Assessing absorptive capacities for sustainability technologies in emerging economies – experiences with an indicator approach

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Abstract:

The challenge posed by sustainable development is becoming increasingly urgent from a global perspective. For the development process in the rapidly growing economies, knowledge transfer and technology cooperation are becoming important issues. The prospect of exporting sustainability technologies can add an additional incentive for emerging economies to move towards sustainability technologies.

Both strategies require absorptive capacities and technological competences in the sustainability technologies. Based on the heuristics of a system of sustainability innovation approach, these issues are analysed empirically for 15 countries. The general framework conditions are analysed using different data sources. They include R&D indicators, and survey results about the general innovation framework, but also an assessment of the importance of environmental sustainability in the analysed countries. Technological competences in the sustainability fields are a key indicator for the absorptive capacity of sustainability technologies and for the ability to export them. International patents and publications, and successes in foreign trade indicate to what extent a country is already able to 'open up' internationally. The resulting pattern shows various strengths and weaknesses of the countries. Based on the results, the countries are grouped into 4 different clusters, with different starting points for developing strategies and policy discourses on how to strengthen their absorptive capacities. A disussion about the usefulness of such an indicator approach shows various strengths and weaknesses. Clearly the use of such indicators must be accompanied by careful interpretations, reflections about the limits of the indicators, and additional qualitative analysis.

Keywords: sustainability technologies, systems of innovation, absorptive capacities, patents, trade pattern, emerging economies

1 Introduction

The challenge posed by sustainable development is becoming increasingly urgent from a global perspective. The question raised is how economic growth in transforming and newly industrializing countries can be designed in such a way that it does not undermine the achievement of ecological sustainability goals. At the same time, sustainable innovations can also play an important role for the economic and technological development of transformation and emerging economies. In addition, the prospect of establishing lead markets for sustainability technologies adds an additional incentive for emerging economies to move towards sustainability technologies.

Based on an innovation approach, prior work has been done to assess these issues for the BRICS countries (Walz et al. 2008a). In this paper, the analysis is enlarged to 15 countries on the one hand. On the other, the first experiences gained are used to trigger a methodological reflection about the experience with such an indicator based approach.

The first part of the paper deals with conceptual issues. First, the importance of innovation and technology cooperation are discussed within the traditional view of environmental economics on global environmental challenges. Second, prerequisites for successful technology cooperation and establishing lead markets for sustainable development are presented. Finally, the empirical research concept and its integration into a system of sustainability innovations are explained.

The remainder of the paper analyses 15 countries and is based on an updated and enlarged version of the analysis for the German Council for Sustainable Development (Walz et al. 2008). In addition to taking 15 countries into account, the technological capabilities and the research system is analysed with regard to 6 fields of sustainability technologies: (1) energy efficiency, among residential and industrial energy users, (2) environmental friendly energy supply technologies, including renewable energy, cogeneration and clean coal, but excluding nuclear energy (3) material efficiency, including renewable resources, ecodesign of products and recycling, (4) transport technologies, (5) water technologies, and (6) waste management technologies. The empirical results include a rough assessment of the development of the environmental pressure and an assessment of the general framework condition for innovation. Furthermore, the technological fields are analysed with innovation indicators such as publications, patents and specialization in trade.

Based on these results, a first discussion about the use of indicators in assessing absorptive capacity is performed.

2 CONCEPTUAL ISSUES

2.1 Technological innovations as key to tackle environmental challenges

There is general consensus that environmental sustainability requires an integration of environmental friendly technologies in the economic catching up process of the emerging economies. This challenge is discussed within the concept 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 suggested for income inequality and economic per capita income.

Within the global environmental debate, it is argued that emerging economies do not necessarily have to follow the path of the industrialized countries. An alternative development path 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 draw on the experience of industrialized countries allowing them to build a “strategic tunnel” through the EKC. Here, clearly technological development and knowledge transfer play a key role. Thus, technological cooperation and knowledge transfer becomes a key for reconciling environmental sustainability with economic development. However, there are two critical questions to this concept: First, is the interest of the emerging economies strong enough to push in that direction, and second, are the countries – given their stage of development - able to absorb the sustainability technologies?

2.2 Prerequisites for sustainability technologies innovations

Based on the pollution haven hypothesis and the environmental dumping mechanism it can be argued that there might be a disincentive for strong environmental policies in the emerging economies in order to attract pollution intensive industries (see Copeland/Taylor 2004). However, there are also different incentives for emerging economies to push for sustainability technologies. Firstly, the sustainability technologies analysed in this paper influence many of the most discussed environmental problems (see section 2.3). Thus, their diffusion would help to improve the environment in the home countries. However, this argument holds less for global environmental challenges such as global warming, which lead to impacts across the world and which require global action. Secondly, the analysed sustainability technologies improve the infrastructure, e.g. in the energy, water or transportation sector, or address the growing demand for raw materials in the emerging economies. Thus, they are part of a necessary modernization strategy. Thirdly, moving towards environmental sustainability will create huge international markets for technologies. It is estimated that the sustainability technologies will be a major market in the future, surpassing other key sectors such as automotive or machinery. Forecasts for the world markets up to 2020 show that the average annual growth rates for technology demand in the fields of energy supply, energy efficiency, transport, water and material efficiency amount to 5 to 8 % per year. These high growth rates will lead to an annual demand for technologies in these five fields above 2.000 billion Euro in 2020 (Roland Berger 2007). Thus, another incentive is that the emerging economies engage in the development and production of these technologies and compete with the North for lead roles in supplying the world market with sustainability technologies.

The potential for technological cooperation focuses on the knowledge base required by the technologies and on enabling competences in the countries. Since the end of the 1980’s, the concepts of Social or Absorptive Capacity (Abramovitz 1986; Cohen/Levinthal 1990) are widely known. The results of the Knowledge Management Research (e.g. Nonaka/Takeuchi 1995) and of the catching-up research in the last years (e.g. Fagerberg/Godinho 2005; Nelson 2004) have underlined the importance of absorptive capacity. Furthermore, there is increasing debate about the changing nature of technology transfer and cooperation with regard to learning and knowledge acquisition. One aspect to consider is the effect of globalisation on the mechanisms for knowledge dissemination. Archibugi and Pietrobelli (2003) stress the point that the import of technology has little impact on learning, and call for policies to upgrade cooperation strategies towards technological partnering. Nelson (2007) highlights the changing legal environment and the fact that the scientific and technical communities have been moving much closer together. All these factors lead to the conclusion that indigenous competences in sustainability related science and technology fields are a prerequisite for the successful absorption of sustainability technologies in emerging economies.

