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EUROPÄISCHE WIRTSCHAFT
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Global Economic Sustainability Indicator: Analysis and Policy Options for the Copenhagen Process

Diskussionsbeitrag 174
Discussion Paper 174

Europäische Wirtschaft und Internationale Wirtschaftsbeziehungen
European Economy and International Economic Relations

ISSN 1430-5445

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February 2010

Herausgeber/Editor: Prof. Dr. Paul J.J. Welfens, Jean Monnet Chair in European Economic Integration

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JEL classification: Q54, Q01, O57
Key words: CO_2 Emission, Global worming, Sustainability, International country competitiveness

Summary: The traditional discussion about CO2 emissions and greenhouse gases as a source of global warming has been rather static, namely in the sense that innovation dynamics have not been considered much. Given the global nature of the climate problem, it is natural to develop a more dynamic Schumpeterian perspective and to emphasize a broader international analysis, which takes innovation dynamics and green international competitiveness into account: We discuss key issues of developing a consistent global sustainability indicator, which should cover the crucial dimensions of sustainability in a simple and straightforward way. The basic elements presented here concern genuine savings rates – covering not only depreciations on capital, but on the natural capital as well -, the international competitiveness of the respective country in the field of environmental ("green") goods and the share of renewable energy generation. International benchmarking can thus be encouraged and opportunities emphasized – an approach developed here. This new EIIW-vita Global Sustainability Indicator is consistent with the recent OECD requirements on composite indicators and thus, we suggest new options for policymakers. The US and Indonesia have suffered from a decline in their performance in the period 2000-07; Germany has improved its performance as judged by the new composite indicator whose weights are determined from factor analysis. The countries covered stand for roughly 91% of world GDP, 94% of global exports, 82% of global CO2 emissions and 68% of the population.

Zusammenfassung: Die Diskussion über die Rolle von CO2 Emissionen und Treibhausgasen als Quelle der globalen Erwärmung war bisher eher statischer Natur, insbesondere insoweit, als dass Innovationsdynamik kaum berücksichtigt wurde. Aufgrund der globalen Reichweite der Klimaproblematik bietet es sich an, eine dynamische, globale Schumpetersche Perspektive zu entwickeln, die auch auf Aspekte wie Innovationsdynamik und „internationale grüne Wettbewerbsfähigkeit" eingeht: Wir beschreiben die Kernpunkte der Entwicklung eines konsistenten neuen globalen Nachhaltigkeitsindikators, der die wesentliche Bereiche der Nachhaltigkeit auf eine einfache und direkte Art abbildet. Die wesentlichen Aspekte hierbei sind die wahre Sparquote – in welche neben den Abschreibung auf Kapital unter anderem auch Abschreibungen auf natürliches Kapital eingehen -, die internationale Wettbewerbsfähigkeit eines Landes im Bereich von Umweltgütern und der Anteil der erneuerbaren Energien an der gesamten Energieerzeugung. Mittels eines solchen Indikators können internationale Benchmarks erstellt und Chance für die einzelnen Länder dargestellt werden – ein Ansatz, der hier entwickelt wird. Der neue EIIW-vita Globale-Nachhaltigkeit-Index ist konsistent mit den Anforderungen der OECD an zusammengesetzte Indikatoren; die Gewichtung der Teilindikatoren erfolgt über eine Faktorenanalyse. Es wird gezeigt, dass die USA und Indonesien starke Einbußen in ihrer Performance in den Jahren 2000-2007 zu verzeichnen haben, während Deutschland seine Performance verbessern konnte. Die Länder, die in Bestimmung des Indikators eingehen, stehen für nahezu 91% des weltweiten BIPs, 94% der globalen Exporte, 82% der globalen CO2 Emissionen und 68% der Weltbevölkerung.

We appreciate the technical support and the comments by Samir Kadiric and Peter Bartelmus, New York, Columbia University; editorial assistance by Michael Agner, University of Odense and Lilla Voros (EIIW) are also appreciated. This research has benefited from financial support from vita foundation, Oberursel.

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Discussion Paper 174

Table of Contents

Table of Contents .... **I**
List of Figures .... **II**
1. Introduction **1**
2. Traditional Approaches to Environmental Damaging and Innovation Theory **6**
2.1 Characteristics of Environmental Innovations and Sustainability 9
2.2 Innovations and Importance of Technology Diffusion for Developing Countries 12
3. New Indicator Concept **14**
3.1 Strategic Views 18
3.2 Basic Reflections on Constructing a Comprehensive Composite Indicator 21
3.3 Weights from Factor Analysis 29
4. Policy Conclusions **33**
Appendix 1: Eigenvalues and Components **35**
Appendix 2: Europe 2000 and 2007 .... **36**
Appendix 3: List of Environmental Products **37**
Appendix 4: List of Data Sources **40**
Appendix 5: Indicators showing the Influence the SoRRCA, respectively **41**
Appendix 6: Absolute CO_2 Emissions (thousand tons of carbon) **43**
References **45**

List of Figures

Figure 1: CO_2 Emissions (kg) per Unit of GDP (Nominal, kg CO_2 per 2000 US$) 2
Figure 2: CO_2 Emissions (kg) per Unit of GDP (Purchasing Power Parity) 3
Figure 3: Global Footprint of Nations: Ecological Creditors and Debtors 8
Figure 4: Use of Back-stop Technology[1] 10
Figure 5: Genuine Saving versus Gross Domestic Saving* 15
Figure 6: CO_2 Emissions 17
Figure 7: Normalized Indicator on the Share of Renewables in Selected Countries: 2000 vs. 2007 20
Figure 8: Volume-weighted RCAs for the Year 2000 23
Figure 9: Partial Indicators Used 24
Figure 10: Indicators Showing the Influence of the Standard RCA Indicator vs. the Volume-Weighted RCA Indicator 25
Figure 11: Indicators Showing the Influence of the CO_2 indicator 27
Figure 12: EIIW-vita Global Sustainability Indicator 31
Figure 13: Estimated Weights from Factor Analysis 31
Figure 14: The EIIW-vita Global Sustainability Indicator 32
Figure 15: Eigenvalues and Components 35
Figure 16: EIIW-vita Indicator for Europe 36

