The cultural shaping of technologies and the politics of technodiversity

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1. The Social Shaping Perspective Specified: The Meaning of Culture in the Technological Development and its Implications for Technology Policy[1]

Traditional discourses on technology gave little attention to culture and the specificity of social institutions: the long-standing and prevalent technological determinist view as a case in point. This was associated with a technocratic type of technology policy. Similarly, later economic analyses of technological development focussed on rational choices between different technologies, on the return of investments in R&D and on the impact of technological change on economic growth and the wealth of nations (see e.g. Freeman and Soete 1993). Universal criteria of efficiency were imputed. This led to the *politics of techno-globalization*: all firms follow the best practice of the champion in a technological field, and all nations reorganise their innovation system in line with the winner in the international technological competition.

However differences of cultures and social institutions have significant consequences, too. The cultural diversity of technical practices, the cross-breeding of different engineering traditions and the mix of regional techno-regimes may become the unexpected source of start-ups of innovative firms, emerging technological fields and new networks of innovation. The cultural shaping view which is presented in this paper emphasizes the role of different symbolic orientations, patterns of practices and institutional regimes in the process of technological development. It opens the space and offers the tools for a new kind of technology policy that I call the *politics of technodiversity*. This involves a variety of projects and programmes; it includes a diversity of collective actors; and it takes advantage of different local and institutional conditions.

The cultural shaping approach extends and specifies the broad body of knowledge that is collected under the label of social shaping or social construction of technology. It is one aim of this paper to extend this focus towards institutional uncertainty and towards the processes of cultivating new technologies (see Russell and Williams, Chapter 3 in this volume). The *social shaping* of technology is now a widely accepted perspective (see Cronberg and Sørensen 1996). It is a well-established research strand in technology studies to analyze how social relations affect the precise design characteristics of particular technologies, how they influence the choice between alternative paths of technical development, and how they are fostering or inhibiting particular technologies (MacKenzie and Wajcman 1985: 24).

The shaping of technologies, however, cannot be conceived as a single closure process and a local deliberate decision that takes place during the design phase and outside institutionalized spheres (see Pinch and Bijker 1987; Kline and Pinch 1994; Bijker 1995). Social constructivism has been criticized for neglecting the multi-stage character of technical development and overlooking the constraints of established social structures (see Russell 1986; Vergragt 1988; Rosen 1993; Hård 1993). The development of technologies should better be conceived as a continuous process of creative variation, taking place in and

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between various technology projects, enacted by different social actors, closed and re-opened by negotiations in multiple arenas of conflict and selected by some institutional filters (Rammert 1997).

We summarize the debate about the shortcomings of social constructivism and say more precisely what the term *"shaping"* in our concept of cultural shaping means:

a) There are multiple influences on the technological development, not a single one.
b) Shaping involves two-way interaction, not a one-way process of determination.
c) It is a kind of "heterogeneous engineering" (Law 1987) or "extended translation" (Callon 1993; 1995), not a homogeneous representation of a social form in the technical medium.
d) It is situated in particular "time-space zones" (Giddens 1987: 148); it is not a universal act.
e) There are plenty of critical events (Van den Ven and Garud 1994) during the whole technological development process, from inception to use; there is not a single point of decision or a limited time for closure.

If the shaping process is defined in this way, it opens up the door for a combined cultural and institutional approach of shaping technology. The *notion of culture* itself suffers from too much interpretative flexibility. One can define culture as a special sphere of values and norms or even as a particular system besides economy, politics, or technology, as Talcott Parsons did and many sociological followers are still doing. One can define culture as the ensemble of all ideas, artefacts and practices which are highly valued in a society and draw a distinction towards profane culture or simple civilization. But in this context of shaping technologies I shall follow the broad anthropological perspective and define *culture* as a special "frame" (Geertz 1983: 21) or mode,

- how things are viewed differently,
- how things are done differently, and
- how these activities are institutionally arranged differently.

Consequently, culture is opposed not to economy or politics, but to certain abstract and formalized concepts of them. This concept of culture contains a particular comparative perspective which emphasizes empirical practices and which deconstructs the myths of universality. Thus, culture does not imply highbrow and idealism, but is rooted in everyday life and pragmatism. This notion of culture encompasses three elements:

- configurations of valued signs and symbols (semantic aspect),
- patterns of practices (pragmatic aspect), and
- regimes and styles: how something is instituted (syntactic or institutional aspect).

