilities can be analysed, and mapping and reflection tools can be constructed on that basis, which enlighten actors about the process they are involved in, rather than setting out expected impacts. How to effect changes is a difficult question; the idea of modulation of *de facto* governance arrangements (including sociotechnical arrangements) remains a promising way to go.

Together, these discussions allow me to offer, in the final chapter, thoughts and suggestions about research themes for the BMBF Programme.[4]

While I have written the chapters in the body of the report as an elaboration of the co-evolutionary perspective on technology and society, this was done in an open-ended manner, so as to engage the reader in looking differently and seeing new things. These "new things" can be appreciated as such, without having to accept the co-evolutionary perspective. As a ladder which has been used to climb to the next level, the perspective can be thrown away after it has served its purpose. Although I must confess I still find it important to develop the perspective further and link it with other important theoretical perspectives.

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[4] This Expert Review complements, and to some extent overlaps with, a study done for the STRATA Programme of the European Union (Rip 2002b). In the latter study, the emphasis was on practical and policy-oriented conclusions.

Chapter 2: The co-evolutionary approach and the emergence of reflexive co-evolution

2.1: A brief consideration of the literature

Co-evolution is often used as a broad characterisation of co-development and mutual shaping, without specific reference to evolutionary theory. In the ESRC Report on Genomics and Society, business and economics are "shaping and being shaped by genomics", while the next page has "co-evolution of laws and legal structures and genomics" (IAF/CRIC 2002, Report 1, p. 8, 9). Such terminology carries a message (and an important message): things hang together and linear cause-effect relationships are the exception rather than the rule. Similarly, Nowotny et al. (2001) emphasize the co-evolution of science and society, not as a theory, but as a diagnosis, and a plea for more interaction between science and society. "Co-evolution denotes an open, and certainly more integrated, system of science-society interaction which enhances the generation of variety, whether in the choice of scientific problems, colleagues or institutional designs, on the one hand, or the selective retention of certain choices, modes or solutions on the other hand." (Nowotny et al. 2001, p. 248)

Under such a broad heading, interactions between (science,) technology and society can be studied. Insights may then be interpreted in terms of specific co-evolutionary theories or approaches, and thus contribute to theoretical understanding. One might also explore possible convergences in the various bodies of knowledge (as indicated in Box 1).

(Source: Geels 2002)

Co-evolution is increasingly recognised as an important isssue, e.g. in evolutionary economics (e.g. Nelson, 1994, 1995), long-wave theory (Freeman and Louçã, 2001), innovation studies. It has always been an important theme in science and technology studies, with its emphasis on seamless webs, emerging linkages between heterogeneous elements and co-construction. In diffent literatures many partial aspects of co-evolutions have been distinguished, e.g.

- Co-evolution between technology and users (Coombs *et al*., 2001; Lundvall, 1988; Clark, 1985; Leonard-Barton, 1988; Windrum and Birchendal, 1998; Witt, 2001; Lie and Sørensen, 1996; Aversi *et al*., 1999; Schot and De la Bruheze, 2002).
- Co-evolution between technology, industry structure and policy institutions (Nelson, 1994a,b, 1995; Van de Ven and Garud, 1994; Rosenkopf and Tushman, 1994; Lynn *et al*., 1996; Carlsson and Stankiewicz, 1991; Leydesdorff and Etzkowitz, 1998; Leydesdorff, 2000)
- Co-evolution of science, technology and the market (Callon *et al*., 1992; Stankiewicz, 1992)
- Co-evolution of science and technology (Kline and Rosenberg, 1986; Layton, 1971, 1976, 1979)
- Co-evolution of technology and culture (Du Gay *et al*., 1997; Van Dijck, 1998)
- Co-evolution of artefacts, beliefs (of designers) and evaluation routines (testing standards, equipment) (Nelson and Winter 1982; Garud and Rappa, 1994).
- Co-evolution of technology and society (Rip and Kemp, 1998; Freeman and Soete, 1997).

Box 1: Literature on co-evolution of technology and society

The link with explicit evolutionary and co-evolutionary theory is sometimes made, but often it is only the overall connotation of the terms 'evolution' and 'co-evolution' that is used. Even Nelson, one of the "founders" of the evolutionary approach in economics, particular in the economics of technology, appears to be willing to use the terminology in such a loose way, as in this quote:

> "Recognition of the role of technical societies in the development of modern technologies opens the door to seeing the wide range of institutions that may co-evolve with technology. Often legal structures may need to change. (..) There almost always are issues of regulation (..). In many cases new public sector activities and programs are required. (..) These examples indicate that the evolution of institutions relevant to a technology or industry may be a very complex process, involving not only the actions of private firms, but also organizations like industry associations, technical societies, universities, courts, government agencies, legislatures, etc." (Nelson, 1994: 56-57).

In the literature, three types of explicit evolutionary approaches which address technological development can be found:

- the mutation, selection, and retention (heredity) approach of Nelson and Winter (1977, 1982) and Mokyr (1990, 2000), and a more descriptive version in Basalla (1988). The Ziman (2000) volume remains within this framework, in spite of its intention to cover broader, cultural evolution. The specific topic of speciation is discussed by Levinthal (1992, 1998).
- the quasi-evolutionary or sociological version introduced by Van den Belt and Rip (1987) and developed further in Van Lente (1993) and Hoogma (2000); with links to self-organisation approaches (Allen 1994). Studies in the social construction of technology can sometimes be read as showing how selection works on meanings attributed to (new) technology (Bijker 1995).
- the selection on variety-in-a-population approach of Metcalfe (1998), see also Metcalfe and Boden (1992), and the related approach for innovation systems (McKelvey 1997).

In addition, there is the approach (developed furthest by Leydesdorff), where 'systems' have selective effects on each other and can lock in so as to create a higher-order dynamic (as in the triple helix of government, industry and universities).[5] Technological developments are not conceptualised as such, however; they are sites to study triple-helix interactions.

A key point is that patterns occur in co-evolution, and that some of them stabilize and shape further actions and interactions; a well-known example is a technological regime (Nelson and Winter 1977; Van den Belt and Rip 1987). Actors experience the constraints of such a regime. In open and fluid situations, they might actively try to create

[5] Interestingly, co-evolution of three dynamics (rather than two) leads to endless innovation. Each of the separate spheres "composed of sub-dynamics like market forces, political power, institutional control, social movements, technological trajectories and regimes, but the operations can also be expected to be nested and interacting" (Etzkowitz and Leydesdorff, 2000, p. 113). Perturbations in one sphere will trigger further changes in the other. During the co-evolution process tensions and asynchronicities may emerge. "Uncertainties in the relations between the helices open windows of potential innovation (and conflict) in (sub)systems that otherwise have to be reproduced" (Leydesdorff, 2000: 244). "In contrast to a double helix (or a coevolution between two dynamics), a triple helix, in which each strand may relate to the other two, is not expected to be stable. (..) The sources of innovation in a triple helix configuration are no longer synchronized a priori. They do not fit together in a pregiven order, but they generate puzzles for participants, analysts, and policymakers to solve" (Etzkowitz and Leydesdorff, 2000: 112).

a regime that is of advantage to them (for example in the battle about an industry standard).

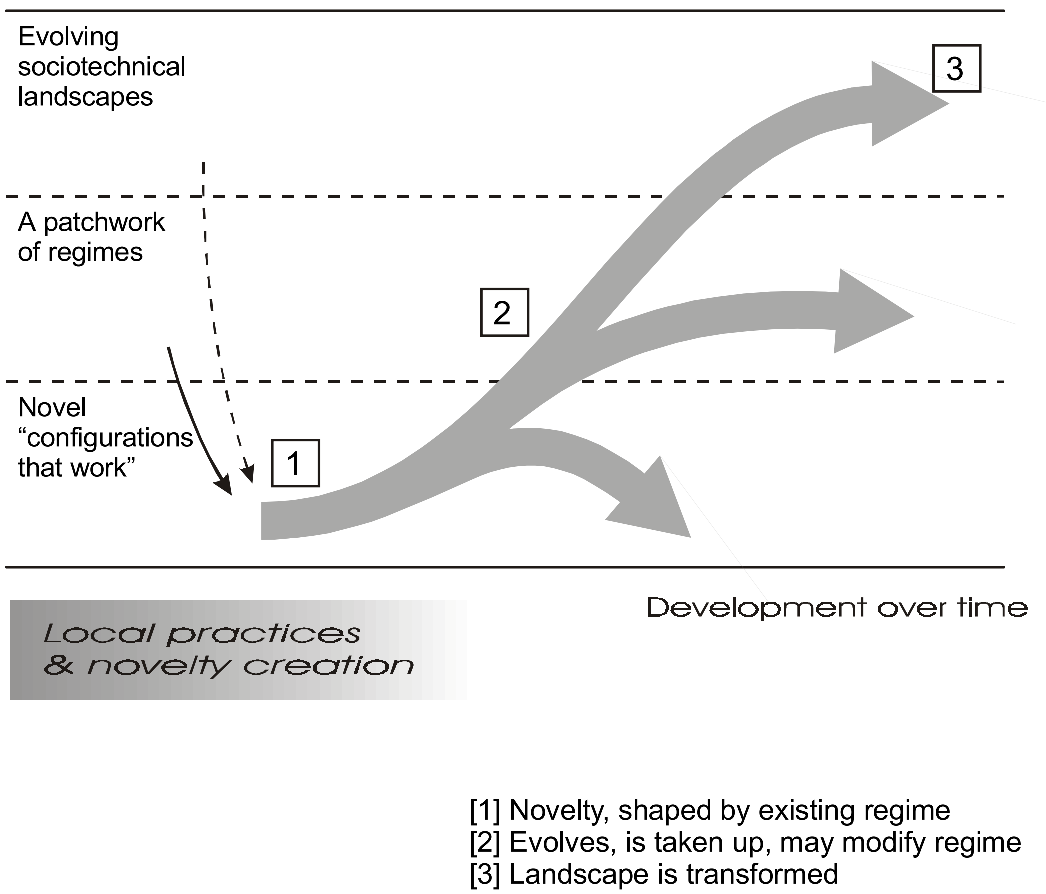
First-order evolutionary explanations are framed in terms of variations (and variety in a population), selections and retentions, but this cannot be the whole story. The tension with actor-centred explanations has to be resolved. When actors introduce a novelty (i.e. a variation) they know what they are doing, and anticipate on the conditions the novelty (at first still a "hopeful monstrosity") has to meet to be successful (Rip and Schot 2002). Their action is a reflexive action, and if their anticipations are sensible and are met in practice, there will be successful implementation. This actor-centred view, however, has to complemented by a recognition of the emergence and effect of repertoires and regimes at a more collective level.[6] Kemp et al. (2001) discuss this, and add a further point about a slowly changing sociotechnical landscape as the backdrop for actions and regimes.

They visualize the multi-level process of technological innovation as in Figure 1, supporting it by reference to earlier and ongoing studies of regimes and socio-technical landscapes. Concrete configurations that have to work are a constraint: not everything goes. Regimes offer rules how to develop technologies; such rules enable as well as constrain. The sociotechnical landscape consists of the physical landscape, other technologies, regulations and institutions, which together constitute a landscape in the sense that there are gradients which make travel in certain directions ("downhill") much easier than in other directions ("uphill").

Technological regimes are grammars or rule-sets which orient (up to disciplining them) the work of engineers and other actors developing new technological artifacts and systems (cf. Nelson and Winter 1982, Van de Poel 1998), but can be broader and shape the interactions of actors with the relevant artifacts and systems and how these are embedded in society. Staudenmaier (1989) shows this for the motorcar and the maintenance of the transport regime building on the motorcar. What Figure 1 adds (in line with the work of historians of technology like Staudenmaier) is the sedimented landscape resulting from earlier actions and cumulating infrastructure, which changes only slowly, the *longue durée* as Braudel (1966) called it. Like regimes, the socio-technical landscape enables and constrains, but not through rules.

Figure 1: The Dynamics of Socio-Technical Change

[6] Actor-centred institutionalism (as developed by Renate Mayntz and others, and applied to technological developments in Weyer 1997) is another attempt to address this tension.



2.2 Modulating co-evolutionary processes

In a (co)evolutionary process, modulation is done by selection. This is an almost empty claim, though, because selection is notoriously underconceptualized. A distinction made in biological theory can be used as a first step: the “fitness landscape” can be given, with evolution adapting to the landscape (and achieving a local optimum), or the landscape can change and co-evolve in response to the agents (Kauffman 1993, quoted after Van den Bergh and Fetchenhauer 2001). Institutions (in the sociological sense of rules) and social order more generally are a backdrop to actions and interactions, enabling and constraining them in the same way as a “fitness landscape”. At the same time, this landscape is the product of earlier actions and interactions.

When modulation occurs, it is not an independent input, coming from outside. It is part of the co-evolution, and is partly determined by the existing landscape. But it can change (modulate) the process, for example by creating linkages which become institutionalized. After some general considerations, I will discuss examples of such linkages between variation and selection which have become or are becoming institutionalized, and thus form a *nexus*.

Co-evolution is the linked evolution of two (or more) dynamics, each of which can be conceptualized in terms of variations and selections (and retentions). The linkage may give rise to patterns with dynamics of their own. The term has been used by Nelson (for technology, firms and institutions), Leydesdorff (for science, government, industry) and Rip & Kemp (for technology and society) – see Box 1 for references. Other studies not using the term still address such a question, for example in the analysis of historical path dependency (North 1990).

For actors, there is the experience of co-evolution (in terms of mutual interdependencies, and the force of path dependency) and anticipation on selection, as well as, even more precariously, anticipation on emerging patterns (the struggle for an industry standard is an obvious example). Intentional and strategic action now contributes to the co-evolution and the patterns, even if the patterns may not be desired by any of the actors (as in the high-tech races, for example for smaller and faster integrated circuits).

