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Rainer Walz and Frieder Meyer-Krahmer

Fraunhofer Institute for Systems and Innovation Research
Karlsruhe, Germany

Innovation and sustainability in economic development

Abstract

Ever since the term sustainable development entered the political debate, it has been characterized by the two aspects of ecological sustainability and economic development. Clearly, innovation plays a key role for both objectives. The paper will focus on the interrelationship of these three concepts. The framework of the Environmental Kusnetz Curve which analyzes the relationship of environment and economic development will serve as starting point. The argument brought forward from environmental innovation research in the North will be examined, which states that various innovation strategies and policies open up the potential to mediate the conflict between environment and economic development. The question will be addressed whether or not this development paradigm can also form a valid basis for sustainable development in the countries of the South.

1 Introduction

A main topic of innovation research has been the heuristic concept of systems of innovation. It has been suggested that future research in this field should address, among others, both issues of sustainability and the application to the economic development in countries of the South (Lundvall et al. 2002). Thus, this paper focuses on the interrelationship of innovation and sustainability in economic development.

The paper starts with a short review of the different interpretation of sustainable development within both politics and economics (section 2). It is argued that, above all, a common ground of both strings of interpretation is the relationship between ecological sustainability and economic growth. In section 3, the framework of the Environmental Kuznets Curve will serve as starting point for analysing this relationship. It will be argued that reconciling economic development and ecological strategies require the promotion of technological progress and structural change. In section 4, the argument brought forward from environmental innovation research in the North will be examined, which states that various innovation strategies and policies open up the potential to mediate the conflict between environment and economic development. In section 5, three different scenarios are presented which address different roles of innovations as a basis for sustainable development in the countries of the South. Based on this analysis, section 6 deals with first conclusions and open question to be addressed in the future.

2 Interpretation of sustainable development

2.1 Sustainable Development in Politics

The concept of sustainability owes its great significance above all to the international political discussion which has been waged since the beginning of the 1970s. The combination of the two words "sustainable" and "development" appears in 1972 already in the final document of the preparatory conference for the environment summit of the United Nations in Stockholm (see on the following Walz 2002). Sustainable development was discussed again intensely in the World Conservation Strategy of the International Union of Concerned Scientists (IUCN), and in the programme "Six Steps to a Sustainable Society" presented by the Worldwatch Institute in 1982, both very strongly emphasising the environmental aspect. The term "sustainable development" made its breakthrough in the final report of the World Commission on Environment and Development (WCED) set up by the UN in 1983, which is often called the *Brundtland Commission* after its chairwoman. Its much quoted definition of sustainable development is as follows: "Sustainable development is development that meets the need of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). Not only the northern representatives who called more strongly for protection of the environment, but also the southern delegates who demanded development possibilities for their countries were able to agree on this general definition. At the same time, this term expresses the tension between ecological sustainability and economic development which runs through the entire WCED report.

The discussion that started after the publication of the WCED report ensured that at the UN summit conference for Environment and Development (UNCED) in 1992, the so-called Rio Conference, the vision of sustainable development was recognised as a model worldwide. The individual chapters of the *agenda* 21 can hereby be interpreted as defining sustainable development more precisely (see Walz 2002). Together with the Climate Framework Conference which was also held in Rio, the *agenda* 21 was responsible for giving international environmental policy a new impulse still present today, which is described as the Rio process. The Rio documents formulate a general model in the sense of a programme of principles. Its contribution is seen above all in having collected various elements of the environmental policy discussion into one pattern and placed it in a broader context (Walz 2002). This process has led, above all, to the Johannesburg declaration in 2002, which defines various additional sustainability goals (e.g. access to safe drinking water and sewage treatment) be met in the future.

2.2 Economic Interpretation of Sustainable Development

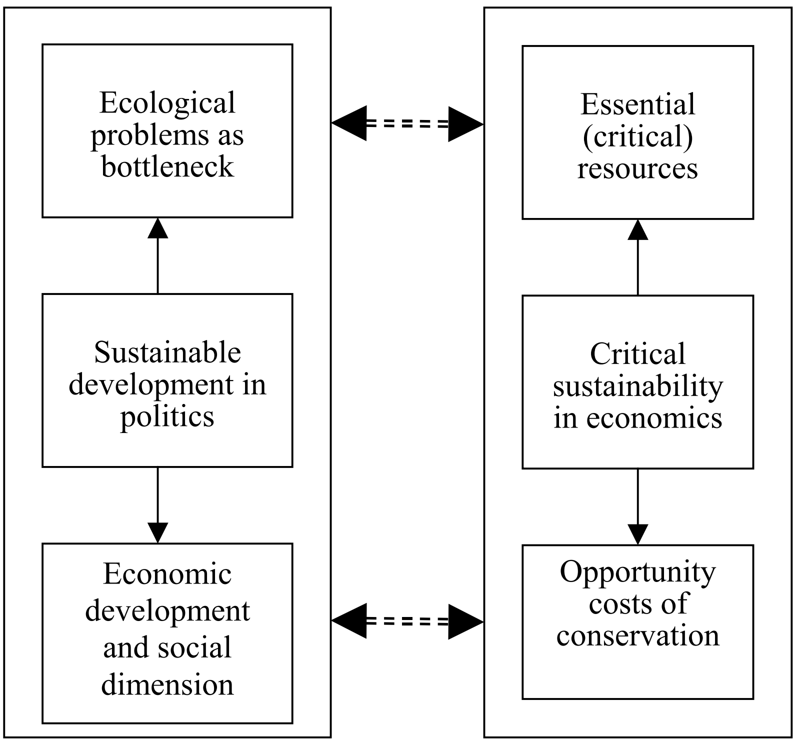
In addition to the political debate, there has been an intensive discussion how to interpret sustainability within economics. Building on the constant capital rule developed within the economic growth literature of the 1970's, the concepts of weak and strong sustainability were developed. Both of them emphasise the ecological side of sustainability. However, they differ with regard to the possibility that the natural capital stock can be substituted for by man made capital.

