Introduction

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1 The need for sustainability innovations in newly industrialising countries

The growing need to reduce environmental pressure and to combat global environmental problems has led to an increased interest in analysing innovations, which result in a reduction of the environmental burden regardless of what the cause of their development has been. Very often, the term 'sustainability innovations' is used for this kind of innovations, to highlight the economic and social dimension of these innovations.

Achieving the Millennium Development Goals (MDGs) will require the enhancement of knowledge and application of new technologies (UN Millennium Development Project, 2005). This general need is underlined by specific trends for environmental sustainability: With the rapid economic development in the Newly Industrialising Countries (NICs), sustainability innovations are becoming increasingly urgent for various reasons: First, the economic development process leads to increasing environmental problems in the NICs. Second, tackling global environmental problems such as global warming also requires that low emission technologies are used all over the world. Third, these innovations also open up the opportunity for modernising the infrastructure, e.g., for renewable electricity generation, which in turn can lead to a feedback loop supporting further development and innovations (Ridley et al., 2006). Fourth, the growing market for sustainability technologies may open up the opportunity that NICs base their export-based economic development strategies on these technologies. Thus, there is a strong need to look specifically into the conditions for these kinds of innovations happening in the NICs.

2 Starting points for analysis of sustainability innovations in NICs

There has been considerable research on sustainability innovation, which can form a starting point for further analysis: On the one hand, the existing research on sustainability innovations, which predominantly has been dealing with countries of the North, can be extended to NICs. On the other hand, work on innovations and economic development

in NICs, which has been increasing lately, can be extended to specifically address sustainability issues. The following lines of research are especially important:

- the concept of tunnelling through the Environmental Kuznets Curve (EKC) or environmental leapfrogging
- empirical studies on determinants of eco-innovations within firms
- the concept of absorptive capacities as a prerequisite for economic and technological development
- the systems of innovation and sustainability transitions approaches
- the debate about innovation policy strategies and supporting strategic intelligence.

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. Within the global environmental debate, it is argued that NICs do not necessarily have to follow the emissions path of the industrialised countries. An alternative development path can be labelled "tunnelling through the EKC" or 'leapfrogging' (Munasinghe, 1999; Perkins, 2003; Gallagher, 2006). 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, because they can draw on the experience of industrialised countries allowing them to leapfrog to the latest sustainability technology. This leads to a 'strategic tunnel' through the EKC. Here, environmental economists put faith into quick technological development and knowledge transfer as a key for reconciling environmental sustainability with economic development in NICs. Thus, key issues seen within this concept are mechanisms to finance the transfer of the latest technology from the countries of the North to NICs, and policy concepts such as climate funds are based on this concept. However, the process of leapfrogging and the necessary conditions for technology transfer remain unclear. Innovation processes and technology transfer are a black box within this concept.

Another line of research has been concentrating on the behaviour of firms. There have been various studies recently using survey results for analysing the influence of various determinants of sustainability innovations in firms. Rehfeld et al. (2007) show that organisational aspects are of importance. Arimura et al. (2007) and Rennings et al. (2007) support the hypotheses that policy stringency is an important factor. Horbach (2007) stresses the point that different factors – environmental policy, management tools and general innovation capability of the firms – all contribute to sustainability innovations of firms. Popp et al. (2009) point towards the importance of restructuring markets and consumer pressure, respectively. Furthermore, there is evidence that firms that are very active in sustainability innovations also are economically very successful (Horbach, 2007; Frondel et al., 2007). However, these empirical studies have been dealing typically only with firms from the North. Thus, it is a challenge to extend this research approach towards NICs to find out whether these factors and findings are also valid in the NICs. Another topic on the firm level is the knowledge flow between companies and the role of FDI. Recently, also outward FDI activities of firms from the NICs have been investigated, e.g., in a special issue of the *International Journal of Globalisation and*

Technology (see Gammeltoft, 2008). It will be interesting to analyse what role sustainability innovations play in these activities.