Improving outcomes is possible for each actor through a better understanding of their selection environments and the dynamics of co-evolution. Since other actors will react, the improved strategies cannot be stable. In fact, an enlightened actor understands his action as modulation of interactions and emerging patterns of which he himself is a part, rather than linear steps toward goal achievement.

The same holds for actors (governmental or otherwise) with a governance responsibility. Modulation of ongoing processes rather than forceful shaping is the enlightened approach. There is a large literature on steering by governments (and another large literature on managing organisations) which includes criticism of rational planning and control approaches of the principals for their “lack of behavioural realism” (Lane), as well as outlines of, and experiences with, interactive approaches, policy networks, self-regulation etc. The argument often starts with the lack of power (and knowledge) of the principal, so that ‘disjointed incrementalism’ (Lindblom) is the best one can do. The concept of ‘modulation’ is close to ‘disjointed incrementalism’, but adds that there are patterns in ongoing processes which allow modest intervention – provided they are understood for what they are.

Methodologically, the analysis should endogenize (as economists would say) all steering attempts, including those of the principal or other focal actor, as elements of the overall process. “Instead of the heroism of the policy actor *vis-à-vis* the system, there is a variety of actors and roles, and a ‘distributed coherence’ which is self-organized. Some actors may contribute more to the self-organization than others, but there is no general rule. Or better, there are lots of rules, dominant positions etc., but these are contingent and cannot be taken for granted. Instead of steering, there is reflective (and reflexive) intervention: mutual translations (that's what happens anyway) are now seen as the basic process.” (Rip 2002a)

If a comprehensive model of the overall process is possible, this would allow suggestions for modulating the process from specific positions within it – taking into account recursivity and reflexivity. When actors anticipate on co-evolutionary interactions and outcomes, and define and adapt their actions and interactions on the basis of understanding of the co-evolution, the dynamics of co-evolution will change. Another reason to call it reflexive co-evolution, and probably a message of despair for attempts at comprehensive modeling. On the other hand, we might be able to do better than present modernist theories.[7]

Modulation can occur through more or less institutionalized activities and patterns in the co-evolution. In particular, as Van den Belt and Rip (1987) have shown, institutionalized links, a *nexus*, between variation and selection have emerged. An interesting example is the test lab: a protected space, protected against immediate selection pressures, but simulating them in the conditions of the test – as it were a micro-cosm substituting for the real world. Test labs were first established in the German synthetic dye industry in the last decades of the 19th century to recreate conditions of the selection environment (then, the dyers' shops). A test lab is an arrangement which enables anticipation and feedback to the technology developers. Test labs, and more generally, tests of performance and further effects (including risks), help developers to be prepared for later selection pressures.[8] Such enlightened self-interest, however, has also societal effect: there is some pre-selection. The ELSI/ELSA studies of genomics, which will be the topic of the next chapter, can be seen as a "test" through studies. Rather than exposing society to new technologies in a trial-and-error manner (cf. Krohn and Weyer 1994), a kind of test-lab is created by doing ELSA studies about possible effects and their assessment: "trial" by studies.

Compare this with what has been called a 'probe and learn process' for market introduction of novel innovations (Lynn *et al*., 1996). Firms like Motorola introducing cellular phones and Corning introducing optical fibres engage in series of market experiments with technical prototypes in early phases of their development. Probing and learning is initially more important than immediate success. The market is ill-defined and evolving, the technology is ill-defined and evolving, and the two interact. Although the final outcome is unknown, the probing and learning process is not blind; it is guided in every step by visions, expectations and ideas about possible uses. These visions and expectations are changed on the basis of the outcomes of practical experiments. Ideas within the firm about user preferences and design rules are becoming increasingly aligned during the process.
A recent version of engaging future users and learning from their reactions are the 'Try Me' shops, where visitors can taste and test products that might eventually be introduced on the market. It reduces the cost of trial and error. Interestingly, there is also the opposite strategy, common in Japan, where dozens of possible versions of a product are

[7] A concrete example is how R&D evaluation can look at the overall system and its dynamics, rather than focus on whether a particular programme or institution had achieved its mission. This was done by Arnold, Kuhlmann and Van der Meulen (2001).
[8] This is why Wynne (2001, p. 477-478) emphasizes that testing (of Genetically Modified Organisms) has less to do with control – as promotors say reassuringly – but with defending the project.

turned out in the hope of hitting one that is preferred by many customers. In other words, external selection is sought. Such a strategy can be used by Sony for walkmans, but not by an enegry company for power plants – too costly. Leonard-Barton (1995) refers to the Sony strategy as Darwinian selection, and distinguishes in addition to 'product morphing' (the test and adapt strategy), 'vicarious experimentation' where firms learn from the experiments of others. This can happen in an opportunistic way when (established) firms wait and let the pioneers suffer the costs of early experimentation: they learn from others' mistakes. But firms may deliberately share learning experiences, so as to speed up the pace of technological development. The USA Department of Defense sometimes requires contractors in a consortium to share their results with other members of the consortium.

Collective experimentation and learning draws attention to activities at the collective level and the role of intermediary actors and patterns of interaction. For example, professional associations and technical societies can play a role as a reservoir of knowledge; while they often also do some lobbying on behalf of a new technology, to create favourable regulation, have some protection from outside competition, and mobilise public support. The complexity of the picture (and the contrast with simplistic views about the market as the selection environment) is brought out by Callon when he introduces the notion of a techno-economic network:

> "a techno-economic network (TEN) is a coordinated set of heterogeneous actores – for instance, public laboratories, centres for technical research, companies, financial organisations, users and the government – who participate collectively in the conception, development, production and distribution or diffusion of procedures for producing goods and service, some of which give rise to market transactions" (Callon 1992, p. 73)

Some TENs continue over time, and their type of collaboration becomes accepted, even a model for actors to emulate. Some of the networks in the biotechnology sector functioned that way, at least until the recent shake-out.

In terms of co-evolution, the interesting aspect is that a TEN can be seen as a way to arrange the technology promotors with actors traditionally located in the selection environment, so as to improve the chances of success for the innovation. Many more realignments are necessary to achieve success, so the actor, or better, actor-network, must accordingly be more complex. In fact, there are now conscious attempts to guide and improve the introduction of new technologies into society through special initiatives, as for an Electronic Superhighway, or platforms as for telework. I have used the term 'alignment macro-actor' to describe such efforts, and argued that such macro-actors can be set up ("constructed") if the emergent networks promise insufficient re-alignment (Rip 1995, p. 426).

While these examples refer to attempts, initiated by technology actors and/or government agencies, to improve the introduction of a new technology, and thus modify selection, the idea of re-alignment and possible 'alignment macro-actors' is also applicable to situations where there is criticism and so-called new stakeholders raise their voice. This can lead to contestation, but increasingly such voices from the selection environment are listened to, and more recently, incorporated in the techno-economic network – to anticipate better on the selection environment and/or to make it harmless. In fact, for the same reason a platform promoting telework (in which I participated at the time) included old stakeholders, spokespersons for trade unions and professional workers' leagues.

These developments are linked to broader processes in which, increasingly, other actors than traditional stakeholders take an interest in the firm, and make a difference to its successful performance. Credibility, always important for credit, now also depends on the new stakeholders. In the grey area between private firms and public agencies, populated by a variety of actors, new patterns of interaction emerge. Beck (1992) has identified the role of sub-politics, talking of technology and risk in general terms only. Clearly, long-term developments and patterns in the co-evolution of science, technology and society play a role in interaction with what happens for specific technologies and issues.

2.3 bridging the gap between technology promotion and control

At a macro-level, co-evolution of science, technology and society can lead, and has in fact led, to stable patterns or regimes (or a social contract – an explicit governance arrangement). This is, for example, how Nowotny et al (2001) locate the academic-disciplinary "Mode 1" of knowledge production. We can see this as a protected space at the macro-level, for science-as-we-knew-it (Rip 2002c). The present time is then witnessing a punctuation of the earlier equilibrium, and many new varieties of doing science are appearing.

For technology, the situation is more complex, because technology was much less separable from society than science was. In fact, the distinction between technology variation and societal selection which carried part of my argument about an evolutionary approach being applicable, is actually predicated on the existence of a historically evolved regime where technology development is separate from uptake and use (Rip and Kemp 1998). Then, variation and selection are institutionally separated – and have to be bridged again in anticipations, experiments, and interactions.

Historically, the separation was part of the industrial revolution. In a further step, during the 19th century, engineers and other technology actors were given a mandate to develop new technologies and confront society with them, as long as this could be presented as progress (Van Lente 1993). This was complemented by the emergence of the idea of 'technology' in general, symbolically linked to ideals of progress (Smith and Marx 1994; Rip and Kemp 1998). The mandate and its symbolic justification offered a macro-protected space. It was maintained until the 1960s (when Harold Wilson, the UK Prime Minister, could proclaim the "white-hot technological revolution"), but then started to break down. Another punctuated equilibrium?

The existence of the mandate, and the macro-protected space for technological developments, had, over time, allowed the establishment of institutions and divisions of labour which could not simple be turned back. Shifts occur, there are contestations. But modulation from the selection side, other than market reactions or plain refusal at a late stage, is not easy. The rhetoric of the evolutionary metaphor, where selection is all-powerful, breaks down in the face of the actual patterns in co-evolution.

Let me be more specific. In our modern societies there is an asymmetry between "impactors" (those at the source of impacts of technology) and "impactees". This can be a difference in power, but is always a difference in timing. Initiators of technological development know more, and have invested more, at an early stage, and impactees and spokespersons for society have to wait and in a sense, follow their lead. The asymmetry has another component: technology developers are insiders and do not necessarily know very much about the outside. Adoption and diffusion, however, is up to “outsiders”, with other interests and expectations. The story of nuclear energy since the 1960s is one of a struggle between insiders and outsiders. At a much smaller scale, the same storyline is visible in the development of cochlear implants for deaf people (Garud and Ahlstrom 1997), especially when it turned out – unexpectedly for the insiders -- that the deaf community was negative about taking deaf people out of their own culture by providing them with implants.

The asymmetry gives rise to a division of TA labour where insiders articulate ‘promotion’ and outsiders ‘control’. A similar division of labour, at one remove is visible in how governments and their agencies handle technology in society. Government technology policy most often focuses on promotion of (selected) technologies, as when stimulating the electronic superhighway. The main question for such technology policy is to “pick the winners”, now at the level of the society. On the other hand, other agencies of the same government are occupied with reducing the human and social costs of the introduction of new technology, for example through safety and environmental regulation. This dichotomy between promotion and control of new technology is thus part of the *de facto* constitution of modern industrialised societies, and is reflected not only in the division of labour between government agencies, but also in cultural and political views, as in the assumption that there will be proponents and opponents to a new technology (Rip and Talma 1998).

TA becomes a victim of these views when technology promotors see, and condemn, technology assessment as technology harassment or arrestment. Contestation will continue, but there is increasing interest in constructive approaches. For TA (broadly speaking), one can see a “philosophy” of TA at work, which has been described as: to anticipate on impacts and feed back such anticipations in ongoing processes and practices (including decision making) in order to reduce the human and social costs of learning how to handle technology in society – compared to what happens if we continue to do this by trial and error. (Schot and Rip 1997)

The precautionary principle, a recent addition to the arsenal of control, can be seen as articulating the TA philosophy in a particular direction: avoid learning by trials because the errors may well be too risky. In this reading, it is a behavioural principle, and it is not contrasted with science-based regulation, but with another behavioural principle: embrace trials, because this how progress can be made.[9]

The difference in timing exacerbates a fundamental dilemma about handling new technology in society which is often referred to as the anticipation & control dilemma (Collingridge 1980). At an early stage of technology development, the nature of the technology (and the articulation of interests) are still malleable – but it is unclear what the effects and impacts will be. By the time these become clear, the technology is entrenched and vested interests make it difficult to change the technology. As with the pesticide DDT, the only possible response is then forbidding further deployment of the technology.

[9] Even without such explicit principles, there will always be trade-offs between overcaution and undercaution – in other words, which kind of error are we prepared to make?

One generic strategy to avoid decision regret is to keep flexible as long as possible (at the risk that none of the various options will be pursued sufficiently far so as to see what they are worth). This is Collingridge's (1980) preferred approach, and Lindblom and Woodhouse (1993) discuss it as an important option. A concrete example is the 1991 French Law on nuclear waste handling which requires three options to be maintained for a period of perhaps 15 years, and with annual public evaluation of progress and prospects. The Parliamentary *Office d'évaluation des choix scientifiques et techniques* is involved, and over time, modifications can be made to the trajectories. (See Kuhlmann et al. 1999 for a brief discussion of this example; also Callon, Lascoumes & Barthe 2001.)

Another generic strategy is to work towards "good" technologies from the beginning. If there is a problem with sustainability, we will set sustainability as a requirement for new developments. In general, as part of the requirements envelope, or specifically as in so-called technology-forcing regulation where, say, emission levels in exhaust gases are set that cannot be achieved with present technology, and it is up to the technology actors to develop new technology. Another route within this overall strategy is to develop fail-safe technologies. The option of an inherently safe nuclear power plant would be an example, and so-called terminator technology in plant biotechnology can be seen as a fail-safe technology as well. Obviously, there will always be the nagging doubt how safe exactly the fail-safe technology is.

A third generic strategy emphasizes ongoing learning. It starts from the observation that more is possible than the original and stark version of Collingridge's control dilemma appears to say. Assessments occur all the time, not only at the beginning and the end of the development trajectory, and one can try to improve them as to their quality and their impact. This can be linked to a further process observation: One cannot remain flexible all the time (Verganti 1999). Thus, it is important to understand the process of increasing irreversibilities. At an early stage of the "innovation journey" (Van de Ven 1999; Rip and Schot 2002), a new technical or socio-technical option is open-ended and its performance is still fairly limited. Over time, the options become articulated (technically, economically, socially) and link up with the surroundings, which themselves change and to some extent adapt to the possibilities of the new option.