Finally, the so called critical sustainability concept has been developed. It calls for a limited substitution of natural by man-made capital. However, at the same time, it calls for a minimal level of essential resources which should must be preserved. This so called critical capital is defined as „that set of environmental resources which, at a described geographical scale, performs important environmental functions and for which no substitute in terms of manufactured, human or other natural capital currently exist" (Noel/O'Connor 1998, p. 78). This interpretation implies that not all environmental problems are sustainability problems. Even though it is difficult to reach political consensus, there is a tendency developing that problems which are irreversible (e.g. loss of biodiversity), global (e.g. global warming) and reaching far into the future (e.g. storage of nuclear waste) are endangering sustainability very substantially (Pearce 1994; Walz 2002).

The critical sustainable development interpretation, however, also considers the problem of uncertainty about the impacts of the environmental problems. Thus, the preservation of the critical capital stock is subject to the impacts of the costs of conservation, by emphasising the so called safe minimum standard. In short, it calls for the conservation of a resource unless the social costs of doing so are unacceptably large (Bishop 1978; Bishop 1993; Pearce 1994).

To sum up, the meaning of sustainability has been intensively debated in both politics and economics. However, no consensus on a coherent framework has been reached. Nevertheless, both the political and the economic interpretation have in common that environmental problems are a key challenge to sustainability, which, however, cannot be debated without its impact on the social and economic dimension (Figure 1). Above all, this puts the relationship between ecological sustainability and economic growth in the forefront.

Figure 1: Similarities between political and economic interpretation of sustainable development



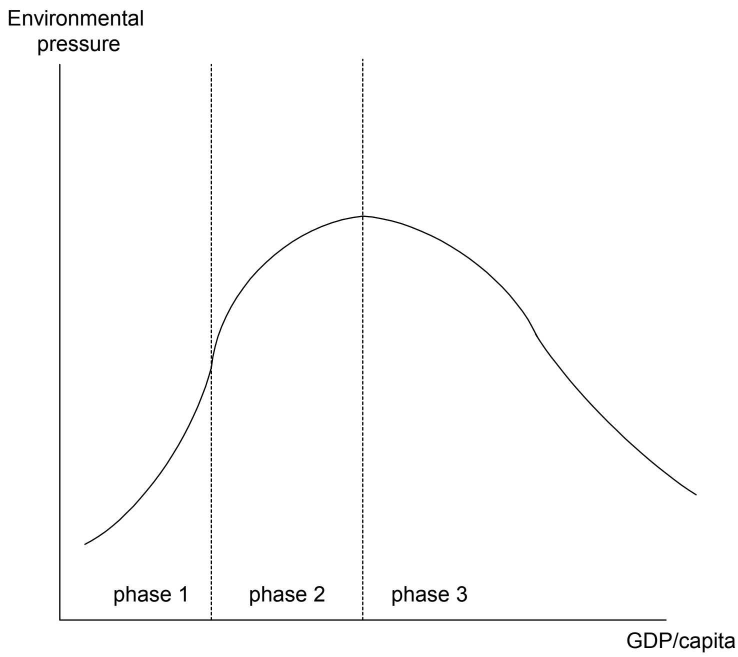
Source: Walz 2002, p.40

3 The relationship between economic development and ecological sustainability in the North

3.1 Concept of Environmental Kuznets Curve

Starting in the 1990's, the growth-environment debate received much attention in the form of the Environmental Kuznets Curve (EKC). According to the EKC-hypothesis, environmental pressure grows faster than income in a first stage of economic development. This is followed by a second stage, in which environmental pressure still increases, but slower than GDP. After a particular income level has been reached, environmental pressure declines despite continued income growth. Graphically, this leads to an inverted U-curve similar to the relationship Kuznets (1955) suggested for income inequality and economic per capita income (Figure 2).

Figure 2: Concept of Environmental Kuznets Curve



Source: According to de Bruyn 1999

The empirical evidence of the EKC hypothesis is mixed. Some studies have claimed to find clear evidence (e.g. Shafik, 1994; Grossmann/Krueger, 1995; Cole et al. 1997; Cole 2003). Others, however, have criticized the EKC hypothesis and come up with different conclusions (see Arrows et al. 1995; Ekins 1997; de Bruyn/Heintz 1999; Stern/Common 2001). A general explanation for the differences is that data and methods employed vary among the studies, e.g. with regard to pollutants and indicators used to measure environmental pressure, or the common problem of using an appropriate exchange rate for converting national income figures into comparable monetary units. Furthermore, the results also depend on the countries included into the analysis.

3.2 Explanations of the EKC

The different empirical results call for an explanation about the driving forces of the relationship between environmental income and economic development. The following explanations have been used (see Neumayer 1998; de Bruyn/Heintz 1999):

- Behavioural changes: Environmental quality is regarded as a superior good, that is its income elasticity is above unity. Thus, with increasing income people are willing to sacrifice increasing portions for the preservation of the environment.
- Institutional changes: The increasing slope of the EKC is often attributed to policy distortions such as the subsidisation of resource consumption, e.g. for fuel consumption or water use. With increasing income, the need for subsidisation is reduced, and environmental regulations are imposed at the same time.
- Technological changes: Within a growing economy, it is more likely that the capital stock is replaced with new, environmentally more friendly technology. Furthermore, higher income enables additional R&D efforts to develop clean technologies.
- Structural changes: The structural compositions of the economy changes during the process of economic development. When agriculture and heavy industry are dominating, the environmental pressure is high. With the service oriented sectors becoming more and more important, the environmental pressure is thought to be declining. Thus, the underlying notion behind this explanation is that economic development is not equivalent to rising material output, but to rising output in value terms. Thus, there might be a delinking between economic development and material output.