The debate on absorptive capacities and technological gaps gained prominence among the scholars developing an evolutionary theory of trade (e.g., Soete, 1985; Perez and Soete, 1988; Dosi et al., 1990). Technological cooperation focuses on the knowledge base required by the technologies and on enabling competences in the countries. Since the end of the 1980s, the concepts of social or absorptive capacity (Abramovitz, 1986; Cohen and Levinthal, 1990) and technological capabilities (Lall, 1992; Bell and Pavitt, 1993) are widely known. The results of the research on technological development in NICs and the factors that influence the build-up of their technological capabilities (e.g., Lall, 1998; Lee and Lim, 2001, Lee et al., 2005; Lee, 2005; Fagerberg and Godinho, 2005; Nelson, 2007; Malerba and Nelson, 2008; Rasiah, 2008; Wamae, 2009) have underlined the importance of absorptive capacity and competence building. This challenge has to take into account the changing conditions for learning and knowledge acquisition. One aspect to consider is the tendency that the build-up of technological and production capabilities is increasingly separated (Bell and Pavitt, 1993). Another aspect relates to the effect of globalisation on the mechanisms for knowledge dissemination. Archibugi and Pietrobelli (2003) stress the point that importing technology has per se little impact on learning and call for policies to upgrade cooperation strategies towards technological partnering. Nelson (2007) points to the changing legal environment and the fact that the scientific and technical communities have moved much closer together. All these factors lead to the conclusion that domestic competences in sustainability-related science and technology fields are increasingly a prerequisite for the successful absorption of green technologies in NICs.

In the 1990s, the heuristic approach of systems of innovation gained wide acceptance (see, e.g., Lundvall et al., 2002; Edquist, 2005). In addition to the demand and technology factors, this approach underlines the manifold aspects of the intra-firm determinants of innovation, the characteristics of innovation as an interactive approach, the role of institutions in shaping activities, the importance of the home market as a base for competitiveness on the international markets and the regulatory framework. The key notion of the systems of innovation approach is that these factors influence each other, highlighting the importance of feedback mechanisms. This results in an expansion of the influencing factors. In addition to players estimating the profitability of innovations and the communication patterns between the participants, increased significance is being attached to soft context factors, such as the regulatory pattern between policy and those governed. More recently, the system of innovation framework has been applied to analyse technological or sectoral systems (Carlsson et al., 2002; Malerba, 2005). These approaches share the starting point that innovations can be best explained by characterising the components of an innovation system, such as actors, networks and institutions (including regulation) and their interaction with each other.

Like the systems of innovation approach, the sustainability transitions approach also is based on evolutionary economic thinking. It analyses the conditions that a sustainability innovation, which competes with an existing technological regime under a given landscape, can grow out of its niche (e.g., Haxeltine et al., 2008). Thus, this approach highlights problems such as path dependency, which are of uttermost importance especially for innovations in network-based industries. Recently, the transitions management approach has led to new advances in quantitatively modelling the innovation and diffusion processes (Köhler et al., 2009). Furthermore, there is an

increased interest in how to apply the framework of transitions management to NICs (Berkhout et al., 2009a, 2009b).

The system of innovation concepts is increasingly used also for environmental technologies. The number of publications in this field is increasing, especially with regard to renewable energy. Some of this literature suggests that an innovation system can be best analysed by looking at how the different functions an innovation system has to meet are fulfilled (Hekkert et al., 2007; Bergek et al., 2008). At the same time, there is work going on how to apply and adapt a system of innovation approach towards the countries of the south (Muchie et al., 2003; Muchie and Baskaran, 2007; Malerba and Nelson, 2008; Cassiolato and Vitorino, 2009; Malerba and Mani, 2009; Naclerio, 2010). Clearly, there is a strong need for research, which combines these two developments and uses a system of innovation approach for analysing sustainability technologies in NICs. Important questions here are, for example: To what extent do sustainability innovations in NICs depend on their ability to adopt current sustainability technologies from the OECD countries? How to measure absorptive capacities in the NICs? What are the best policies to increase this capability, and what are the incentives for NICs to concentrate their efforts in this policy arena? To what extent are firms in NICs becoming part of global production networks, where technology is shared between firms as part of a vertically integrated production network of firms in different countries? What are the economic prospects of NICs in pursuing such a strategy, e.g., with regard to becoming an important supplier of sustainability technologies on the world market?

