Sustainable Development and the Regional Dimension of the Innovation System

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1. Introduction

During the last ten years, the 'systems of innovation' approach has developed into a useful tool for studying, explaining and, to some extent, even for influencing innovation activities and technological change. This approach shares with other theories the assumption that innovation is an important factor that stimulates economic growth but that has developed into a more complex model. A system of innovation brings together all the major factors that affect technological progress (Edquist 1997) and tries to form a systemic model of these factors. Such an exclusive focus on technological change and economic growth, however, is not enough to tackle the current socio-economic problems, as innovation does not represent a positive sum game (Boden and Miles 2001).

While the system approach has mainly dealt with determinants of knowledge creation and knowledge diffusion, it has hardly paid attention to socio-economic consequences resulting from the diffusion of innovation. As a focus on the creation of a knowledge stock and its diffusion is too narrow and not sustainable, we have to study feedback on radical product and process innovations more carefully (Lundvall and Archibugi 2001). Taking into account that the innovation system is part of the economy and the wider society and as such impacts on other natural, social and technical systems, such as the labour market or the ecological system, feedback becomes an important aspect of innovation processes. It might be the case that an increasing innovation capability of a territory only creates short-term advantages but actually undermines its capability to produce long-term economic growth. This is the case when the costs of dealing with social and ecological problems as unintended consequences of technical development become bigger than the benefits resulting from innovation and change. Moreover, it is through feedback that the innovation system shapes the framework conditions for its own functioning (Cooke and Schienstock 2000).

The fact that costs of innovation can more than compensate possible gains makes it necessary to introduce sustainable development and sustainable competitiveness as an important criterion of innovation processes and the innovation system as a whole. Here we apply a wider interpretation of the term sustainability; it integrates the ecological, social and economic dimension into a holistic approach. Thus sustainable development and sustainable competitiveness imply simultaneously an environmentally, socially and economically compatible development, as

is reflected in the so-called 'three-column model'. In the following, we will direct our attention primarily to environmental sustainability.[1]

2. From Path Dependency to Path Creation

The system approach considers innovation processes to be evolutionary and has focused mainly on path dependency. The strength of this concept is in that it does not separate innovation from past developments, but assumes some kind of continuity in the process of technical change. Innovation lines up with earlier changes, which means that it has historical antecedents of novelty. "(...) the dynamic process itself takes on an essentially historical character" (David 1985). The term "path" means that a specific technology has been chosen among a variety of different alternatives, which leads to large profits for the innovator and the first users but does not necessarily result in macro-economic advantages in the long run. Path dependency always carries the risk of turning into a so-called 'lock-in' (Grabher 1993; Johnson 1992; Schienstock 1997). Traditional technology can lock the market into an inferior development option and may result in a loss of competitiveness and retarding economic growth in the long run.

Does environmentally beneficial technology constitute a new path of economic development? There are quite a few scholars arguing that the sustainable development imperative is exerting a force to change the dominant technological paradigm and to shift the existing technological trajectories, although it will probably not constitute a new upswing in the long cycles (Fukasaku 1999). Nevertheless, integrating the aspect of environmental sustainability as an aimed output of the innovation system means that we have to change our analytical perspective.

Instead of focusing on the path dependency of technological innovation, we have to analyse processes of unlocking and path creation. The traditional economic model is based on a number of technological development paths, which have been successful due to framework conditions of an insufficient economization of natural resources (Hübner and Nill 2001). Sustainable development implies that the economic and social value system underpinning the current development path is changing. Traditional technologies have created a 'lock-in' since they tend to undermine natural capital. Environmental sustainability, therefore, requires a change in the mode of operation of the economy. There is a need to create a new development path oriented more towards saving resources and complying with both environmental sustainability and economic competitiveness.

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[1] Environmental sustainability, however, is often closely linked with social sustainability. Modern societies, as some scholars argue (Bergmann et al. 1969), are characterised by new forms of social inequality which do not result from class structures. Instead, they represent the accumulation of several disadvantages, in which the environmental factor plays an important role. Highly polluted areas, for example, are unlikely to attract new industries which create highly skilled jobs; instead, these areas may only provide low-skilled and poorly paid jobs and, in addition, cause major health problems.

