TECHNOLOGY FORESIGHT AS INNOVATION POLICY INSTRUMENT – LEARNING FROM SCIENCE AND TECHNOLOGY STUDIES

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Abstract

This paper aims at contributing to theoretical aspects of Foresight from the perspective of the interdisciplinary body of knowledge that has become known as STS - Science and Technology Studies (c.f. Jasanoff 1994). Drawing in particular on STS insights on the Social Shaping of Technology (SST) we would like to investigate the possibility of Foresight to support policy makers in influencing innovation trajectories according to societal needs.

In this paper, we highlight four different modes of policy support Foresight is expected to deliver: Foresight as systemic innovation policy instrument fostering innovation capability, Foresight orienting innovation towards societal needs, Foresight as agenda setting process and Foresight a provider of anticipatory intelligence as a base for decision making.

From these starting points, we turn to Social Shaping of Technology. Central to SST is the idea that technology co-evolves in a complex interaction with society which is reflected in both the design of individual artefacts and systems, and in the direction or trajectory of innovation programmes. Different routes are available, potentially leading to different technological outcomes. This paper discusses some relevant insights on the character of technologies, as well as their social implications, that are problematised and opened up for enquiry in SST; Contingency and constraint of variation, Role of expectations and visions, Importance of downstream phase of innovation, Importance of localisation and Insights on steering possibilities for technological trajectories

These insights allow us to elaborate one the concepts of Foresight as a process moderator, Foresight as expectation management, Provision of anticipatory intelligence and Localisation through Foresight.

Keywords: Innovation policy, Science and Technology Studies, Expectations

1 Introduction

As stressed in the anchor paper for this thread of the FTA seminar there is a variety of interpretative frameworks for giving meaning to FTA activities. In this contribution we would like to explore an interpretation of Foresight from the perspective of the interdisciplinary body of knowledge that has become known as STS - Science and Technology Studies (c.f. Jasanoff 1994). Drawing in particular on STS insights on the "social shaping of technology" we would like to investigate the possibility of Foresight to support policy makers in influencing innovation trajectories according to societal needs.

The study of technological developments is a complex issue. First of all, technologies are not given in nature, but man-made constructs; they are the products of cultural evolution. The various actors involved may use different definitions of technology. Furthermore, technologies are continuously evolving in a social context. With the further development of technologies, their definitions and relevant perspectives may also have to change. These definitions and perspectives, however, are basic to the discursive traditions studying technology and its relevant contexts. We distinguish several perspectives in the study of technology: STS dealing with social and economic co-evolution of technology, and science and technology (S&T) policy analysis and R&D management through foresight. We argue that the combination of these three perspectives challenges us to consider technological change as a complex and reflexive process. From this combined perspective, it is implied that taking a holistic view on the future by looking at societal and technological elements together and aligning or even integrating companies and users visions on the future is not at all an easy thing to do. To actually develop socio-technical future visions Foresight needs to look at societal development and technological possibilities with the same degree of openness and expertise. STS results may give some indications for Foresight practice aiming to adopt such a holistic approach.

In the first section of this paper we will briefly outline how Foresight is interpreted as 1) systemic innovation policy instrument fostering innovation capability, 2) orienting innovation towards societal needs, 3) agenda setting process and 4) a provider of anticipatory intelligence as a base for decision making.

Starting from the assumption that the ability to guide policy makers on the implications of technological innovation for the wider socio-economic framework would need to be based on a clear understanding of the interplay between technological and socio-economic change we will then turn to Science and Technology Studies that deal in particular with this issue. We will briefly summarize how STS scholars have characterised technological innovation as a co-evolutionary process between technology and society and how the use of technology is described as a relevant feature of the selection environment shaping the direction of technological trajectories. STS is characterised by an insistence that the `black-box' of technology must be opened, to allow the socio-economic patterns embedded in both the content of technologies and the processes of innovation to be exposed and analysed (MacKenzie and Wajcman 1985, Bijker and Law 1992). SST studies show that technology does not develop according to an inner technical logic but is instead a social product, patterned by the conditions of its creation and use. We will focus on the issues of Contingency and constraint of variation, Role of expectations and visions, Importance of downstream phase of innovation, Importance of localisation and Insights on steering possibilities for technological trajectories.