There have been some studies performed looking into the importance of these factors, among them decomposition analysis of changes in environmental pressure into the three factors level of growth, structural change, and technological change (see Walz et al. 1992; Rose 1999). These studies clearly support the importance of technological change as the major driver of reducing environmental pressure in the past. Structural change, however, is difficult to measure precisely. In the form of intrasectoral structural change, it is hard to distinguish it from technological change. Thus, part of the large role of technological change might perhaps be attributed to intrasectoral change. Furthermore, structural change takes place as change within both composition of demand and sectoral interlinkages in production. Thus, it is not astonishing to see mixed empirical evidence about its importance for the development of environmental pressure.

The debate about the driving forces for an EKC has been taken place primarily within environmental economics. From the point of view of innovation research, however, another line of argument with regard to the driving forces can be deducted. Clearly technological change and - to some extent - structural changes of the economy depend on the innovation dynamics within the countries. Thus, the ultimate explanation for the differing results between countries can be seen that they also represent different systems of innovation, e.g. on the national or the technological level. Even the factors referring to institutional and cultural effects (influencing income elasticities for the good clean environment) can be included in the systems of innovation heuristic. Thus, to sum up, the relationship between economic development and ecological sustainability clearly depends on the system of innovation prevailing.

3.3 Policy Implications

The EKC hypothesis offers an easy solution for "environmental optimists": Ecological sustainability problems, from that point of view, is not much more than a transitional phase of an economy moving towards ever increasing economic welfare. However, there are various shortcomings in such an argument:

- Even if the safe limits are violated for a transitional time period only, this might cause irreversible and global effects. This is especially the case for the environmental problems with a high priority for ecological sustainability.
- The empirical results indicate that the EKC hypothesis might be rather valid for short term environmental problems with a high direct local effect; however, the evidence is mixed especially for the opposite kind of problems which are highly relevant for ecological sustainability.
- The differing empirical results clearly imply that the negatively sloped tail of the EKC is not a natural development, but depends on factors such as technological development and structural change, which (partially) can be influenced by policy.
- The regulatory environment is an important factor within the systems of innovation. With environmental pollution being an external effect within the market system, it can be assumed that public policies play an especially important role in guiding the innovation process towards ecological sustainability.

To sum up, there is not much evidence that the ecological sustainability problems can be left to the market alone. Instead, policies are necessary which foster sustainable innovation strategies.

4 Innovation strategies for sustainable development

4.1 From end-of-pipe technologies to structural changes

The debate on the environmental Kuznets curve concluded that the successes in specific emission reductions most to often are compensated for by economic growth. Therefore new industrial models for an environmentally acceptable economy are needed which are not only desirable, but also (both for enterprises and consumers) economically attractive, so that they have a chance of being realised. We differentiate three models of this kind (Böhm/Walz 1995; Kuhlmann, Meyer-Krahmer 2001; Walz 2002):

- more extensive use of environmentally acceptable technologies (end-of-pipe as well as integrated) as a traditional model,
- the closing of materials cycles,
- the integration of product policy and product use.

It has been shown that the more extensive use of environmentally friendly technologies results in substantial environmental relief. Furthermore, they have brought economic success to a number of produces of these technologies, e.g. in the U.S. or Germany. The basic problem with this model is that, on its own, more extensive use of environmentally acceptable technologies does not produce enough of the necessary efficiency gains for an environmentally sustainable economy (Moors, Mulder 2002; Lustosa 2001).

There are already several examples of the closing of materials cycles in production which represent economically interesting options (including utilisation cascades). The present massive efforts towards establishing recycling economics also follow this model; its limits are set largely by the fact that the reconversion of products into raw materials and into secondary materials that are reintroduced into the production process still represents a relatively wide 'cycle', whereas for sustainability reasons the cycle should be as narrow as possible, meaning on as high a level as possible and with a possible minimum of additional transport demand.

The shift from production responsibility to product responsibility, which is laid down in various waste management or 'ecocycle' laws of some OECD countries, also entails a fundamental change in the model of 'integrated product policy.' In this context, environmentally acceptable management does not simply denote 'defensive' protection of the environment (e.g. the observance of regulations) but also creates an opportunity for enterprises to adopt new innovation and business strategies. This strategic change can be made possible or supported by changes, e.g. in the price system (internalisation of external costs from the consumption of resources), public regulation, voluntary agreements, public procurement programmes and changes in consumer behaviour. It is these entrepreneurial innovation strategies which will really determine the dynamics of the path towards an environmentally acceptable economy under conditions of partially regulated market economies (Dyllick, Hockerts 2002; Ekins 1998; Dormann, Holliday 2002; Dewick e.a. 2002; Moors, Vergragt 2002, Majer 2002).