Cultural orientations are rooted in processes of signification and semantic framing of action and perception. They are condensed into visions, paradigms, cultural models or directing metaphors. Patterns of practice rise in the processes of pragmatic structuring of action. They crystallize into dominant habits and different styles of activities. Institutional regimes grow out of processes of syntactic regulation of action. They gain durability as national traditions and established arenas of negotiation. In a certain way, this conception of culture is paralleled by the Cultural Studies approach. This approach is well-known for its studies of the production and consumption of cultural artefacts in the field of media and mass communication. But it also concentrates on processes of "meaning-making" and on "social practices" (du Gay et al. 1997: 11).

If culture is defined in this way, it can be demonstrated that cultural patterns are shaping the development of technologies more intensely and more frequently than we usually assume. I shall argue in the first part *that the cultural shaping of technology plays a significant role in the design of artefacts, in the direction of technological development and in the diversity of engineering traditions, user cultures and innovation regimes.*

The subject of the cultural shaping approach is the distributed process of innovative actions encompassing all kinds of actors and practices: technological, economic, political, and cultural. When we examine the political implications of this framework, it is evident that the scope and scale of conventional technology policy must be changed. I shall show below *that interventionist types of technology policy geared towards particular technology programmes or issues need to be complemented or even replaced by an interactive and network-oriented type of innovation policy that caters for technological and institutional diversity across the whole innovative process and in the long run.*

Both parts of the paper are connected by the central argument *that the cultural shaping view recommends the particular politics of technodiversity.*

2. How to Cope with the Circle of Uncertainty: The Shift from a Techno-Economic to an Institutionalist-Cultural View

The idea of economic shaping of technologies reaches far back in the tradition of the Social Sciences. Karl Marx and Max Weber unanimously believed that economic criteria finally determine the rate and direction of technical change. However examining the two main strands of economic theorizing about technological development indicates a slight shift from a techno-economic to an institutionalist-cultural view: the neo-classical approach of rational choice and the evolutionary approach of routines and technological regimes.

The adherents of the neo-classical style of reasoning dissolve technological development into many technological choices. These choices are conceived as rational decisions between substitutable goods. This type of techno-economic reasoning has been widely criticized for its empirical improbability and theoretical inconsistency. Herbert Simon demonstrated that only "bounded rationality" can be achieved and that strategies of "satisficing" can be realistically expected. Kenneth Arrow (1962) emphasized the critical role of "uncertainty" and argued that an economic calculus cannot be applied to processes of decision-making in the cases of invention, research and development. The neo-classical approach to Economics fails to explain technical change, because it has developed an "over-rationalized" conception of economic action.

The proponents of an evolutionary approach to the economic shaping of technologies have learnt from the shortcomings of the techno-economic view. They emphasize local variations from routine behaviour and the selective retention of technological paradigms and regimes (see Nelson and Winter 1982). They argue that organisational "routines of decisions" and technological "rules of thumb" characterize the firms' innovative behaviour more than "rational choices". The normative concept of a market equilibrium is replaced by a more empirical and broader perspective of "selective environments" that includes market relations, state regulations, and socio-cultural preferences. The emergence of the new is explained by the unconscious modification of search routines and the unplanned confluence of different R&D strands. The success of a new technology is derived from its adaptability to the selective institutional environments, not from an universal technological superiority. The new technologies and relevant social institutions influence one another in a kind of co-evolution. In this way the techno-institutional interdependency stabilizes into a new technological regime (see Dosi 1982; Nelson 1994).

This Nelson-Winter-Dosi model of technical change can be criticized for the deterministic overtones in the concept of technological trajectories and technological regimes (see Rip and van den Belt 1987), for the neglect of the actors' capacities to intervene, and, moreover, for the neglect of their capabilities for creative and reflective action. The evolutionary approach to the economics of technical change shows some weaknesses, because it is based on an "under-rationalized" concept of innovative action. But this approach introduces the notion of institutional environments and non-rational orientations into economic reasoning and thereby paves the way for an institutionalist-cultural view. *A conceptual change from economic determination and rational decision to institutional shaping and routine selection has taken place.*

Both concepts of economic shaping have difficulties in coping with the central problematics of innovation. Any really new technology is fundamentally uncertain in many aspects. Any firm which decides to invest in, and any government agency which wants to foster the development of, a new technology can neither rely on sound economic calculation nor upon stable technological prospects. This eminently uncertain character of new technologies at the outset constitutes a sequence of problems that I call *the circle of uncertainties* (Rammert 1999). This circle consists of a wide range of uncertainties which are mutually intertwined in many ways. If an actor wants to develop a new technology or if s/he decides to follow one path of innovation, s/he is confronted with a great number of uncertainties,

- whether s/he gets access to the information about this technology,
- whether s/he is able to select the relevant information out of the flood of information,
- whether s/he has the capacity to process and to convert it into useful knowledge,
- whether the innovation comes up with a feasible technical product,
- whether this product can be produced economically,
- whether a new market can be established,
- whether the users accept the product and tolerate its unintended consequences,
- whether the developer gets a fair return to his/her investments and risks,
- whether his/her property rights are sufficiently protected, and
- whether the product meets the compatibility requirements of technical standards and legal norms.