In the final sections, we will then again turn to Foresight and ask what lessons can be derived from these insights for the possible role of Foresight in supporting policy makers in intervening into this co-evolution process. We will elaborate one the concepts of Foresight as a process moderator, Foresight as expectation management, Provision of anticipatory intelligence and Localisation through Foresight.

2 Foresight and its role within the innovation process

2.1 Focussing on Foresight – some definitions

When discussing Foresight we are referring to a systematic process of reflection and vision building on the future among a group of stakeholders. The characteristics distinguishing Foresight from future studies and other long term thinking approaches such as strategic planning are (cf. e.g. Havas 2005):

- Participatory – In a Foresight process the relevant stakeholder groups are actively participating. Foresight results are disseminated and debated within a wider audience.
- Action oriented – In Foresight there is always the attempt to link insights about the dynamics of change to today's decision making, e.g. by elaborating strategic options to reach certain objectives or development of robust strategies to prepare for different future developments.
- Open – Foresight does not aim to predict a predetermined future but explores how things might evolve in different ways.

Foresight processes may take place in any kind of organisation to orient long term strategy building or to foster future oriented attitudes. However, in this paper we are focussing on Foresight activities that are carried out in support to policy making. Over the last ten to fifteen years Foresight has been used in support to policy-making not only for research and innovation policy but also in other policy fields. Policy oriented Foresight exercises have been addressing a wide range of different issues. A rough distinction can be made between exercises focussing on a geographical territory such as a region or country, those that focus on a certain socioeconomic domain such as an industrial sector or a policy field such as transport and those that deal with a certain problem such as disease prevention (thematic Foresight).

While in the early years Foresight was mainly aiming to assess technological developments in order to inform priority setting in research policy and therefore tended to focus rather narrowly on technological and scientific developments the majority of exercises today is taking into account a wide range of social and economic aspects related to technological developments (Georghiou 2001, Salo & Kuhls 2003). Accordingly, the term “Technology Foresight” has gradually been dropped in favour of simply Foresight. However, research and innovation policy as well as technology policy are still the main clients for Foresight which means that even if a broad socio-economic view is adopted the recommendations for action will often target technology policy. Secondly, with technology having become deeply entrenched into modern society, reasoning about the future within almost any policy domain will involve thinking about technological aspects. Therefore, with the impact of Foresight on innovation processes and technological trajectories we are addressing a core dimension of the field.

2.2 Role of Foresight within innovation processes

Whereas early Technology Forecasting approaches were based on a rather linear understanding of the policy process on the one hand and the innovation process on the other, Foresight is nowadays conceptualised as one element in a continuous policy learning process that is contributing to a more reflexive mode of policy making (Weber 2006). At the same time innovation is no longer understood as a linear process where research spending automatically leads to innovation and application with certain impacts on society. Both these insights imply that giving recommendations for research funding priorities will not necessarily result in any innovation activity or effect changes in technological pathways (Salo & Kuhls 2003). Accordingly, the way Foresight is thought to impact on policy has become more subtle and complex. We would like to highlight four modes of policy support Foresight is expected to deliver:

1. Foresight as systemic innovation policy instrument fostering innovation capability
2. Foresight orienting innovation towards societal needs
3. Foresight as agenda setting process
4. Foresight a provider of anticipatory intelligence as a base for decision making

1. Foresight as systemic innovation policy instrument

Policy researchers have for some time now been stressing the need for "systemic" innovation policy instruments to complement classical tools such as direct research subsidies or public procurement (Smits and Kuhlmann 2004). These instruments are meant to enhance the capability of innovation systems for self-organisation so they address innovation policy on a system level. Systemic instruments aim to provide platforms for learning and experimenting, facilitate the management of interfaces, foster new alignments of elements, and stimulate demand articulation, strategy and vision building (ebd. 12).