It is very difficult to get out of path dependency, however. Perez (1983) has pointed out that fundamental technological novelties can only become transformative together with organisational and institutional changes. It is likely that the social and institutional framework, hospitable to one set of technologies, will not be suitable for a radically new technology. Whereas incremental innovations can be easily accommodated, it may not be the case with radical innovations, which by definition involve an element of creative destruction. A new fundamental and path-creating innovation, we can conclude, requires the development and coordination of a vast array of complementary tangible and intangible elements: new management techniques, new organisation forms, new kind of workforce skills, and new habits of mind. But many other types of institutional changes such as standards, patents, new services, new infrastructure, government policies and public organisations are also called for (David 2000; Freeman 1997).

However, being locked in a specific technological development path is not irreversible, as some scholars seem to argue. Garud and Karnoe stress the importance of entrepreneurship in the processes of path creation. Path creation, as they argue, "provides a way of understanding how entrepreneurs escape 'lock-in'" (Garud and Karnoe 2000). Path creation, according to the authors, is a process of mindful deviation; it implies de-embedding from the structures that embed economic actors.

There is no doubt that individual entrepreneurs and entrepreneurship have a key role to play in the process of creating a new techno-economic development path. But the creation of such a new path is first of all a collective process. Freeman (1997) argues that the deflection from an existing development path and the diffusion of a new techno-economic paradigm is a process of trial and error, involving a great institutional and organisational variety. Sabel (1995; see also Schienstock 1996) has characterised path creation processes as 'bootstrapping reforms', also stressing the importance of trial and error. He argues that stable and lasting processes of path creation and diffusion can only develop when all actors are marching in steps, monitoring each other's change processes and adapting to them. But it is beyond the capacity of social actors to come to terms with the future techno-economic structure, simply because it is unknown. What they can do, however, is continuously reflected on the previous change processes and in the light of their experiences and based on the diversity of knowledge to make corrections and change directions, if needed. To be able to create and stabilise a new development path, continuous exchange of information and knowledge in dialogues and multilogues is needed. Interactive learning is a precondition for the establishment of a new development path. Interactive learning means that learning is co-dependent on the communication between people or organisations with different types of required knowledge (Meeus and Oerlemans 1999).

The greening of the innovation system and the development of a sustainable development path are special insofar as they extend the idea-innovation chain to the households as end-users. Their consumption habits and practices can support but also hinder the greening of the economy to a great extent. So far, systems of innovation, if we take a narrow definition, identifies the R&D departments of firms, universities, research institutes, technology transfer institutes, and government agents involved in technology and innovation policy as social actors. Only

those organisations are included that are directly related to the process of search for new knowledge. Not even a wider definition of the innovation system[2] includes end-users as actors in the innovation process. This is due to the fact that the focus of research lies mainly on knowledge creation and effective distribution of an innovation, while the aspect of use and possible consequences of use patterns are more or less unrecognised.

3. Innovation as a Strategy to Achieve Environmental Sustainability

The view that the greening of the economy is associated with a new technological development path entails that economic growth and environmental degradation can be de-coupled by the creation and diffusion of new technologies. There are, however, different views on whether economic growth and sustainable development are compatible with each other. Many scholars are sceptical in this respect; they see economic growth and sustainable environmental development as two contradictory aims (Altvater and Mahnkopf 1999; OECD 1992). The argument is that economic growth depends on the use of additional natural resources, and because these are limited, further growth is not possible without neglecting the principle of sustainable development. This implies that if we want to achieve environmental sustainability, we have to preserve our natural resources through reducing economic growth. In this scenario, the consumer has to play the most important role. Therefore, environmental issues that have received attention were less associated with production processes and more with consumption and post-consumption (Howes et al. 1997)

To use natural resources sparingly will probably have positive environmental effects. But climate change, waste reduction and sustainable transport technology are all problems that concern consumers as well as producers (Fukasaku 1999). One can doubt whether it is possible to achieve environmental sustainability through strategies of changing consumption patterns only, particularly in a period of stiffer global competition, in which the capability to continuously produce new products becomes the most important competitive edge (Schienstock 1999). It seems that strategies of sustainable development without product and process innovations have little economic and political chances to become successful; on the contrary, technology is critical in securing sustainable development goals. We can therefore characterise the new development path as 'innovation-oriented development model of environmental sustainability'.

Notions such as eco-efficiency and zero emission indicate the growing perception that a strategy to achieve ecological, social and economic sustainability needs to be based on environmentally beneficial technological innovations (Petschow et

[2] A wider definition also including 'higher-level organisations', whose objects are to facilitate learning processes and that can provide additional input into the innovation process (Teubal 1998).

al. 1998). "(...) companies can improve resource productivity by producing existing products more efficiently or by making products that are more valuable to customers – products customers are willing to pay for" (Porter and van der Linde 1995).