Above all, for technology-intensive goods, success in foreign trade depends on the innovation ability and the achieved learning effects of a national economy and its early market presence. If there is a forced national strategy to increase the use of sustainability technologies, these countries tend to specialise early in the supply of the necessary technologies. If there is a subsequent expansion in the international demand for these technologies, as indicated by the high market forecasts quoted above, then these countries are in a good position to dominate international competition due to their early specialisation in this field (see Blümle 1994; Porter/van der Linde 1995). Thus, emerging economies could develop an economic interest to push for diffusion and development of sustainability technologies in their countries, in order to reap the benefits of this first mover advantage.

For first mover advantages to be realised, however, the domestic suppliers of the technologies have to be competitive internationally so that they and not foreign suppliers meet the growing demand at home and on the world market. Taking the globalisation of markets into account, this requires establishing lead markets with competence clusters which are difficult to transfer to other countries. These competence clusters must consist of high technological capabilities linked to a demand which is open to new innovations and horizontally and vertically integrated production structures. The following five factors have to be taken into account when assessing the potential of countries to become a lead market in a specific technology:

(1) Lead market capability of the technology: One prerequisite is that competition is driven not by cost differentials alone, but also by quality aspects. This is especially valid for knowledge-intensive goods with high innovation dynamics and high potential learning effects. In general, the technology intensity of sustainability technologies can be judged as being above average or even high tech.

(2) Competitiveness of industry clusters: Learning effects and user-producer interaction are more easily realized if the flow of (tacit) knowledge is facilitated by proximity and a common knowledge of language and institutions. These factors are not easily accessible, difficult to transfer to other countries and benefit from local clustering (see Asheim/Gertler 2005; Kline/Rosenberg 1986; Lundvall/Johnson 1994). The empirical results of Fagerberg (1995b) underline the importance of this effect. By and large, sustainability technologies have very close links to electronics and machinery. Thus, it can be argued that countries with strong production clusters in these two fields have a particularly good starting point for these technologies.

(3) The importance of the demand side is stressed by Dosi/Pavitt/Soete (1990), van Hippel (1988), or Porter (1990). There are various market factors which influence the chances of a country to develop lead market position (see Beise/Cleff 2004). In general, a demand which is oriented towards innovations and readily supports new technological solutions benefits a country in developing a lead market position. The price advantage of countries is very important which benefits countries increasing their demand fastest and thus most able to realize economies of scale and learning effects.

(4) In addition to technological and market conditions, a lead market situation must also be supported by innovation-friendly regulations (Blind/Bührlen/Menrad/Hafner/Walz/Kotz 2004). This is especially true for sustainability innovations in infrastructure fields such as energy, water or transportation. In these fields, the innovation friendliness of the general regulatory regime, e.g. with regard to IPR or the supply of venture capital, must be accompanied by innovation-friendly sectoral and environmental regulation resulting in a triple regulatory challenge (Walz 2007).

(5) Since the Leontief Paradox and subsequent theories such as the Technology Gap Theory or the Product Cycle Theory, it has become increasingly accepted that international trade performance depends on technological capabilities (see e.g.

Archibugi/Michie 1998; Fagerberg 1994). This has been supported by recent empirical research (e.g. Fagerberg 1995a; Fagerberg/Godinho 2005; Wakelin 1997) which underlines the importance of technological capabilities for trade patterns and success. Thus, the ability of a country to develop a first mover advantage also depends on its comparative technological capability. If one country has performed better in the past with regard to international trade than others, it has obtained key advantages on which it can build future success. Furthermore, a country has an advantage in developing future technologies if it has a comparatively high knowledge base as shown by patents.

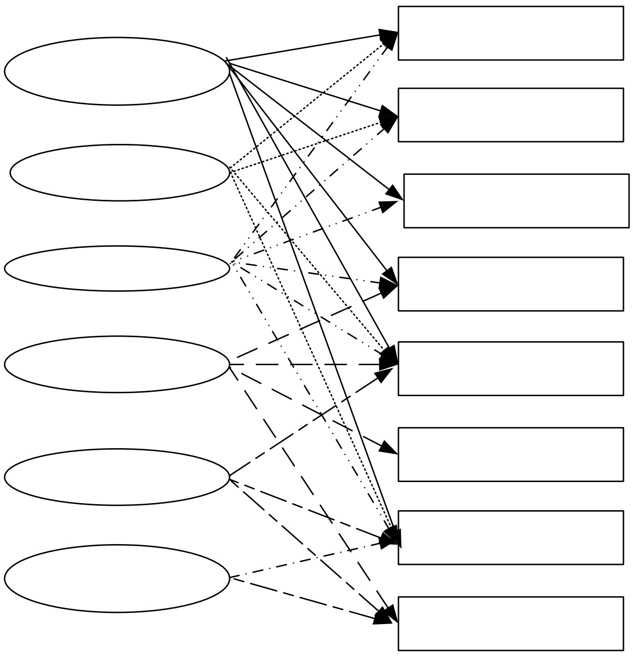
Altogether, it is more and more acknowledged that the absorption of developed technologies and the development of abilities to further advance these technologies and their international marketing are closely interwoven (Nelson 2007). For both strategies - transfer of knowledge from traditional industrialized countries and establishing export oriented lead market position – it is necessary to develop a functioning system of sustainability innovations.