4.2 Sustainability and Learning: Innovation Strategies of Firms

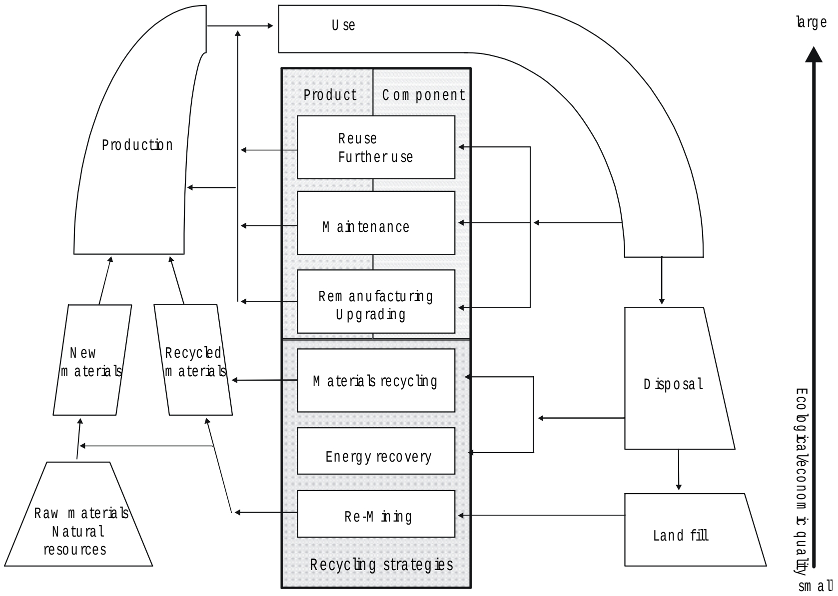
This shift in perspective will continue, as is to be expected in an evolutionary economic system. Entrepreneurial innovation strategies will determine the essential dynamics of the way towards environmentally sustainable economics under market economy conditions. To illustrate this view, innovation strategies to intensify product utilisation and to prolong the life cycle will be treated in detail.

Generally speaking, the following strategies for designing an improvement of the utilisation and life span of products can be distinguished (see Figure 1):

- products designed to last longer,
- increased use of maintenance and repair,
- the upgrading of products in use through modernisation,
- the re-use of components from used products in manufacturing new products, as well as
- service strategies (sales of utilisation instead of sales of products; divided, joint or multiple use; selling the service ‘function guarantee’ instead of selling substitute products).

The changes in perspective contained in such strategies open up new market possibilities through introducing new consumer durables to the market, or through introducing new modes of usage for such goods (e.g. by selling the function instead of the product itself). The benefits expected from usage will finally determine how the product is actually acquired (buying, rental, leasing, user coops, use on public offer), as well as the most suitable product design. Thus the strategy ‘sales of results (practical use) instead of goods’ means that the economic emphasis of the enterprises is shifted from manufacturing (production) to product management, that is from production companies to operating and leasing companies (‘fleet management’). This is accompanied by a far-reaching manufacturer’s liability, which requires the constructors to design products of great reliability, tolerance of misoperation, protection against unauthorised or improper use, which also inevitably means an extended life cycle for the goods. A holistic product policy also demands a substantial change in the requirements of continuous incorporation of technical change into the products.

Figure 3: Technical Strategies for Closing the Material Loop for Products



Source: Meyer-Krahmer (1998), p. 77

A longer active life for products has considerable impacts on the economic structural change, the way to deal with the existing stock of goods (stock management), as well as on R&D, for example:

- Components and products that can be flexibly repaired and adapted to future requirements and technologies, open systems with a high degree of exchangeability, in order to continually integrate technical advances into existing systems (without having to exchange a complete system, thus slowing down progress), should be developed. ‘Life cycle engineering‘ is called for in product development, in order to close the loop of material flows.
- Substitution of central manufacturing plants by decentralised workshops staffed by specialist craftsmen (servicing, maintenance, technological upgrading).
- Increasing significance of the insurance business through the growing importance of product liability.
- Shift from a production-oriented industrial society to a utilisation-oriented industrial service society.

Completely novel entrepreneurial strategies can be realised with this approach. They contain a variety of objectives such as cost-saving, quality improvement, new business fields, as well as combined product/service offers, and are at the same time compatible with the aim of an ecologically sustainable economy. There are already markets and companies which pursue these strategies. Examples are to be found in the aviation industry, manufacturers of photocopiers, drink vending machines and component manufacturers (Stahel 1994; Meyer-Krahmer 1998; Roome 1998; Green e. a. 2002).

The speed with which such innovation strategies are adopted depends not least on the changes in the political framework conditions, the shifts in consumer preferences and also the 'mental structural change' in the enterprises. In any case these innovation strategies will bring about a radical sectoral structural change. This is illustrated by the following results dealing with

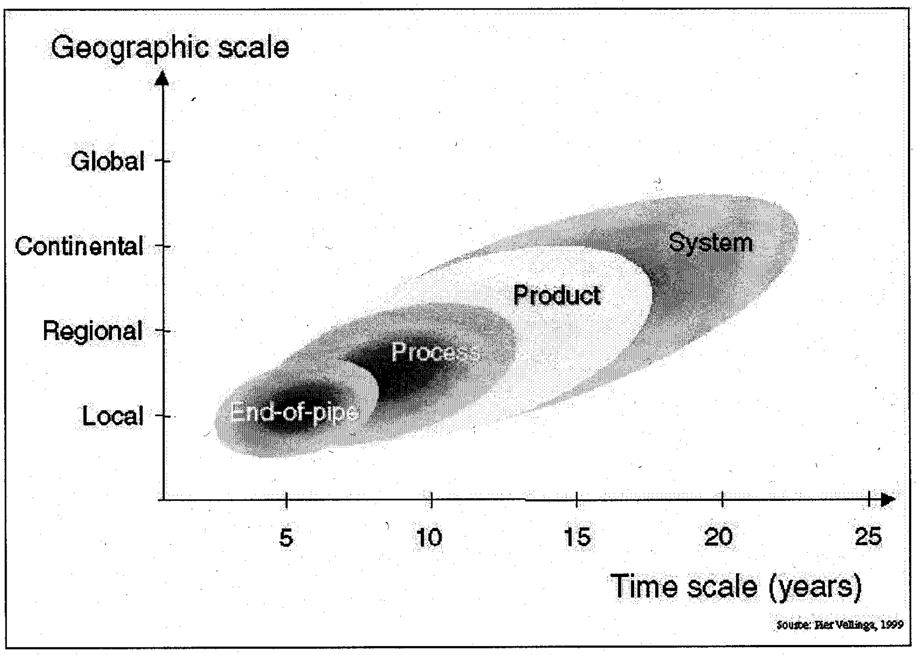
Therefore, finally the speed of dissemination of such innovation strategies is substantially influenced by the power of the winners and losers. Here lies the real line of conflict determining the speed with which these guiding principles assert themselves. This battle is not joined between left/right, ecological/non-ecological, employer/employee, but runs right through the economy, society and politics.