In de-linking economic growth from environmental degradation and unsustainable resource use the development of environmental beneficial technology becomes critical (OECD 1999). However, only if technological advancement is accompanied by organisational, institutional and behavioural changes, will it be possible to achieve sustainable development goals like reduction in energy consumption, pollution emission, and waste production. These issues call for technical as well as organisational innovations. In addition, systemic innovations characterising processes of fundamental transformation also have to include institutional changes; they are indispensable in devising sustainable transport systems, for example.

This suggests that the greening of the economy depends upon the business sector as a carrier of innovation to a great extent. The advantage of an innovation-based strategy in achieving environmental sustainability is that it not only introduces novelties into the economic analysis, but also triggers a process of creative destruction (Schumpeter 1939) and therefore supports the transition from one development path to another. But what are sustainable technologies?

4. The Concept of Sustainable Technologies

Innovation is generally defined from the perspective of the creator of new products and processes. Innovation is then conceptualised as something fixed, as a well-defined 'objective' artefact. However, technology by itself has no value; its value comes from beneficial use (Dearing 1999). The locus of innovation is social practice; we can speak of an innovation only when a technology is in use (Tuomi 2001). Particularly the focus on sustainability makes it necessary to define innovation primarily from a user perspective. A technical artefact itself has no environmental impact; only if it is used in concrete production and in consumption processes does it become ecologically relevant. Here we will concentrate on production processes.

Besides a technical dimension, social practices also have an organisational and a cultural dimension; innovation therefore implies the concurrent emergence of technical, organisational and cultural changes. The use of new technology is associated with new forms of division of labour and co-operation as well as with new meanings. If we apply such a user perspective, then the concept of environmental beneficial technology means more than reducing emissions technically, for example. To speak about sustainable technology implies that a new technology needs to be embedded in new sustainable practices and it has to be given a new environmentally beneficial meaning. Progress towards sustainable development requires not only new ways of doing business, but also far-reaching shifts in corporate atti-

tudes. Environment has to be internalised in corporate culture (Schmidheiny 1992).

If we look at concrete company strategies, we can identify a focus on technologies of waste disposal and recycling; they are mainly end-of-pipe technologies. These technologies are supplemented to the original production process without the introduction of major changes into the technical system. They are additive in the sense that the existing technology is supplemented by a new component with the aim of avoiding or reducing the damage to the environment, caused by the traditional technical system. Typical are filtration and purification plants, deposition methods and recycling technologies.

'End-of-pipe technologies' do not contribute to creative destruction; their aim actually is to continue production without changing the existing technical system. End-of-pipe technologies stabilise the existing technological system by repairing possible environmental damages (Diekmann and Preisendörfer 2001); they do not trigger the development of a new technological development path. They only produce incremental improvements along established pathways and may in the end lead to a situation of 'lock-in' (OECD 1999).

Applying the above user perspective, we may actually doubt whether we can characterise 'end-of-pipe technologies' as environmentally sustainable technologies. We have argued that innovation incorporates technical, behavioural and organisational changes as well as changes in the meaning of technology. However, 'end-of-pipe technologies' do not introduce significant changes in existing social practices. Employees involved in social practices do not have to change their work behaviour to a great extent; they are not forced to learn. Moreover, the meaning given to the existing technological system does not change; its major aim is to produce products or services in the most efficient way and not to ameliorate the ecological environmental.

From our viewpoint, only 'integrated environmental technologies' can be characterised as sustainable innovations because they introduce changes in social practices. They represent technical solutions that do not produce or at least directly reduce environmental damages (Diekmann and Preisendörfer 2001). As they aim at preventive avoidance of environmental damage either in the form of clean processes or clean products, the technology is also given a new meaning. While 'end-of-pipe technologies' contribute to the stabilisation of the existing development path, 'integrated environmental technologies' contribute to creative destruction and thereby help creating a new development path.

5. Coping with Uncertainty as a Rationale of Companies' Investment in Clean Innovation

There is, however, as some scholars have observed, a change in corporate environmental strategies from a defensive, reactive attitude to a pro-active and positive one. While the traditional 'resistant adaptation' resulted in the use of 'end-of-pipe technologies', there is now a shift to the development and use of cleaner products and processes (Fischer and Schot 1993). How can we explain this shift?