As we conceive technological development as a heterogeneous and distributed process, where decisions, actors, aspects and artefacts are dispersed over time and space, we have to take into account a multiplication of uncertainties. If the complexity of the innovative situation is increased in such a way that economic techniques of calculation cannot be applied any longer, then cultural patterns of orientation and experience-based practices are substituted for economic accounting.

Three kinds of cultural patterns can be distinguished in this techno-economic context. First, visions and technological paradigms can be seen as cultural orientation complexes: sets of ideas that help orient and co-ordinate technological development, if its complexity and its openness cannot be reduced by other "rational" means. Second, building routines out of experimental inquiry, learning by doing, and recursive learning can be described as another cultural pattern of practice to handle the insecurity of unknown situations. Third, the cultural orientation complexes and patterns of practice are embedded in institutional regimes with longer duration and wider expansion. Paradigms of technological solutions pave the way towards stable paths of technological development; the mutual adaptation of technological construction and institution-building crystallize into particular regimes of innovation. Practices that are experimentally produced and that because of successful experiences are often reproduced turn into traditions and particular patterns of institutional arrangements.

Cultural orientation schemata, cultural patterns of practice, and institutional regimes together shape the development of technologies at times and places where markets fail and firms cannot calculate. The territories of high technology development and the periods of early technology generation constitute these particular uncertain and complex zones. A sensitive and sustainable technology policy should concentrate on these early times of the technological development when the conception and design of new technologies are pre-shaped, because the variety of technological alternatives is rich, and the paths of development are still open.

3. Technology Projects and Innovation Regimes: The Cultural Construction of the Design and the Institutional Shaping of the Technological Development

New technologies do not arise as hard artefacts and finished systems, although they are often presented to us in this way. They are part of a broad stream of conceptual variation and experimental design - as many historical studies about the shaping of technologies have demonstrated. Controversies about technological superiority and quarrels about the safety of a technical design indicate the inherent openness and contingency of technical development. They can only be limited by institutional closure and cultural consensus mechanisms. Economic criteria or technological parameters are not effective at this early stage of development, because they are dependent variables rather than fixed points of reference. Any technical construction must to this extent be seen as a cultural construction, because the choice, the evaluation and the configuration of technical elements are shaped by cultural patterns.

Particular *technology projects* are the concrete places where the general interaction between these cultural patterns and technological potentialities are organised. These technology projects restrict the openness and the contingency of technical development, because promoters follow particular visions of use, because engineers choose certain concepts, and because firms establish different traditions of design.

According to traditional concepts, technologies are supposed to be shaped foremost by parameters of technological perfection and criteria of economic efficiency. But with new technologies, who knows what it means to be "better"? Better under which aspects? Better for how long and in which place? And better in comparison to which alternative? With our two-way interaction view of shaping in mind, technological parameters can be seen as cultural artefacts. They are the products of cultural evaluation and social negotiation processes. The features of a new technology are, besides other factors, mainly dependent on three cultural forces:

- first, on the *visions of function and use*, including an orientation by paradigms, an interpretation of the function and an image of the prospected user, which align the further technical development,
- second, on the *concepts and styles of engineering*, which grow out of different academic, professional and organisational cultures and which are inscribed in the technical design, and
- third, on *traditions and regimes*, which reflect the particular attitudes and established relations between the actors in the field and which stabilize the way how the development of technologies is institutionalized.

The cultural shaping of technology takes place in processes of symbolic interpretation, material inscription and social institutionalization.