The debate about strategies of innovation policies is also highly relevant for sustainability innovations in NICs. Recently, innovation policy strategies for low carbon technologies are debated. Given the need for radical innovations towards a low carbon economy, a targeted approach is necessary. However, the differences to the traditional mission-oriented approaches such as the Apollo project make a new approach necessary (Mowery et al., 2010). Indeed, the need to push both incremental and radical innovations in various technological fields, which have to be supported by numerous organisational and institutional innovations and which will involve much more actors over the entire value chain of the technologies, requires nothing less than a new approach, which might be called visions-based sustainability innovation policy. The integration of the various policy arenas involved will be a key challenge. However, this debate is so far only just emerging for traditional industrialised countries. Within NICs, first results for the BRICS countries indicate that there is hardly a targeted approach for sustainability research at all (Walz, 2010). Furthermore, it has to be seen whether the NICs will frame sustainability innovations also as an object of industrial policy, and if they will start to tackle the associated problems of policy integration.

The innovation policy debate early on has expressed the need to support policy making by measurement of innovations. A substantial amount of work exists using innovation indicators and building aggregated innovation indexes, and the success and drawbacks of the methodologies are reflected upon recently (Freeman and Soete, 2009; Archibugi et al., 2009). For the traditional industrialised countries, work has been started recently to apply innovation indicators to sustainability innovations, e.g., within the context of the OECD (Johnstone et al., 2008) or to support national government strategies (e.g., Walz et al., 2008). However, there is a clear need to further elaborate these methodologies towards the specific requirements of sustainability innovations, and – even more important – to apply and adapt them for this field in the NICs.

3 Contents and structure of the special issue

The papers included in this special issue on "sustainability innovations in NICs" are all related to the concepts introduced in the previous section. In the first part, the papers by Watson and Sauter, Peuckert, Walz and Marscheider-Weidemann, Doranova et al. and Liu et al. address cross-cutting questions about the state of capabilities in the NICs, and the process to enhance them. In the second part, case studies on sustainability technologies – wind turbines, fuel cells and biofuels – are analysed by Lewis, Zeeda, Dantas, and Lopes de Souza and Hasenclever.

In their paper "Sustainable innovation through leapfrogging: a review of the evidence", Jim Watson and Raphael Sauter from SPRU review the experience with leapfrogging in various sectors. Sufficient level of absorptive capacity is a core condition for successful leapfrogging. Absorptive capacity is often built up over a significant period of time and countries tend to build capabilities in fields related to existing strengths. It includes not only technological capabilities (i.e., the resources for generating and managing technical change), knowledge and skills, as well as supportive institutions in terms of laws and regulation, but also informal habits and routines for knowledge exchange. The accumulative nature of knowledge poses a challenge for leapfrogging, because it implies a non-linear relationship between absorptive capacity and catching-up. Specific opportunities for leapfrogging of NICs may arise because NICs can draw on earlier experience with the technology, which lowers their risk, or because they have avoided an earlier lock-in into an existing technology, which enables them more quickly utilise the opportunities of the emergence of new technological paradigms or disruptive innovations.

Jan Peuckert from the Technical University of Berlin contributes a paper on the "Assessment of the social capabilities for catching-up through sustainability innovations". He uses survey data and principal component analysis to derive both an index for the general innovation capabilities of 15 NICs, and of the sustainability selection environment. His work shows that both innovativeness and sustainability are to a very high degree positively correlated. The results suggest that there are basic institutions such as the educational system, the quality of infrastructure and international linkages that promote both innovation and sustainability.