Cleaner technology is not a criterion for practical technology choice. Companies' engagement in clean technology cannot be understood as being motivated by a moral change in values. Companies do not diverge from the economic logic for the benefit of an environmental conviction. They do not invest in clean technology if they do not expect to be rewarded by the market. "(...) corporate decision-making", as Fukasaku argues, "is rarely based on purely environmental considerations, or on the selection of cleaner technologies for their own sake (...)" (1999). On the other hand, companies' environmental activities are seldom motivated by short-term profit expectations or by the aim to cope with actual damage (Dresel and Blättel-Mink 1997).

It is argued that companies increasingly associate clean technologies with a win-win situation (Porter and van der Linde 1995). The authors assume that clean technologies can generate environmental benefits and are at the same time cost-saving from companies' point of view. This argumentation seems to be too simplistic because, on the one hand, an investment in clean technology is often very costly, while, on the other hand, economic returns are highly uncertain, because investment in cleaner technologies will probably pay off only after a longer period of time. Therefore, it is only seldom the case that companies consciously use the concept of clean technology to shape their strategies (Dresel and Blättel-Mink 1997).

Rather, investment in clean technology represents a more general change in corporate strategy development. In an increasingly turbulent environment companies try to get control over the areas of uncertainty which could have an impact on their long-term strategies and revenues. Innovation can then be seen as a corporate activity aiming at getting control over situations of uncertainty by reacting to anticipated events and changes. "Clean technology" as Fukasaku argues, "is not a criterion for practical technology choice, but rather an element of broader corporate strategy, which can refocus it at a higher level in such a way as to build environmental criteria into decision making and the technology development process" (1999). Investing in clean technology therefore entails the same business logic as quality management, human resource management, or improved customer relationships. All these activities represent an attempt to give companies more control over situations of uncertainty in order for them to be able to secure the achievement of long-term economic goals.

6. New Insights into the Innovation Process and the Regional Dimension

The so-called linear model of innovation was the dominant approach in innovation research for quite a while. It mainly deals with explicit knowledge developed in research processes. In this model, basic research is placed at the beginning of a causal chain that ends in productivity growth mediated by innovation and diffusion. Each level in the linear model produces outputs that are transferred to the next level as inputs. The flow of knowledge is unidirectional, which means that later stages do not provide inputs for earlier stages (Kline and Rosenberg 1986). The main assumption of the linear model is that new knowledge will always find its way into marketable products without major transformation problems. But as Freeman argues, there is now increasing evidence that the linear model of innovation represents an exception rather than a rule (1987).

The 'circular model' suggests that, instead of interpreting innovation as a linear process, we have to understand the creation of novelty as a recursive process (Schienstock 1999). This means that we have to take into account complicated feedback mechanisms and interactive relationships involving science, technology, learning, production, and demand (Edquist 1997). While explicit knowledge is in focus in the linear model, the circular or recursive model emphasises tacit and codified but sticky knowledge. It conceives of innovation as an interactive process of a social nature, emphasising co-operation, not competition (Lundvall 1999). Much more than with the linear model, the focus is on the connection among company-internal, company-external, and technological factors (OECD 1992). As there is no clear development logic, an efficient innovation and knowledge management within and increasingly among firms becomes crucially important. Networks among firms and with knowledge producers are seen as the most efficient way of organising innovation processes. The main argument is that networks allow companies to specialise because they can expect to receive complementary knowledge from their network partners. And networks support inter-organisational learning, which is crucial for the necessary trial-and-error approach in innovation processes.

Particularly for the successful development of radical innovations, including sustainable technologies, spatial proximity and efficient knowledge management becomes crucial, as communication and knowledge exchange is increasingly difficult because codes, developed to communicate a constant, or a gradually changing technology, become inadequate. On the one hand, producers who have followed a given technological trajectory will have difficulties in evaluating the potentials of the new paradigm. Users, on the other hand, will have difficulties in decoding the communications coming from producers developing new products built according to the new paradigm. "The lack of standardised criteria for sorting out what is the best paradigm implies that 'subjective elements' in the user-producer relationships – like mutual trust and even personal friendship will become important. These subjective elements are not easily shared across regional borders" (Meeus and Oerlemans 1999)

We can assume a close relationship between the level of tacitness and stickiness of knowledge and the importance of spatial proximity. The fact that a larger territorial space may contain more diversity will not necessarily lead to innovation as long as there is not enough proximity to support intensive communication. The above argument suggests that, due to their radical character, codified knowledge is less relevant for environmental beneficial products and processes. Instead, the development of these technologies depends to a great extent on the exchange of tacit or sticky knowledge on the basis of trust and social capital. Also, the fact that concerned people and households have to be involved in the creation of a new development path points to the great importance of spatial proximity.