Visions of function and use open up new options and paths of technological development and at the same time limit the wide range of other possibilities. Visions bundle heterogeneous elements within an integrating perspective (see Dierkes, Hoffmann and Marz 1999). The closer we move to the inception and generation stage of new technologies, the circle of uncertainty increases and the variety of possible projects increases. Visions of how to use a device and for what purpose give a first orientation to technical development. For instance, the idea substituting programmable machine for the disciplined operations of human computers (Turing 1937; Heintz 1995) pointed the way to hardware and software development in computer technology. The vision of computers as "augmented knowledge workshops" (Engelbart 1962) and as "personal dynamic media" (see Kay and Goldberg 1988; Mambrey and Tepper 1992) later diverted computer development from big calculating machines to the new trajectory of small personal computers. Examples indicate that c*ultural interpretations can have technological and economic consequences*.

Concepts and styles of engineering are parts of design cultures. They are based on engineering routines and standard solutions. They give more concrete orientation than visions. They determine the particular design of a technical system, for instance whether you can interact with the computer via keyboard, natural language or screen contact. The design depends on the user model that designers have in their heads. The conceptualization of machines, programs or networks shapes the frames of social relations. For instance, once a design concept is chosen, it is inscribed into the techno-structure. This fixes who does the work, the bank or the client; who may intervene, the manager or the employee; who gets access to the relevant data, the administration or the citizen. *This process of inscribing concepts of use, user models, and supplier-user relations into technical systems can be seen as a cultural construction of technology.*

What seems to be the result of an explicit rational technological or economic decision, can sometimes be revealed as routine-based and an inherent feature of engineering culture, such as implicit models, hidden curricula, or *traditions* of engineering. Engineers often stick to their proven concepts, to their learnt styles of engineering and to the established state of the art, even if they are designing new technologies. In following routines and tested traditions they want to minimize uncertainties and to keep away the risk of non-functioning. Besides the “technological momentum“ of large technological systems (Hughes 1982) and the “irreversibility“ of complex networks (Callon 1993), this structural conservatism of the engineering culture (Knie 1989) is an important factor, which can explain why new visions quickly lose their variety-enforcing power and why different conceptual options are constricted to traditional lines of development.

The telephone, for instance, was in the beginning seen as a one-way media like the established telegraph. Following this one-way transport concept German telecommunication engineers designed the telephone in the first years as a local device for the prolongation of the telegraphy system. Hungarian engineers experimented with a one-to-many communication concept and pre-structured the star-like pattern of radio mass communication. The vision of a two-way media only became dominant some years after the patent application and led to the well-known network-like architecture of the telephone system (Rammert 1993).

The development of computer technology offers another example. Although the visions of a "universal machine", of a "personal tool", and of a "media of communication" existed - remember Turing`s vision of an intelligent machinery (Turing 1950) and other early inventors like Vannevar Bush, Douglas Englebart, Carl Adam Petri and Allan McKay -, for a long time computers were built and improved according to a single technological tradition. It was dominated by the paradigm of the calculating machine. The development aimed at the design of supercomputers for central and faster calculations (MacKenzie 1991). The computer engineers continued to improve the speed, the reliability centralising of technical system; but they did not search for alternative uses and different designs. Military influence and the conservative engineering style were responsible for this "natural trajectory" in computer development from the forties up to the sixties of the last century.

Technologies cannot be separated from the techno-structure of which they are a part. A machine, for instance, is coupled with other machines to function as a production system; a machine is integrated in a whole system of technical infrastructure which provides for the necessary energy, material, and information; the whole technical system is associated with many social institutions, like organisations and legal norms, which constitute the socio-technical complex to fulfil a social function. But functions are defined in a cultural context, and the corresponding institutions grow along historically chosen pathways. These socio-technical complexes or large technological systems are shaped by national traditions and particular institutional frameworks (see Hughes 1983; Mayntz and Hughes 1988; Mayntz and Schneider 1988; Kubicek, Dutton and Williams 1997). They are not the same all over the world and they are not organised like functionally specialized systems. The features and the arrangement of institutions constitute different *technological regimes.*

The American Fordist regime of car mass-production differs from the Japanese Toyota regime of intelligent and flexible production. In Germany, one can observe a high quality incremental innovation regime in the machine tool and chemical industries which is suited to developing complex goods and which needs long term trust relations between the developers and the users of new technologies. In the USA and Great Britain, the institutional framework favours radical innovation in biotechnology and microelectronics (compared to the co-operation and regulation culture as in Germany. Here, risk-taking and strong competition are rewarded even in the higher education system (see Soskice 1996; Hage and Hollingsworth 2000).