1. Introduction

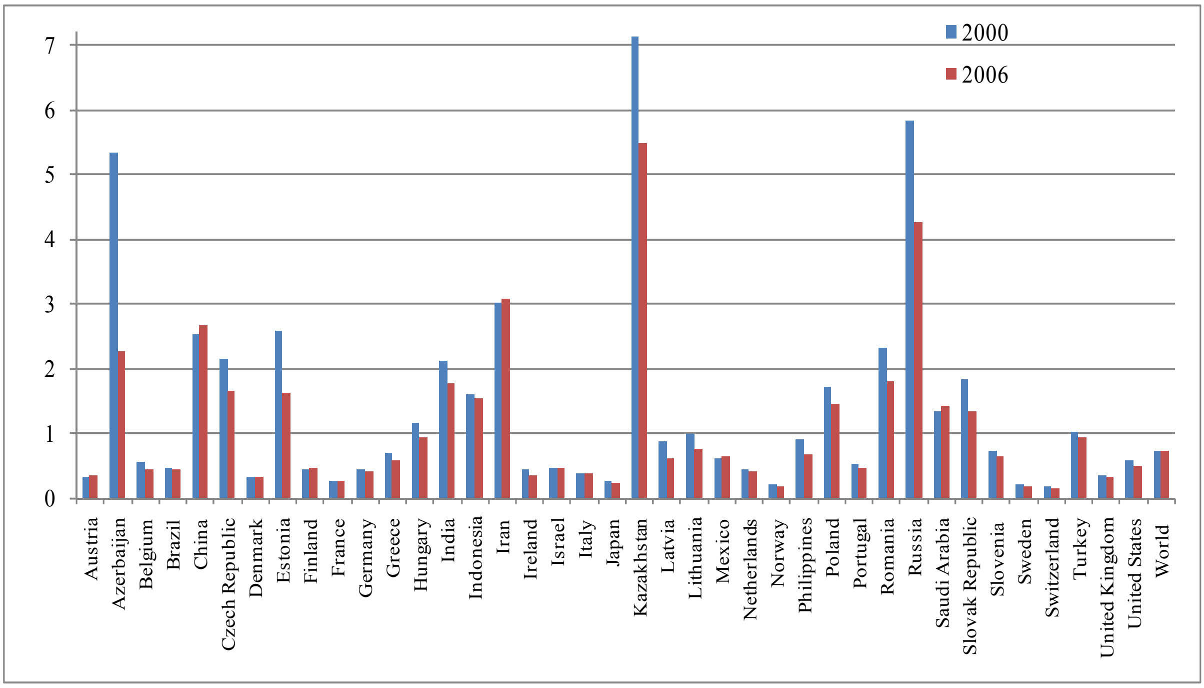
In the post-Kyoto process, it will be very important to face the global climate challenge on a broad scale: simply focusing on the OECD countries would not only imply the restriction of attention to a group of countries, which around 2010 will be responsible for less than 50% of global greenhouse gas emissions; it would also mean to ignore the enormous economic and political potential which could be mobilized within a more global cooperation framework. The Copenhagen Summit 2009 will effectively set a new agenda for long-term climate policy, where many observers expect commitments to not only come from EU countries, Australia, Japan and Russia, but also from the USA and big countries with modest per capita income, such as China and India. The ambitious goals envisaged for long-term reduction of greenhouse gases will require new efforts in many fields, including innovation policy and energy policy. If one is to achieve these goals, major energy producers such as the US, Russia, Indonesia and the traditional OPEC countries should be part of broader cooperation efforts, which could focus on sustainability issues within a rather general framework:

- Sustainable development, in the sense that the national and global resource efficiency strongly increases over time, so that future generations have equal opportunities, as present generations, in striving for a high living standard,
- Sustainable investment dynamics in the sense that investment in the energy sector should be long term – given the nature of the complex extraction and production process in the oil and gas sector and in the renewable sector as well (not to mention atomic energy, where nuclear waste stands for very long-term challenges); investment dynamics will be rather smooth when both major supply-side disruptions and sharp price shocks can be avoided. The current high volatility of oil prices and gas prices – with both prices linked to each other through some doubtful formula and international agreements – is largely due to instabilities in financial markets: Portfolio investors consider investment in oil and gas – in the respective part of the real sector in some cases, in many cases, simply into the relevant financial assets – as one element of a broader portfolio decision process, which puts the focus on a wide range of assets, including natural resources,
- Sustainable financial market development: If one could not achieve more long-term decision horizons in the banking sector and the financial sector, respectively, it would be quite difficult to achieve rather stable long-term growth (minor cyclical changes are, of course, no problem for the development of the energy sector). With more and more countries facing negative spillovers from the US banking crisis, more and more countries will become more interested in more stability in global financial markets. At the same time, one may not omit the fact that emission certificate trading systems established in the EU have created a new financial market niche of their own. With more countries joining international Emission Trading Schemes (ETS approaches), the potential role of financial markets for the world's efforts in coping with climate policy challenges will become more important over time. It may also be noted that stable financial markets are required for financing investment and innovation in the energy sector. From this perspective, overcoming the international banking crisis is of paramount importance, however, the progress achieved within the G20 framework is rather modest – not the least because there is still weak regulation for big banks (for which, the problem of too big to fail is relevant) and because more competition, as

well as better risk management, has been hardly achieved in 2009; transparency is still lacking, not the least because the IMF has not yet published the Financial Sector Assessment Program for the US, which is now overdue for many years. Without more stability in financial markets and banks, there is considerable risk that the creation of new financial instruments associated with emission trading will simply amount to creating a new field of doubtful speculation activities with massive negative international external effects.

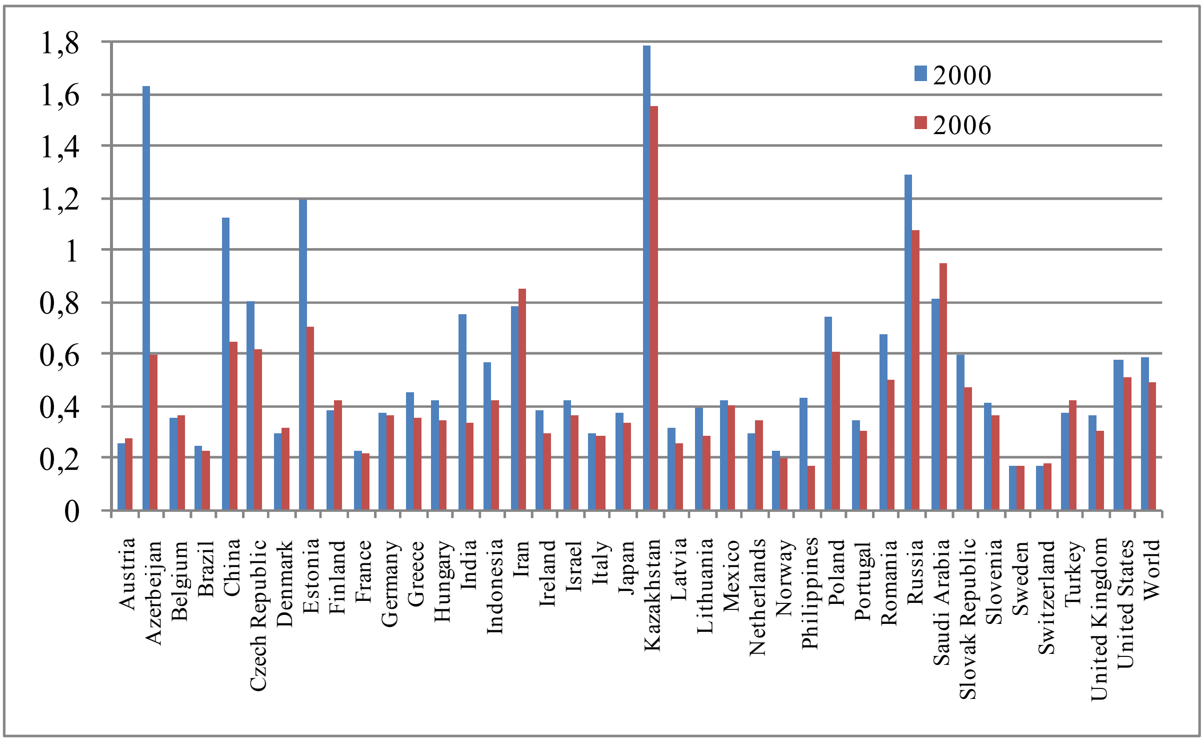
Sustainability so far has not been a major element of economic policy in most OECD countries and in major oil exporters and gas exporters, although sustainability policy may be considered to be a key element of long-term economic and ecological modernization; sustainability implies a long-term perspective and such a perspective is typical of the oil and gas industry. The use of fossil fuels, in turn, is of key importance for climate change and sustainable development, respectively – and the use of such primary energy sources in turn causes CO_2 emissions. In contrast to general discussions in the international community, which typically puts the focus on CO_2 emissions per unit of GDP (or per capita), it is adequate to consider CO_2 emissions per unit of GDP at purchasing power parities (PPP); otherwise, there would be a crucial bias in the comparison of CO_2 emission intensities. The PPP figures look quite different from the emission intensities based on nominal $ GDP per capita data; e.g., China's performance on a PPP basis is not much worse than that of Poland (see Fig. 2).