Figure 1: Aspects of absorptive capacity for sustainability technologies

2.3 Research concept

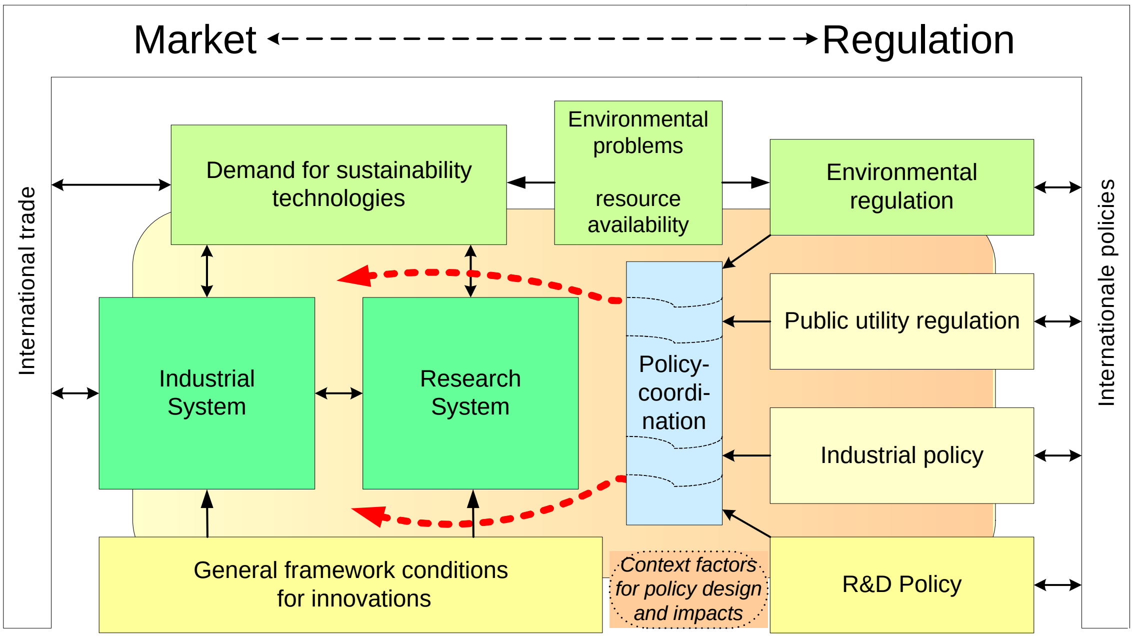
The research concept looks at sustainability technologies in the six areas of energy supply, energy efficiency, material efficiency, transportation, water, and waste managemen. These technological areas address many of the most pressing environmental problems in both OECD countries and emerging economies (Figure-2). The indicator approach chosen is applied to 15 countries, which sometimes are labelled under the term emerging economies: Argentina, Brasil, Chile, China, India, Indonesia, Malaysia, Mexico, Phillipines, Singapor, South Africa, South Korea, Taiwan, Thailand, Venezuala; 8 of these countries also belong to the Group of 20 (G 20). Thus, the countries analysed are increasingly becoming an important factor on the global political scene.

Figure 2: Influence of selected sustainability technologies on environmental themes



The systems of innovation approach serves as heuristic background of the analysis. This approach highligths the various actors and their communication pattern. In addition to traditional R&D policies the factors influencing the demand for technologies are also an important driver for future innovations. However, sustainability technologies differ from "normal" innovations in manufacturing in this respect. The formation of demand depends strongly on the specific role of regulations which are especially important for innovations in the energy, water and transportation field: environmental regulation, which act as an important driver for the demand of technologies in this field, and economic sector regulation, which is necessary in order to deal with monopolistic bottlenecks so common in network based industries, but also influences the incentives of the actors in technology decisions. Thus, sustainability technologies face a triple regulatory challenge (Walz 2007). This also leads to the conclusion that policy coordination between the different regulatory regimes becomes a major challenge for policy making.

Figure 3: Scheme of a system of sustainability innovations



The concept of a system of sustainability innovation (Figure 3) can also be used to explain the manifold aspects which must be addressed in empirical research. In the remaining of the paper, empirical results for the following 3 aspects are presented: (1) The framework conditions for innovations are analysed by using science and innovation indicators, and survey data from WEF (2006). Thus, the results depend on the analytical framework of these approaches, and must be cautiously interpreted. (2) Survey results on the importance of sustainability in the countries, and results of environmental indicators are used for describing environmental problems. (3) The technological capabilities of the countries are associated with the industrial and research systeme. They are analysed with innovation indicators (see Grupp 1998 and Smith 2005). Patent, publication, and trade indicators are used:

- The publication data draws on publications in the SCI index. For each country, the development of publications in the field “environmental engineering” are contrasted with the development of the total publication of the country in the SCI. It is acknowledged that especially for engineers, publications are only one possible outlet of research results. However, especially by looking at the dynamics over time, this indicator gives important hints about the relevative importance of different fields and their change over time.
- The patent searches primarily draw on patent applications at the World Intellectual Property Organization and thus international patents. In this way, a method of mapping international patents is employed which does not target individual markets such as Europe but is much more transnational in character. The emerging economies' patents identified in this way reveal those segments in which patent applicants are already

taking a broader international perspective. The years 2002-2006 were chosen as the period of study so that a statistically more reliable population is achieved in which chance fluctuations in individual years are evened out.

- The database UN-COMTRADE is referred to for foreign trade figures. This is not limited to trade with OECD countries, but also covers South-South trade relations. In addition, the classification of the technologies is using the Harmonised System (HS) 2002. This foreign trade classification allows more disaggregation and therefore a better targeting of the sustainability technologies compared with the older classifications common in international comparisons (Standard International Trade Classification (SITC)).
- For both patent and trade indicators, the share of the countries at the world total was calculated (patent share, world export share). Furthermore, relative indicators (relative patent share (RPA); relative export share (RXS) and revealed comparative advantage (RCA) were calculated, in order to analyse whether or not the emerging economies specialize on the sustainability technologies. All specialization indicators are normalized between +100 and –100 (see Grupp 1998). Positive values indicate an above average specialization on the analyzed technologies, a negative value shows that the country is more specializing on other technologies.
- Sustainability technologies are neither a patent class nor a classification in the HS-2002 classification of the trade data from the UN-COMTRAD databank which can be easily detected. Thus, for each technology, it was necessary to identify the key technological concepts and segments. They were transformed into specific search concepts for the patent data and the trade data. This required an enormous amount of work and substantial engineering skills. Furthermore, there is a dual use problem of the identified segments, and some segments – especially in the trade data - don't necessarily indicate that the technology contributes to sustainability as such. In order to reflect that ambiguity the term sustainability relevant technology is used.

3 EMPIRICAL RESULTS

3.1 General framework conditions for innovations

The data on quantitative innovation capacity give a first indication of the general conditions for innovation. The volume of national R&D intensity or the sectoral share of the R&D expenditure of industry is very different for the emerging economies covered. It reaches from very small numbers to values typical for OECD countries, like for Singapor, Taiwan, or South Korea. Thus, there is considerable heterogeneity the analysed countries.