We have seen that the cultural construction of technologies can sometimes be more crucial to economic success and social diffusion than technical improvement alone. Real new-to-the-world-technologies bring up a lot of uncertainties, concerning the choice of technical parameters, the test of adequate functioning, envisaged user groups, and the commercial pay off. This circle of uncertainty is interrupted by cultural concepts which guide the technical development by implicit paradigms and explicit visions. It is reduced by routines and rules that build the institutional framework and embed technical development in society (see the contributions in Dierkes and Hoffmann 1992). *What at a later point of time appears to be determined by parameters of technological perfection and by criteria of economic calculation, can at an earlier point of time be disguised as the contingent product of cultural construction and can be analyzed as an institutional shaping of technological development by routines and regimes.*

The policy implications of this insight are evident. It is at these early times of construction and development that a vivid debate about possible different visions should be initiated. The greater the variety of ideas and concepts of design and use that can be mobilized in the early technology generation stages, the greater are the opportunities to find a creative and socially acceptable path of technological development in the long run. An evolution of technology whose characteristics are not made explicit and whose consequences are not debated easily runs into irreversibility (see Callon 1993) and risks getting locked-in (see Arthur 1988) in later times. Further, it is not wise to apply established technological parameters and economic criteria to radically new technologies. Innovations need different criteria of testing and evaluation. This paradoxical relation requires a politically mediated process of experimental projects and experience-seeking in protected places. The development of solar technologies, windmills or electric cars should therefore be developed in such “niches” of evolution (see Rip and Schot in this volume; Hård and Knie 1994). The institutions that are built up in close cooperation with established technologies must also be reshaped to give room for a new co-evolution of technologies-in-action and institutional regime-building. New technologies need new markets and new forms of work and organisation. And they need new tools and a new kind of technology policy, that caters for its uncertain, open and distributed character.

4. Multiple Policy Arenas and Local User Cultures: The Public and Private Construction of Technical Practices

The development of new technologies does not end with their production, but continues during the diffusion and use of new technical devices, too. And so does the cultural shaping of technology via recursive learning processes between developers and users.

How do new technologies disseminate into private households? An engineer of the development department would answer that new devices convinced people because of their technical efficiency. A business economist would emphasize that they were selling goods with a reasonable price. These conditions of diffusion are not sufficient. The users also must make out a meaning and recognize the usefulness of a device. They must be able to appropriate it and to fit it into their everyday life routines without problems. Even more, new technologies must offer playgrounds to experiment and invent new uses. The Sony walkman, for instance, was designed to be used by young people or professional musicians only listening to the music of their choice when they are not at home. But after a short time, people of all ages and professions invented a diversity of uses indifferent places which later on influenced the design that became more and more distinctive (du Guy et al. 1997).

The meaning and usefulness of a new technology are not self-evident. The visions of the inventors, the concepts of the engineers, and the images of the salesmen are only proposals for a sensible use of the new technical artefacts, though they have pre-structured the production of prototypes. From the outset on, there is experimentation on possible uses and negotiation about the reasonable use of a new technology. Within the firm since no-one knows what the user really wants, the different departments are in competition to configure the user (see Woolgar 1992 and Akrich 1995).

Many collective actors participate in this process wherein the meaning and reasonable use of a new technology is defined and negotiated. No single actor can impose his/her concept of computer use to the others. For instance, the quick diffusion of micro computers in American households was mainly caused by the self-augmenting and self-organising cultural movement of hackers and computer clubs (Allerbeck and Hoag 1989). Neither the persuasive marketing strategies of the producers nor the political decision to introduce computer education at schools were responsible for that success. *The non-military and non-commercial use of computers can be seen as a cultural invention, a creative process of re-defining and domesticating (see for this term Sørensen 1994) the big calculation machine and its use.*

The cultural shaping view encompasses two interdependent processes: the public construction of the sensible uses and rules how and for which sake to use the new technology, and the private construction of the meanings and styles of a new technical practice. We have observed the *public construction* of the micro computer as a useful private gadget in Germany after 1970 in three arenas (see Rammert 1996). Producers and sellers of computers on the one side and user clubs and consumer organisations on the other side constituted a *techno-economic arena*: They discussed the problems of a fair price and negotiated about the service and the quality standards. Struggles between the police, government institutions, and data-bank owners on the one side and hackers and political groups fighting for the freedom of information or the protection of personal data on the other side established a *political arena*. Those engaged negotiated about the definition what is a legitimate, what legal, and what is criminal use of computers. In the *cultural arena*, quite different groups, such as computer artists and marketing people, scientists and computer clubs, were competing together in creating new applications and cultivating new styles of computing.