Figure 1: CO_2 Emissions (kg) per Unit of GDP (Nominal, kg CO_2 per 2000 US$)



Source: WDI and International Energy Agency Online Database.

Figure 2: CO_2 Emissions (kg) per Unit of GDP (Purchasing Power Parity)



Source: WDI and International Energy Agency Online Database.

Greenhouse gas emissions, toxic discharges in industrial production and deforestation are among the key aspects of global environmental problems. Long-term economic growth in the world economy will intensify certain problems; at the same time, growth is coupled with technological progress, which in turn could allow for a decoupling of economic growth and emissions. It is not clear to which extent countries and companies contribute to solving environmental problems, although some countries – e.g., Germany, Switzerland and Austria – claim that exports in environmental products strongly contribute to overall exports and also to the creation of new jobs (SPRENGER, 1999). Under the Obama Administration, the US has also taken a fresh approach to environmental policy, where innovation is one key element emphasized by the US in the context of a new approach to climate policy.

While certain fields of environmental problems have seen some improvement over the past decades – e.g., the quality of water in many rivers within Europe improved in the last quarter of the 20th century –, other challenges have not really found a convincing solution. In the EU, the EUROPEAN ENVIRONMENTAL AGENCY (2008) reports on various fields of economic improvement. The BP report (2009) also presents progress in a specific field, namely the reduction of CO_2 emission per capita in OECD countries. The global picture is different, however. Greenhouse gases have increased over time, and while emission trading in the EU has made considerable progress, the global dynamics of CO_2 and other greenhouse gases have been strong.

While global political interest in sustainability issues has increased over time, the recent transatlantic financial market crisis has undermined the focus on sustainable development. It is also fairly obvious that financial markets shaped by relatively short-term decision horizons – and short-term oriented bonus schemes – are undermining the broader topic of sustainability. It is difficult to embark on more long-term sustainable strategies in companies and households, if both banks and fund managers mainly emphasize short- and medium-term strategies.

For the first time, energy consumption and greenhouse gas emissions were larger outside the OECD than in the OECD countries in 2008. This partly reflects the dynamics of successful economic globalization, namely that countries such as China, India, Indonesia, Brazil, etc. have achieved high, long term growth, which goes along with rising emissions. Economic globalization has several other aspects, including:

- Enhanced locational competition which reinforces the interest in foreign direct investment and multinational companies.
- Higher global economic growth (disregarding here the serious short-term adverse effects of the transatlantic financial crisis and the world recession) which correspond with stronger competition and a broader international division of labor on the one hand, and with potentially fast rising emissions and growing trade in toxic waste on the other.
- Fast growth of transportation services and hence of transportation related emissions which particularly could add to higher CO_2 emissions.

From a policy perspective, it is useful to have a comprehensive assessment of the pressure on the environment. Several indicators have been developed in the literature, which give a broader picture of the environmental situation. The EU has emphasized the need to look not only at GDP but at broader measures for measuring progress (EUROPEAN COMMISSION, 2009).

Most sustainability indicators are mainly quantitative (e.g., material flow analysis, MFA) which to some extent is useful for assessing the ecological burden of the production of certain goods and activities. Total Material Requirement is an interesting indicator when it comes to measuring resource productivity since it considers all materials used for a certain product, including indirect material input requirements associated with intermediate imports. A very broad indicator concept – with dozens of sub-indicators - has been developed by researchers at Yale University and Columbia University (YALE/COLUMBIA, 2005) which derive very complex indicators for which equal weights are used. Very complex indicators are, however, rather doubtful in terms of consistency and the message for the general public, industry and policymakers is often also opaque. Thus one may raise the question whether a new indicator concept - following the requirements of the OECD (2008) manual and taking into account key economic aspects of green innovation dynamics – can be developed. Before presenting such a new approach a few general remarks about the System of National Accounts are useful to make clear the analytical line of reasoning developed subsequently.

The most common indicator used to assess both economic performance and economic well-being is gross domestic product (GDP: in line with the UN Systems of National Accounts), which indicates the sum of all newly produced goods and services in a given year. If one wants to consider long term economic development perspectives one would not consider gross domestic product, rather one has to consider Net Domestic Product (Y') which is GDP minus capital depreciations. Taking into account capital depreciations is important since an economy can maintain its production potential only if the stock of input factors – capital K, labor L and technology A - are maintained; ultimately one is only interested in per capita consumption C/L which is the difference of per capita production (y=:Y/L) and the sum of private gross investment per capita (I/L) and government consumption per capita (G/L). However, in reality natural resources R – consisting of renewable and non-renewables – also are input factors in production. Therefore, "Green Net Domestic Product" may be defined here as net national product minus depreciations on natural resources. To indeed consider such a GNDP is important for many countries which are used to heavily exploiting their respective natural resources. Exploiting nonrenewable resources comes at considerable costs for long term economic development since running down the stock of non-renewables implies that future production will decline at some point of time t.