To make the underlying dynamics visible, a useful entry point is Abernathy and Clark's (1985) idea of architectural innovation: technical competencies and customer/market linkages are broken because they are irrelevant for the success of the new option, and new competencies and linkages have to be built up. Abernathy and Clark limit themselves to well-articulated new products. In general, one should also consider shifting and some break-up of functional linkages and societal linkages (for example, new types of regulation necessary for biotechnology, or issues of access, privacy and security with information and communication technology). The new linkages will be part of evolving alignments (technical, socio-economic, societal). Recent economics and sociology of technology have shown how path dependency increases over time in technological development, and how co-production of impacts occurs along those paths. If other actors than technology promotors can be involved, the path may well turn out differently (not necessarily better: selection agents are not all-wise).

What we have seen in this chapter is how micro-institutionalization of specific patterns and nexuses occurs in the co-evolution of technology and society, but also macro-institutionalization of larger and longer-term patterns. The processes at the two levels interact, and should be studied jointly.

One implication is that the interest (and effort) spent on technology assessment, public awareness, participation, may remain fragmented when focussing on problem solving (like resolution of conflicts, legitimation problems, new agenda building). For example, to find out how consensus conferences can be organized better, it is not enough to evaluate a number of cases and identify so-called best practice. These consensus conferences function at the interface between technology and society, and what they can achieve is part of larger co-evolutionary processes. A dynamic evaluation is necessary. Such an exercise is useful even for those who do not share the co-evolutionary perspective, because a broader picture is created which helps to articulate what is known (understood) and what is not known (understood).

The focus on modulation of inovation journeys – itself already a broadening of the common tool & problem-solving approach – must be complemented by the challenge of modulating macro-arrangements, or at least, taking the possibility of such effects into account. Management and governance studies, institutional design and political philosophy all come in here. But their "solutions" will not be definitive, for the same reason that institutionalized patterns will not be stable. Novel technological options will appear. Uncertainties about (new) technology and society are associated with risks of the unknown and the need to do something (anything) about them, and with the variety of views and values and interests involved which make decision making and *de facto* acceptance of new technologies difficult (and difficult to anticipate).

Chapter 3: Emerging interactions: the case of ELSA (study of ethical, legal and social aspects) in genomics research programmes

Genomics
In this case study we focus on interactions between science, technology and society in the domain of genomics.[10] There is no precise and agreed definition of genomics, and boundary work occurs linked to promises (and hype) as well as distancing with respect to biotechnology, in particular "green" biotechnology and the concerns and conflicts surrounding it.

Harris (2001) suggests the following definition: Genomics is "anything relating to genetic information encoded in DNA".[11] While broad, there is still a specific element in the reference to information. Bio-informatics is a key component of genomics. And genomics is "primarily a knowledge industry" (IAF/CRIC 2002, Report 3, p. 20).

Our empirical object, research funding programmes in the field of genomics, allows us to do without further specification of the domain of genomics. We can follow the different countries with their own definitions.

Emerging institutionalization
We observe a growing number of studies addressing social and ethical implications of basic research and technology development in the field of genomics. And they are not just incidental activities, but become institutionalized as part of national research programmes in which they are being seen as essential ingredients for the creation of new knowledge.

We interprete this observation as indicators for an emerging institutionalization of a specific interaction between variation and selection processes of technology. In our country reports we will briefly describe some current activities in the domain of genomics. Our question is about the extent of institutionalisation, and its possible impact, in particular how far this bridges the gap between science & technology and society.

3.1 Country reports

3.1.1 Ethical, Legal and Social Issues (ELSI) programme in the United States

The United States Human Genome Programme (US HGP) was conceived in the mid 1980's. The two responsible institutes, the Department of Energy (DOE) and the National Institutes of Health (NIH), presented their plans for the programme in 1990. One of the components of the US HGP was the Ethical, Legal and Social Issues (ELSI) programme. James Watson, NIH's first HGP director, explained ELSI's intent in 1989:

"The goal of the ethics component of the Human Genome Program is to address, anticipate, and develop suggestions for dealing with such problems in order to forestall adverse effects." (cited in McCain, 2002).

Whether ELSI was born out of sincere intentions or as a mere lubricant for getting financial support of the HGP is not clear. According to McCain (2002, p. 114) there were some who doubted the sincerity of the

[10] In this study we have focussed more on societal aspects of genomcis than ethical aspects, despite the great interest in bioethical issues. An interesting report on ethical issues of emerging technologies was written by Battye, Blar & Mellor (1999).
[11] References to literature and documents are given at the end of this chapter, not in the general bibliography.

intentions of Mr. Watson and saw ELSI as mere politics – " Watson pre-empting criticisms about the project to maintain support in Congress by mollifying potential critics with promises of funds for cash-poor social science and bioethics research." "Watson himself concedes that he saw ELSI initially as a shield and a sounding board. "It kept us from being attacked" by those who were concerned about the consequences of genetic research, Watson says." (Marshall, 1996).

The ELSI programs became institutionalized at DOE and NIH. The department of Energy and the National Institutes of Health devote 3-5% of their annual HGP budget towards the ethical, legal and social issues surrounding the availability of genetic information.

In Table 1 the evolution of the ELSI programme goals is pictured. The goals of the 1993-1997 program differ only slightly from those before 1993 (McCain, 2002). Table 1 shows that the goals of the 1998 program are much more specific than those until 1993. The accent on anticipation of adverse effects and the development of policy options has shifted towards a mere 'examine and explore' programme. According to McCain (2002) there has been a lot of debate about the extent in which ELSI is able to provide policy options to the Nation, to the congress or executive branch.

Goals of ELSI programs until 1993	Goals of ELSI programs from 1998-2002
1. Anticipate and address the implications for individuals and society of mapping and sequencing the human genome; 2. Examine the ethical, legal and social consequences of mapping and sequencing the human genome; 3. Stimulate public discussion of the issues; and 4. Develop policy options that would assure that the information is used for the benefit of individuals and society.	(a) Examine the issues surrounding the completion of the human DNA sequence and the study of human genetic variation. (b) Examine issues raised by the integration of genetic technologies and information into health care and public health technologies. (c) Examine issues raised by the integration of knowledge about genomics and gene-environment interactions into nonclinical settings. (d) Explore ways in which new genetic knowledge may interact with a variety of philosophical, theological, and ethical perspectives. (e) Explore how socioeconomic factors and concepts of race and ethnicity influence the use, understanding, and interpretation of genetic information, the utilization of genetic services, and the development of policy.

Source: McCain, 2002

Table 1 : Changing Goals of ELSI programs

According to McCain (2002, p. 132) "the ELSI experience so far does not support an early contention by James Watson and others that public science programs can sufficiently monitor and address their own social impacts. ELSI-type programs are unlikely to help shape research agendas and may delay development of new technologies to address correlated social concerns."

The evaluation report by the ELSI Research Planning and Evaluation Group states that "Over the years, the ELSI research programs have done an increasingly good job of ensuring that the findings of ELSI researchers are communicated beyond the ELSI research community to those involved in the basic genomic and genetic research enterprise. There are a growing number of genetic researchers who not only recognize the importance of these issues, but who are actively involved in ELSI research and policy discussions." (ERPEG, 2000, p. iv)

However, the report also observes that there are some in the scientific community who remain indifferent or even hostile to ELSI research. Therefore, " the ELSI research programs should strenghten activities that promote communication and collaboration between basic genetics and genomics researchers and ELSI researchers. Enhancing such communication will not only improve the dissemination of relevant ELSI research findings back to the scientific community, but it will also help to ensure that ELSI research continues to address the most critical issues in genomic and genetic research. The annual contractor and grantee workshops held by DOE, are a good model for the kind of effort that should be enhanced and regularized across both the DOE and NHGRI ELSI research programs." (ERPEG, 2000, p. 26)

Beckwith (2001) was a member of the first ELSI working group and confirms this observation of hostility among the scientists of the Human Genome Project towards ELSI-studies. Beckwith views his experiences as a reflection of a more broad problem: a communication gap between scientists and those interested in the ethical and social issues. On both sides their is not always respect for the other's discipline and also lack of understandig of the other's discipline.[12] He states: "The communication gap between the two cultures holds dangers for us all." (Beckwith, 2001, p. 194)

The ELSI research programmes can be viewed as an indicator of emerging institutionalization. It is also interesting to observe that the ELSI programmes themselves have yielded some forms of institutionalization. For example the formation of the Department of Health and Human Services' Secretary's Advisory Committee on Genetic Testing, " which is responsible for identifying policy issues raised by genetic testing and making policy and procedural recommendations to the Secretary on how such issues should be addressed." (ERPEG, 2000, p. 8)

3.1.2 Ethical, Legal and Social Aspects (ELSA) programmes in the European Framework Programmes

The first ELSA-like activities saw light in the Second Framework Programme (1987-1991). An ad hoc ethics committee (ESLA : Ethical, Social and Legal Aspects) was established as a result of opposition to the implementation of a pilot programme on " predictive medicine", to analyse the human genome. This committee adopted recommendations, organised public debate on the programme and selected 18 studies which were granted limited funding for one year (Elisalde, n.d.).

This research on the field of bioethics was further extended in the Third Framework Programme (1991-1994). The subarea Medical Ethics of Biomedicine was introduced. Furthermore, the programme Biotechnology included support for a series of studies aiming at the assessment of socio-economic impacts of biotechnologies (Elisalde, n.d.).

The Fourth Framework Programme (1994-1998) saw a further extension of bioethics research. All three programmes in the field of Life Sciences and Technologies: Biotechnology, Biomedicine and Health, and Fisheries and Agriculture Research had an ELSA sub-area. ELSA stands for Ethical, Legal and Social Aspects. (Elisalde, n.d.). According to José Elisalde, Head of Unit XII.E.5 (Ethical and Legal Aspects, Life S&T):

"What had begun as an ad-hoc measure, focusing on the Human Genome programme in 1990, has been increasingly extended to Medical Ethics and a thorough application of the precautionary principle in biotechnological research, and has arrived [..] at a common ELSA [..] approach in all Life Sciences and Technologies. Thus [..] these interdisciplinary projects are effectively building bridges between the "two cultures" of humanities and natural sciences [..]." (Elisalde, n.d.)

The ELSA approach is extended to all RTD programmes under the 5th Framework Programme (1998–2002) especially under the programme "Quality of life and management of living resources". One of the evaluation criteria of projects to be funded by this programme is the 'socio-economic dimension' of the projects. Proposers should address the socio-economic impact of their application. Each key action pays attention to socio-economic issues. This programme is built around six key actions:

[12] Mehta and Gair (2001) state that social scientists and others often seem to have little understanding of biotechnology and genetic engineering. Their article identifies some areas of inquiry in these technologies.

- Food, nutrition and health
- Infectious diseases
- The cell factory
- Environment and health
- Sustainable agriculture, fisheries and forestry, and integrated development of rural areas including mountain areas
- The ageing population and disabilities

With regard to the socio-economic dimension, look for instance at the key action infectious diseases. One of the main objectives of this key action is "to improve the prevention and treatment of infectious diseases of major public health importance through the development of new and improved preventive and/or therapeutic vaccines and vaccination strategies"(QoL, 1999, p. 6). The workprogramme states that also support will be given to "Organisational and economic aspects of human and animal health. Comparative assessment of the efficacy and effectiveness of different interventions for infectious disease control, including vaccination programmes. Studies on the determinants of public acceptance of community intervention against infectious diseases. Understanding of socio-economic factors and the role of human behaviour in relation to disease prevention, transmission and control."(QoL, 1999, p. 8).

Although the 'socio-economic dimension' is a key element in all the activities of the programme, there are also specific studies foreseen in the following areas:

- Public health and health services research
- Research relating to persons with disabilities
- Bioethics
- Socio-Economic aspects of life sciences and technologies

The year 2000 report on socio-economic impact of the Quality of Life programme (EC, n.d.) stated that the programme was 'not fully successful' with realising the socio-economic dimension and tried to improve this situation. According to the report this was due to communication problems. R&D scientists[13] did not fully grap the socio-economic message and they had difficulties to interact with socio-economic experts and other concerned parties. We have seen this communication problem also in the section above about ELSI in the United States.

One of the measures to overcome these obstacles was the establishment of a web site (http://biosociety.cordis.lu). This website was launched to stimulate exchanges of ideas between bio-technological researchers and socio-economic experts. The site includes a database of socio-economic experts to enhance interaction between researchers.

Furthermore, the European Group on Ethics in Science and Technologies stated in a paper (Archer & Hottois (eds.), 1997) that fundamental ethical principles must be respected and implemented in the Fifth Research Framework Programme. The European Parliament and the European Council established an ethical framework for research that is conducted under the Quality of Life programme. For example, it excludes research involving human cloning for reproductive or therapeutic purposes (EC, 2001).

3.1.3 United Kingdom

The Economic & Social Research Council (ESRC) of the United Kingdom has launched a new programme (worth £ 10 M) which explores social and economic issues surrounding genomics. This programme is part of a broad UK research initiative in the field of genomics, and ESRC collaborates with the other research councils (in this field and more generally, cf. the launch of their joint strategic body Research Councils UK (RCUK) on May 1, 2002).

[13] With R&D-scientists probably is meant non-social scientists who fill in applications for funding under one of the six key actions, e.g. the development of new vaccines.