The integrated Product Policy (IPP) approach, which has been developed gradually over the last decade, is now generally recognised as being a potentially very effective way to address such a product dimension (CEC 2003, Rubik, Scholl 2002). This approach is based on four key principles: Life-cycle thinking – it considers a product's life-cycle and aims for a reduction of its cumulative environmental impacts; stakeholder involvement – it aims to encourage all those who come into contact with the product (i. e. industry, consumers and government) to act on their sphere of influence and to encourage co-operation between the different stakeholders; continuous improvement; a variety of policy instruments.

Within the innovation literature the concept of co-evolution of subsystems is a well-known concept. This concept is a key to understand the interplay between innovation and environmental sustainability and to design appropriate policies. Kemp, Rotmans (2001, p. 1-2) express this fact in the following way: "Environmental policy has been unsuccessful in changing behaviour and bringing about societal transformations, involving a change in both technology and behaviour. There is a consensus that the existing trajectories in transport, energy, and agriculture are not sustainable, but the alternatives are not clear or deemed unsatisfactory by experts. There is a conflict between short-term goals of policy and the long-term change needed for sustainability. We need more comprehensive responses, involving a change in production chains, in product-service systems, and the ways in which we consume and live "(see also Kemp and Soete, 1992, Weaver et al. 2000, Ashford et al. 2001).

According to these authors system innovation transcends a single country or a single continent and goes beyond the use of more efficient manufacturing processes and green products. Or as Freeman (2002, p. 209) puts it: "The growing environmental problems facing the whole world may also impose a rather different pattern of economic and political development than that which has prevailed in the 20th century. The development of environmentally friendly technologies and their universal diffusion may impose a more cooperative civilisation and an entirely new pattern of institutional change and of knowledge accumulation." The transformation may be beyond those that the dominant industries and firms are capable of developing easily, at least by themselves. The time scale for system innovation, one generation or more, is long from a policy point of view. An indication of the time scale and geographic scale of system innovation (vis-à-vis the scales for other types of change) is given in Figure 2.

Figure 4: Time scale and geographic scale of societal responses to the issue of environment



(Source: Vellinga/Herb 1999)

4.3 Internationalisation and Sustainability: The Shift from Technology to (Lead) Markets

Obviously, globalisation follows different paradigms in different entrepreneurial functions (see Gordon 1994): (1) the internationalisation of markets is determined by the search for markets with high income and low price elasticities of demand in conditions of free world trade, (2) the transnationalisation of production locations is driven by the regime of production possibilities (qualified workforce, supplier-producer networks, costs and other comparative advantages, closeness to market), and lastly, (3) globalisation is characterised by the pursuit of system competence through global "R&D sourcing" and the orientation towards the excellence of (national) innovation systems and related institutions.

At the same time, there is evidence that the three worlds postulated in the above "three-different-paradigms" approach repeatedly impinge on one another, so that the various paradigms merge again to some extent: recent studies on determinants of location factors of the internationalisation of research and development (see Reger, Beise, Belitz 1999; Jungmittag, Meyer-Krahmer, Reger 1999) show that in different key technologies the three paradigms play varying roles. Differences between sectors regarding the degree of liberalisation of international trade, the regulation of streams of direct investments, specific features of regional demand, economies of scale in production and the internationalisation of technological knowledge, result in different levels of internationalisation. Surveys in three selected technology fields indicated that the internationalisation of R&D is mainly influenced by three factors, namely:

- early linkage of R&D activity to leading, innovative clients ("lead users") or to the "lead market"
- early coordination of the enterprises own R&D with scientific excellence and the research system
- close links between production and R&D.

Our analysis showed that internationally active enterprises think in terms of value-added chains and process chains (Jungmittag, Meyer-Krahmer, Reger 1999). Consequently, the criteria for selecting a location for R&D include not only factors of supply, such as a well-developed research infrastructure, but also demand factors, which increasingly play a more important part in the decisions of enterprises. Only by linking various value-added chains can (relatively) non-transferable "performance alliances" be created, establishing a country internationally in selected fields as a location for competence centres which could hardly be transferred, or duplicated, elsewhere.

The importance of lead markets in anchoring existing industrial R&D activities and attracting new activities has increased. The market's function as a "lead market" is decisive for innovations which only fully mature when they come into close contact with demanding, innovative customers. In fields of technology that are strongly science-based, it is the results of scientific research that constitute a driving force in the internationalisation of innovation processes. In both cases, regional proximity to external partners such as customers, competitors and scientific institutions is an advantage. If there is a close inter-linking of production and R&D activities, internationalisation of R&D follows internationalisation of production. The internationalisation of production is then the main driving force behind the internationalisation of R&D.

What are the characteristics of lead markets? They match one or more of the following criteria:

(1) a demand situation characterised by high income elasticity and low price elasticity or a high per capita income

(2) a demand with high quality requirements, great readiness to adopt innovations, curiosity concerning innovations and a high acceptance of technology

(3) good frame conditions for rapid learning processes by suppliers

(4) authorisation standards that are 'setting standards' for permit authorisation in other countries (e.g. pharmaceuticals in the US),

(5) a functioning system of exploratory marketing (‘lead user’ principles)

(6) specific, problem-driven pressure to innovate

(7) open, innovation-oriented regulation and frame conditions.