The World Bank has highlighted the role of depreciations on natural resources, namely by calculating genuine savings ratios S'/Y where S' is standard savings S minus depreciations on capital minus depreciations on natural resources (and also minus expenditures on education which are required expenditures for maintaining the stock of human capital; and minus some other elements which are detrimental to sustained economic development – see the subsequent discussion). One should note that there is some positive correlation between gross domestic product per capita and subjective well-being as is shown in recent analysis (STEVENSON/WOLFERS, 2008). Policymakers thus have a strong tendency to emphasize that rising GDP per capita is an important goal. At the same time, it is fairly obvious that the general public is not aware of the difference between Gross Domestic Product and Net Domestic Product (NDP) – let alone the significance of NDP and Green Net Domestic Product (Sustainable Product). The problem is that the UN has not adopted any major modernization of its System of National Accounts in the past decades although there have been broad international discussions about the greening of national accounts (see e.g. BARTELMUS, 2001). The UN has developed an approach labeled System of Integrated Economic Environmental Accounts (SEEA) which, however, has not replaced the standard Systems of National Accounts. SEEA basically considers depreciations on natural capital, but the system is rather incomplete as appreciations of natural resources are not taken into account – e.g. the SEEA does not adequately consider improvements of the quality of natural resources (e.g., water quality of rivers which has improved in many EU countries over time). An interesting indicator to measure the quality of life is the UN Human Development Index which aggregates per capita income, education and life expectancy. Life expectancy is related to many factors where one may argue that the quality of life is one of them. Another indicator is the Index of Sustainable Economic Welfare (ISEW), based on John Cobb (COBB (1989)), who basically has argued that welfare should be measured on the basis of per capita consumption, value-added in the self-service economy (not covered by the System of National Accounts) and consumer durables, but expenditures which are necessary to maintain production should be deducted (e.g., expenditures on health care, expenditures for commuting to work). The elements contained in the ISEW are not fully convincing, and the policy community has not taken much notice of this.

In the subsequent analysis, it will be argued that one should focus indeed on broader concepts of Global Sustainability:

- A broader concept should take into account the role of international competitiveness and technological progress adequately – the emphasis on some Schumpeterian elements in sustainability analysis could not only deepen our analytical view of economic-ecological challenges but also help to alert decision-makers in industry and in the policy community to take adequate decisions in the field of innovation and modernization. The focus will be on green international competitiveness as measured by the modified revealed comparative advantage (mRCA), which basically indicates to which extent the respective country has positively specialized on exports – and production – of goods relevant for improving the quality of the environment. Additionally, CO_2 emissions per capita and the role of the genuine savings rate will be considered. Basic aspects of aggregation are taken into account, but no econometric analysis is presented which allows for drawing firm conclusions for the issue of weighing the components of the summary indicator.

- Reconciling economic convergence between North and South – that is a declining long term per capita income gap between the North and the South – and achieving sustained economic growth in the world economy will be easier to achieve if one had a consistent indicator which helps to identify economic-ecological progress and green international leadership.

The basic approach presented here suggests that a new set of indicators is useful for the discussion about global sustainability issues. The analysis is organized as follows: Section 2 presents standard approaches to environmental damaging, section 3 highlights insights from factor loading analysis and presents a comprehensive composite indicator. At the end we draw some critical policy conclusions.

2. Traditional Approaches to Environmental Damaging and Innovation Theory

Standard approaches to environmental damaging emphasize much of the issue of non-renewable resources. This focus is not surprising, as some vital resources used in industry are important non-renewable inputs. However, one should not overlook the fact that innovation dynamics and technological progress typically can mitigate some of the problems in the long-run – here, the focus is on both process innovations, which economize on the use of resources, as well as product innovations, which might bring about the use of different non-renewable or of synthetic chemical inputs. At the same time, one may argue that until 2050 there will be considerable global population growth and most of the output growth will come from Asia – including China and India. In these countries, emphasis on fighting global warming is not naturally a top priority, rather economic catching-up figures prominently in the political system are; and economic analysis suggests that China and India still have a large potential for economic catching-up and long term growth, respectively (DIMARANAN/IANCHOVICHINA/MARTIN, 2009). Nevertheless, one may emphasize that economic globalization also creates new opportunities for international technology transfer and for trade with environmental (green) goods. If there is more trade with green goods and, if certain countries successfully specialize in the production and export of such goods, the global abilities in the field of environmental modernization might be sufficient to cope with global warming problems: This means the ability to fight global warming, on the one hand, and on the other hand, the ability to mitigate the effects of global warming. A potential problem of putting more emphasis on innovation dynamics is that a wave of product innovations could trigger additional emissions, which would partly or fully offset the ecological benefits associated with higher energy efficiency that would result in a generally more efficient way to use natural resources.

Sustainability means the ability of future generations to achieve at least the same standard of living as the current generation has achieved. If one adopts a national sustainability perspective this puts the focus on sustainable economic development in every country of the world economy. Analytical consistency in terms of sustainability imposes certain analytical and logic requirements:

- As a matter of consistency one may expect that if there is a group of countries which represents – according to specific sustainability indicators – sustainable development other countries converging to the same structural parameters of the economy (say per capita income and per capita emissions as well as other relevant parameters) will also be classified as sustainable;

- if all countries are sustainable there is sustainability of the overall world economy. What sounds trivial at first is quite a challenge if one considers certain indicators as we shall see.

An important approach to sustainability has been presented by the World Bank which calculates genuine savings rates. The basic idea of a broadly defined savings rate is to take into account that the current per capita consumption can only be maintained if the overall capital stock – physical capital, human capital and natural capital – can be maintained. To put it differently: an economy with a negative genuine savings rate is not sustainable. The genuine savings rate concept is quite useful if one is to understand the prospect of sustainable development of individual countries. The figures presented subsequently basically suggest that OECD countries are well positioned, particularly the US. This, however, is doubtful, because it is clear that in case the South would converge to consumption patterns of the OECD countries – and would achieve economic convergence in terms of per capita income – the world could hardly survive because the amounts of emissions and waste would be too large to be absorbed by the earth. For example, the CO_2 emissions would be way above any value considered compatible with sustainability as defined by the IPCC and the STERN report.