The ESRC initiative started with with a national consultation: how can social science interrogate genomics? One of the components of this consultation was an email/web consultation in which the academic and user communities were asked about the strategic aim, research topics and organization of the new programme. Based on the submissions, the final report of this consultation formulated the following mission for the new initiative. The strategic mission should be:

1. "To establish the voice of social science in genomics through detailed empirical and theoretical engagement with the social, economic, psychological, political and other social scientific and legal aspects of the new genetics.
2. To use social scientific expertise to assess the multiple social implications of genetic knowledge and technology, at the levels of individuals, families, groups and communities.
3. To develop and enhance opportunities for lay participation in discussing, challenging and using developments in genetics, including the ways such developments impact on them as individuals, families, groups and communities.
4. To forge multidisciplinary research teams across the core social scientific disciplines, and to include biomedical scientists (in genetics and medicine), and the disciplines of theology, philosphy, law and ethics; to enhance further the UK's research capacity in this field, and improve its quality; to use international perspectives.
5. To develop greater insights into the practical and policy implications of genetics, with research that can inform, improve and develop the work of geneticists, nurses, counsellors, GPs, other doctors and scientists, politicians and policymakers." (Graham, 2001, pp. 4-5)

The ESRC also commissioned a scoping study to inform the development of proposals for new survey work on genomics. This study conducted a review and evaluation of existing genomics related surveys and other public consultation forums (Pevalin, 2001; Pevalin, no date). The ESRC invited applications for a new survey of attitudes and behaviours towards genomics.

In parallel, a Call for Outline Applications for a Centre for the Social and Economic Context of Genomics was made (due in September 2001), and the Institute for Alternative Futures (Alexandria VA, USA) and the ESRC Centre for Research on Innovation and Competition (CRIC) were commissioned to organize and prepare a scenario workshop in January 2002 (IAF/CRIC 2002).
Four (out of twenty or so outline bids) were selected, and full proposals were received in December 2001. The review process has been concluded, but there is no information about the final choice on ESRC's website.
The title and profile of the Centre, as sketched in the Call, are interesting because of their inclusion of economic aspects, and their relegation of ethical aspects to an additional aspect, rather than putting it upfront as in most ELSI/ELSA programmes. One could envisage an alternative version of the ELSA acronym: Economic, Legal and Social Aspects.
In the scenario exercise as well, there is a strong interest in economic aspects (and a decision to equate genomics with biotechnology when drawing up forecasts of application of genomics).

In addition to the stimulation of genomics related research through the research councils, the government of the UK also funded the formation of six Genetic Knowledge Parks (Oxford, Cambridge, London, the NorthWest, Newcastle and Wales) and two new National Genetics Reference Laboratories (Salisbury and Manchester).

In the proposal for the formation of the Genetics Knowledge Park in Wales (Sampson, Kille & Lucus, 2001) an ethical and social component is included. At Cardiff, there already existed the Centre for Research in Genetics and Society. The Centre's research is oriented towards the study of practical problems experienced by families and professionals involved with the Medical Genetics Service for Wales. On its future agenda are topics as genetics and identity, genetics and insurance, interactions between biomedical and social sciences and the development of economic, ethical, legal and social frameworks for the effective delivery of genetics services.
The independent research-funding charity the Wellcome Trust has a biomedical ethics programme since 1997. Its first program ran from 1997-2001 and had a budget of £5 million. A new six year programme started in 2001 and has an increased budget of £15 million. Both programmes supported ethics, legal and public policy research with a focus on neuroscience, mental health and genetics. In 2001, the Wellcome

Trust conducted a review of the first programme to assess progress towards its aims and to inform decisions on the future of the initiative.
The objectives of this programme were:
1. to support timely, high-quality research into the social, ethical and public policy consequences of scientific advances in biomedicine
2. to build and enhance national capaciy in the field
3. to ensure, as far as possible, that research is relevant to public policy and effectively communicated to policy makers

One of the conclusions of the review was that effective communication and dissemination of the research funded is vital to the success of the Programme. Therefore consideration should be given to how communicate research findings beyond the academic, according to the review. 36% of the researchers had already communicated their research outside academia, a further 55% were planning to. Furthermore, the applicants had a variety of disciplinary backgrounds: social sciences, medical sciences, genetics, ethics, law, medicine etc. The projects granted also often had a multidisciplinary composition. E.g. one project contained sociologists and geneticists, another was composed of ethicists and a political scientist.

3.1.4 The societal component of genomics programme in the Netherlands

In the Netherlands, there are currently four national genomics programmes:
- NWO[14] programme Genomics (2001-2005)
- NWO programme Biomolecular Information Technology (2001-2007)
- NWO programme Societal component of genomics research (2001-2005)
- Innovation-oriented research programme Genomics, Ministry of Economic Affairs (2000-2003)

Systematic effort towards the study of societal aspects of genomics research was promoted via several channels. The Advisory Council on Science and Technology Policy (AWT) was asked to conduct an exploratory study on the field of societal aspects of developments in human genetics. In its letter of 2001 to the ministries of Education, Culture and Sciences; Economic Affairs; Health, Welfare and sport, it concluded that at that moment there was too little attention for the discussion on the full length of societal aspects of human genome knowledge. A earlier study commissioned by AWT concluded that research on ethics, behaviour and society related to the human genome was underway, but research on legal and economic aspects was still in its infancy. A temporary advisory commission about the knowledge infrastructure of genomics also concluded that there was too little research in the Netherlands about societal aspects and advised to invest in studies on this issue. The committee advised to invest 23 million euro (8%) in research towards societal aspects of the aimed total of 272 million euro. The Dutch government subscribed to the importance of reseach on and communication of societal aspects of genomics research.

The concerns with societal impacts, adverse public reactions etc. were visible and led NWO to also start up a program on the Societal Component of Genomics Research. It aims to conduct research on the societal component of genomics research, including communication and interaction between genomics-research and society.
The programme 'the societal component of genomics research' intends to encourage ethical, legal and social scientific research on the social component of genomics research. The focus is on the interaction between genomics and society.

3.1.5 Information on ELSA-type programmes for genomics in other countries

Norway
In Norway, currently two national research initiatives are supporting research in the field of ethical, legal and social aspects. Both were initiated in the same period.
- FUGE : Functional Genomics in Norway (starting from 2002).

[14] NWO : Dutch funding organization for scientific research

- ELSA : Ethical, Legal and Social Aspects of biotechnology (2002-2006)

FUGE is a national plan for research in functional genomics in Norway, submitted by a unified Norwegian research community, and administered by the Research Council of Norway (RCN), also see RCN (2001). FUGE will mainly be supporting biotechnological research and infrastructure buildup, but it also has reserved money (NOK 3-5 million [15]of the total 100 million for 2002) for projects addressing ethical, environmental and social issues. The programme and the applications will be coordinated with the ELSA programme. The two activities (FUGE and ELSA) have an estimated budget of NOK 7-8 million each year during 5 years.

ELSA is initiated by the Research Council of Norway and all the divisions of the Council participate in the programme, see also RCN (2002). The steering committee of ELSA consists of genetic scientists, social scientists and representatives of the Ministry of Environment and the Ministry of Health. The representative of the Ministry of the Environment is the leader of an informal committe for coordination of biotechnology between the Norwegian ministries. The Steering Committee of FUGE consists mainly of genetic scientists but also has representatives from the industries both national and international.

During the establishment of the ELSA programme information was gathered on other related initiatives such as ELSI in the US and ELSA in Europe, but there was little direct contact with other activities in the field. However, the committee knew the existence of the evaluation report of ELSI (ERPEG 2000).

The NRC is planning to co-operate with the Swedish ELSA programme and other related initiatives. The ELSA programme will also co-operate with other organizations such as the Biotechnology council and the Technology council that advise the Norwegian government. Furthermore it is one of the goals of the ELSA programme to contribute to a dialogue between experts and lay people. To this end also co-operation is sought with mediating institutions (e.g. the biotechnology council).

The extent to which projects funded by the ELSA programme should deliver policy recommendations will vary. The programme also does not aim (like ELSI does) to educate the public or practicioners. Instead, the programme focusses on research education. The programme strives to improve doctoral courses, e.g. ethics for biotechnology students.

FUGE/ELSA does not aim to promote the establishment/development of organisations, e.g. permanent advisory committees on the field of genetics and society. However, it might aim to promote the establishment of information networks (of scientists) or institutes that are active on the interface of genetics and society, but decisions on these type of activities have not yet (May 2002) been made by the boards/Steering Committees.

Sweden

In 1999 a new ELSA programme was established by the Swedish Foundation for Strategic Research. In fact, this was a follow-up of an earlier initiative in the period 1995-1998 to study ethical, legal and social aspects of genome and gene technology research (Rider, 2000).

The aim of the Swedish ELSA-program is “to stimulate research focused on the ethical, legal and social implications of genome research and gene technology research and its implementation in different sectors of society. [..] The primary goal of the program is to initiate new projects and identify prospective researchers at the doctoral and postdoctoral levels by providing grants and organizing seminars. Scholars and researchers in all disciplines, both at the doctoral and post-doctoral levels, and at all academic centers in Sweden have been invited to apply in an open competition for grants. The research program is financed by the Swedish Foundation for Strategic Research. Uppsala University is host of the program.”(Rider, 2000)

[15] Compare 3-5% of the budgets of the US HGP projects of US DOE and NIH are devoted to ELSI issues.

Germany
In a press announcement of 24.01.2001, the German government announced the launch of a biotechnology research programme, worth 802,7 million EURO over 5 years. The document which describes the scope of the research programme (BMBF, 2001) discusses at several point societal issues of this biotechnology research programme. It states that it will assess ethical, social, legal and environmental consequences of biotechnology and that these activities can help to identify and value chances and risks in an early stage to enable a timely response. In an earlier strategy paper (BMBF, 2000) several goals (7) are described for the period 2000-2010. One of the goals (the last mentioned) states:
"Internationalisierung der bioethischen Debatte (soziale, rechtliche und ethische Implikationen der Anwendung)." (BMBF, 2000, p. 3)

The strategy paper also pays attention to the way this goal should be achieved:

> *"Die Fortschritte der Humangenomforschung und Humangenetik führen zu deutlichen medizinischen Fortschritten sowie zu tiefgreifenden Veränderungen in der medizinischen Versorgung und in anderen neuen Bereichen des Umgangs mit medizinischer Information. Die Ergebnisse der Genomforschung bringen im Einzelfall auch gewichtige ethische, rechtliche und soziale Probleme mit sich. Der naturwissenschaftliche Erkenntnisfortschritt ist deshalb durch geistes- und sozialwissenschaftliche Forschung zu begleiten, welche frühzeitig wesentliche Entwicklungsmöglichkeiten, problematische Aspekte und neuartige Fragestellungen bei der Erzielung und Anwendung neuen Wissens in der Humangenomforschung erkennt, analysiert und bewertet. Deshalb ist die Förderung ethischer, rechtlicher und sozialer Aspekte durch das BMBF ein integraler Bestandteil unserer Genomforschungsstrategie. Nach einer Phase der Förderung interdisziplinärer Fachtagungen hat das BMBF im Jahr 2000 mit der Förderung von Forschungsvorhaben zur Aufarbeitung ethischer, -rechtlicher und sozialer Aspekte der Genomforschung begonnen. Dafür stehen bis 2002 jährlich ca. 3 Mio. DM (5 %)[16] zur Verfügung. Die Forschung zu ethischen, rechtlichen und sozialen Aspekten der Genomforschung wird also integraler Bestandteil der Genomforschung bleiben und sich verstärkt in der direkten Kooperation mit den Naturwissenschaftlern entfalten. Die gemeinsame Initiative des BMBF und der DFG zur Bioethik wird in die Aktivitäten zur Genomforschung einfließen."* (BMBF, 2000, p. 19-20)

Australia, New Zealand, South Africa
In all three countries, genomics is not a separate priority (with the minor exception of the Australian Research Council setting up a Genome/Phenome Research Initiative). Genomics is taken up as part of the larger priority of biotechnology.

In Australia, a National Biotechnology Strategy has been defined, which includes attention to public awareness. 'Biotechnology Australia' was established to implement this goal, and does so in terms of providing information (including a list of "myths about biotechnology"). When public concerns are recognized, they are addressed by spelling out the present regulatory framework – with the message that there should be no cause for concern.

In New Zealand, the debate about biotechnology has an added dimension because of the special situation of New Zealand, where 'biosecurity', the defense against biological contamination from abroad, is a strong concern. Genetic modification can be seen as potentially similar to such contamination. The official debates emphasize awareness (of the public, but also of scientists) and the need for communication. In addition, there is a strong concern about New Zealand, as a peripheral country, competing in a global world.

In South Africa, there is little debate about biotechnology and genomics (other than a concern about property rights to the genetic riches of indigenous plants and animals). Many other concerns are more pressing. Ethical, social and legal puzzles about the new genomics seem a luxury in a country facing the effects of global competition and the AIDS epidemic.

[16] Compare: 3-5% of the budgets of the Norwegian FUGE programme and the US HGP projects of US DOE and NIH are devoted to ELSI issues.

Japan, South Korea, China

The contrast, in Japan, between forward looking initiatives in science and technology policy, and actual interaction with society has been noted before. A consensus conference on genetic modification was a bottom-up initiative supported by some private foundations. Genomics research does not seem to feature high on the research agenda, let alone ELSA of genomics research. A recent initiative for Studies on Science and Technology for Society (by the revamped Ministry of Education, Culture, Sports, Science and Technology) did emphasize interaction between natural scientists and social scientists, but focussed on addressing societal problems like risks and the social order.
As was apparent in the recent international symposium in Tokyo (Feb 28 and March 1, 2002), organized by NISTEP, on *New Articulation of Science and Technology System*, there is a groundswell of interest in and concern about new developments in science and technology, but no way to "articulate" them in TA and ELSA accompanying measures.

The difference with South-Korea is interesting, in that there the earlier emphasis on economic growth is now complemented by official requirements (in the Science & Technology Framework Law of July 2001) to do technology assessment exercises and to widen participation of non-governmental experts and related groups "in order to raise the transparency and rationality of S&T policy". According to Eun-Kyoung Lee (of the Science and Technology Policy Institute of Korea), these clauses in the Framework Law were a response to activities of NGOs and the attempt of the Ministry to assuage concerns by establishing a Korean Bioethics Advisory Commission with a broad composition. I am quoting her paper for the NISTEP 2002 conference here. She continues to voice her concern that these measures will remain at the surface (and only help the Ministry to survive in difficult times). Her alternative, closer links with Parliament, is not supported by the experience in the USA and some European countries, however.