Figure 4: R&D indicators for the analysed economies

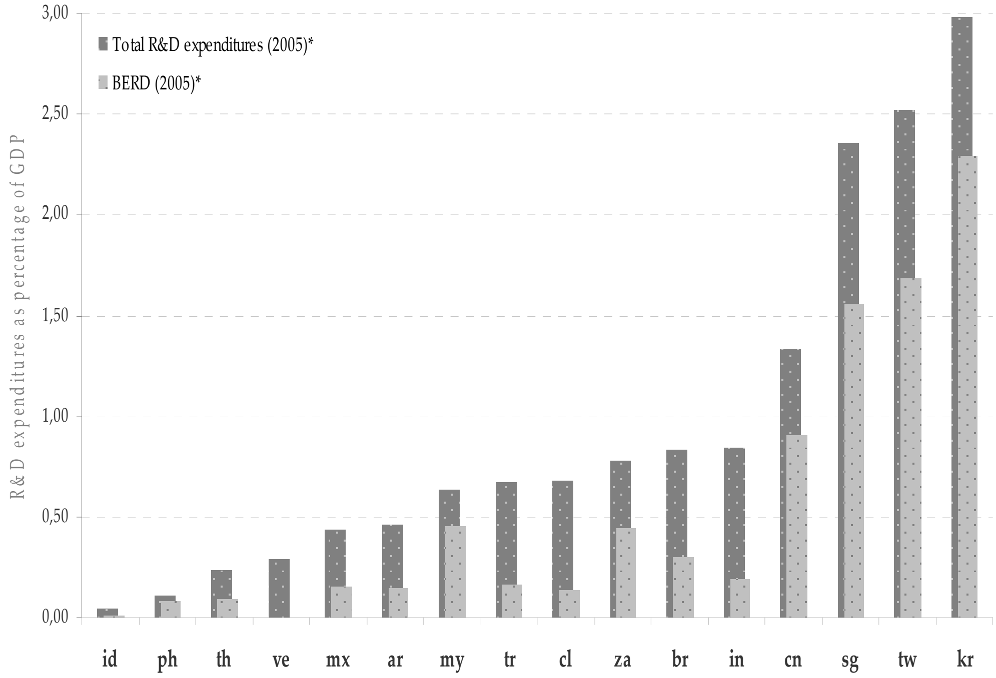
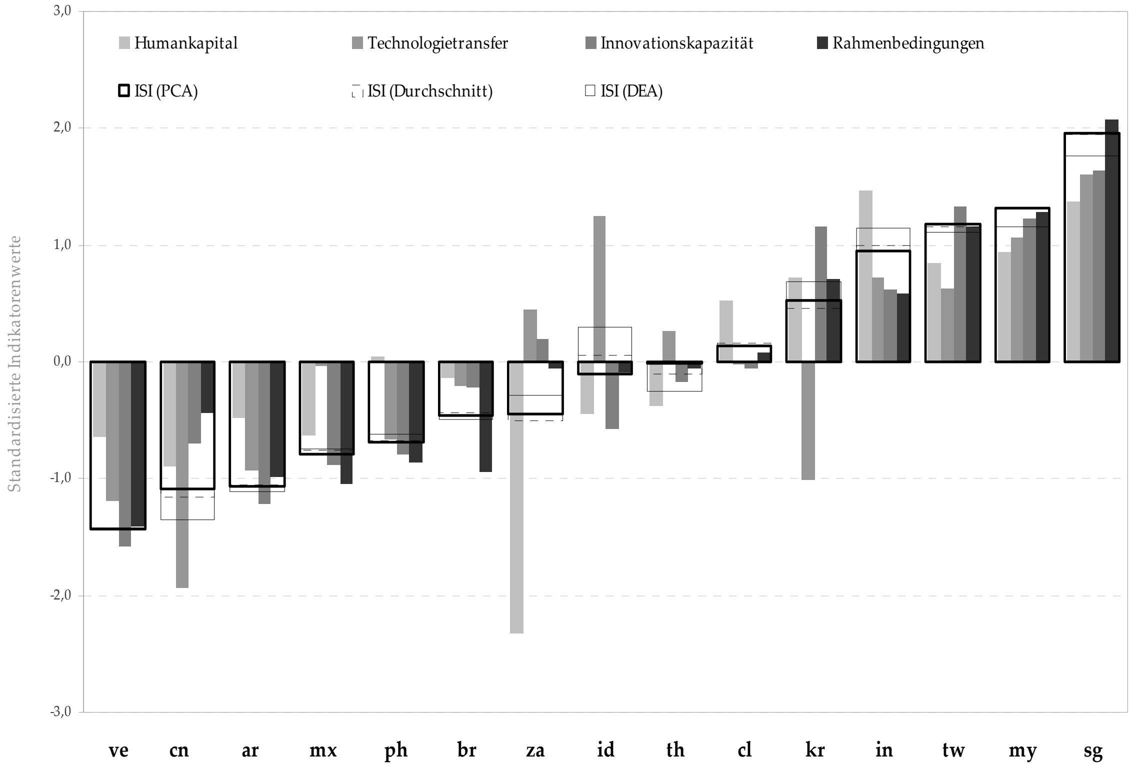


Figure 5: Results according to survey data from WEF and IMD to the general innovation conditions in the BRICS countries



A second approach for the analysis of the general framework conditions follows the survey data of the WEF (2006). The indicators are divided in human resources, technological absorption, innovation capacity and innovation friendliness of regulation. They are aggregated using principal component analysis (see Peukert 2008). According to these survey results, Singapor, Taiwan and South Korea, but also Malaysia and India are classified as those countries with the best framework conditions among the analysed countries. Various sensitivity analyses to account for the effects of different aggregation methods have been used, without significantly influencing the result. Thus, from that particular technical point of view, the results are rather robust (see also chapter 4).

3.2 Environmental Problems and Importance of Sustainability Issues

Environmental problems and growing resource consumption are an important driving force for the diffusion and development of the sustainability related problems. However, even after many years of development of environmental indicator data, there are still important deficiencies in the availability of a comparable worldwide database. Part of the problem arises that the available data are only of limited use for analysing the state of the environmental data. In the case of water pollution, for example, it is feasible to get simple data such as the biological oxygen demand, however, there is only limited emission data available even for mass pollutants such as nitrogen and phosphorous or hazardous substances such as heavy metals.

Looking at the available data, it becomes clear that there are substantial differences within the emerging economies at a per capita level. On the other hand, in each country, there is a strong push towards even higher emissions levels, accelerating the environmental problems evern more. Thus, there is a growing need to reduce emissions levels in order to prevent health damange and negative ecological consequences from environmental problems in all countries.