The attractiveness of a country or a continent from this perspective is determined not so much by comparative, static competition factors such as costs and wages, as by its ‘dynamic efficiency’. Economic theory differentiates between static efficiency - relating to one point in time - and dynamic efficiency - relating to a long-term development. It is quite possible for static and dynamic efficiency to conflict with one another. This is largely dependent on the extent of social and organisational intelligence in the finding and acceptance of new structures and markets. Will complex system innovations be elaborated in a region, which will be used worldwide? Offensive learning through numerous field trials and pilot schemes for the finding of technical, economic, legislative and social solutions is important. Learning processes of this kind often take years. The stipulation, fostering and organisation of this learning process in the area of complex innovations (such as road pricing systems, closed-cycle economic concepts, integrated product policies) is one of the most prominent tasks of such a policy. The innovation system that first succeeds in mastering these complex solutions gives participating enterprises competitive advantages, and appears more attractive to foreign investors.

5 Three scenarios of the role of innovations for economic development and ecological sustainability in the South

5.1 Technology transfer: tunnelling through the Environmental Kuznets Curve?

The discussion of the EKC hypothesis casts serious doubts that environmental problems are just a transitional problem. If one looks at the reductions of CO_2–emissions necessary to reach a stabilisation of the GHG concentrations, for example, it is evident that this target will not be reached if the forecasted increases in energy use in the countries catching up economically will be realised. Thus, a wait and see policy until the turning points in the EKC are reached will violate the critical sustainability thresholds (Figure 5).

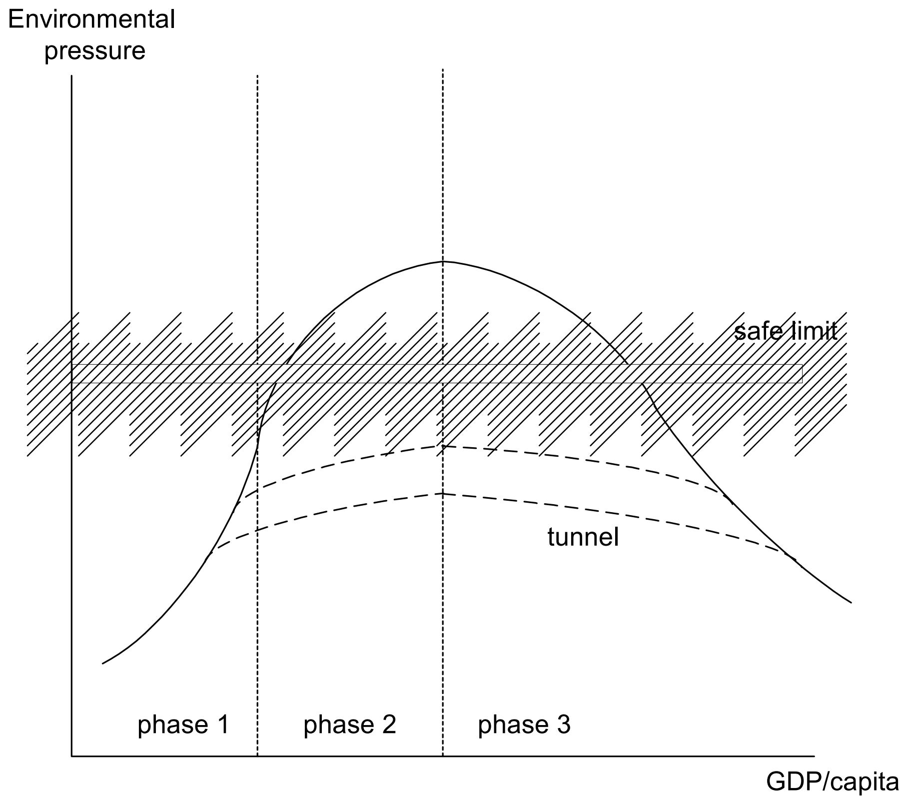
One scenario approaching this problem can be labelled "tunnelling through the EKC) (Munashinghe 1999). It is argued that countries catching up economically can realise the peak of their EKC at a much lower level of environmental pressure than the developed countries. Developing countries could learn from the past experience of industrialised countries allowing them to build a "strategic tunnel" through the EKC. Clearly technological development plays a very important role here. The development of the economies catching up can draw on the latest technologies which have not been available when the developed countries were going through the stages environmental pressure was peaking. Thus, in this scenario, technology transfer becomes a key for reconciling sustainability with economic development in the South.

The are a number of problems associated with this concept:

- The evidence on the existence of an EKC in the North is especially weak for the problems highly relevant to ecological sustainability. Thus, copying the technological structures of the North cannot guarantee ecological sustainability.
- A major obstacle to economic catching up is the lack of capital. Thus, countries catching up face problems to use the newest technologies in all sectors at the same time. Instead, a reasonable strategy is to concentrate on the latest technology in the sectors especially important for catching up (in the past, growing markets such as communication and information technologies were targeted as key sectors for economic development), and relying on rather average technology in the sectors not so important for success on the world market. This argument is consistent with first empirical results that indicate a substantial increase in the demand for second-hand heavy industry technologies with higher than state of the art emissions factors (German Council for Sustainable Development 2003).

- The effect of decreasing environmental pressure in the later stages of the EKC depends on the changing composition of the economy, with the heavy industrial sectors loosing importance. However, part of this effect might be due to an international specialisation pattern, leading to a reallocation of heavy industry to the countries of the South. Thus, the EKC may simply record a displacement of dirty industries from countries with high income level to countries with lower income level, leading to negatively sloped EKC in the first case and increasing slope of EKC in the latter case (de Bruyn 1999). However, such a realloction effect might work for parts of the world, as long as there are other parts to which the dirty industries can be shifted to, but it cannot work on a worldwide level. Thus, if the EKC hypothesis indeed is based on such a reallocation effect, it cannot be used as paradigm for the South because in absence of structural effects working towards sustainability the improvements in technology will be not be strong enough to balance the effects of economic growth on environmental pressure.