It is because environmentally beneficial innovations involve a great degree of tacitness and stickiness of knowledge that the regional innovation system is put into the spotlight. Efficient management of such knowledge is more easily achieved at the regional than at the national level. Some scholars have recently pointed to the key role of social capital in innovation processes (Lundvall 1998). Transformative innovations, it is argued, depend on trust-based relationships and a high amount of accumulated social capital as the production of these novelties often involves intensive exchange of confidential information and tacit knowledge. Dense and frequent links between people and organisations are more likely to develop in regions than in large countries, which explains their relevance for the greening of innovation systems. As regional institutions provide the basis for the development of trust and the accumulation of social capital, we will probably see intensive co-operation among involved organisations and open knowledge exchange supporting interactive learning and collaborative innovation processes.

7. Instruments of Sustainability-Oriented National Innovation Policy

So far, an innovation policy for sustainability is still far from being developed. Traditionally innovation policy was conceptualised as a dualistic model. According to Braun (1994), innovation policy has two functions. It should support, enhance and accelerate the development and use of technology, with the ultimate goal of strengthening the economy. But, in addition, it should also regulate the use and development of technology in such a way as to minimise risks posed by technology to health safety, the social fabric and the natural environment.

There is no doubt that risk management through environmental regulations has led industry to develop and adopt various pollution-control techniques and equipment, for example. In addition, as Porter and van Linde argue (1995), companies that are forced to adapt to high environmental standards may benefit from the 'early-mover advantage'. However, such a command and control approach (Fukasaku 1999) has seldom stimulated radical technical change. In many cases, forms of environmental regulation have been a predictable stimulus to small, incremental improvements along established pathways, often in the form of 'end-of-pipe tech-

nologies' (OECD Working Group on Technology and Sustainable Development 1999).

It is very unlikely that the regulatory approach solves the problem of under-investment in sustainable technologies.[3] To overcome under-investment in sustainable technologies, the state may be legitimated to intervene in the market process. A more dynamic environmental policy is needed, which focuses on the development and diffusion of clean technologies and integrated approaches aiming at promoting prevention rather then abatement (OECD 1999). Schienstock (1994) differentiates between two broad categories of innovation policies, namely direct technology policy which offers financial incentives to companies for their innovation programmes and innovation-enabling policy which focuses on public supply for infrastructures with the aim to attract companies to set up research activities and innovative production. The aim of direct technology policy is to help environmentally beneficial technologies over the initial barriers to acceptance by giving them a selective advantage via the tax system or direct subsidies. The fact that environmentally beneficial technologies compete against other technologies which have been developed under selection criteria where ecological aspects have widely been ignored, legitimates public intervention through the use of economic instruments.

The key problem with direct technology policy is that the government needs to be able to pick up winners. But more radical innovations are characterised by high technological and market uncertainty. Why should state bureaucracies be able to deal with these uncertainties in a more effective way than corporate management and select the most promising technologies? Because it is becoming increasingly difficult to anticipate technological, economic and social aspects, public agencies do not often have a solid basis for directing the change process and defining clear strategies of change, although technological foresight may help them to identify useful areas for technological development and to decide where to put the money.

It is certainly the case that the innovation-enabling policy type has increased, particularly due to the fact that economic competitive advantages can be constructed deliberately. In a competitive global environment, governments have to upgrade their institutional infrastructure to attract technology-intensive activities. Particularly in the case of developing a new sustainability-oriented techno-economic path, the countries that can provide the needed support for systemic innovation will have a competitive edge. The greening of the whole economy is not possible without institutions that provide new scientific knowledge, new skills and competencies, new legal regulations, needed financial resources, and a proper communication infrastructure. But while national governments can set up new supporting institutions, it is more difficult for them to make the system working

[3] Two aspects have been mentioned to explain under-investment in sustainable technologies. First, the traditional market failure argument (Arrow 1962), which holds true for innovation in general, is particularly applicable for sustainable innovations (Hübner and Nill 2001: 73). Second, sustainable technology has to be developed outside the existing development path and therefore requires particular effort.

because here proximity is often decisive. In this respect, regional governments may be more efficient.

8. Regional Policy for Sustainable Development

As environmental problems are often of a local character, it is obvious that regional authorities have a monitoring function concerning environmental pollution, for example. However, regional governments can play a much more active role in the greening of systems of innovation as the above new insights into the nature of innovation processes suggest. The specific instruments of innovation policy need to be adapted within a broader framework that stresses the importance of policy coherence and of inter-linkages within innovation systems.