The need for systemic instruments is driven by a number of structural changes in the socio-economic framework of innovation activities and in particular changes in the speed and modes of knowledge generation (c.f. Smits 2001, 2 ff.). Based on empirical research on various national and sectoral systems of innovation the capability to innovate has increasingly been characterised as a system capability where the connectivity between various elements (such as universities, firms, research institutions, government bodies) is of the same importance as the quality of the elements themselves. This notion of "innovation systems" as a core concept in explaining innovation capability is forming the background for the approach of systemic instruments.

At the same time the nature of policy making is changing. Due to the increasing system complexity, the traditional linear model of policy making incorporating successive phases like conceptualisation, implementation, evaluation and then modification and new decision making is no longer adequate. Policy and strategy formation is becoming more and more a continuous learning process (Lundvall and Borrás 1998). These changes are complemented by the emerging new models of governance such as multi-level governance driven by political challenges such as the EU integration (Kuhlmann 2001).

Within this framework Foresight is positioned as a systemic innovation policy instrument. It is argued that by establishing linkages between actors and providing platforms for joint learning Foresight helps to improve the ability of the system to react to changes and thereby to initiate and keep up innovation processes. Already in 1999 Martin and Johnston proposed to place Foresight in the framework of the NIS (national innovation systems) approach and described the crucial function of Foresight for innovation as "wiring up the innovation system" through "strengthening the connections within the national innovation system … and the system as a whole can become more effective at learning and innovating". This is very well in line with the notion of systemic innovation policy instruments serving to foster interaction between various actors of innovation (Smits 2001, 21) such and users and producers of innovation, actors from scientific and technological realms or different disciplines and professional background as well as policy makers from various related policy fields. Foresight, so it is argued, fosters the flow of knowledge among all these actors and increases connectivity and coordination (Webster 2002, 6). Due to the forward looking nature of the Foresight process the effect is thought to be more than just networking as such. It is reckoned that through Foresight activities actors develop a better awareness of future risks and opportunities and a stronger inclination towards long term strategic thinking and better access to relevant knowledge for developing their strategic planning. This way, Foresight contributes to an infrastructure of "distributed intelligence" that is enabling the whole system to better address future challenges (Kuhlmann 2001).

2. Foresight orienting innovation towards societal needs

Besides improving the general system capability there is a more particular claim that Foresight can increase the quality of innovation processes by linking science and technology more closely with societal demands (Martin, Johnston 1998). By offering a forum for exchange between demand and supply perspective, it is argued, Foresight can orient innovation towards societal needs and future users' demands in an early phase of the innovation trajectory. (Salo & Cuhls 2003, pp. 79).

3. Foresight providing information as a base for decision making

The idea of Foresight as a systemic innovation policy instrument is drawing on benefits that mainly arise from the Foresight process whereas the actual product that is generated within this process such as a report or even a recommendation is more of a means to structure this process. In line with this, the so called "process benefits" have more and more been emphasised by Foresight practitioners.

However, this does not imply that the actual provision of anticipatory intelligence to policy makers to inform their decision making is becoming less important. Foresight is still aiming to generate information for policy makers on possible pathways for the future and policy measures needed to foster these pathways. A solid set of methods is available in Foresight to generate this kind of intelligence based on the wide range of diverse knowledge of the Foresight participants. With respect to technological developments it is often elaborated in Foresight reports how certain technological developments may impact on the society and economy (exploratory Foresight) or the other way round how certain desired objectives can be reached through certain technology developments (normative approach). It is reckoned that due to the high diversity of knowledge sources that can be mobilised in a participatory Foresight process the quality of this information is better than just narrow expert advice. Often this type of information is directed at guiding research policy in priority setting for R&D funding. Typical products are scenarios and roadmaps describing future technology in society. In some exercises explicit policy recommendations are produced on how to reach the desired scenarios.

4. Foresight as agenda setting

In a number of Foresight exercises visions are elaborated describing future states of the domain that is tackled by the exercise. On the one hand these visions are just used as a means to derive anticipatory intelligence as outlined above. However they are also meant to have a function on their own: they evoke certain expectations towards a technology and thereby motivate actors to mobilise resources and invest in certain technological trajectories. For policy makers and other innovation actors such as engineers and managers they can become guiding visions that influence the way a technology is perceived designed and framed thus influencing the further evolvement of the trajectory. It is reckoned that within the networks formed by Foresight a common understanding of a certain future challenge emerges and some actors even orient their actions towards joint visions (soft coordination).