Rainer Walz and Frank Marscheider-Weidemann from Fraunhofer ISI address the measurement of technology-specific absorptive capacity for sustainability technologies. In their paper on "Technology-specific absorptive capacities for green technologies in Newly Industrialising Countries", they use publication, patent and export indicators to measure the technological capability of 14 NICs with regard to six clusters of sustainability innovations. Their results show which of the NICs are more likely to participate from the economic opportunities arising from green innovations, and which are less likely to do so, at least in the near future. However, they point towards the need that such an analysis has to be performed on a disaggregated, technology-specific level. Furthermore, the indicator approach has to be augmented by qualitative case study research to account for the complexity of the factors relevant for the success of an innovation system.

The paper of Asel Doranova from Technopolis, Ionara Costa from UNU-MERIT and Geert Duysters from Eindhoven University on "The role of absorptive capacity in technological learning in CDM projects: evidences from survey in Brazil, China, India and Mexico" looks on the build-up of firm-level technological capabilities. They focus on

absorptive-capacity-related determinants of technological capability building in the CDM projects, such as prior knowledge, personnel qualification and training efforts. On the basis of a survey of CDM host companies, they use econometric analysis to establish that a strong positive association between prior knowledge and success of the CDM projects to transfer knowledge exists. Thus, their results also confirm the nature of knowledge as an accumulative process.

The topic of the determinants of sustainability innovations is addressed by Xielin Liu, Hongyi Dai and Peng Cheng from the Graduate University of the Chinese Academy of Sciences. Their paper on "Drivers of integrated environmental innovation and impact on company competitiveness: evidence from 18 Chinese firms" examines the drivers of the innovations and their respective effects on company competitiveness based on 37 interviews of 18 Chinese firms. They find that environmental innovation in China is driven by a mixture of factors of environmental regulation, cost pressure, competitive advantages and customer pressure. They also see evidence that environmental regulation stimulates innovation and leads to 'win-win' opportunities where simultaneously pollution is reduced and competitiveness increased.

In the paper "Building a national wind turbine industry: experiences from China, India and South Korea", Joanna I. Lewis from Georgetown University explores the strategies used by the domestic wind power technology companies in each of these three countries to develop wind turbine technology. Its focus is to understand how three newly industrialised countries have acquired and assimilated advanced technologies. It finds that the primary technology transfer and acquisition strategies utilised by firms in South Korea, China and India included licensing arrangements and mergers and acquisitions that resulted in the transfer of technology ownership and partnerships for the joint development of new technology.

Fatimah Mohamad Zeeda from the University of Malaya contributes a paper on "The emergence of fuel cell technology and challenges for catching-up by latecomers: Insights from Malaysia and Singapore". She uses the functions of a technological system of innovation to investigate the challenges faced by latecomer countries in their efforts to catch-up in the development of an emerging technology like fuel cells. Her comparative study reveals that higher development of the fuel cell innovation system can be attributed to three institutional factors: presence of primary actors to align activities, synergy between complementary policies and openness to internationalisation activities.

The paper by Eva Dantas on "The evolution of the knowledge accumulation function in the formation of the Brazilian biofuels innovation system" combines a technological system of innovation approach with the capability approach. The latter is used to specifically investigate how the knowledge accumulation function within the technological innovation system of biofuels has been developing. It is shown that the Brazilian biofuel innovation system initially built upon adaptations and improvements of a well-known technology. A number of factors contribute to explain the development in knowledge accumulation in the Brazilian biofuels innovation system. Central among them were home demand and market formation and the creation of institutional incentives for the firms.

Taynah Lopes de Souza from Inmetro Brazil and Lia Hasenclever from UFRJ also analyse "The Brazilian system of innovation for bioethanol: a case study on the strategic role of the standardisation process". They start from a national system of innovation approach and focus on the role of the standardisation process as a case example of the need of institutional and organisational innovations co-evolving together with the

technological innovations. They conclude that standardisation is of strategic importance for the innovation process, and call for active governmental policies to develop competences for standardisation in NICs.

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