The development of a systemic vision, or a new *Leitbild* of techno-economic and social development, can be seen as a key element of the network-enabling innovation policy. A *Leitbild* can be defined as a symbolic scheme for creating reality; it includes general ideas about the future structures of the economy and society (Berger and Luckmann 1966). But a *Leitbild* also has a normative dimension, as which it becomes the basis of practical restructuring processes. A major advantage of a *Leitbild* is that it makes communication among social actors possible, even if they have different interests and preferences.

In order to foster the greening of the economy, propagating 'sustainable development' as the new *Leitbild* of economic development can be seen as an important element of modern innovation policy (Renn 1997). But too general a *Leitbild* hardly releases concrete restructuring activities, as it becomes very difficult to deduce strategies for solving existing problems. A Leitbild developed on the regional level is probably closer to concrete problems than the one developed at the national level and is therefore more likely to become the basis of practical restructuring processes. This is the more the case, the more interests are represented in the process of creating the new Leitbild. Again, regional systems have an advantage because they represent genuine communities of economic interest and can take advantage of true linkages and synergies among economic actors (Ohmae 1993).

9. Supporting Innovation Networks as a Core Element of Regional Policy of Sustainable Development

Policies that promote research collaboration, facilitate firm networking and clustering, encourage institutional ties, and involve people concerned are taking on new significance (OECD Working Group on Technology and Sustainable Development 1999). A new type of innovation policy that can be characterised as network-facilitating policy emerges (Schienstock and Hämäläinen 2001)[4]. In the en-

[4] The following part relies heavily on this publication.

vironmental realm, partnerships and networks are valuable because processes of specialisation can accelerate the development and diffusion of clean technologies and reduce obstacles (OECD Working Group on Technology and Sustainable Development 1999). As networking becomes the core of a new sustainability-oriented innovation policy, regions assume a much more important role in this field.

The specialisation, dynamism and social embeddedness of networks makes network-facilitation a demanding challenge for policy-makers. Sophisticated interventions require deep knowledge about the major problems to be dealt with, the relative efficiency of different organisational alternatives, as well as the specific strengths and weaknesses of potential support institutions and partner firms. Regional governments often have an information and knowledge advantage over national agencies in this respect. Moreover, since the feasibility of carrying out complex inter-organisational co-operation declines with geographical distance and increasing knowledge diversity, the preconditions for successful networking are also best at the regional level (Scott and Storper 1992). It is similarly important that involving households and people concerned in sustainable innovation processes can best be practised at the regional level.

From the viewpoint of industrial innovation and sustainability, regions have an additional advantage. Due to their proximity and flexibility, regional networks provide an ideal platform for carrying out social innovation experiments which are often very complex and involve a great number of actors, needing close interaction between various kinds of firms, consumers and government agents. Meyer-Kramer (2001) mentions the change from product-ownership consumption to use-oriented consumption as an interesting social experiment in which regions can provide an appropriate basis for the implementation of social experiments, and the experimenting with various options. The aim here is to encourage households to change their patterns of behaviour significantly, to transform products into services, and to stimulate new technical concepts.

The practical problems of networking change in different phases of the networking process. The following analysis of such problems follows the phases of a typical networking process (Schienstock and Hämäläinen 2001): (a) firms' awareness of networking opportunities, (b) search for partners, (c) building trust and a shared knowledge base, (d) organising the network, (e) adding complementary resources, (f) stimulating demand, (g) involving concerned persons, and (h) stabilisation of co-operation.

The nature and potential benefits of network co-operation are not always very well known and internalised, particularly not among small firms. This information problem may slow down organisational adjustments among firms that could benefit from active network co-operation. Regional governments can promote firms' awareness about networking, for instance, by arranging seminars, by distributing information and by trying to get the media to cover successful examples of networking. It is important to form a 'critical mass' of firms and other knowledge creating partners for the formation of innovation networks.

Finding appropriate partners for co-operation involves another problem. Many surveys have shown that the most important reason for not participating in co-

operative networks is that there are no suitable partners available or that they are difficult to find. Particularly SMEs have difficulties in finding partners within universities or other research institutes that can provide the knowledge needed to develop clean products or eco-efficient processes. Governments can support firms' own search for network partners with information, brokerage and matching services (Lundvall and Borrás 1997).