The Chinese situation is different again. On the one hand, the last few decades saw a revival of genetics research in China. Research in this field virtually ceased to exist in the period after W.W.II. and the late 1970's. In 1998 the Chinese government launched major initiatives in human genomics, including the creation of two human genome centres. It is realised by for instance one of the directors of these centres that geneticists should be educated about the economic, legal and social issues of their research. By 1998, this was not seriously taken up.
Certain clauses of China's Maternal and Infant Health Care Law of 1994 were criticized by non-Chinese geneticists as excessively eugenic. This law proposed systematic abortion based on genetic screening, to reduce the incidence of mental disease. Foreign scientists threathened to suspend cooperation with Chinese researchers if action was not taken. A growing number of Chinese geneticists acknowledge the need to address the economic, social and legal implications of their research (Dickson, 1998).
Since then, genetics and genomics research in China has made great advances, but without any public debate about bio-ethical issues. If we can believe journalist Van der Putten (2002), it is the "Wild East" of science. While some Chinese geneticists, supported by colleagues from abroad, ask for some bounding and advice, if only to remain in tune with what is happening elsewhere.

3.2 Analysis

The national programmes of the UK and the Netherlands are relatively new programmes, compared to the ELSI programme in the United States and the European activities. For the last two programmes we analyzed which projects were funded.
According to the ELSI Research planning and Evaluation Group (ERPEG, 2000a) all the granted projects and program activities fall into four programme areas:
- Privacy and fair use of genetic information
- Clinical integration of genetic technologies
- Ethical issues surrounding genetic research
- Education and resources

According to ERPEG there are some gaps in the programme:

- Specific content in the four areas
- There are too less theoretical, analytical studies
- There is an under representation from certain disciplines (economics etc.)

To compare the situation in the United States with European activities we analysed a sample of 53 funded projects related to biotechnology and genetics under the Fourth Framework Programme (1994-1998). We looked at projects with high socio-economic relevance and projects funded under auspicies of ELSA.[17]

For this analysis we used different categories to characterize the studies. In the tables below we give for each category a representive examples of a study that received funding.

Type of study	**Example of a study**	**Brief description**
Impactstudy	Future impacts of biotechnology on agriculture, food production and food processing : A Delphi survey	In the project the future impacts of biotechnology on agriculture, food production and food processing will be analyzed in Germany, the Netherlands, Italy, Greece and Spain.
Anticipation on impacts / technology strategy	Mammalian cloning in Europe: prospects and public policy	This study is designed to provide an assessment of mammalian cloning technology, its possible risks and benefits, and how public policy might help steer its development in a manner which is both socially acceptable and economically useful.
Ethical study	Consistency in ethical reasoning concerning genetic testing and other health related practices in occupational and non-occupational settings	The major objective of this project is to develop a methodology allowing for comparing ethical reasoning of practices in different fields and countries, and to provide substantive material for a public debate on the acceptability of practices and the need for regulations.
Social/policy study	A longitudinal study of parent-child relationships and the emotional, social and identity development of children conceived by assisted procreation	Systematic research on the nature of the difficulties, if any, experienced by families created as a result of assisted procreation is of theoretical importance for increasing our understanding of the role of genetic ties in family functioning, of clinical importance for preparing couples embarking upon assisted procreation for parenthood, and of social and ethical importance for informing the development and integration of European policy and legislation.
Legal issues	Comparative law study on biotechnology patents of therapeutical use in USA and European Patents	Analysis of the legal practice in relation with the contents of Biotechnology Patents of Therapeutical Use. Study of claims and description. Scope of protection of Biotech. Patents.
Emerging industry structures	Impact of Intellectual Property Rights on development of Biotechnology	This multi-centred research project (GB, FR) aims to assess the impact of intellectual property rights (IPR) on inter-firm research collaboration in the European biotechnology industry.
Education	Production, dissemination, implementation and and evaluation of Educational materials on biotechnology	[..] to develop innovative educational materials which will enable scientific and technological aspects of biotechnology to be explored in the context of relevant economic and societal issues. The materials will have the teaching of science and non-science syllabuses in mind.
Economic issues	The exploitation of the European Science Base in Gene Therpay	This project is designed to assess the current competitiveness of Europe's gene therapy

[17] Sources: (EC, 1998); (Vanvossel, n.d.); (Theofilatou, n.d.); (Luchetti, n.d.)

Type of study	Example of a study	Brief description
	bridging the "Commercialisation Gap"	industry, examine the extent to which the European science base in this area is being industrially exploited and suggest how public policy might help overcome the main barriers to the commercialisation of gene therapy research in Europe.

Table 2: Type of study

Output of a study	Example of a study	Brief description
Stimulating interaction between basic genomic scientists and society	European Federation of Biotechnology Task Group on Public Perceptions of Biotechnology – 2	The objective of this project is to increase public awareness and understanding of the life sciences throughout Europe and to inform and advance the public debate concerning them.
Public education	European travelling Exhibition Initiative	These [..] exhibitions aim to inform the non-specialist public about contemporary practice in bio-technology, especially genetics.
Specific policy development	Genetics and public and professional policy in Europe: The geneticists' approach	The overall objective of this proposal is to issue policy statements, guidelines and reports on ongoing topics of concern in the field of Human Genetics. These documents will contribute to the debate among the community and will serve as references for policy makers in European countries and at the European Union level.
Policy development towards integration of science and society	Moral competitiveness of biotech companies : Bioethics and Companies	The objective of the project is to get an answer to the following two questions: - Which issues are on the Moral Agenda of biotech companies? - Do these issues and their related ethical activities match with what society and the government expect them to do?
Establishment of information networks of scientists on societal matters of genomics/bio-technology	Xenotransplantation: ethical, social, economical and legal aspects	On one hand the project intends to produce an intensive cooperation from scientists with different disciplines to set up a transeuropean network. The network shall also stock after the project itself is finished. On the other hand the project also aims to represent and weight the xenotransplantation under ethical, social, economic and legal points of view.

Table 3: Output of study

Many of the funded projects fell under two or more categories. Moreover, it was difficult to characterize a project only on the basis of the available abstract. Therefore, the figures below can only be an indication of the type and output of the relevant studies under the Fourth Framework.

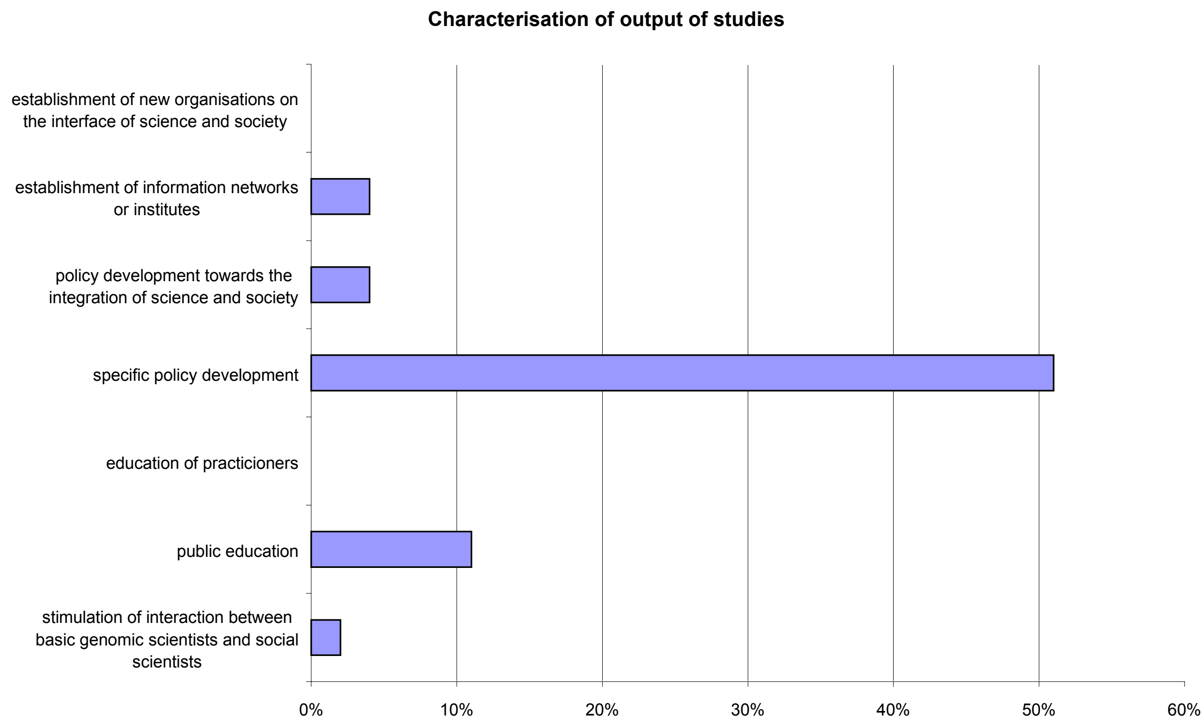


Figure 1: Characterisation of output of studies

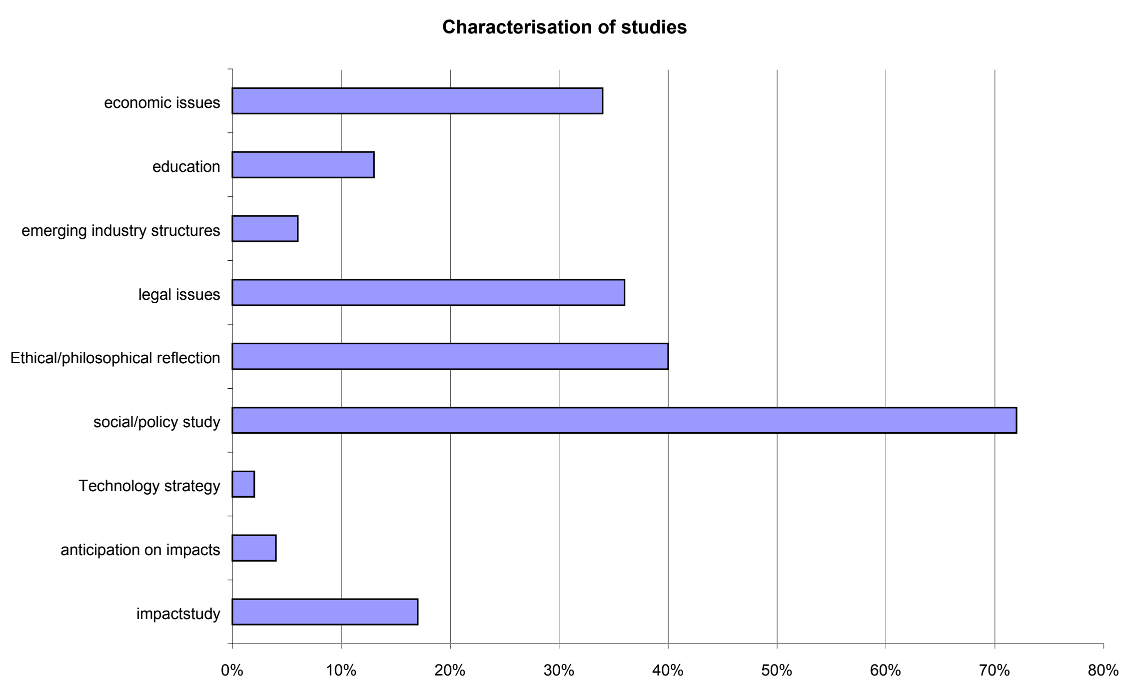


Figure 2: Characterisation of studies

From figure 1 we conclude that the majority of ELSA studies formulated some kind of policy recommendations. Only a few studies were oriented at developing policies on establishing durable links (institutionalization of interactions) between science and society.

The four program areas of ELSI do not explicitly mention economic issues. Together with the observation of the ERPEG-committee that there is a lack of researchers with an economic background within ELSI studies, this suggest that ELSA has relatively more attention for economic issues concerning genetics and biotechnology (see figure 2). That ELSA pays much attention to economic issues is understandable because of the economic orientation of the Framework Programmes. In addition, there might be a difference between the US and Europe in that promotion (with which economic aspects are associated) and control (the social, legal and ethical aspects) are more strictly separated in the US than in Europe. In the UK, at least, a continuum is visible in the activities of ESRC. In Norway, the Call for Proposals in the ELSA/FUGE programme received a number of proposals addressing changing industry structures and other economic aspects.

There is also a commonality in the programmes: the need/attention for more theoretical, analytical studies. ERPEG (2000a) observes this as a gap in the project portfolio of ELSI. Within the Fifth Framework Programme under the Quality of Life programme, studies of a generic nature are especially mentioned. The programme suggests studies as technology forecasting, implications of new technologies for policies, etc. Experts who reviewed the proposals for this type of studies stated that a much greater effort should be made to encourage researchers to send this type of proposals and that these issues demand great attention (Ragucci, 2002). The lack of this type of studies is illustrated for instance by the low percentage (<5%) of studies in the Fourth Framework that are devoted towards technology strategy (see figure 2).

In terms of promotion and control of technology and variation and selection of technology we conclude that the funded projects are mainly oriented on the control and selection side of technology / science.

3.3 Emerging institutionalization

When Borganonkar & Shah (1970) wrote about recent advances in human genetics and their impact on society, they asked for society at large to be better informed about these matters and be involved in relevant decision-making processes. Whether this has been realized or not is moot, but a major change has occurred in how society looks at genetics and genomics research. The watershed events are Paul Berg's letter to Nature (and Science) in 1973, the Asilomar Conference in 1974 and the subsequent temporary moratorium on recombinant-DNA research. These events have shaped the further co-evolution of genetics reearch and society, as well as genetics screening and counseling practices.