2.3 Summary

We have been discussing 4 main ways Foresight may impact on technological innovation processes or help policy-makers to do so:

1. Foster innovation capability (systemic instrument)
2. Oriented innovation towards societal & user demands
3. Inform policy makers on possible socio-economic implication of technological trajectories
4. Agenda setting across relevant actor groups

Finally it should be emphasised that most Foresight exercises follow a mix of these strategies to impact on technology policy. However, the emphasis and depending on it the approach is widely varying.

3 Social Shaping of Technology

There is a rich body of research results from various disciplines investigating the complex relationship between technology and society that has become known as SST (social shaping of technology). SST is characterised by an insistence that the `black-box' of technology must be opened, to allow the socio-economic patterns embedded in both the content of technologies and the processes of innovation to be exposed and analysed (MacKenzie and Wajcman 1985, Bijker and Law 1992). In this sense it emerged through a critique of 'technological determinism'.

The insights from SST have gained increasing recognition in recent years as a valuable research focus, for its broader significance for the scientific and policy claims of social sciences. SST has offered a greater understanding of the relationship between scientific excellence, technological innovation and economic and social well-being; and in broadening the policy agenda, for example in the management of technological change and innovation.

SST studies show that technology does not develop according to an inner technical logic but is instead a social product, patterned by the conditions of its creation and use. Every stage in the generation and implementation of new technologies involves a set of choices between different technical options. Alongside narrowly `technical' considerations, a range of `social' factors affect which options are selected - thus influencing the content of technologies, and their social implications.

3.1 Co-evolution of society and technology

As mentioned, the point of departure for SST research is the rejection of "technological determinism" that is the conceptualisation of technology as a phenomenon that is external to society and developing out of an own inner logic. While the opposition to technological determinism is a common denominator for SST studies the range of perspectives and approaches as well as disciplines is wide. However, across the diverse approaches a common understanding has emerged of technological change as a continuous process of socio-technical reconfiguration without any predetermined dominance of either material artefacts or social structures. Technological change and social change are analysed as being deeply intertwined and not to be isolated from each other. Many studies have highlighted the complexity of this co-evolution leading to the emergence of certain socio-technical patterns. SST research groups have focussed on different aspects in their analysis of co-evolution.

Studies from a background in evolutionary economics rather start from the observation of certain patterns of technology development on a macro level. These scholars interpret the emergence of technological trajectories as a process of variation and selection with the selection environment being formed by socio-technical regimes on various levels (Geels 2004). As a result of this process it is argued, some new ideas develop into more stable technological trajectories. With increasing integration into socio-economic framework and embedding into institutional change these trajectories gain momentum and cannot easily redirected (path dependency). In order to better understand the dynamics of this process, investigations from this group of researchers have been aiming to closer define the interplay between variation and selection on various levels. Within STS, evolutionary economists have influenced the discipline during the 1980s using concepts like trajectories and regimes (Dosi 1982). The utility of using a particular technology increases with the number of adopters (the network effects). Therefore, stabilisation can emerge spontaneously, leading to the "lock-in" of one technology. This phenomenon has been related to the emergence of dominant designs in the history of various industries.

One well-known example of a "lock-in" is the QWERTY keyboard (David 1985). This keyboard was engineered in order to optimize typing speed in the case of mechanical typewriting. It had been designed so that the type bars have a minimum chance of jamming given the character frequency distribution in the English language. Since mechanical typewriting is out of use, the QWERTY keyboard has become suboptimal. However, one is no longer able to break out of the lock-in given learning curves and network externalities (Arthur 1988).

Another group of researches from the SST field has investigated the activities of innovation actors actively trying to shape the co-evolution process by weaving heterogeneous networks of material and social elements (Law & Callon 1992). Others have described how in early phases of innovation processes relevant social groups with their different interests negotiate the interpretation of new artefacts thereby continuously opening up new socio-technical options until finally a kind of closure is achieved (Bijker et al 1987). The importance of power of social groups in defining this process has been highlighted (Hard 1993, Woolgar 1991).