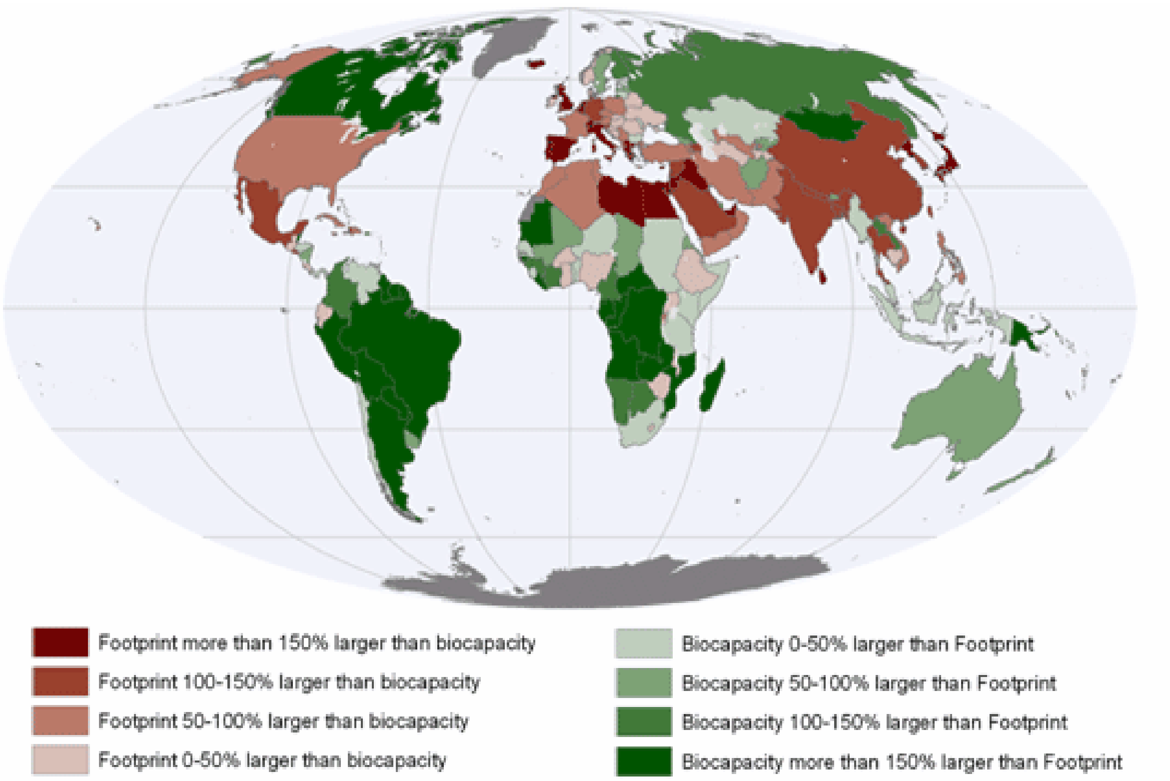
The World Bank approach is partly flawed in the sense that it does not truly take into account the analytical challenge of open economies. To make this point clear, let us consider the concept of embedded energy which looks at input output tables in order to find out which share of the use of energy (and hence CO_2 emissions) are related to exports or net exports of goods and services. For example, the US has run a large bilateral trade deficit with China – and indeed the rest of the world - for many years and this implies that the "embedded genuine savings rate" (EGSR) of the US has to be corrected in a way that the EGSR is lower than indicated by the World Bank. Conversely, China's EGSR is higher than indicated by the World Bank. To put it differently: While the genuine savings rate indeed is useful to assess sustainability of individual countries at first glance, a second glance which takes into account the indirect international emissions and indirect running down of foreign stocks of resources (e.g., deforestation in Latin America or Asia due to net US/EU imports of goods using forest products as intermediate inputs) related to trade represents a different perspective; EGSR should not be misinterpreted to take the responsibility from certain countries, however, EGSR and the genuine savings rate concept - standing for two sides of the same coin - might become a starting point for more green technology cooperation between the US and China or the EU and China.

Considering the embedded genuine savings rate helps to avoid the misperception that if all countries in the South of the world economy should become like OECD countries the overall world economy should be sustainable. According to the World Bank's genuine savings rate, the US in 2000 has been on a rather sustainable economic growth path. However, it is clear that if all non-US countries in the world economy had the same structural parameter – including the same per capita income and the same emissions per capita – as the United States there would be no global sustainable development. If, however, one considers embedded genuine savings rates, the picture looks different. For instance, if one assumes that the embedded genuine savings rate for the US is lower by 1/5 than the genuine savings rate, it is clear that the US position is not as favorable as the World Bank data suggest.

The ideal way to correct the World Bank genuine savings rate data is to consider input-output and trade data for the world economy so that one can calculate the embedded genuine savings rate; however, such data are available only for a few countries, but in a pragmatic way one may attribute China's depreciations on natural resources and the CO_2 emissions to the US and the EU countries as well as other countries vis-à-vis China runs a sustained bilateral trade balance surplus. A pragmatic correction thus could rely on considering the bilateral export surplus of China – e.g., if the ratio of total exports to GDP in China is 40% and if ½ of China's export surplus of China is associated with the US then 20% of China's CO_2 emissions can effectively be attributed to the US. One might argue that considering such corrected, virtual CO_2 emissions is not really adequate since global warming problems depend indeed on the global emissions of CO_2, while individual country positions are of minor relevance. However, in a policy perspective it is quite important to have a clear understanding of which countries are effectively responsible for what share of CO_2 emissions in the world economy. As sources of CO_2 emissions are both local and national, it is indeed important to not only consider the embedded genuine savings rate but also to know which country are responsible for which amount of CO_2 emissions.

In the literature, one finds partial approaches to the issue of global sustainability. The concept of the ecological footprint (WACKERNAGEL, 1994; WACKERNAGEL/REES, 1996) – as suggested by the WWF (see e.g. WIEDMAN/MINX, 2007) – is one important element. Ecological footprint summarizes on a per capita basis (in an internationally comparative way) the use of land, fish, water, agricultural land and the CO_2 footprint in one indicator so that one can understand how strong the individual's pressure on the capacity of the earth to deliver all required natural services really is. At the same time, one wonders to which extent one may develop new indicator approaches which emphasize the aspects of sustainability in a convincing way.

Figure 3: Global Footprint of Nations: Ecological Creditors and Debtors



Source: GLOBAL FOOTPRINT NETWORK, WEB

The Global Footprint indicator calculated by the World Wildlife Fund and its international network indicates the quantitative use of resources for production, namely on a per capita basis. It thus is a rather crude indicator of the pressure on the global biosphere and the atmosphere. However, it has no truly economic dimension related to international competition and competitiveness, respectively. If, say, country I has the same global per capita footprint as country II, while the latter is strongly specialized in the production and export of green goods – which help to improve the quality of the environment and to increase the absorptive capacity of the biosphere of the importing countries, respectively – the Global Footprint approach does not differentiate between country I and country II.

If the general public and the private sector as well as policymakers are to encourage global environmental problem solving it would be useful to have a broadly informative indicator which includes green international competitiveness – see the subsequent analysis. One may argue that a positive RCAs for certain sectors is economically and ecologically more important than in other sectors, however, we consider the broad picture across all sectors considered as relevant by the OECD (see list in appendix). Modified RCAs are particularly useful indicators since they are not distorted by current account imbalances – as is the traditional RCA indicator which simply compares the sectoral export import ratio with the aggregate export import ratio (Comtrade data base of the United Nations and World Development Indicators/WDI are used in the subsequent calculations).

As regards as adjustment dynamics, it is clear that a static view of the economy and world ecological system is not adequate; rather Schumpeterian innovation perspective is required.