Some twenty-five years later, an article appeared in *Nature* that discussed the rapid growth of bioethics as a focal point of public concern of new technologies (Wadman, 1997). According to this article the number of bioethicists and their output is growing rapidly. The ELSI programme has certainly stimulated this growth, but also the European ELSA programme funded many ethical studies. On the other hand, the article questions whether US bioethicists have substantially shaped either the culture of science or the political decisions of recent years. According to Arthur Caplan, director of the Pennsylvania Center for Bioethics " bioethics has a lot of authority but no real power. We are the proverbial mosquito biting a large elephant." (Wadman, 1997, p. 658).

The emergence of the ELSI programme in the United States in the early 1990s can be viewed as a period of change and the trigger for a more cohesive programme of research of societal aspects of genetics. Before this period there was also, though fragmented, a debate on these aspects, for instance the debate on eugenics and screening (although not based on genetic diagnostics). A few forces influenced the establishment of ELSI. Based on our research we identified the following forces:

- ELSI as a means to gain political support for the large financial investment required for the Human Genome Programme.
- ELSI as a method to take care of possible consequences of the new possibilities in the field of genetics created by new insights in molecular biology.

- The nature of the HGP itself: insights about identity of man.

As to the latter, questions were raised about the genome as the secular equivalent of the soul (cf. also Fleising 2001). Such a “deep” question about hidden determinants of what we will eventually be has links with another, less deep but pervasive question: the promise of genomics is the upstream solution of downstream problems. ELSA is then positioned as a further consideration of these solutions, and their possible problems. But the basic view that genomics is here to offer solutions is not put into doubt.

In this case study we mainly focussed on national research programs which can function as a channel between science and technology on the one hand and society on the other hand. The integration of studies towards societal issues and studies towards basic research on genomics within a national program can be seen as indicators of an emerging institutionalization of interactions between science and society. At least in the field of genomics (see also the section above with some historic remarks). As a consequence of our focus on scientific research, we have paid little attention towards for instance policy development on genetic issues, public understanding of genomics, education etc.

All the national programs studied in our country reports promote the interaction between basic genomic scientists and social scientists. However, to quantify the extent of this interaction is rather difficult. For the ELSI and ELSA programmes during the early 1990s we found no evidence of interaction or co-operation between genomic and social scientists. In our interviews we found some indications that this situation is about to change. For instance, one of the objectives within the MC Genomics of the Netherlands is to promote such interactions.

However, this increasing interest in interaction between genomic scientists and social scientists also articulates some problems. First their is the practical communication problem: scientists from these two categories do not speak the same ‘language’. Secondly, our interviews indicate that lack of trust in the value of each other’s discipline may result in barriers for interaction.

There is a third dimension: the openness for societal concerns under genomic scientists is different for scientists in different positions. Scientists in leading and/or visible positions are more open to these concerns, and have to be because they are exposed to interactions with the outside world. For the bulk of the scientists, it depends on their attitude, and such attitudes are distributed as in the population as a whole. A third category is the group of professional scientists who interact more closely with the public, for instance during genetic counseling or during the collection of data for genetic research. This category is exposed to comments and therefore more appreciative of societal concerns.

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Information sources:

Website:	**URL**
Bioethics in the Internet, weblinks compiled by the Wellcome Trust	http://www.wellcome.ac.uk/en/library/homlib/weblinks/bioethics.html
Bioethics: resources, links and definitions	http://www.eurodoctor.it/bioethics.html
Bundesministerium für Bildung und Forschung	http://www.bmbf.de/
ELSA website of the Fourth Framework Programme	http://www.cordis.lu/elsa/home.html
ESRC : Economic and Social Research Council Home Page	http://www.esrc.ac.uk/
Ethical, Legal and Social Implications of Human Genetic Research, website of the US National Human Genome Research Institute	http://www.nhgri.nih.gov/ELSI/
Ethical, Legal and Social Issues Research, website of the US Department of Energy	http://www.ornl.gov/hgmis/research/elsi.html
European Bioethical Research, links to other bioethics sites	http://www.bioethics.org.uk/other.htm
European Group On Ethics in Science and New	http://europa.eu.int/comm/european_group_ethics/index_en.htm

Technologies.

Geneletter – Genetic News and Information	http://www.geneletter.org/
Journal New Genetics and Society	http://www.tandf.co.uk/journals/carfax/14636778.html
Links for Ethical, Legal and social issues	http://www.cdc.gov/genomics/links/ethical.htm
Research Council of Norway	http://www.forskningsradet.no/english/
Swedish ELSA research programme	http://www.bioethics.uu.se/elsa/
The Center for Bioethics at the University of Pennsylvania	http://www.med.upenn.edu/bioethic/
The European Commission: Socio-economic research in the life sciences and the emerging biosociety	http://biosociety.cordis.lu/
The Wales Gene Park	http://walesgenepark.cf.ac.uk/
The Wellcome Trust website	http://www.wellcome.ac.uk
Website of the company Celera	http://www.celera.com/
Website of the magazine Nature	http://www.nature.com/
Website of the magazine Science	http://www.sciencemag.org/

Chapter 4: Anticipation and interaction: new nexusses in co-evolution of technology and society?

ELSA of genomics is an example of en emerging nexus, a channel between variation and selection. What flows in such a channel? The flow is enabled and constrained by the nature of the nexus. For ELSA, it is the focus on "trial" by studies (cf. Chapter 2). In general, anticipation is important: "how to put the future at the service of the present" (Bernstein 1996, p. 1). And interactions, up to the challenge how to "manage" co-evolution from within the process.

In this chapter, I will review TA (and some Technology Foresight) approaches as examples of anticipatory intelligence.[18] I continue to show that there are real possibilities of prospective technology analysis. And conclude with a discussion how *de facto* governance arrangements like a nexus constrain and enable.

4.1. A review of TA approaches

Anticipation and attendant (and interactive) learning is a key element making co-evolution reflexive. When its results become available, one can speak of "intelligence", of various kinds, as it plays a role in the governance of co-evolution. TF and TA (and R&D evaluation, I add) can be seen as part of distributed intelligence, and to some extent addressed in an integrated manner (Kuhlmann et al. 1999). Intelligence is important for policy making, but also for society in general. Especially in a co-evolutionary perspective, there is no need to exclusively focus on policy actors (indeed, this could be counterproductive).

Anticipatory intelligence envisions the future, not as an exercise in prediction, but as a contribution to present reflection and articulation of strategies:

> "Foresight can be defined as a systematic, participatory, future intelligence gathering and medium-to-long-term vision building process aimed at present-day decisions and mobilising joint actions. As such, foresight cannot only improve anticipatory intelligence, but also contribute to an increased awareness of knowledge resources and strategic orientations of the actors that participate in the foresight activities." (Van Langenhove 2002, p. 2)

Constructive TA is presented as a support for reflection and strategy articulation: "Just as there are Decision Support Systems of various kinds, there is now an RSASS, Reflection and Strategy Articulation Support System." (Kirejczyk and Rip, forthcoming; see also SocRobust 2001). Van Langenhove (2002, p. 1) broadens the scope even further:

> ".. thinking about the future can play an important role in order to capture what already 'lives' in society and in order to make explicit the complex relationship between science and innovation systems and rest of society."

What is available already in terms of tools and approaches, and how do these bridge the gap between technology promotion and control?

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[18] In this chapter I draw on my STRATA Report (Rip 2002b) and earlier papers used for that Report, including my article on Technology Assessment in the *International Encyclopedia of the Social and Behavioral Sciences* (Elsevier Science, forthcoming).

Let me start by showing that the production of anticipatory intelligence, primarily TA/TF, takes different forms depending on the actors involved and decision contexts. For example, TA is also done when firms, consultancies and technological institutes, agencies in health care and other social sectors, want to assess the promise, and the profit, of new technological options, and/or do a broad version of cost-benefit analysis, sometimes also including risks. (Hastbacka and Greenwald 1994) This strand of TA has developed relatively independently of 'public domain' TA, but links are emerging because of the need of firms to take possible societal impacts and public acceptance into account. The biotechnology sector is a clear example at the moment (Deuten, Rip and Jelsma 1997). The 'insiders' are interacting with the 'outsiders' (Garud and Ahlstrom 1997), and the effect is that prudent firms encounter public-interest assessments.

In the public domain, impact assessments are done using similar methods, only the dimensions along which the assessment is done will derive from the public responsibility, say for environment or health. Environmental Impact Statements are now required in many countries before projects can be implemented (Vanclay and Bronstein 1995). Medical and health care TA is a recognized specialty with its own international society and meetings, focussing on evidence-based evaluations of concrete medical and health care activities and options (cost-benefit analysis, risk analysis), not on wider societal impacts.

Wider societal impacts can be put upfront, but the decision context then becomes more diffuse. There is a tradition of 'public service' TA with the USA Office of Technology Assessment (OTA) as its exemplar. OTA has, during its lifetime, developed a robust approach to TA studies (see Wood 1997). Other TA bodies serving national parliaments and/or national governments now tend to include participatory TA methods in addition to expert- and stakeholder-based approaches. This then merges into TA exercises oriented to the public arena more generally, and focus on articulation and building an agenda for handling new technology in society. This recent strand takes up the increasing calls for participation (at least by new stakeholders) and is therefore linked with new governance models (cf. also Grin and Van de Graaf on interactive TA). While it is particularly visible and more or less institutionalised in some European countries (Denmark, the Netherlands), participatory methods like consensus conferences are now taken up all over the world. The direct impact of public-service TA on science and technology policy and decision making has not been large, except when there are controversial issues and the TA exercise provides ammunition for the contending parties.

Agenda-building TA has a longer history, if one accepts that controversies over new projects or new technologies (and the studies and documents produced in the course of the controversy) induce learning (about potential impacts) and articulation (of the value of the technology). (Rip 1986) Agenda-building TA merges into informed consultation processes to reach agreement on the value of new technology. Thus, there is overlap with recent more general political and policy approaches for articulation and learning (e.g. hermeneutic policy making).

Technology Foresight is a necessary component when TA addresses new technologies like genomics or nanotechnology. The social-science fiction of TA needs some science fiction as a reference point. This linkage is underdeveloped, partly because TF first created distance to technological forecasting with its neglect of dynamics of development (Schaeffer 1998) and then focussed on visioning and on supporting R&D priority setting. It will become important again with the emerging interest in doing TA of novel technologies in the life sciences and in nanotechnology. Constructive TA, with its close link to technology dynamics, has a role to play here (Schot and Rip 1997), even if it is not quite clear what "broadening" of design of technology (a defining characteristic of Constructive TA) would be in this case.

This brief *tour d'horizon* shows a variety of approaches for TF/TA, many of which were developed and optimized to serve particular decision contexts. Starting from the general idea of anticipatory intelligence, one can see further examples even when the label TF and/or TA is not used. 'Early warning' would be such an example (it was actually one of the arguments in the US discussion in the late 1960s, early 1970s about having an Office of Technology Assessment, but OTA became focussed on service to Congress). Societal experiments with the introduction of new technologies, for example electric cars, would be another example when used as occasions for societal learning about new technologies and (hopefully) feedback into further development and uptake. They have been used to developed a generic strategy of Strategic Niche Management (Weber et al. 2000, Hoogma et al. 2002).

One implication of the link between TF/TA approaches and decision contexts is that methods cannot simply be imported from another context. FORMAKIN (2001) has made the further point that the effect of a method or approach will also depend on the (social) configuration of the domain. For example, in a close-knit configuration, foresight is not needed because coordination occurs already, while in a loose-knit configuration there is insufficient incentive to produce coordination (as a collective good). In-between configurations will profit from foresight exercises. TF/TA can and must profit from this broader view by positioning themselves (and optimizing their approachs) as part of anticipatory intelligence produced as well as taken up in context.

For our normative question (of bridging the gap) we can check what the various strands of TA, as they have developed over time, have to offer. In the table below we present an overview

Technology assessment category	+/-	*Nature of bridging*
"picking the winners"	±	Initiated at the variation side, selection in own terms, with some anticipation on societal aspects.
strategic niche management, societal experiments	+	Joint effort from variation and selection sides
Medial and Health Care TA/ environmental impact assessment	+	Bridging from the selection side.
OTA / Policy analysis style	-	No bridging, because OTA was doing policy support for US congress. Other parties may use results for bridging.
Public debate & Agenda Building	±	Bridging from the selection side, still rare. Could occur through credibility pressure, depending on circumstances.
Participatory TA, hybrid fora, interactive TA	±	Bridging sometimes possible, sometimes not. Depends also on composition of the forum.
Constructive TA	+	Introduces "selectors" in the development at the variation side. If

		well done, bridges by definition – but may revert to enlightened probe & learn from the variation side.

4.2: Emerging irreversibilities and how to improve on them

Anticipatory intelligence has to come to terms with the difficulties of anticipating the future. The reports produced, and the increasing number of workshops held under the labels of technology foresight and technology assessment, may be no more than incantations, attempts to exorcise the uncertainties of the future. That they fulfil a need does not imply that the contents of the anticipations have any predictive value. Authors like Rosenberg (2001) emphasize this, but do not consider the non-predictive role of anticipations. In co-evolutionary terminology, one could say they improve the selection environments (making it more intelligent, or at least less blind) while it provides orientation to actors producing variations.[19] The other route to enlighten selection environments is normative: articulating desirable directions. This can work through credibility pressure, as when the chemical industry set up its programme Sustainable Care.[20]

Still, there is an element of prediction-in-context. The key phenomenon is the emergence of new alignments between actors, and between actual activities and promises being made. Such alignment will improve performance as well as create mutual dependencies, and lead to paths being followed which gradually harden and become increasingly irreversible, *i.e.* harder to break out from. This phenomenon has been identified and analysed in terms of path dependencies; the QWERTY keyboard of typewriters, but now also of computers, is a well-known example of a path-dependent outcome (David 1985; the recent debate among economists about the scope of this example is not relevant for my point). But also in terms of irreversibilities (OECD, 1992), core capabilities turning into core rigidities (Leonard-Barton, 1992), the emergence of dominant designs and of standards after an era of ferment (Tushman and Anderson 1997), and the shift from fluid to specific industry structure (Garud, 1994).