In addition to the growing pressure shown by environmental indicators, the importance of environmental problems also depends on the way the problems are perceived, and on the policy reactions they trigger. Thus, existing surveys from WEF on the importance of the environment within the emerging economies were used. The results are given in Figure 7. It becomes clear that the importance of environmental topics does not always reflect the growing pressure. Furthermore, the same survey also asks for the importance of social sustainability issues. Figure 8 shows both environmental and social sustainability in a two dimensional diagram. It becomes obvious that the importance of both issues is working quite often in parallel. Furthermore, the results of the survey of the general innovation capabilities were included into the diagram in form of the size of the circle. In general, there is a tendency that larger innovation capability (large circle) seems to go along with higher importance of social and environmental sustainability issues.

Figure 6: Selected Environmental Indicators for the analysed countries

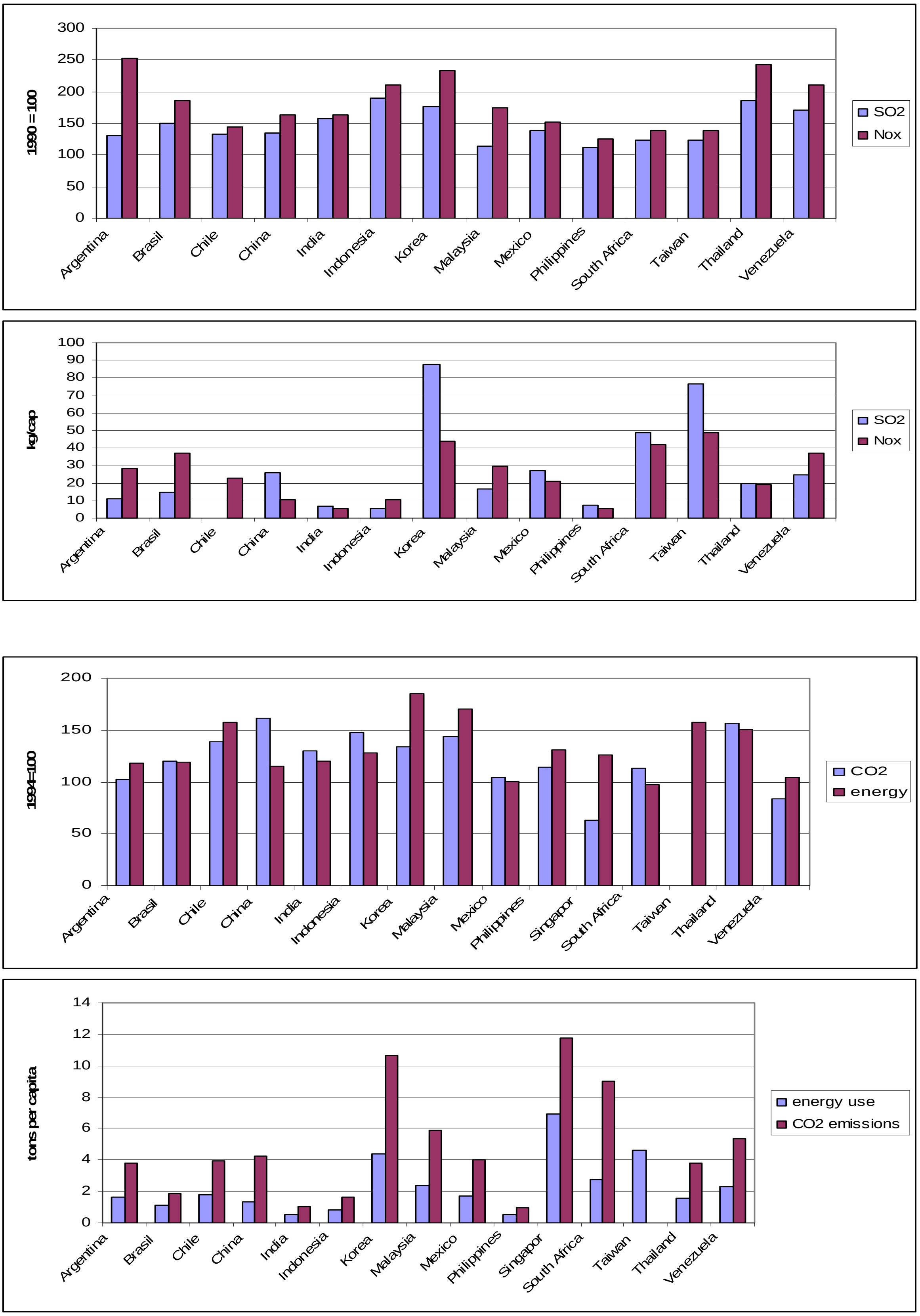


Figure 7: Results of survey on importance of environmental sustainability topics in the analysed countries