The SST field is characterised by a number of detailed empirical case studies of past and current technological pathways elaborated by historians or sociologists of technology and scholars from a number of other disciplines. Based on these cases a number of concepts have been proposed to understand the emergence of certain technological trajectories. To collect insights relevant for the impact of Foresight on technological innovation we will pick up upon on some basic insights from SST research in more detail: Contingency and constraint of variation, Role of expectations and visions, Importance of downstream phase of innovation, Importance of localisation and Insights on steering possibilities for technological trajectories

3.2 Flexibility and contingency vs. constraints in the design phase

The co-evolution process is at the same time contingent in the sense that it could evolve different depending on the context but on the other hand structured through the embedding in an existing framework. This seems to be of special interest for the early phases of technological trajectories that is often targeted by R&D policy and Foresight activities. Some SST studies have focussed on the phase of invention and emphasised the interpretative flexibility and contingency of the technology design process. On the other hand the way design is structured by its embedding into existing regimes (e.g. firm routines, best practice rules etc.) has been highlighted.

For example Williams and Edge (1996) describe how, in the IT sector we find many complex patterns of stabilisation and destabilisation. The emergence of industry standard products (black-boxed solutions) `creates' markets. These offer cheaper products, and give users both a greater choice of suppliers, and confidence that a product will not become obsolete (Swann 1990). This creates an incentive for suppliers to collaborate in creating larger and more stable markets. Increasingly, firms are coming together, with competitors and suppliers of complementary products, to agree standards for emerging technologies (Cowan 1992, Collinson 1993). Future technologies/markets are being pre-constructed in a virtual space constituted by the collective activities of players. However there is not, of course, a unidirectional shift away from competition. For example, these markets may attract new entrants (e.g. the proliferation of vendors of IBM pc `clones'). Where accommodation or collaboration is not favourable, firms may promote proprietary solutions. Dominant players may seek to destabilise solutions and erode industry standards, to monopolise their links with users - for example the recent, largely unsuccessful, attempt by IBM to tie in existing users to their next generation of personal computers by launching the new OS2 operating system in place of the industry standard DOS.

3.3 Role of visions and expectations

Expectations or visions about technologies can be defined as “real time representations of future technological situations and capabilities” (Borup 2006, p. 286). From early on, SST studies have investigated the role of visions and expectations in shaping technological trajectories. Different perspectives have been taken.

On a more micro level it has been observed how collective visions of users and use of technical artefacts held by engineers and technicians influence design decisions and, once embodied in the artefact, structure later users' possibilities of use (Konrad 2004, Akrich 1992, Woolgar 91). It has been stressed how such visions are closely tied to specific social experience of actor groups.

A growing number of studies in SST are tackling the role of collective expectations in shaping technological innovation on a more meso and macro level. Often, emerging technologies are associated with certain benefits such as positive impact on quality of life, environment or economy. Expectations that are shared among a group of actors in a certain domain have been shown to be of considerable impact on the technological trajectory. Studies with an evolutionary economics background have placed the dynamics of expectations as a central interface between various levels of the selection environment determining technological trajectories. So e.g. due to positive expectations niches are granted where new technologies can be developed in a protected space and learning between developers and users takes place. Within the niche the new socio-technical configuration can stabilise and later modify the wider regimes on meso or even macro level leading to a regime change or even transition (Kemp 1994). Thereby on all levels of the innovation process visions and expectations play a performative role. The reason for their strong influence is the ability to bridge between different groups of actors such as policy-makers and research community, managers and scientists, users and providers of innovation (Borup 2006). This does not imply that expectations are always fulfilled. In the contrary many of them fail because of too naive and linear projections (Geels & Smit 2000). Nevertheless the existence of the expectations directs the innovation activities as promises and expectations are translated requirements for further technology development. The whole process has been described as a "promise-requirement cycle" (Van Lente 1993).)