While prediction, in the positivistic sense, is out of the question, these socio-technical dynamics and emerging irreversibilities imply that there is an *endogenous future*. Embedded in the present are preferred directions which imply that a trajectory will be followed (Dosi 1982). Even if paths are created while "walking" (Garud and Karnoe 2001), emerging paths can be mapped, and the way they emerge can be analysed (prospective technology analysis) – and this can be fed back to actors. In some cases, such activities have become institutionalised as "technological roadmapping", for example in the integrated-circuit industry. The predictions based on Moore's Law are a guideline, and thus become self-fulfilling.

Basically, what happens is that scenarios are created in which impacts can be (speculatively) identified and assessed – a kind of social science fiction. Actors always work with partial and diffuse versions of such scenarios to orient themselves – and others. A social-science supported TA might improve the quality of their scenarios. A

[19] There is still the problem of misguided orientation, which points in the wrong direction. One might then be better off without such anticipatory intelligence.

[20] "Shaping the Selection Environment" then becomes a key action, as is clear in the activities of environmental groups to put "Chlorine in the Dock" (McMeekin 2000).

structural problem is that actors tend to project a linear future, defined by their intentions, and use this projection as a road map – only to be corrected by circumstances. Mapping tools which force actors to consider the non-linearity of evolution, and accept the complexity, can be developed to make them more effective (if they are prepared to accept such social-science based support).

Interestingly, a well-known paradox of anticipation exercises can be turned into a reflective tool. Understanding the dynamics of the process in which they are involved will make actors act differently – and thus shift the dynamics. This undermines the applicability of the original studies. The results of the studies are offered to the actors involved, as histories of possible futures. They will react, and this will change the object studied and on which the future histories were based. This may well falsify the original diagnosis – a strong case of such a falsification would be an early warning that was heeded and so turned into a self-negating prophecy. The aim, however, is not generalisable knowledge about specific futures, but to provide support for reflection and articulation of strategies by the actors. There are generalisable products, but these consist of increasing knowledge and understanding of patterns in the co-production of impacts.

A potentially important mapping tool was developed in a European Union project, SocRobust (2002), drawing on Techno-Economic Network analysis (Callon et al. 1992) and Constructive TA tools. The scripts or diffuse scenarios of the future outcome and impact of RTD-projects, in the heads of the project managers as well as implied by the structure of the project, are reconstructed and critically evaluated. The result provides a mirror for the project managers to look at themselves and do better, that is, be less imprisoned by their own linear projections. In this way, the actors can become more prudent.

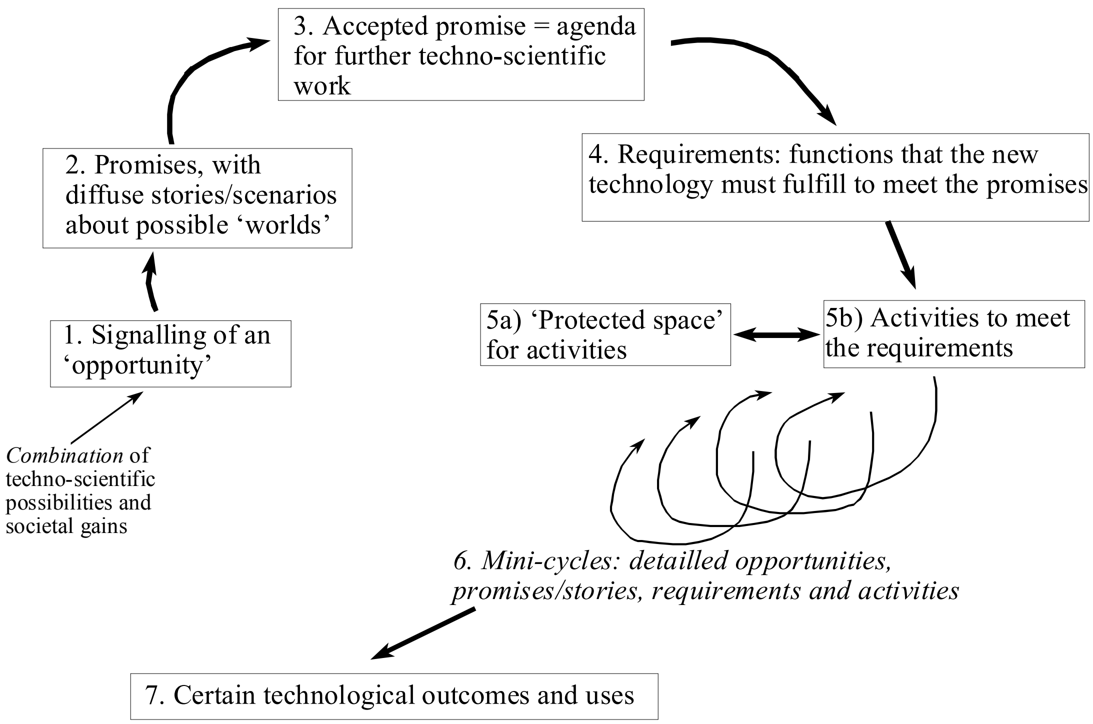
The dynamics of development can be included using tools of prospective technology analysis like identifying heuristics carried by relevant networks (cf. Dosi (1982) and Van den Belt and Rip (1987) on trajectories), the script implied in a gradually materializing artefact and the construction of socio-technical scenarios (Kirejczyk and Keesmaat 2001).

There are other entrance points. Especially at an early stage, expectation dynamics are important. For xample, promises are inflated, and have to be inflated in order to get a hearing – so will almost inevitably lead to disappointments (unless one can make people forget by pushing new promises). As Geels and Smit phrase it:

> "The reason that initial promises and expectations are too optimistic is *not* that forecasters or futurists are ignorant or shortsighted. Instead, the promises are strategic resources in promise-requirement cycles. Initial promises are set high in order to attract attention from (financial) sponsors, to stimulate agenda-setting processes (both technical and political) and to build 'protected spaces'. Promises thus play a role in the social processes that are part of technological development. This performative dimension of future images provides a complementary interpretation of the failure of some future speculations." (Geels and Smit 2000, p. 881-882)

The general idea of expectation dynamics was originally set out by Van Lente (1993) and Van Lente and Rip (1998)), and a visualization of their point about an expectations-requirements cycle is visualized below (the figure is taken from Geels and Smit 2000, p. 881).

Figure 2: The dynamics of promises and requirements in technological developments



In the domain of genetics and genomics, many examples of the importance of expectation dynamics can be found, as in the construction of markets and products of gen therapy in the USA (Martin 2001), and the "selling" of the Icelandic genomic data (Fortun 2001). "Geno-hype" (Fleising 2001) is everywhere, and leads to "geno-hope" as well as the emergence of paths and path dependencies.

Here and in general, quality control of promises and expectations is an important challenge. It has to address content, but cannot be done in terms of its eventual "truth" – which is itself at issue (and never unequivocal because of self-fulfilling and self-negating "prophecy" effects – a general sociological phenomenon! (Merton 1948)). The way to go is to focus on the quality of the process of promises and requirements and the eventual outcomes; this is more important than a debate on the probability of certain predictions.

The same point can be made about early warnings and the quality of the expectations and counter-expectations involved. With reference to the precautionary principle, I already identified the need to articulate and check the 'threat scenarios' involved in the warning. Similarly, one can think of methods to articulate 'promise' scenarios and check the quality of how the scenario was made.

Already at the early stage of "hype" and "hope", actors start moving, taking positions, buidling alliances – this is how networks and industry structures emerge. For our question of analysis of dynamics of irreversibilisation, this is an important process. It has been studied by a few industrial economists, evolutionary economists and network economists (e.g. Håkansson and Snehota 1995), while actor-network theory, with its interest in "warm", that is, fluid situations, and how they cool off, offers additional intellectual resources (Callon 1998).

There are striking differences: The growth of biotechnology was carried by small R&D firms, allied to venture capital and/or big firms in the agrofood and pharmaceutical sectors. Genomics is already linked to genetic counseling, but also, at one remove, to life and health insurance companies; and to pharmaceutical and agricultural companies. For nanotechnology one sees only a few small companies producing prototypes. It is not quite clear what effects these different structures (and their dynamics) will have on further co-evolution. Thus, a challenge can be defined for disciplines like industrial economics and regional economics. In TA/TF, there is some recognition of the issue because prospective questions have to be taken up. An example is how the scenarios drafted for the UK ESRC's social and economic context of genomics initiative (and the background studies) pay attention to evolving industry structures (IAF and CRIC 2002).

Embedded in prospective technology analysis is the question of the direction the development of technology-in-context will take. Then, the issue of what is the "right" direction – of ongoing developments, as well as possible modulation – cannot be avoided. In fact, Collingridge's dilemma of knowledge and control, as discussed in 2.3, is really a trilemma: the third horn says that it is unclear, at an early stage, what the right direction is. In backward approaches to anticipation, a desirable future situation is sketched and the subsequent question is about the way to get there. The Dutch have experimented with such a "backcasting" approach. In a more limited way, the backward approach occurs when regulators set requirements (e.g. on exhaust gases) and leave it to the actors to develop the necessary technology (technology-forcing regulation).

In forward approaches, as foregrounded in prospective technology analysis, the articulation of hopes and concerns, of values and guiding principles, has to be taken up in parallel with the study of dynamics and impacts. This is the focus of agenda-building TA, and there is a range of participatory TA exercises, with consensus conferences and national debates being the most popular (especially in life sciences and technologies). A problem with these exercises is the intra-mural trap: outcomes depend on the task set in a conference centre, or more generally, within the bounds of the exercise, while constellations and forces in the larger world have different dynamics, which will (re)assert themselves when the results of the exercise are delivered (Rip 2001b). Furthermore, the exercises may be more effective in offering legitimation, and thus have an alibi-function, than in articulating values and approaches which are actually taken into account and make a difference.

In articulation of desirable directions, path-dependency effects can occur, as when actors in agrofood biotechnology give up further activity because of their being harassed by opponents. This is actually occurring in Europe, and the effect is the same as when there had been a considered discussion and choice to stop with GM crops. A *de facto* value choice.

4.3: Stabilized patterns as de-facto governance arrangements

In an evolutionary perspective, the starting point are emerging *de facto* governance arrangements rather intentionally designed and precariously implemented arrangements. Actors bind each other through the rules of an emerging regime without necessarily intending to do so. A variety of actors are interested in influencing technological change in terms of their own goals, be it market success, strategic advantages, quality of life, sustainability. It is through the actions and interactions of these actors, guided by their assessments and occasional, more or less systematic anticipation exercises that regimes emerge which constrain and enable – and thus "govern". This includes the "evolution of expectations into binding agendas for action" (FORMAKIN 2001, p. 36), and the networks of mutual dependencies.

When paths emerge, and actors want to exert influence and change that path in another direction, they face the momentum that has been built up and the loss of malleability because of increasing alignment. Again, there is *de facto* sociotechnical governance – sociotechnical because it relates to a dominant design or a (socio-)technical regime. Such arrangements work behind the back of the actors – as it were, "small invisible hands" (Rip and Groen 2001). And sometimes the "hands" are not so small. The motor car regime, centred on the liquid-fuel explosion motor and bimodal transport, for example, extends throughout our societies and is very hard to change because of sunk investments of various kinds, and optimisation of innovations in terms of the criteria of the present regime.

Socio-technical regimes and sociotechnical landscapes (see Figure 1 on p. 9) are *de facto* governance arrangements, and can be analyzed as to their structure and effect. The infrastructure of electricity generation and use, including networks and billing systems, offers an interesting example. Electricity has become embedded in society, and its use has become so important that it is an almost obligatory passage point for fuels and other energy carriers in order to reach end users. In other words, there is a buffer zone or layer in the socio-technical regime plus landscape which separates ongoing innovation in technologies to generate and distribute electricity, from innovations at the distribution and use side. Selection constrained because it must work through the buffer zone, but the range of variation is contained as well because it must be always lead to, or utilize, electricity. In other words, a *nexus* has emerged, now at the macro-level. This enables productive sociotechnical work, within the limits set by the *nexus*. Alternatives to electricity stand little chance, at least in the short term.

In other words, 'function,' what is done with electricity, how is it distributed, is separated from from 'form,' how to generate electricity. The buffer layer, because of its position, has sociotechnical power, and alternative approaches run against it. Whatever alternative technological option is chosen, it mostly must be shaped so as to (also) be able to deliver to the grid. The implication is that technological regimes of wind energy, co-generation etc. have to relate to the dominant regime, at least to the buffer part of it. Of course, each alternative technology has its own research agenda, but this is shaped by issues of grid connection and load management.[21]

[21] In fact, the picture is even more complex. Behind the functionally defined electricity supply regime there is a mosaic of technological regimes. These compete among each other, but in a situation pre-structured by the historically evolved shape of the electricity supply regime. The regime of electricity supply is also connected

The example serves to show the importance of including technology in the idea of governance. This idea can be emphasized by speaking of sociotechnical governance.[22] Clearly, some parts of the arrangement can be intentional, and over time, there will be reflection on its functioning and attempts to do better (better in general, or better in terms of the position of the actor concerned). In particular, experience of constraints, of limited malleability, does not only lead to attempts to change, but also reflection on the nature and effect of such arrangements.

Especially management and policy actors are interested in learning what "works" and why. They will then start creating governance arrangements intentionally, and sometimes with some effect. Only to be surprised by novel developments breaking through the existing order, so that governance arrangements have to be reconsidered. This is how I concluded Chapter 2. This is also what has been happening with science and technology in society: earlier governance arrangements (the "macro-protected spaces" indicated before, p. 13) shifted and became contested, and actors started, first to repair, and then to look for alternatives. Governance and its challenges has become a key word in Brussels and elsewhere.