Finding potential networks and partners is not easy. It requires deep knowledge about firms' specific strengths and weaknesses and about how they could complement each other. This is particular the case when the aim of network formation is fostering the development and diffusion of sustainable technology, as this implies the co-operation of firms from different industries. With respect to sustainable technology, the diffusion aspect is of particular importance. As knowledge-intensive business service (KIBS) firms play a crucial role in the process of knowledge diffusion, it is important to involve them in the process of network formation from the beginning. However, it is often the case that KIBS firms specialised in problems of sustainable development and sustainable technologies do not exist; public network policy therefore also needs to pay attention to the development of such KIBS firms.

Experiences suggest that the search for potential network partners should take place very close to firms, an aspect, which again favours regional solutions. Furthermore, it suggests that network policies should not aim to create new networks from scratch: network promotion could be focused on emerging but fragile networks, which require further encouragement and support. To solve the problem of finding adequate partners, public/private partnerships to conduct applied research in the field of sustainable technologies can also be set up.

Before networks become more stable and co-operation functions efficiently, many mental barriers must be overcome. In fact, the mental rigidities and old behavioural routines of entrepreneurs are often seen as the biggest hurdle to effective networking. Potential partners need to learn more about each other's worldviews, beliefs and attitudes, values, business strategies, and operating methods. This can only be done through an intensive and open discussion in which the participants gradually build trust and a shared knowledge base. Being a neutral and trusted 'third party', regional governments can often reduce the suspicions and reservations that firms have toward closer inter-firm co-operation and co-opera-tion with research institutes, particularly when some partners come from traditional smokestack industries.

Building shared understandings and trust takes time. As a result, regional governments should favour policies which provide firms with adequate incentives to continue participating in the networking process long enough to build the necessary shared knowledge base and social capital. Setting up long-term network facilitation programmes and building inter-firm meeting arenas may be more productive than trying to more directly match potential partners who have not had enough time to learn to know each other well or to build shared understanding and trust. Once firms understand and trust each other, they can start to build a shared vision, strategy, structure and behavioural rules for the network. A shared vision

of the future is an important co-ordinating mechanism, particularly in sustainability-oriented innovation networks.

New, emerging networks do not often have all key resources and capabilities required for competitive success. For example, a key technology or other input may not be available from the existing network partners. In addition, network-facilitating innovation policy also needs to focus on the development of learning organisations and competence building within networks (Lundvall and Archibugi 2001), as organisational and other social innovations are of particular relevance for the greening of the economy. SMEs, being left alone, will hardly undertake a fundamental transformation of their business structures to be able to continuously develop their ecological competence and improve their environment-related knowledge. To overcome these difficulties, governments can, for example, focus on workforce training and encourage managerial and organisational changes among firms to improve their ability to assess and adopt sustainable technologies (OECD Working Group on Technology and Sustainable Development 1999).

It is often not missing knowledge but a lack of demand that limits the technological progress of sustainable technology. Companies invest only if the market rewards the production of green products and services and the application of eco-efficient process-technologies and consumers demand such changes. This implies that consumers themselves have to change their consumption behaviour, everyday buying patterns and life styles, and to refrain from the current resource intensive habits and practices. However, while consumers have become more aware of environmental issues, it has not yet translated into far-reaching changes in actual life. Regional governments can take initiatives to shift demand towards products that are more supportive for environments. They can, for example, encourage reporting by enterprises on emissions and the environmental implications of their activities. And they can overcome information deficits by increasing consumer knowledge of the ecological impacts of their consumption pattern and product choice through launching their own campaign to foster demand for sustainable products (OECD Working Group on Technology and Sustainable Development 1999).

Technology-related discourses involving various stakeholders can be seen as important co-ordination mechanisms of transformation management. Broader societal participation must be guaranteed and households should be involved in such technology-related discourses, not only to influence their consumption practices. Their involvement is also crucial to get their backing for more concrete steps towards the greening of the economy and to avoid public resistance and serious conflicts in later stages of the creation and development of the new development path. There are major trust implications for the acceptance of specific technological paths and for reaching an agreement on how to manage technological risks. Informing the public is not enough; instead, it is important to establish a discursive confrontation between the persons and organisations who gain from the renewal of the economy and who may suffer from the technical and social innovations (Renn 1997). A technology-related discourse can be viewed as a platform to jointly create and exchange information among social actors. Discursive co-ordination is not intended to create consensus among the participants in the first place, but it aims at initiating learning processes.