2.1 Characteristics of Environmental Innovations and Sustainability

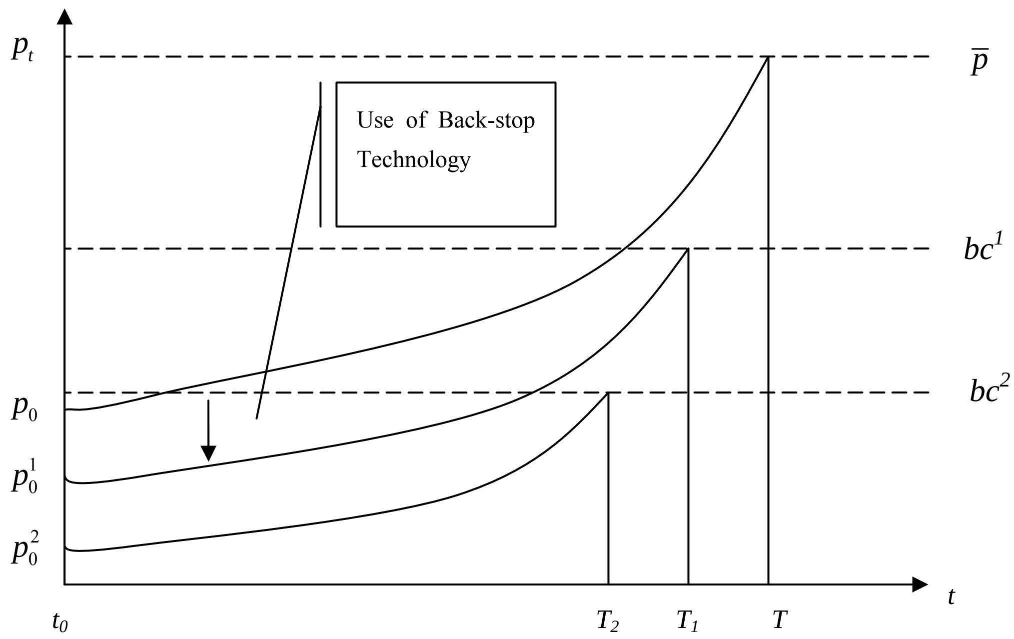
Growth and Exhaustible Natural Resources

Natural resources, pollution and other environmental issues are not considered in the classical growth model of Solow. Many economists – from MALTHUS (1798) to HOTELLING (1931) and BRETSCHGER (2009) – have argued that the scarcity of land and natural resources, respectively, could be an obstacle in obtaining sustainable growth. NORDHAUS (1974) described the impossibility of an infinite and long-term economic growth based on exhaustible energy; he has basically emphasized that non-renewable resources are critical long-run challenges, along with three other aspects:

- Limitations of resources: certain key resources are non-renewable and substitution through alternative exhaustible resources is often complex;
- Environmental effects – the use of resources causes emissions or effluents and dealing with those is costly;
- There will be rising prices of the exhaustible energy resources.

With connection to this, back-stop technologies or innovations have a crucial role for the long-term economic perspective and for the optimal energy price level. The effect of a back-stop technology on the resources price path can be presented in a straightforward way:

Figure 4: Use of Back-stop Technology[1]



[1] HENSING (1998) mentions the following back-stop technologies concerning today's knowledge level: Solar power and hydrogen and other renewable energy technologies, possible nuclear fission systems on the basis of the breeder reactors or light-water reactors with uranium production, new nuclear fusion techniques etc.
Source: (WACKER/BLANK, 1999)

A standard insight - on the assumption of a perfect competition and a linear demand curve - is that the price will rise in the long run due to rising extraction costs. With the use of a new technology (lower marginal costs bc_1) one will have a lower price until the exhaustion of a new substitute. It would, however, be inefficient not to use up new resources completely. In this context, one should emphasize that the initial price must remain below $bc_1 < \overline{p}$. Due to the new attractive supply, the demand will increase, and the resource will be exhausted earlier (T_1). With a more innovative technology, and more favorable extraction costs (bc_2), one achieves an even earlier extraction time (T_2) (WACKER/BLANK, 1999:43). In a similar way, LEVY (2000) shows that a decrease of the initial average costs by one dollar leads to a decrease of the spot prices by somewhat less than a dollar.

WELFENS (2008) distinguishes innovation perspectives on the extraction of exhaustible resources as follows:

- Progress in pure costs of exploitation**:** This means a fall in the real marginal/average production costs of exploiting a given resource site – with no change in the exploitable amount of resources in a given field; thus, we consider a site X in which a profitable amount x could be exploited (say x_0 is 50% of the physical amount contained in site X)
- Progress in pure exploration technology: This represents a rise in the exploitable amount of resources in a given field (at given pure real costs of exploitation); this type of progress is quasi-resource augmenting, in the sense that the share of x in the site X has increased, while pure unit exploitation costs have remained constant.

GRUPP (1999) points out the effects of the crude oil price increases on new environmental technology patents. Looking at the period from 1980 to 1997, on the basis of an econometric analysis, he founds that the rate of innovation is dependent price movements for raw materials and for resources and energy conservation. POPP (2002) have comparable results for the USA and points out energy prices have strong positive impact on innovations. He emphasizes that environmental taxes and regulations only reduce pollution by shifting behavior away from polluting activities but thus encourage the development of new technologies that make pollution control less costly into the long run. RENNINGS (1999) classifies the innovations for sustainability into four groups:

- Environmental innovation: They should be understood as all of the manifestations of relevant, related actors in the marketplace, such as entrepreneurs, policymakers with focus on supporting innovative sustainability projects etc.: New ideas, products, production processes and application that contribute to sustainability
- Technical innovations according to Oslo Manual of OECD
- Social Innovations: Changes in life styles and consumer behavior
- Institutional innovations

There are many environmental problems – such as the degradation of water quality or forest problems – which have a rather regional context, so an adequate regional innovation system could be useful to cope with the challenges at hand. However, controlling global warming stands for a true international public good and thus, one may well consider the problem of how innovative actors from the whole world can interact and how diffusion of knowledge related to cutting greenhouse gases can be organized in an efficient manner. There is much discussion about North-South technology transfer, but considering the big differences in the share of renewable energy sources in the South, one should not underestimate the impact of an enhanced South-South diffusion.

Innovations and Policy Issues

The development and the employment of new energy technologies play a central role for supply security, sustainability and competitiveness. Energy technology research very strongly contributes to the improvement of energy efficiency and to the development of renewable kinds of energy. If global warming is to be controlled, major innovations must be accomplished in the future; also in highly energy-intensive sectors (building, traffic, agriculture industries, etc). For this reason, governments support the research on efficiency and environment friendly technologies. Renewable energies, a broader industrial use of clean coal technologies, development of certain cheap bio-fuels, new sources of energy such as hydrogen, as well as pollution free energy use (e.g. hydrogen cells) and energy efficiency are some of the relevant alternatives.