Figure 5: Tunnelling through the Environmental Kuznets Curve



(Source: According to Munasinghe 1999)

In addition to the open question whether the concept of tunnelling through might provide enough relief in environmental pressure required for ecological sustainability, there are also fundamental problems with such an approach. The concept more or less implies that the improvement is based on technology transfer and the diffusion of (mostly imported) technologies. To phrase it in more political terms: The countries of the South still (perhaps even more) depend on technologies developed in the North, they have to buy them – perhaps adding to unfavourable changes in the terms of trade. Thus, to put it bluntly, this concept perpetuates existing structures of dependencies between North and South.

5.2 Overcoming technological dependencies - lead markets for sustainability innovations in the South?

The shortcomings of the tunnelling through the EKC scenario lead to the question whether or not there is a chance for a more independent role of the South. Clearly, the idea of an autonomous national development independent from the world market, which had been brought forward in some discussions in the 1970's and the 1980's, seems to be obsolete, if one considers the export-oriented strategies of the countries which were able to catch up in the last 20 years, and the momentum of globalisation at the beginning of this century. Thus, the starting point of any strategy must be that it has to work within the paradigms which govern the international allocation decisions (see section 4.3), that is demand conditions, regime of production possibilities, and excellence of (national) innovation systems. Thus, a second scenario is that the countries of the South engage in sustainable innovations themselves and are competing with the North for lead roles in the development of innovations.

It remains an open question whether or not countries of the South have good chances for success with such a strategy. Clearly, the traditional demand situations favouring a lead market, such as high income elasticity and low price elasticity, are difficult to meet. On the other hand there is specific, problem driven pressure to act, which perhaps – together with a more policy driven demand - can make up for some of the deficiencies in the demand conditions. Another factor might be that countries of the South perhaps offer some of the key requirements for the technical functioning of some sustainability innovations (e.g. natural conditions as prerequisite for renewable energy). If rapid learning processes between suppliers and users are of special importance for the technologies involved, this might favour production to be located in these countries. Another chance might be to design favourable regulations and policies for the sustainability innovations, and to enhance the innovation system in such a way that it gains excellence especially with regard to factors important to sustainability innovations. However, such a policy would require much more understanding of the functioning of a technological system of sustainability innovation - a research task still lying ahead.

5.3 Radical innovation strategies for sustainability – advantages in the South?

A third scenario builds on the necessary changes for the radical innovations strategies for sustainability (see section 4.2). They are not incremental innovations along existing trajectories, but rather radical innovations leading to another path of development. However, in order to realise this strategies several obstacles have to be overcome. One key obstacle of radical innovations is path dependency. The third scenarios centres around various form of lock-in situations leading to path dependency. It is based on the assumption that these lock in situations are perhaps less severe in the South than in the North.

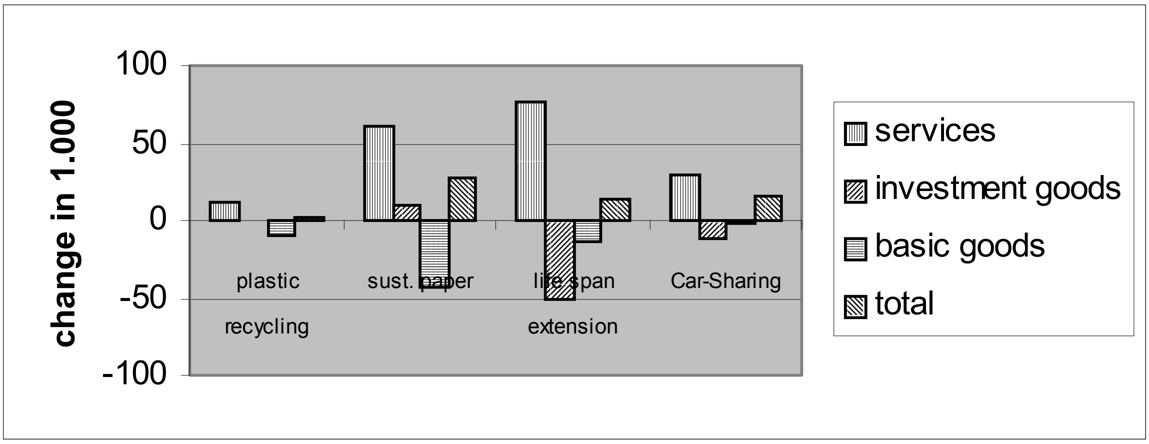
The are various forms of lock-in situations which can lead to path dependency:

- Technological lock-in hindering a change from one technological paradigm to another.
- Political lock-in, if the political power of the losers substantially outnumbers the power of the winners of the new innovations.
- Social lock in, if the social subsystem do not co-evolve in accordance with the potential of the technological subsystem.

With regard to ecological sustainability, technological lock-in in the North is most obvious in the large energy and water infrastructure systems. Both systems are characterised by centralised networks and the resulting monopolistic bottlenecks with both economies of scale and sunk costs. The time horizon of both industries is very long, with reinvestment cycles calculated in decades. Economic regulation has protected both industries, at least until recently. In both cases, however, technology development opens up the potential for a new technological trajectories based on decentralised technologies (e.g. renewable energy as cornerstone of a hydrogen economcy, decentralised water supply and sewage treatment). However, in both cases the economic logic and the problem of securing continuos supply during switching from one trajectory to the other lead to a lock-in into the existing technological paradigm. One possible solution to manage such a transition and to allow for learning is the creation of technological niches for the new paradigms (Kemp et al. 1997; Smith 2002). However, countries with a less developed system might have a better chance to find rather large niches allowing for both faster growth and increased learning effects which help to overcome the lock-in situation. Indeed, some activities in the case of decentralised water systems indicate that this technological path is considered in countries outside the North too (see Inter-American Development Bank 2002; World Bank et al. 2002).