3.4 Importance of downstream phase of innovation

A great deal of SST research has looked into later stages of the innovation process such as diffusion, adoption, consumption of technological artefacts and their embedding into organisational settings. Many SST studies highlight how through appropriation by a socio-cultural context technologies are reshaped and redefined. Cultural studies have particularly emphasised the crucial role of domestication of technology, that is incorporation into daily life routines and assignment of symbolic meanings. The role of users and ways of using in shaping this change has been one of the core lines of investigation of SST scholars (Woolgar 1991, Kline & Pinch 1996, Oudshoorn & Pinch 2003). Results from the many SST case studies investigating current and past cases of technological innovation clearly indicate that users indeed play a major role in the shaping of technology: For a number of technological innovations it has been shown how unexpected forms of use can redefine the concept of technological artefacts and how competing expectations and interpretations from different user groups influence the direction of technological pathways (Hård 2002). Even a successful product is re-contextualised in different ways several times during its innovation trajectory. Accordingly, it has been concluded that the more downstream phases of innovation should be fully considered as part of the innovation cycle. Thus SST research has strongly underlined the move away from linear models of innovation featuring successive phases from invention to consumption. Other terms such as “Innovation journey” or “distributed innovation” have been proposed to emphasise the meandering path of an innovation process (Rip & Schot 2002).

In their book *How users Matter*, Oudshoorn and Pinch (2003, 1) provide some provocative examples of the co-construction of users and technology; "New uses are always being found for familiar technologies. Sometimes these changes in use are dramatic and unexpected. Before September 11, 2001, no one foresaw that an airliner could be turned by a small number of its occupants into a giant Molotov cocktail."

3.5 Importance of localisation

SST studies have found that the interplay between universal and local elements is crucial to understand socio-technical change (see e.g. Hård 1994). Although certain patterns of technological development can be outlined on a macro level, the real process is always characterised by interplay between local configuration activities and universal patterns. Thus the same technology might be incorporated into different socio-technical patterns in different socio-cultural contexts. And on the other hand socio-technical patterns that have been developed on a local level need to be translated before they can feed into universal patterns forming the structuring regime for again other innovation activities.

Especially studies from the so called "actor-network approach" remain sceptical about the nature and influence of broader social and economic structures of power and interests, insisting that actors create the world anew (Latour 1983, 1986 & 1988), and implying that technologies (and social systems generally) are highly malleable to local actors.

3.6 Strategies for intervention

A number of SST scholars have explicitly drawn conclusions from their results as to the possibility of intervention into socio-technical transformation processes (Sørensen 2002). As a first result it needs to be emphasised that the concept of the “social shaping” of technology does not imply easy steering of technological trajectories. On the contrary: The deep embedding of technological elements into socio-technical arrangements implies a high degree of stability and a certain resistance to change. Socio-technological trajectories once emerged carry a momentum causing a certain path-dependency so they cannot be easily redirected. In particular direct head-on intervention is likely to fail or cause unintended consequences. However, the detailed insights into the complex process of socio-technical change allow some different kind of intelligent intervention that may effect a modulation of trajectories (Rip & Schot 2002).

The following modes of intervention for policy have been suggested by SST scholars:

- Support to formulation of socio-technical scenarios in an early stage of emerging technologies (Rip & Schot 2002) to add other interests (e.g. policy goals) to promote diversity of visions into the promise-requirement cycle, (Russel & Williams 2003, p. 62)
- Provision of protected spaces (niches) for social learning about new technologies first on a micro level and later on a meso level e.g. through social experiments (Kemp & Rotmanns 2001)
- Combating entrenchment and early closing by providing wider arenas and constant monitoring (Russel & Williams 2002, p. 54)
- Providing communication channels (Russel & Williams 2002, p. 54) and support the forming of new alliances and networks thereby facilitate alignment of elements into new socio-technical configurations (ebd. 62)
- Foster dialogue between users and providers of innovation (ebd. p. 76)
- Target structuring regimes in the generation of knowledge (e.g. engineering education) (ebd. 68)

4 Some Implications for Foresight

What are the lessons to be learned from the SST results on the possible impact of Foresight on the innovation process? As discussed above, Foresight is aiming at such an impact on the one hand through providing intelligence as a base for decision making and on the other through moderating processes that enhance the responsiveness of the arena. We consider that for both types of impact Foresight insights from SST can be exploited. The following main inroads for SST on Foresight concept and practice can be highlighted:

4.1 Foresight as process moderator

The relevance of a systemic innovation policy instrument that is working on the process aspect of innovation by establishing networks and providing spaces for mutual learning is clearly confirmed by SST results. Indeed SST research implies that this type of intervention might be even more effective than classical measures targeting demand or supply side in isolation or attempt to intervene more directly. In particular SST results confirm that the quality of any innovation system is likely to benefit greatly from the provision of joint learning spaces between users and producers of innovation.