This public construction of a new technology's meaning and usefulness functions as a backstage for the *private construction* of a new technical practice. At first, we have to realize the difference of *places* where computer use is practised. It makes a big difference, whether an information system is used at work or at home or in public places. In the work setting, one can expect that the employee has the professional competence to use it and will follow the use instructions. But particular professional styles and organisational cultures will also shape the style of computing. In the private setting at home, we will meet a great variety of skills and interests: systems should therefore be open for creative and experimental uses and give enough room for emotional needs and amusement (Dholakia 1994). In public places, the system designer has to imagine the "occasional user" (Kubicek and Taube 1994) with limited skills and a low frustration tolerance. If we look at the new communication technologies, like the Walkman, the mobile phone and the internet, we can observe that even the limits between the places are dissolved. Music listening, a private amusement at home or a collective event in a concert hall, is turned into a very individual experience and private listening in the public domain when one uses the Walkman (du Guy 1997: 114). If we focus on the new information technologies and the different places where they are practised, it can be seen that the cultural concepts of the 'standardized user' and of the conventional distinction between private and public worlds are fading now.

Second, the differences between *cultural milieu and life styles* have to be considered. Beyond traditional class divisions sociologists observe an "individualization" and "multiplication" of life styles (Beck 1986). Private users cannot any longer be conceived as "passive consumers", buying goods driven by nearly the same motives and using the products in nearly the same manner. In particular the new information technologies which are open to flexible and creative use require the "active user", who shapes and appropriates the technical system according to his individual needs and personal style.

The micro computer, for instance, does not move into the household as a fact and finished good, but it is constructed and configured along sub-cultural images and tastes. As the computer is eminently suitable as a projection surface, like a Rorschach-test (see Turkle 1982), it would be quite unreasonable to expect the one-dimensional computer user, the freak with a pale face, or the man with a mechanical character (Weizenbaum 1976; Pflüger and Schurz 1987). As our deep empirical study of about fifty computer users, (men and women of all social classes and aged between 18 and 60) demonstrated, one will find different ways of defining the computer, different styles of using the computer, and different social and cultural impacts conditioned by these differences of domestic computer cultivation (Rammert 1996; see also Turkle 1984; Eckert et al. 1991).

5. Consequences for an Extended Technology Policy: Caring for Technodiversity and Creating Interactive Networks of Innovation

The cultural shaping view broadens and intensifies the perspective on technological development. It focuses on the whole process of innovation. It includes both, the early stages of the inception and generation of new technologies and the later stages of diffusion and use as well. It analyzes the complex interrelations between all aspects of the innovative process. That is why more conventional views of technological or economic shaping of technologies are too crude and restricted to lay the foundations for an extended and evidence-based innovation policy. Their utility remains limited; insofar as the technological view succeeds in turning its method from mere technological forecasting into multi-optional scenario building, and insofar as the economic view is prepared to put more emphasis on the social embeddedness of technological choices and on the co-evolutionary character of technical change. Additionally, the cultural shaping view stresses the role of actors, their practices, and their relations with one another in negotiating arenas. Innovation is seen as a distributed process of various activities, enacted or mediated by heterogeneous elements and happening at dispersed places and at different times (see Rammert 1998).

These insights should have consequences for the formulation and practice of technology policy. An innovation policy based on evidence rather than disciplinary myths needs a high awareness of these complex interrelationships and a deep understanding of how technological projects are turned into dominant designs and what is needed to assure and to shape the innovative process. It can no longer rely on the mere monitoring of technological trends and policies to strengthen promising paths of development by pushing big projects and entrenching long-term programmes (see for new concepts Rip, Misa and Shot 1995). As social shaping research has shown, this technocratic kind of technology policy remains blind to both social implications and excluded alternatives. It runs the risks of subsiding big companies, excluding other social actors, and of getting locked-in in an unwanted technological trajectory. An innovation policy that is informed by cultural shaping research cannot restrict itself to the economic problems of looking for the one best technological solution, of searching for the most efficient allocation of resources and for bench-marking the highest performance. Such a rationalistic view is not based on sound empirical work, but on formal and normative models. It narrows the political perspective to aspects of commercial exploitation and best management practices. At the same time, the conditions of long-term innovativeness may be undermined when the range of possible technology projects is reduced by strong economic calculations, when the variety of practices and institutional settings is stream-lined towards a globalized standard model of innovation management.