To improve long-term perspectives of business partnerships, regional governments can set up specific institutions that provide the needed services for the stabilisation and further growth of co-operative networks in close co-operation with national agents. Here we can mention centres of expertise in environment technology, eco-industrial parks, or regional environmental cluster programs. Network policy, however, can also produce failures. Business networks may become dependent on state support, which may actually hinder necessary change processes. Lundvall and Borrás (1997) mention the integration/flexibility dilemma. The advantage of networks is seen in their flexibility and openness; however, in later stages and due to invested interests, they can become mechanisms which prevent network partners from adapting to new conditions. Particularly in a period of rapid technological change, specific networks may become inefficient and block the environmentally beneficial renewal of regional economies.

While there is general agreement that establishing co-operation networks, including technology-related discourses, becomes an important instrument in the creation of a sustainable development path and gives regional governments an important role in technology policy, there is little knowledge about how such a policy can be conducted. What exactly is the new role of regional policy-makers in the greening process of the economy? How should they intervene in the transformation process?

10. The Role of Government and Policy Learning

Particularly the region-state, as we have argued above, has an important role to play in the process of path creation and transformation management. However, it becomes quite clear that in a period of a changing development path, the role of the state must be reconsidered. Governments can no longer assume the role of a sovereign economic actor steering the innovation process through bureaucratic forms of control. Creating a new development path implies a lot of uncertainty. Therefore, in a transformation period, the significance of technical, macroeconomic management may decrease but the role of the state as a facilitator and orchestrator of different interests of various social actors remains strong (Hirst and Thompson 1992).

The role of the state in a transition period towards a green development path can be described as a catalyst for innovation processes, a supporter of ongoing research and innovation activities, a facilitator of co-operation in R&D, an organiser of a dialogue between various social actors about future development, and as an initiator of critical questions and new tasks. Sabel (1995), as we have mentioned earlier, characterises the role of the state in transformation periods as an initiator of bootstrapping reforms; his main task is to get actors moving in the same direction because it might be more risky to stay put than to move in the wrong direction.

In the context of a major transformation, we can characterise innovation policy as a process of policy learning. Such an interpretation is quite different from tradi-

tional conceptualisation of innovation policy, which assumes that a decision-making process consists of three clear-cut stages: setting goals, developing programmes, and implementing projects. The learning approach, on the other hand, provides a fluid perspective of a policy process in continuous transformation and evolution where no such stages can be discerned (Lundvall and Borrás 1997). Policy learning relies on intelligent benchmarking, policy evaluation, technological foresight, and assessment studies. The main aim of these instruments can be seen in promoting a dialogue among users, producers, other social groups concerned as well as policy-makers.

11. Conclusion

In this paper we have argued that the traditional focus of systems of innovation on knowledge creation and knowledge diffusion might be too narrow. We have stressed the need of feedback analysis pointing to possible unintended consequences of an accelerating innovation dynamic such as environmental damage and social segmentation and exclusion. This implies that sustainability needs to become a key aim of systems of innovation.

We agree with Fukasaku, who argues that the sustainable development imperative implies a change in the dominant technological paradigm to shift the existing technological trajectories (1999). Environmental issues have to be associated with production technology, we can no longer focus on consumption and post-consumption; instead, sustainability concerns business. Talking about sustainable technology, however, means more than 'end-of-pipe technologies'; they actually do not trigger a fundamental transformation process of the innovation system. Integrated environmental technologies, on the other hand, contribute to creative destruction and thereby bring about the basis for a new development path, demanding complementary behavioural, organisational, and institutional changes at the same time.

New insights into the nature of innovation, we have further argued, have led to the adoption of new instruments of innovation policy, which focus on the interlinkages within innovation systems. Policies that promote research collaboration, facilitate firm networking and clustering, encourage institutional ties, and involve people concerned are taking on a new significance. At the same time, regional governments become key players in the innovation system. Developing business networks, including the establishment of technology-related discourses involving a variety of different stakeholders, we have stressed, are in the centre of regional innovation policy. In this paper we have discussed the various stages and strategies of such a network policy. We have also argued, however, that such a policy needs to be applied with care because, particularly in a period of rapid technological change, specific networks may become inefficient and block the renewal of regional economies.

While it is important to better understand the new role of regional governments in innovation processes aiming at sustainable development, it is also crucial to link

regional activities with processes at the national and trans-national level. Many problems are too complex for only national or even concerted international activities to resolve. Innovation policy that aims at sustainable development therefore needs a much broader approach combining various instruments and integrating various policy levels. We are far from the application of such an integrative approach and we have definitely not enough knowledge of how to design and implement it.