However, the SST insights do also suggest some issues to beware of. The complexity and contingency of socio-technical change as emphasised by SST implies that the selection of actors to be involved in the process is not at all a straightforward one. A careful mapping of the arena of change taking into account a wide range of possible trajectories of change and especially the downstream parts is needed. It cannot be assumed that central actors themselves stemming from either supply or demand side organisations such as companies or associations that are typically involved into a Foresight process have an adequate overview of this space. The involvement of social scientists into the stakeholder mapping phase of Foresight might be very useful. Foresight that is just working with the "usual suspects" is in danger of even increasing lock-in situations into less desirable trajectories. The creation of diversity is important needs to be systematically targeted through the design of the exercise (Könnölä et al forthcoming).

4.2 Foresight as expectation management

SST results clearly confirm the relevance of expectations and visions in directing technological trajectories especially in an early phase. SST researchers have highlighted the support to vision building as one of the possible loci of policy intervention. However SST research also indicates that not any kind of vision is suitable to modulate innovation trajectories towards policy goals. On the contrary, narrow visions that are pushed out of interest of only a limited range of actors might become a barrier to flexibility and openness of innovation towards various societal demands. The primary concern of Foresight should therefore be a diversification of expectations and visions.

Also, visions that project technological developments into the future in a linear way without taking into account the complexity of the innovation journey and especially the appropriation phase of innovation cycle are not likely to be of use to policy strategy building. Possible ways of policy intervention on the demand side do not become visible if the uptake of a certain technology is just taken for granted in a vision. At the same time, possible barriers grounded in the process of appropriation might well be overlooked. This means that visions and expectations do indeed matter and provide an important inroad to influencing technological trajectories but to be useful they need to be as rich on the side of society as on technology. To actually develop such meaningful **socio-technical** future visions Foresight needs to look at societal development and technological possibilities with the same degree of openness and expertise. This again demands expertise on the dynamics of social change just as much as expert knowledge about technologies. Again, social scientists will have a contribution to make here. Furthermore, the involvement of the relevant social groups (e.g. potential user groups) themselves will greatly improve the quality and usefulness of the visions developed.

Finally, a suggestion might be derived from SST results with respect to the format of visions developed in Foresight. As SST has shown, expectations and visions will never be fully met. Instead within the 'promise requirement cycle" (Van Lente 1993) visions are continuously adapted along the line. Nevertheless their function is to motivate resource allocation but also to orient experimenting. This means that they need not necessarily be exhaustive in the sense that they describe a whole set of possible socio-economic frameworks around the "new technology". Instead, it might sometimes be more relevant for the visions to be rich in suggestive detail and contain a number of imaginative thought provoking elements. A set of small narratives or scripts describing possible future socio-technical ensembles might sometimes be useful to replace or at least complement large scale scenarios if the aim is to modulate technological trajectories)

4.3 Provision of anticipatory intelligence

Whereas for visions diversity and creativity are crucial "anticipatory intelligence" that is used as a base for policy decision making is bound to give insights that can be operationalised into policy action. Therefore it is important that it takes into account the real world processes of technological change. Anticipatory intelligence therefore needs to focus on co-evolution processes as described by STS research. Socio-technical scenarios giving realistic descriptions of use and embedding into socio-cultural context or various organisational settings can give valuable insights on possible points of intervention. However, also other Foresight methods are able to generate knowledge about co-evolution provided that this is carefully targeted (van der Meulen 2003) e.g by considering appropriation processes as diligently as technological developments. In such a way reflexive anticipation is likely to allow for the identification of possible pathways for transition towards desired trajectories as well as the design of adequate process oriented policy measures (Geels 2002, 360).