The shift from a techno-economic view to an institutionalist-cultural view implies a shift in technology policy. The fundamental problem of an innovation policy that refers to an enlarged space of shaping has to cope with the *paradoxical problem of reducing uncertainty without strangling creative diversity*. Creative diversity refers to three main sources of innovation:

- “technological diversity” - the knowledge bases of various scientific and technological research fields;.
- “actor diversity” - the heterogeneity of innovative actors and the distributedness of the innovative activities;
- “institutional diversity” - the variety of institutional settings, national regimes and forms of social embeddedness.

Technology studies have opened the black box of technology. Its students have analyzed the implicit cultural models of rational man, gender, social inequality or exploitable nature. By this work of making explicit the tacit dimension of design and the hidden curriculum of development they are multiplying the paradigms and defining perspectives. These insights need to be transferred into the cultural arenas where public debates about visions of use and the value of concepts should be initiated. At this early stage of inception and technology generation, it is the main task of a sensitive technology policy to open minds to the multiplicity of perspectives and the variety of possible paths of technological development. It is not sufficient to do this by the conventional tool of scientific policy consulting; a democratic and sustainable innovation policy requires the organisation of public discourses in different arenas in order to mobilize a broad spectrum of ideas and views. After this period of variety enforcement, a publicly controlled closure process needs to be induced. Different visions, concepts, and expectations have to be melted into the amalgam of an enriched cultural model, a kind of leitmotif, that is stable enough to give orientation to further development and flexible enough to give room for reorientation, if necessary.

This idea is far removed from traditional technology policies to find and fix a putative “one best way” and to fit a ready-made technology definitely in the existing technical infrastructure. The new innovation policy acknowledges the paradoxon of opening and limiting the range of innovation paths. It augments the diversity of knowledge bases and visions. It initiates discourses and mediates conflicts in public arenas. Thereby a variety of ideas and distinctive views are linked with one another. As the outcome of these negotiations, a leitmotif can be finally composed that weaves the different and dispersed threads of technological development together. Under this semantic aspect, *the politics of technodiversity involves creating a space for multiple options and a variety of ideas and views and connecting them loosely by presenting leitmotifs.*

A second aspect of cultural shaping concerns the process of pragmatic structuring: Technological development is seen as a distributed process of innovative activities. Different social actors are involved who follow particular standards of rationality and who are guided by often opposing interests. Different practices of research scientists, inventors, entrepreneurs, lawyers, users and political system builders have to be matched with one another. The key problem is to balance the driving and inhibiting forces in order to smooth the critical passage points between the different social worlds without sweeping away productive frictions. Scientific research practices, technological development practices and economic innovation pratices should be orchestrated in a better way to enhance new technologies and products, but early patent claims should not inhibit the research process (as feared in the field of biotechnology). The one-way relation between developer, producer and user of new technologies should be turned into an interface of recursive innovation. Time, money, and trust should not be gambled away, as it is done with the traditional strategy, initially developing a technology under isolated efficiency and profitability criteria, and afterwards improving usability, applying attractive design, and caring about the range of sensible uses. One can imagine a temporal coupling of the technological engineering and the cultural construction processes, e.g. iterative, evolutionary software development where time is reserved for learning with users (see Floyd 1987), or the integration of technology assessment in the early development process, while spaces for experimentation still exist (Rip and van den Belt 1988; Rammert et al. 1993; Wynne 1995).

Recursive innovation means that the practices of the other social worlds, e.g. of the appliers or users, should be represented and integrated in the early design and developmental process. Reflexive innovation calls for a competence to understand the rationality of others and to take the role of the other participants in the distributed innovation process. Standardization, contracts and market competition are also strong co-ordination forces, but they have the tendency to impose one 'best' technology too rigidly upon the other participants. ***The politics of technodiversity requires a reflexive type of innovation policy that caters for the plurality of perspectives and practices. It prefers connecting diverse actors by interactive patterns of practices and by trust relations instead of strong standards. Thereby it keeps the space for different paths of design and development open as long as possible and it arranges platforms for joint innovative actions and recursive learning between the actors of the innovation network.***

The innovation process is split into many events that take place in different institutional spheres. In modern societies, the production and distribution of new knowledge has been mainly organised in the academic and public research system. The utilization of new ideas has been concentrated in particular public agencies and in the R&D-departments of the industrial system. The setting of priorities, the allocation of resources, and the regulation of the whole "national system of innovation" (see Lundvall 1992 and Nelson 1993) have been the legitimate tasks of the political system. But actually, the established national systems of innovation that were mainly based on the functional autonomy of institutional spheres and on the coordination via market or via hierarchy are dissolving. The standard biography of an innovation that runs from inception to diffusion, stage by stage, is breaking up. Innovations are shaped at the same time in many different "functional arenas" which are embedded in national institutional regimes, and loosely connected on a global level by "idea-innovation-networks" (see Hage and Hollingsworth 2000; Hollingsworth 2000).