One such problem of shifting governance can be told in terms of the gap between technology promotion and control (section 2.3). For new scientific and technological developments, with their uncertainties, all the actors are limited by their situation. Actors internal to the development are constrained in their views by their inclusion in the "enactment" dynamics, while external actors (also with limited views) have to overcome the distance between inside and outside. A contest of forces may ensue, one which may become larger than the original occasion. The debate (and sometimes battles) about GM crops and GM food are a case in point.

Such contestations are embedded in larger socio-cultural and socio-political repertoires, and feed into them. For example, risk repertoires emerge in which the impacts of a new technological development are treated similarly to those of earlier ones. In the 1970s and early 1980s, the risks of recombinant DNA research were seen as those of a run-away organism and addressed with probabilistic risk analysis, exactly as had become accepted for nuclear power plants. In addition, some activities and developments tend to draw more attention than others: there is a historically evolved stratification of risks. TA and public debate play a reflexive role here (and have to face the choice in which issues to invest TA effort; cf. my discussion of second-order TA in Rip 2002b).

In a sense, Beck's diagnosis of sub-politics is confirmed here. Not because the action is below the level of traditional politics, and carried by non-traditional actors. This also happens, very visibly so in the actions and interactions around new life science and technology like biotechnology and genomics. But because old sociotechnical governance arrangements have broken down and new ones are emerging (for example in the

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with materials regimes. Improvements in the energy efficiency of steam turbines and gas turbines were achieved mostly through the use of better materials that allowed for combustion at higher temperatures. Technological regimes are thus connected with each other, they mutually shape each other. The demand for high temperature resistant materials for electricity generation shaped the research agenda of the materials regime.

[22] This continues, and is an improvement on, Latour's thesis that artifacts are non-human actors shaping human action (Latour 1992). His examples of seat belts, door closers and hotel keys all "work" because they are part of a sociotechnical regime creating gradients of effort for its participants. The artifacts are nodes in the regime, reinforcing it and structuring it in specific directions.

redefinition of roles and responsibilities with regard to genetics) without necessarily anybody being in charge. While it may well be driven by conscious attempts to do better, the eventual result will not be predictable because determined by multi-actor processes at various levels

Governance shifts in other ways as well. Consider how a big oil company like Shell (or the European Commission for that matter) accept, albeit grudgingly, critics like Greenpeace in order to remain credible – which then confers credibility to Greenpeace. This may actually lead to a lock-in, also because spokespersons who push a storyline (here, about the environment) and represent it, become characters in their own storyline and are forced to act according to the plot.

There is, by now, a grey area between private firms and public agencies, populated by a variety of actors other than traditional stakeholders . Environmental and citizen groups play a role and may make a difference to the firm's performance. Intermediaries like supermarket chains were important in the shift away from PVC wrappings and packaging, and have now become important for the issue of GM (or "Frankenstein") foods). Insurance companies exert leverage on risk decisions, and are now forced to become a player in human genetics, so that certain barriers to its further development (in relation to genetic testing) can be overcome.

It may be too soon to speak of a new governance arrangement here. But clearly, there is much more in place than prudent firms (and other technology-developing actors) encountering the public interest (as I phrased it on p. 36). What is being seen and defined as the public interest is refracted in and through these new constellations of actors.

This way of viewing what is happening leads me to a final comment. Clearly, the shifts in *de facto* governance arrangements have implications for the constitution of our societies. One may reflect on these implications in terms of traditional political theory, for example democracy. But an important driver of these shifts is the advent of novel scientific and technological developments and the de-alignment and re-alignment of sociotechnical orders. The constitution of our late-modern, technological societies has itself a technological component. This is not meant to argue, like Latour does, for a Parliament of Things (Latour 1993) – although his argument deserves to be heard and understood. It is saying that the entanglement of technology (and science) in *de facto* governance and the constitution of our society is a challenge for the co-evolution of scholarly disciplines. A *nexus* should be created between science & technology studies and political science.

Chapter 5: Opportunities and challenges for research

I have taken an unusual cross-section of scholarly and professional literatures. Thus, there is no single addressee for the research themes that can be identified. In fact, I have tried to create, with the (co-)evolutionary perspective as a starting point, a rich picture out of which my readers can distill their own themes for further research. What I shall do in this concluding chapter is to present the results of my exercise in drawing out research themes, in general and for the *Förderinitiative* Science Policy Studies. In an appendix to this chapter I copy the list of seventeen "tasks", that is, themes for policy-oriented research, which formed the conclusion of the study for the European Union STRATA Program which is complementary to this Expert Review (Rip 2002b).

There are two key substantial conclusions which imply broad challenges for research:

(1) The institutionalization of TA is one of the indicators that the co-evolution of technology and society changes its character. The interest in TA is an effect of this change, rather than an independent input. So further study of overall dynamics is in order.
(2) TA is an input, making co-evolution more reflexive, when it develops further, in particular when it is closer to the (co-)shaping of technology. Insight in the dynamics of these process forms the basis for developing further tools and interactions.

In addition, there are analytical implications of the overall (sociotechnical as well coevolutionary) approach to technology in society. The dynamic development of technology in society plays havoc with traditional distinctions between micro and macro, and between agency and structure, but also with analysis of long-term developments which take technology as an external force impinging on society.

<u>general/theoretical</u>
It is important to compare (and contrast, perhaps combine) the three main theoretical approaches which can address the foundational questions about micro/macro, agency/structure, long-term developments, while keeping a focus on technology:

- actor-centred institutionalism (e.g. Weyer 1997, but also theory of Large Technical Sstems)
- actor-network theory (in its social-semiotic version, so including narratives and regimes)
- co-evolutionary theory (with explicit attention to multi-level processes)

The links with substantial theory of reflexive modernity (Giddens etc) and risk society (Beck) should be explored further, in particular because technology is neglected, or at least remains exogenous in these theories. In this respect it would be particularly important to have a better understanding of long-term developments of technology in society, for example the emergence of the gap between technology promotion and control. The forthcoming volume *Technology and Modernity* contains essays which go some way in addressing such long-term developments (Misa et al. 2003).

While the various literatures indicated in section 2.1 (p. 6-7) overlap, there are also differences in scope and in disciplinary approach which create unnecessary divides. A diagnosis of the differences (as in Geels 2002) can lead to the identification possible synthesis and productive ways to go forward

The existing work on the politics of technology has mostly remained in the tradition set by Langdon Winner. The idea of *de facto* sociotechnical governance arrangements is compatible with this tradition, but is better able to capture emerging phenomena and patterns of change. The combination of case studies and theoretical reflection should be exploited in further research on this point.

The idea of (institutionalized) *nexus* between variation and selection and how this shapes further development is reasonably clear for anticipation on selection. A movement in the other direction can be seen in the observation of new actors (stakeholders) in the grey zone between prudent firms (and other technology-developing actors) and public interest agencies. If this would become a *nexus*, it could be positioned as interactive neo-corporatism (Rip and Groen 2001). The public interest is itself refracted in and through such new constellations of actors. There is a link with Beck's ideas on sub-politics, and with the literature on policy networks (cf. Mayntz 1993), but the specificities deriving from the role of technology should be worked out. (Including the differences between various technologies, cf. below.)

<u>Theory of change action in a co-evolutionary world:</u>

- non-linear: individual action is no more than part of overall dynamic
- patterns in co-evolution and how to get the "right" patterns
- specific mechanisms, esp. nexus (study of the variety of nexuses)
- "modulation" of developments and the possibility of privileged *loci* for intervention
- the role of 'authority' (esp. government action) and the 'shadow of authority' in the overall dynamic

This defines a cluster of research themes. Each of the bullet points can be elaborated and examples could be given.

This cluster can be positioned against the backdrop of a general phenomenon: institutionalization creates stable practices, rules, alignments which function as it were behind the back of the actors, and derive their effectivity from it. Such structures, regimes, strategic games enable and constrain like small invisible hands, without much pretense at overall optimization. As I have pointed out (in Rip and Groen 2001), the role of analysts (and reflective actors) can then be seen as making the work of these invisible hands visible. This will allow the actors to play their games better (cf. prudent actors), not necessarily improve overall directions.
This way of looking at the role of analysts can be starting point for reflection, supported by study of cases where effects of making invisible hands visible can be traced.

prospective technology-in-context analysis

Under this heading, a number of quite concrete research themes can be developed, but they should always remain sensitive to the background dynamics of emerging irreversibilities and larger co-evolutionary shifts.

- How to map emerging paths, and analyse the way they emerge – and how to feed this back to actors productively.
- Quality control of promises and expectations (also early-warning dynamics). This is also important for the question which new developments should be studied more closely (are a cause for concern).
- Tracing emerging networks and structures which will constrain and enable. In particular, non-traditional industry (and service) structures. New combinations of economics (industrial economics, evolutionary economics and network economics) and sociology (primarily recent sociology of technology) are in order.
- Possibilities to evaluate the directionality of developments, and to link prospective technology analysis with articulation of values and views of the future.

Nelson (in Ziman 2000, . 72) notes: "Bicycles are different from aircraft." And both are different from nuclear power plants and from the mobile telephony infrastructure. Differences between technologies in terms of patterns in co-evolution, while recognized for what they are, have rarely been studied systematically. One interesting entrance point, directly related to the focus on TA in this Expert Review, is the difference between technologies offering a general promise (nuclear in the 1950s and 1960s, genomics now) and technologies like ICT delivering services more or less immediately. The promise-requirement cycles are different, and doing ELSA-type studies seems only relevant for the former type. In other words, ELSA-type studies must be understood as part of such general promise dynamics, adding some reflection.

emerging patterns in co-evolution

The case study of genomics indicated the possibility of addressing empirical questions about "bridging the gap between technology promotion and control", about the role of ELSA as "lubricant" for the introduction of new technology, and about institutionalization of such studies making co-evolution more reflexive (in principle; how much happens in practice?).

Many more such cases can be studied, with their own emphasis and set of questions. What connects them is the process approach, and the way they can be located as part of broader developments.

Appendix

Task 1: The potential of combining TA, Foresight and RTD Evaluation is recognized (cf. Kuhlmann et al. 1999), but has to be developed to provide better anticipatory intelligence to practices (including decision making). This will be (and must be) distributed intelligence. Kuhlmann et al. (1999; 71-74), in one of their "fictions" offer a picture how distributed intelligence can work in the development of a new EU Technology Programme – which must then also be a more decentralised process.

Task 2: Technology Foresight (especially in its Delphi version) is often naive about economic and broader societal aspects. Technology Assessment should be able to address those, but there is a gap between impact assessment, more or less after the fact and speculative stories about possible impacts. A key insight is that eventual impacts are co-produced, and that the processes of co-production, and the patterns in these processes, can be traced. To develop practical, but sufficiently sophisticated tools, insights from (sophisticated) RTD evaluation about attribution of impacts can be used in addition.

Task 3: TA, combined with foresight and other prospective exercises, must be linked with broader concerns (e.g. risk society) and governance issues. TF/TA methodologies must reflect this, including the need to do 'real time' analysis in interaction with relevant actors.

Task 4: Invest in bridging the gap between technology promotion and (attempts at) technology control. Constructive TA focussing on design and development phases is an example that can be elaborated further (cf. also SocRobust 2002). 'Hybrid forums' occur increasingly (cf. Callon, Lascoumes and Barthe 2001) and can provide a connection between impactors and impactees; an example would be how patient associations get involved in medical research (e.g. on genetically determined muscular dystrophy).

Task 5: TF/TA must be formative, or at least emphasize learning possibilities. This will happen in multi-actor and possibly conflictual situations. The experiences of evaluation studies (including the approach of Guba and Lincoln) might be helpful to articulate possibilities.

Task 6: Further develop tools to articulate and analyse endogenous futures in technological developments and their embedding in society. This includes emerging structures and regimes. The further challenge is to assess stability of the path, and susceptibility for change.

Task 7: Develop scenarios as fictive worlds in which to find out about impacts: a micro-cosm as in modelling and simulation, but now on a narrative basis.

Task 8: Increase understanding of how third parties and credibility pressures exert leverage for change. A combination of retrospective case studies and further conceptualization and theory is advisable.

Task 9: A robust methodology for prospective technology analysis must transcend the point-source bias. The only examples available yet are of the narrative, scenario type. Socio-technical scenarios may be the way to go.

Task 10: Understand and design arrangements for social and contested learning, and locate TF/TA exercises in such frameworks.

Task 11: Quality control of expectation dynamics (hype & hope, inflated warnings and concerns etc) is important. TF/TA must play a role in it, but this is new territory. The challenge may lead to new versions of TF/TA. An additional issue is the importance of incidents to break out of earlier socio-cultural (etc) frames.

Task 12: With the increasing number of claims (promises as well as warnings), the selection of what is worth our attention and more sustained effort becomes pressing. There is no “royal road”. The cultural stratification of issues, linked to storylines and archetypes, is unavoidable but should be understood better.

Task 13: Hybrid governance includes mixtures of experts (insiders) and new stakeholders. There is a trade-off between right of participation and actual contribution to productive outcomes. The right mix has to be designed for each particular case.

Task 14: The role of TF/TA in such cases could be focussed on the question how to assess the extent of sustainability in the scenarios of future development. Sociotechnical scenarios show up patterns, but do not allow simple assessment of the functionalities that will be achieved eventually. In a process approach, one could ask how much of the requirements envelope is achieved. But it would be important to include lateral moves and unexpected inputs as well, because such new combinations are often just as important as the regular work to achieve the goals.

Task 15: Regimes and other examples of sociotechnical governance serve to broaden traditional views of governance. It also indicates that TF/TA can play a key role in governance, if they take up on the challenge of assessing the governance implications of sociotechnical regimes.

Task 16: Actions and interactions add up to a *de facto* constitution of our technological societies. Explicating and further articulating such a constitution creates reflexivity, and opens up possibilities to work towards its assessment and improvement.

Task 17: Precautionary principle adds a new dimension to sociotechnical governance. While TF/TA can improve the application of the precautionary principle, they will themselves profit from the concrete challenges in articulating the precautionary principle.

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