With regards to the promotion of these technologies, governments are faced with two different approaches:

- "Technology Push" refers to the identification of a potential technology and the support of the R&D, in order to bring a competitive product on the market. „The Technology Push "- approach basically argues that the primary focus should be on the development of Green House Gas reduction technologies: via public R&D programs and not via obligatory regulations, such as restrictions on emission. Obligatory restrictions may be used only if the innovations would sufficiently lower the costs of green house gas emissions.
- The opposite "Market Pull"-approach stresses that technological innovation must come primarily from the private sector. In this context, the economic interaction of changing needs and shifts in technologies (supply side) bring about new appropriate

products. The focus of this approach lies in the fact that the obligatory restrictions could force the enterprises to innovations in search for cost reduction (GRUBB, 2004:9; HIERL/PALINKAS, 2007: 5).

The origins of environmental problems and the various solutions proposed by businesses and institutions in innovative green technologies, have been often examined since the 80s and 90s: The concepts, as well as the conditions for the emergence and diffusion of technological and institutional innovations are based on so-called nonlinear system dynamics, a theory partly introduced by J. A. Schumpeter, stating that unforeseeable innovative processes with positive externality stand in close relationship with knowledge and learning processes (FARMER/STADTLER, 2005: 172). For most countries, foreign sources of technology account for 90 percent or more of the domestic productivity growth. At present, only a handful of rich countries account for most of the world's creation of new technology. G-7 Countries accounted for 84% of the world‘s R&D, but their world GDP share is 64%. (KELLER, 2004). The pattern of worldwide technical change is, thus, determined in large part by international technology diffusion.

AGHION ET AL. (2009) argue that radical innovations are needed to bring about strong progress in CO_2 emissions: Given the fact that the share of green patents in total global patents is only about 2%, one cannot expect that incremental changes in technologies will bring about strong improvements in energy efficiency and massive reductions of CO_2 emissions per capita; while the generation of electricity is a major cause of CO_2 emissions the share of R&D expenditures in the sector's revenues was only 0.5%.

2.2 Innovations and Importance of Technology Diffusion for Developing Countries

The Kyoto and Bali conferences on climate policy have forcefully asserted that the industrialized countries should support developing countries in the field of technological progress, and flexible instruments, such as clean development mechanisms, joint implementation and emission trading implemented by the Kyoto Protocol, are already contributing to the efficient use of resources in the global economy. However, sharp national productivity differences will remain, explaining a large part of the difference in national incomes. At this point, technology plays an important role in shaping productivity. With connection to this, technology and know-how infusions from abroad are indispensible for sustainable growth in developing countries. KELLER (2004) emphasizes that FDI and international trade are crucial channels of technology diffusion. The evidence is easy to see in terms of imported goods and services, which stand for embodied progress and new knowledge, respectively. Nevertheless, it is fairly obvious that domestic investment in R&D and technology is also necessary. While OECD countries might be willing to transfer certain technologies to the South, it also is necessary that the adaptation of know-how be strongly improved in the South: Developing countries can only benefit from a technology transfer if they reach a minimum level of human capital, which, again, requires investment in education (XU, 2000). KEMFERT (2002) stresses that integration of technological change in a multi-regional trade system improves energy efficiency and could reduce environmental problems. In this context, flexible instruments facilitate technological progress and technology transfer, respectively: This, in turn, increases the prosperity in the host countries, where positive knowledge and spillover effects play an important role (in particular in the developing countries, they also lead to improved international competitiveness – at least if strong inflows of foreign direct investment can be achieved). In this context, the channels for improvements in resource use and greenhouse mitigation through technology transfer can be considered to be a broad range of relevant aspects: technology transfer per trade of goods and services, FDI, international programs and development aid (PETERSON, 2008). In an increasingly internationalized supply side setting, domestic firms can realize improvements in energy efficiency and decrease their energy intensity by investing in new technologies. Higher productivity results from the spillover of advanced technologies and educational improvement, but also from advanced management skills. A number of important questions arise from these reflections: Can free international trade help to increase efficient use of resources? The WTO (1999) has published only one study on trade and environmental problems – which is rather disappointing for such a large international organization.

A positive answer to the question requires a rising technology level, successful restructuring of production processes and a higher level of competition. In this context, the relationship between the internationalization of economies and environmental sustainability has been a key issue since the late 1970s, and interest in the topic has increased tremendously since the 90s; particularly in the wake of the argument of GROSSMANN/KRUEGER (1995), assuming that globalization causes economic growth, the relationship between globalization and environmental quality is not negative. On the contrary, positive effects of economic growth on the environment can be observed for most environmental quality indicators. In addition, a national income per capita of \$8000 a turning point for increasing environmental quality. Similar findings in the field of sulphur dioxide pollution problems have been provided by ANTWEILER/COPELAND/TAYLOR (2001): technology transfer is coupled with the effects of scale created by international trade reduction e.g. sulphur dioxide pollution.

Another important question is, whether the effects of international trade on energy use can be measured via environmental indicators. (COPELAND/TAYLOR (2004) also review the relationship between economic growth, free trade and the environment and provide a summary of important contributions). DEAN (2002) discusses the question of the relationship between economic openness and the environment, taking the example of China's water pollution levels. She claims that freer trade boosts environmental damage via the terms of trade, but mitigates it via income growth. KELLER/LEVINSON (2002) investigate the relationship between FDI inflow into the USA and environmental costs. They find that there is a positive relationship between FDI and environmental protection. On the political level, the debate on climate change after the Kyoto process and the STERN Review (2006) have increased the popularity of the belief in a positive relationship between trade liberalization and the environment. The assumptions of these researchers are mostly based on the advantages brought by capital movement, and above all, on the results of Foreign Direct Investment. The theoretical background of most studies fits the model developed by GROSSMAN/HELPMAN (1995) that allows examination of not only how technology affects trade, but also how trade affects technology. Empirical findings on the basic impact of international capital movements on the environment can be summarized as follows: Investments and new production factors can increase the technology level of the host country through the transfer of know-how. In addition, improvements in productivity and energy efficiency cause "crowding-out effects" and force inefficient local firms to integrate their production processes. Foreign firms stimulate innovation and capital endowment through competition. Above all, trade liberalization enables policy makers and non-governmental organizations (NGOs) to pedal inefficient domestic companies. However, it is also useful to take into consideration research on aspects of the "pollution havens" hypothesis.

It remains doubtful that major improvements in shifting towards much lower CO_2 intensities can be achieved through gradual policy changes and impulses from emission certificate trading. The price of CO_2 certificates is quite volatile and the Transatlantic Banking Crisis has reinforced this problem. One might, however, achieve a critical amount of green innovations if every G20 country and several other countries decide to adopt a critical effort in innovation policies and come up with strongly increased green R&D budgets.