On the one side, markets are an efficient mechanism to coordinate heterogeneous and dispersed activities like those of the innovation process. But they require a certain accountability. Markets fail when uncertainties grow too high and time horizons expand. That is why liberal technology policies that favour commercialization and de-regulation will not be successful in the long run. Though legal and bureaucratic impediments will be abolished, the gaps between heterogeneous fields and the divide between winners and losers are widened. On the other side, state and hierarchy are efficient means of coordination because they can establish accountability and certainty within their own limits. But bureaucratic organisations fail, when differences should be maintained and the time horizon should be kept open, as is required for the innovation process. Therefore neo-corporatist strategies for technology policy will only show a limited success. It subordinates heterogeneous forces and fields under common projects, programs, and priorities. This strong alignment of different visions and innovation cultures risks dampening scientific creativity and deadening entrepreneurial innovative capacities.

Networks of organisation are a third co-ordination mechanism that avoids some disadvantages and combines the advantages of the other two. They are based on four principles: complementarity of resources, mutual adaptation, reciprocity of exchange, and trust-relations (Powell 1990: 296 pp.). Negotiation maintains the flexibility of markets without exhibiting the latter's indifference towards goods and actors. Trust relations reduce uncertainties without eroding creative differences as radically as organisations do. A reflexive and sustainable type of innovation policy should be based on a post-Schumpeterian mode of innovation (Rammert 1998) going beyond focussing only on markets or hierarchy. It centres around a particular kind of innovation networks, which can be defined as heterogeneous networks of collective interactive learning. They differ from the many other networks, eg. the closed personal networks of clans and rotary clubs, the strategic networks of interorganisational management, or the policy-networks of neo-corporatist governance (see Freeman 1991 and Powell and Smith-Doerr 1994).

A new innovation policy has to shape an institutional regime that encourages the creation of such interactive innovation networks in various technological fields and counteracts strategies whereby one principal agent tries to control and exploit the network or exclude others from the network. *The politics of technodiversity requires a balanced process of institutional learning between different actors. This process emerges and succeeds, if the state and its agencies participate themselves as one actor amongst others in the process of shaping technologies; if interactive networking between the heterogeneous innovative actors is facilitated, if reciprocal awareness and trust are raised thereby, and if a translation process between the scientific, economic, and political culture is organised that offers shared leitmotifs and makes sense to all.*

At the end, we can see that the shift of theoretical approaches in science and technology studies suggests a change of technology policy. We learned from the cultural shaping approach that technologies are shaped more intensely by the hidden dimensions of practices and the patterns connecting them together than by explicit technological criteria and articulated economic choices. This insight should have consequences for the governance and management of technological development. That does not mean that the established strategies and tools are always inefficient and should be completely replaced by new ones. Certainly, it remains important for some kind of traditional technologies and for the later stages of technological development to formulate explicit goals and to make clear decisions about priorities and programmes. But it will be more important in the long run to support spaces where diverse technological development projects and different practices of using technology may emerge. It will be more favourable for the sake of innovativeness to create particular arenas of negotiation which give easy access to non-official groups and non-governmental organisations. These multiple arenas should be turned into public places where networks of innovation may develop and where different collective actors may learn and benefit from one another. It will be a prudent policy, if the politicians and administrators are aware of the productive effects of differing institutional designs and of different institutional regimes. They should limit their strategies of simplification and standardization. If they decide to maintain a certain degree of institutional diversity, the restrictive effects of bench-marking can be avoided. Institutional diversity can be used to enforce creative comparisons and to encourage experimental cross-breeding.

Under this perspective of cultivating diversity, the globalization of economic and technological development and the unification of the European states can be seen as a great opportunity to benefit from all kinds of diversity. *The politics of technodiversity proposed reaps benefits from the fact that Europe is rich in cultures, traditions and institutions. It encourages producing a great variety of ideas, projects and perspectives and thereby raising technological diversity. It controls the conditions of exchange and bargaining between scientific, economic and political actors and gives excluded groups access to the public arenas. Thereby it raises actor diversity. Finally, it connects ideas, institutions and people by promoting the building of interactive innovation networks and by stimulating institutional learning whereby institutional diversity is raised.*

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