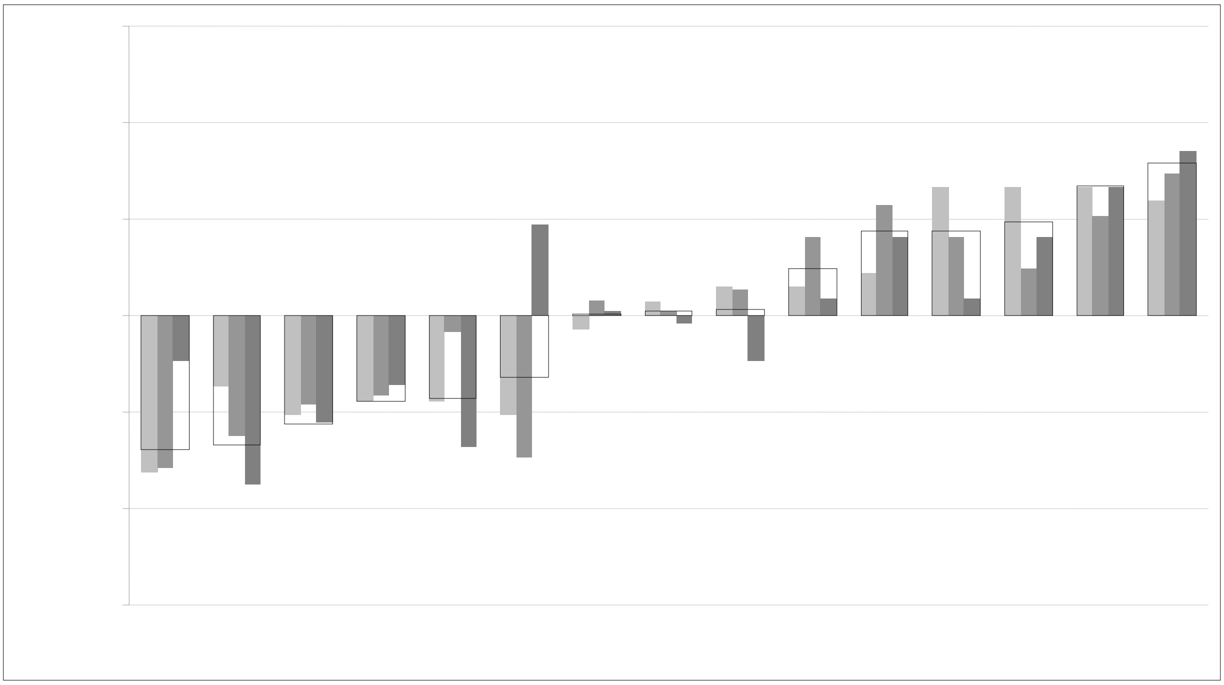
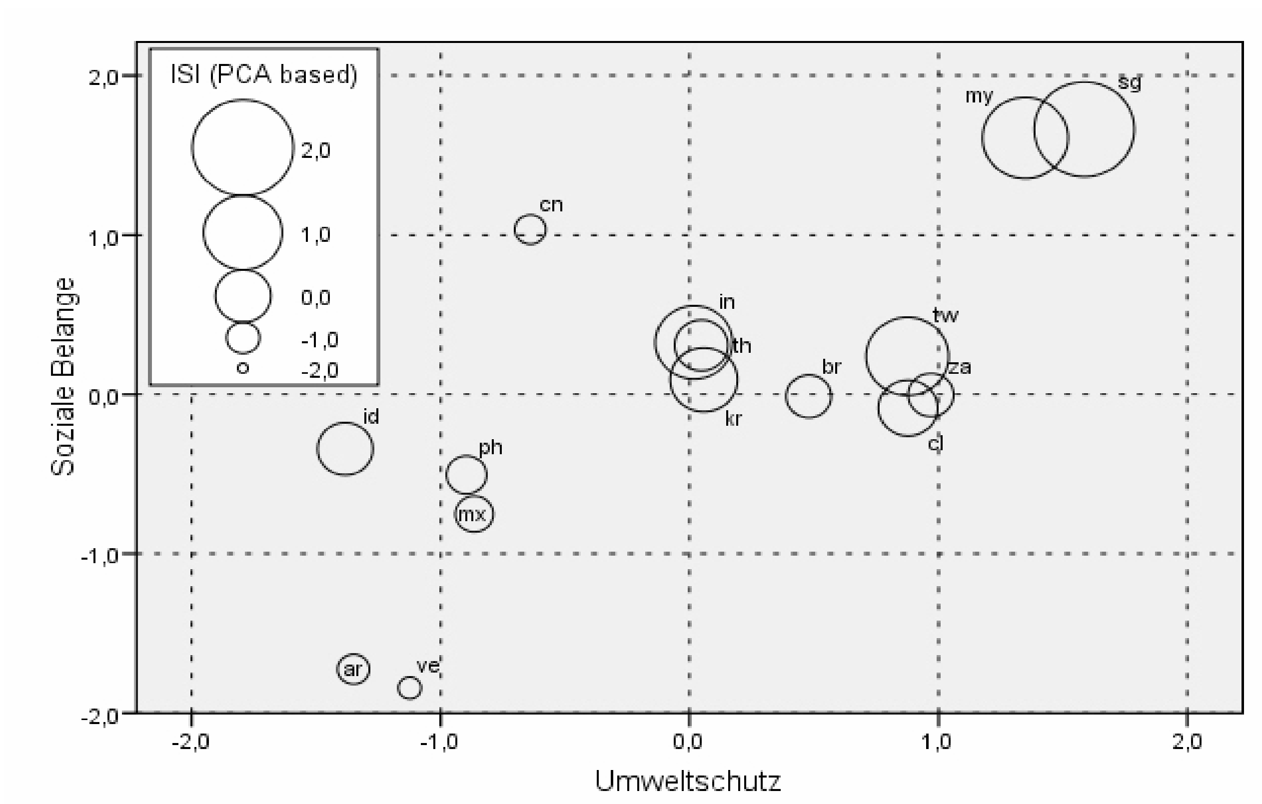


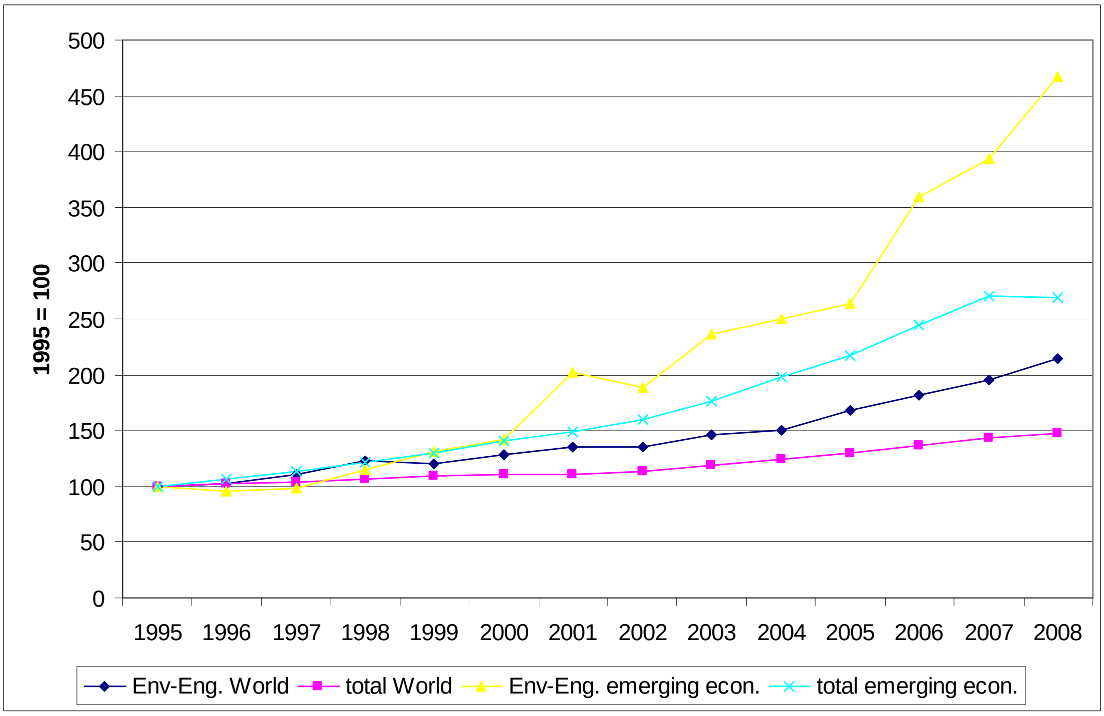
Figure 8: Results of survey on importance of environmental and social sustainability topics in the analysed countries