The second lock-in relates to the political economy between losers and winners. The new innovations strategies clearly alter the traditional picture of political economy of the environment, which had been characterised as a stand-off between environmentalists one the one hand and industry on the other. Instead, the new political economy of sustainability innovations is characterised by winners and losers within the business community (Figure 6). According to the logic of collective action and regulation (Olson 1965; Peltzman 1976), both the conditions to organise as a lobby and the political power of each lobby decide on the political outcome. First empirical case studies for climate protection technologies (Walz 2000) and for case studies of new product concepts such as described in section 4.2. (Walz 2002) indicate that the losers clearly have better opportunities to organise themselves as a lobby than the winners. If this picture emerges as a pattern in the North, but not (as strong) in the South, it could perhaps be politically more feasible to mediate the resistance of the losers in the South.

Figure 6: Change in employment in sectors winning and loosing from sustainability innovation strategies for four case studies



(Source: Walz 2002)

The third lock-in situation relates to obstacles within the co-evolution of subsystems. In section 4.2 the need for changes in sociotechnical systems beyond a change in (technical) components was stressed. In addition to new knowledge, different rules, and sometimes new organisations, this change also depends on cultural and social values in a society. Innovation strategies such as selling services instead of products (e.g. car sharing) are hindered by lifestyles and social norms in which the status of a person is derived from ownership of certain products. Clearly culture has been identified as a factor in shaping national innovation systems. However, whether or not specific countries or cultures have advantages with regard to subsystem's co-evolution towards sustainability remains an open question.

6 Summary and conclusions

This paper focused on the interrelationship of innovation and sustainability in economic development. The following results of the analysis are of special importance:

- Both the political and the economic interpretation of sustainability have in common that environmental problems are a key challenge to sustainability, which, however, cannot be debated without the social and economic dimension. Above all, this puts the relationship between ecological sustainability and economic growth in the forefront.
- A critical analysis of the Environmental Kuznets Curve (EKC) hypothesis reveals that technological progress and structural change are key for this hypothesis. From the point of view of innovation research, the magnitude of these factors depend on the (national and/or technological) systems of innovation.
- There are different innovation strategies for sustainability, reaching from more traditional approaches such as end-of-pipe and integrated technologies to new product concepts and systems innovation, which open up new opportunities for business on the one hand, but emphasise learning effects and the co-evolution of social and technological subsystems on the other.
- There is not much evidence that the ecological sustainability problems can be left to the market alone. Instead, policies are necessary which foster sustainable innovation strategies. Thus, there has to be an integration of environmental policy and innovation policy.
- Under conditions of globalisation, establishing lead markets is becoming more and more important. The stipulation, fostering and organisation of this learning process in the area of complex innovations (such as new pricing systems, innovative forms of regulation; closed-cycle economic concepts, integrated product policies) is one of the most prominent tasks of such a policy. The innovation system that first succeeds in mastering these complex solutions gives participating enterprises competitive advantages, and appears more attractive to foreign investors.
- So far no clear picture for the countries in the South has been emerging. Three different scenarios point towards different paths of innovation and sustainability in economic development for these countries.

The last point deserves some additional remarks. Which of these three scenarios is the most plausible one remains an open question. The scenario “tunnelling through the EKC” relies on technology transfer. However, if this path will successful in reaching ecological sustainability remains highly uncertain. Furthermore, in this scenario, existing technological dependencies are perpetuated. The scenario “Lead markets in the South” opens up a more equal role for the countries. However, it remains unclear whether or not unfavourable demand conditions in the countries of the south really is substituted for by pressure to act and supporting policies. In addition, there is a need for increasing knowledge about functioning of sustainability innovation systems. Finally, existing path dependencies in the countries in the North might open up opportunities for countries in the South, depending on whether or not the lock-in situations are indeed less severe in the latter countries. This seems to be plausible for technological lock-in in some key sectors (e.g. water and energy). However, it is an open question if this also holds for political and social lock-in situations.

The analysis also yields first insights for future research strategies and topics. The following aspects are of special importance:

- Environmental economics can benefit from the heuristic approach of systems of innovations, e.g. with regard to explanations of the Environmental Kuznets Curve. However, this requires to focus future research on the functioning of (technological) innovation systems of sustainability innovations. A unique feature of these systems might be that regulation is perhaps more important than in other fields of technology. However, determining the actors of and key relationships within such systems, and even the measurement of its performance, are among the most difficult research tasks lying ahead (see Carlsson et al. 2002).
- There are a number of unresolved empirical research questions, such as the effects of trade patterns on environmental pressure, or whether or not the sectors targeted predominantly in the strategies for economic catch up are the ones also critical for environmental pressure.
- In order to design policies fostering lead markets for sustainability innovations in the countries in the South, a thorough analysis of existing conditions and bottlenecks is needed taking into account the specifics of the case analysed.
- The question has to be addressed whether or not the lock-in situations are really less severe in countries in the South, as the third scenario assumes.
- Finally, the importance of the factors perhaps favouring countries in the South has to be investigated, in order to come up with an conclusion whether or not their effects are substantial enough to matter, compared with other factors such as the “learning divide” between North and South (see Arocena/Sutz 2003).

To sum up, addressing sustainability issues requires a broad concept of systems of innovation (see Lundvall et al. 2002). Within such a framework, it will be possible to analyse the complex interrelationship between sustainability innovation strategies, learning requirements and competence building for both countries in the North and the South. Furthermore, this concepts is open to integrate the various disciplinary approaches necessary to deal with the future challenges of reconciling sustainability and economic development.

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