4.4 Localisation through Foresight

SST results have shown how local contextualisation is an important element in the forming of technological trajectories. This implies that different innovation systems will each incorporate technological elements in a different way. For Foresight this implies that local level analysis e.g. for a region or city should not just take over visions and pathways from higher levels. The embedding of an innovation into a specific regional setting should itself be considered as part of the innovation process and not just a further "adoption" with specific regional consequences. The same holds for various industrial sectors that will each have to go through their own innovation cycle when taking up new technologies.

5 Conclusions

In this paper it was explored how results from social science research on the social shaping of technology can be exploited for Foresight concept and practice. As a first result it was emphasised that the approach of Foresight to foster innovation capability by initiating a collective learning and vision building process is well in line with SST results. In fact SST research suggests that systemic or process oriented instruments such as Foresight are one of the most likely to impact on the complex interplay of factors governing innovation trajectories. It was furthermore suggested that for innovation policy the creative and visionary aspect of Foresight might even be more relevant than often recognised by Foresight practitioners and users, as SST results highlight the decisive impact of visions and expectations on the innovation process.

We have illustrated how technologies are complex constructs that can be appreciated differently from various perspectives. In general, three main subdynamics have been distinguished: the selection mechanism associated with the market and society at large, the historical generation of technological variation along the time axis, and the wish to control the technological development from a government perspective. These perspectives have different meanings in the context of relevant theoretical traditions (Leydesdorff 1997). Each of the perspectives reduces the complexity by taking a specific angle. When a single perspective is dominant (for example, that of a central state or short-term profit taking), the technological development can be blocked temporarily. Both governments and innovators play a role in changing the technological developments. The lack of closure of technological developments challenges our inventiveness and thereby it liberates the forces of technological innovation for the creative destruction of previous production relations. The desired role of the government is to provide the interface of networking between the actors, to develop a better awareness of future risks and opportunities and a stronger inclination towards long term strategic thinking and better access to relevant knowledge for developing their strategic planning. This way, Foresight contributes to an infrastructure of "distributed intelligence" that is enabling the whole system to better address future challenges (Kuhlmann 2001).

However, cautioning insights from SST towards Foresight practice were also highlighted. It was pointed out that in order to impact on the complex co-evolution process of society and technology, Foresight needs to tackle the social dynamics of change more diligently. In particular Foresight visions need to better reflect the complexity of societal change by taking into account e.g. unexpected forms of social approbation of technology. It was suggested that in some cases there might be a need for more "realistic" visions or scripts of future forms of use of technological artefacts to influence expectations and less for large scale scenarios of socio-technical transformation. Finally it was stressed that when initiating a Technology Foresight process the arena of change needs to be mapped very carefully for relevant actors and stakeholders. Especially on the more downstream side of the innovation process, relevant actor groups need to be considered. The involvement of social scientists into Foresight design seems likely to be useful to fulfil both these demands.

To further exploit SST for Foresight the next step will be to have a look at real Foresight exercises and see how the lessons learned from the theoretical considerations can be translated into Foresight practice.

Finally, we would like to point out some issues worthwhile to explore further in the context of this debate. It seems that the difficulty of Foresight to adopt a more holistic view on socio-technical change might partly be rooted within the structure of the policy arena. Foresight exercises are often financed by R&D departments to decide on R&D priorities with little possibility to act on the wider socio-economic framework. In these cases the challenge for Foresight will be to interpret insights stemming from the holistic analysis of socio-technical co-evolution back into conclusions for modes and content of R&D funding.

While here the attempt has been to make Foresight results more useful for innovation policy by integrating better understanding of real innovation processes it is important to keep in mind that it is still another thing to actually orient innovation towards normative policy objectives such as sustainability or quality of life. There is no guarantee that wiring up innovation systems and even introducing a better user orientation will automatically lead towards such desired directions (Weber 2006). Other approaches such as strategic niche management (Kemp et al 1998, Weber 2006) or transition management (Rotmans et al 2001) will have to be employed if such an impact is desired.)

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