3.3 Technological capability in the sustainability technologies

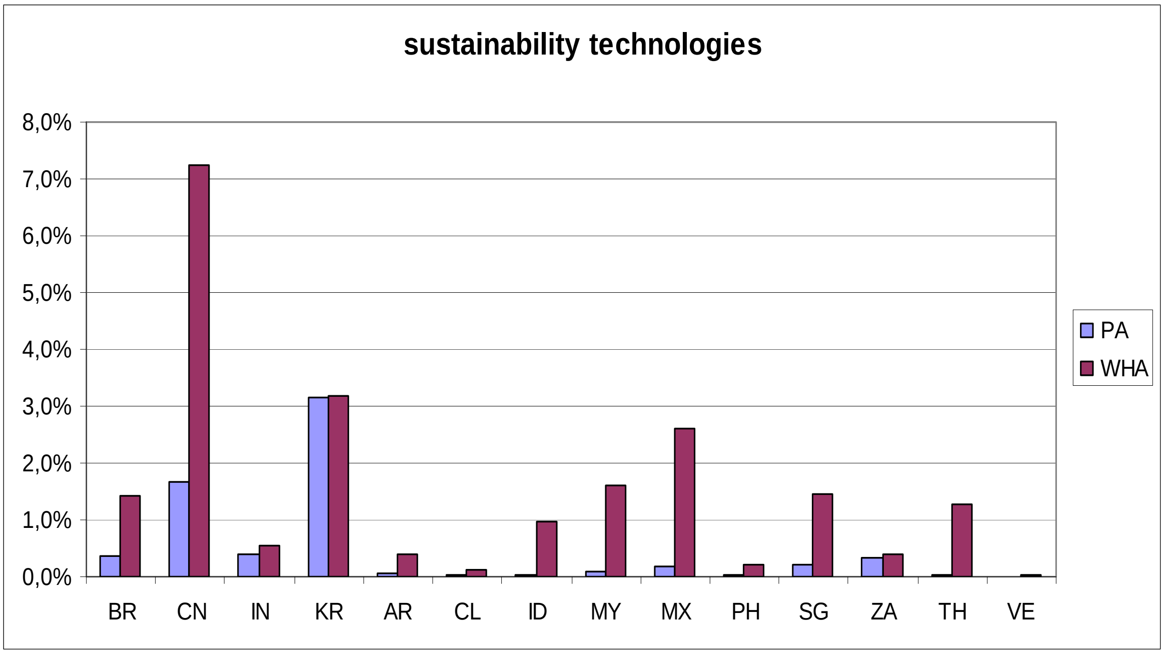
The development of publications can also be used as an indicator for the change in the importance of scientific fields of production over time. Clearly the topic of environmental engineering has received above average importance. For both, the world and within the emerging economies, the growth of environmental engineering publications has outpaced the growth of all SCI publications over the last 13 years. Furthermore, the growth has been much stronger in the emerging economies than the rest of the world. Thus, it can be argued that the topic of environmental engineering has been taking a hold in the scientific community of the emerging economies.

Figure 9: Development of publications in the field environmental engineering in the analysed countries and in the world



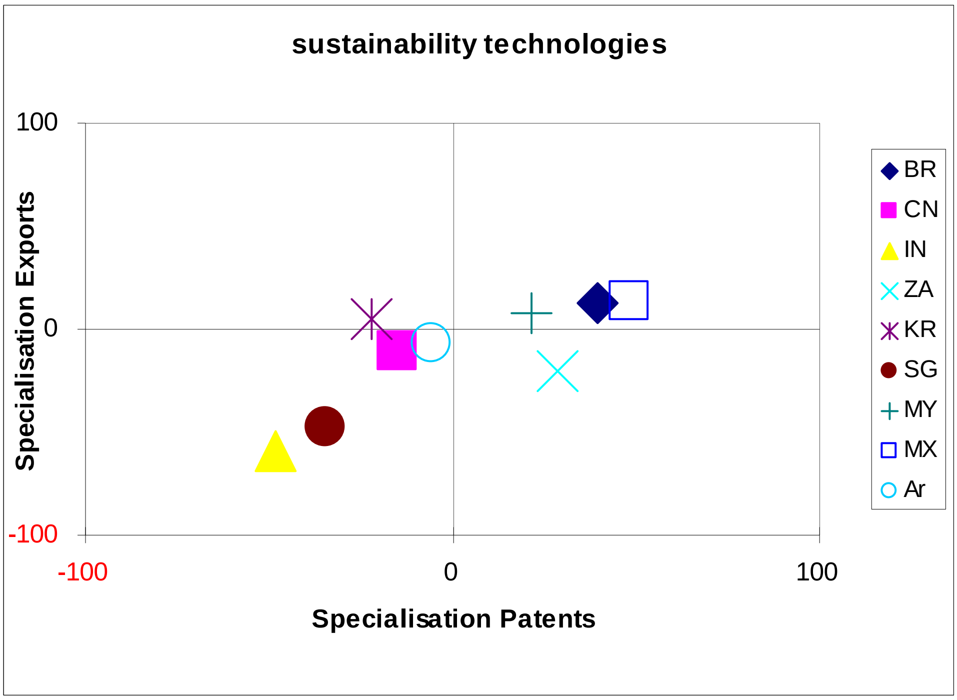
The shares of the emerging economies in the identified patents for the sustainability relevant technologies are between a few per mills to almost 2% for China and 3 % for South Korea. In some countries, e.g. Brazil, China, Indonesia, Mexico, the world trade shares are considerably higher than the patent shares. That shows that these countries are quite active in exporting sustainability relevant technologies, but based on a rather below average patent base from the home country. There are also some countries there the patent indicators show very limited activity in international patenting of sustainability technologies.

Figure 10: Share of emerging economies at international patents and at world exports for the sustainability relevant technologies



The importance of the sustainability relevant technologies within the individual countries is also reflected in the specialization profile. Specialization indicators such as the RPA, RXA or RCA show the knowledge and technological competence in sustainability technologies for every country compared to the average of all technologies. Positive values have an above average, negative values have a below average activity of the country regarding the sustainability relevant technologies. The results show considerable differences between the countries: Brasil, Malaysia, Mexico and South Africa are specialising on th sustainability technologies. In China, South Korea and Argentina, the specialisation indices show an average importance of the sustainability technologies. For the countries with very limited activity in international patenting of sustainability technologies, the use of a specialisation profile is statistically not sound and was omitted.

Figure 11: Specialisation pattern of emerging economies for sustainability technologies



3.4 Clustering of results

The empirical results of the previous sections are summarised in Table 1. The starting point has been that the following aspects are important developing an absorptice capacity:

- the existence of a good general innovation capability, which is measured by the survey based indicators and general R&D indicators,
- the level and importance of technological capabilities in the sustainability technologies, which is measured by both the world shares of publications, patent and exports and the specialisation profile of the countries, and
- broad understanding of the sustainability issues, pressing environmental problems which push towards use of sustainability technologies, and societal acceptance that the environment is an important topic.

The assessment for the countries was used to develop four clusters of countries:

- higher level of absorptive capacities, but without specialisation on sustainability technologies: China, Korea, Singapor, Taiwan
- Specialisation on sustainability with a medium overall level of technological capability: Brasil, Malaysia, Mexico, South Africa
- Medium overall level of technological capability, without specialisation on sustainability technologies: Argentina, Chile, India

- Lower overall level of technological capability: Venezuela, Thailand, Philippines, Indonesia.

For the first two clusters, the indicator approach yields some hypothesis about the chances and strategies to push for increasing absorptive capacities. In the first cluster, the logic would be to transfer the existing experience in building up a level of knowledge also more towards sustainability technology, in order to account for the growing of both environmental needs and increasing worldwide demand of sustainability technologies. For the second cluster, the logic runs more along the notion that these countries should concentrate their efforts in the sustainability fields, which form already a good starting position. Thus, it would be more the argument that the worldwide trends and the growing domestic environmental needs open up a window of opportunity to concentrate the limited domestic resources on promising technological fields. However, it is much more difficult to come up with sound strategies for the other two clusters. This is also related to the question how meaningful the indicator approach is.

Table 1: Results of indicators used for measuring absorptive capacities for sustainability technologies

Country	Survey based indicators on innovation capability	General R&D indicators	Scale effect: level of technological capability in sust. Technologies	Specialisation on sustainability technologies	Importance of environ. sustainability in society
Korea	Higher	Higher	Higher	medium	medium
Singapor	Higher	Higher	Higher	Lower	higher
Taiwan	Higher	Higher	Higher	N/A*	higher
China	Mittel	Higher	Higher	medium	lower
India	Higher	medium	medium	Lower	Medium
Brasil	medium	medium	medium	Higher	Med-higher
S. Africa	Medium	medium	medium	Higher	higher
Chile	Medium	medium	medium	N/A**	higher
Malaysia	Hoch	medium l	medium	Higher	higher
Argentina	Lower	medium	medium	medium	lower
Mexico	Loweer	v medium	medium	Higher	lower
Venezuela	Lower	Lower	Lower	N/A**	lower
Thailand	Medium	Lower	Lower	N/A**	medium
Philippines	Lower	Lower	Lower	N/A**	lower
Indonesia	Medium	Lower	Lower	N/A**	lower

4 HOW MEANINGFUL IS AN INDICATOR APPROACH?

Indicators are helpful in raising important questions, but they are not the answer themselves. There are various shortcomings which must be taken into account:

- Data problems: indicators can only be build for existing data; however, with the problems in data availability and reliability, there are severe gaps.

- There is conflicting evidence for some indicators, e.g. with regard to the results of innovation framework condition assessed by surveys or by R&D indicators. Thus the reliability of the indicators is not always assured.
- The interpretation of some indicators is not always unidirectional: Are a high level of importance for the environment a sign that the population is very environmentally conscious, or are they reflecting a particularily bad environmental state?

Another issue relates to the level of aggregation for which the analysis is taking place. The aggregated numbers disguise the fact that there are strong differences within each country. Thus, a more technology specific analysis is necessary, which distinguishes between the different technologies. For India, for example, which displays an below average importance for sustainability technologies, above average values are found on a technology specific level, e.g. for wind turbines, and technologies related to biopolymers and sea water desalination, or for renewable raw materials. Thus, only looking at aggregate numbers would be disguising important fields in which countries have a good starting point to compete internationally.

A key question relates to the appropriatness of the indicator approach as proxy for absorptive capacity: the indicators should measure both the absorptive capability of the emerging economies for sustainability innovations and at the same time the technological ability for international competition. The used indicator concepts have been derived from experience within OECD countries for goods with above average technological content. Even though sustainability technologies are typically also having an above average technology content, there still might be a problem that important aspects are not covered: First, they do not account for innovations which are not internationally patented because of a low propensity to patent in the country/region or because of the innovation taking place in sectors where it is more difficult to obtain patents (e.g. services, organisational innovations. Secondly, they assume that the emerging economies have a structure similar enough to OECD countries. Thus, they assume that the moving towards higher technology structures typical for OECD countries is also appropriate for all countries. Especially for countries assigned into the third and fourth cluster, this assumption might be questioned.

There are also missing factors which the indicators cannot account for. Sector and environmental regulation are key issues for sustainability technologies. First approaches are looking on how to picture these aspects in regulatory indicators in renewable energies (Walz et al 2008b). However, it still has to be seen if this approach can be succesfully applied for a wide range of technologies. Social factors are another issue which plays a very important role, but is not adequately addressed in the indicator approach so far. The importance of innovations in institutions, or knowledge spill overs from other sectors can be added to that list, together with the important aspects of communication patterns within the system of innovation, lock-Ins, path dependency, and power structures within industry and politics.

Thus, to sum up the argument, indicators can be helpful to give an overview, and form a basis for a first assessment of likely strengths and weaknesses of countries, and the resulting (economic) perspectives of moving towards sustainability technologies. However, they are not able to answer all of the arising questions alone. Clearly the use of such indicators must be accompanied by careful interpretations, reflections about the limits of the indicators, and additional qualitative analysis.

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