3. New Indicator Concept

Basically, one could build indicators based on the individual, which often is a good way to motivate individuals to reconsider their respective style of living. Alternatively (or in a complementary way), one may develop indicators with a focus on individual countries so that the focus is more on political action, including opportunities for international cooperation. A consistent theoretical basis for a global sustainability indicator is useful and it is therefore argued here that one should focus on three elements for assessing global sustainability. Here an indicator set will be suggested where the main aspects are:

- Ability to maintain the current standard of living based on the current capital stock (broadly defined). Hence "genuine savings rates" – including the use of forests and non-renewable energy sources – are an important aspect. To the extent that countries are unable to maintain the broader capital stock (including natural resources) there is no sustainable consumption to be expected for the long run.
- Ability to solve environmental problems: If we had an adequate sub-indicator - related to innovation dynamics - the composite sustainability indicator would then have a true economic forward-looking dimension. If countries enjoy a positive revealed comparative advantage in the export of environmental products ("green goods"), one may argue that the respective country contributes to global solving of environmental problems. As it has specialized successfully in exporting environmental products, it is contributing to improving the global environmental quality; also, countries which have specialized in exports of green goods may be expected to use green goods intensively themselves– not least because of the natural knowledge advantage in producer countries and because of the standard home bias of consumers. Countries will be ranked high if they have a high modified RCA (mRCA) in green goods: The mRCA for sector i is defined in such a way that the indicator is zero if the respective sector's export share is the same as that of all competitors in the world market and it is normalized in a way that it falls in the range -1,1 (with positive values indicating an international competitive advantage).
- Pressure on the climate in the sense of global warming. Here CO_2 emissions are clearly a crucial element to consider. The share of renewables could be an additional element, and a rising share over time would indicate not only an improvement of the environmental quality – read less pressure for global warming – but also reflect "green innovation dynamics".
- The aggregate indicator is based on the sum of the indicator values for relative genuine savings rate (s' of the respective country divided by the world average s'^{W}), the relative CO_2 per capita indicator (CO_2 per capita divided by the average of global

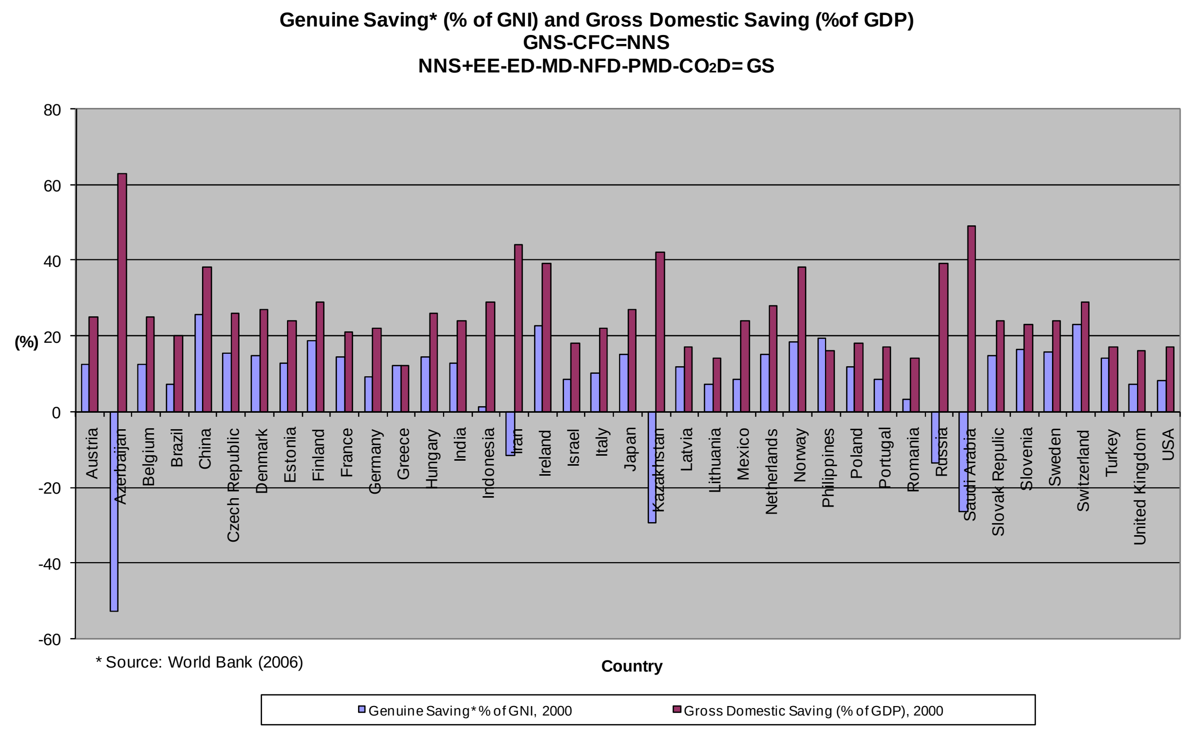
average CO_2 per capita). In principle aggregation of sub-indicators should use a weighing scheme based on empirical analysis.

A synthetic indicator can conveniently summarize the various dimensions to be considered, and this indeed is done subsequently.

For a group of countries, the genuine savings rate and the gross domestic savings rate are shown for the year 2000. The definition of net national savings is gross national savings minus capital depreciations (consumption of fixed capital); if we additionally subtract education expenditures, energy depletion, mineral depletion, net forest depletion, PM10 damage (particulate matter) and CO_2-related damage on has the genuine savings rate.

Sustainability (defined in a broad sense) is weak – based on standard World Bank data - if the genuine savings rate is relatively low. This is particularly the case for Azerbaijan, Kazakhstan, Iran, Saudi Arabia and Russia. The latter two are in a very weak position since the genuine savings rate is negative, having exceeded -10%. Moreover it is also noteworthy that for many countries there is a large gap between the standard savings rate and the genuine savings rate. This suggests that with respect to economic sustainability there is a veil of ignorance in the broader public and possibly also among policy makers.

Figure 5: Genuine Saving versus Gross Domestic Saving*



***Abbreviations:**				
Gross national saving (GNS)	Cons. of fixed capital (CFC)	Net nat. saving (NNS)	Education exp. (EE)	Energy depletion (ED)
Mineral depletion (MD)	Net forest depletion (NFD)	PM10 damage (PMD)	CO_2 damage (CO_2D)	**Genuine saving (GS)**

Data source: WDI/World Bank Data (2008)

A crucial dimension of global sustainability is CO_2 emissions per capita; this indicator mainly is related to the use of energy for production and consumption, respectively. The share of renewable also is a crucial element for climate policies. The energy sector, however, is subject to considerable relative price shifts over time and indeed has reacted with innovations to strong price shocks. High and rising oil prices have undermined global economic dynamics in the period from 2006 to 2008, and representatives of industry and OECD countries have raised the issue as to how, why, and how long such price increases will continue. While it seems obvious that sustained relative price changes should stimulate innovation – see the analysis of GRUPP (1999) for the case of the OPEC price shocks of the 1970s – as well as substitution effects on the demand side and the supply side, it is rather unclear which mechanisms shape the price dynamics in the short-term and the long run. The following analysis takes a closer look at the issues, presents new approaches for economic modeling and also suggests new policy conclusions.

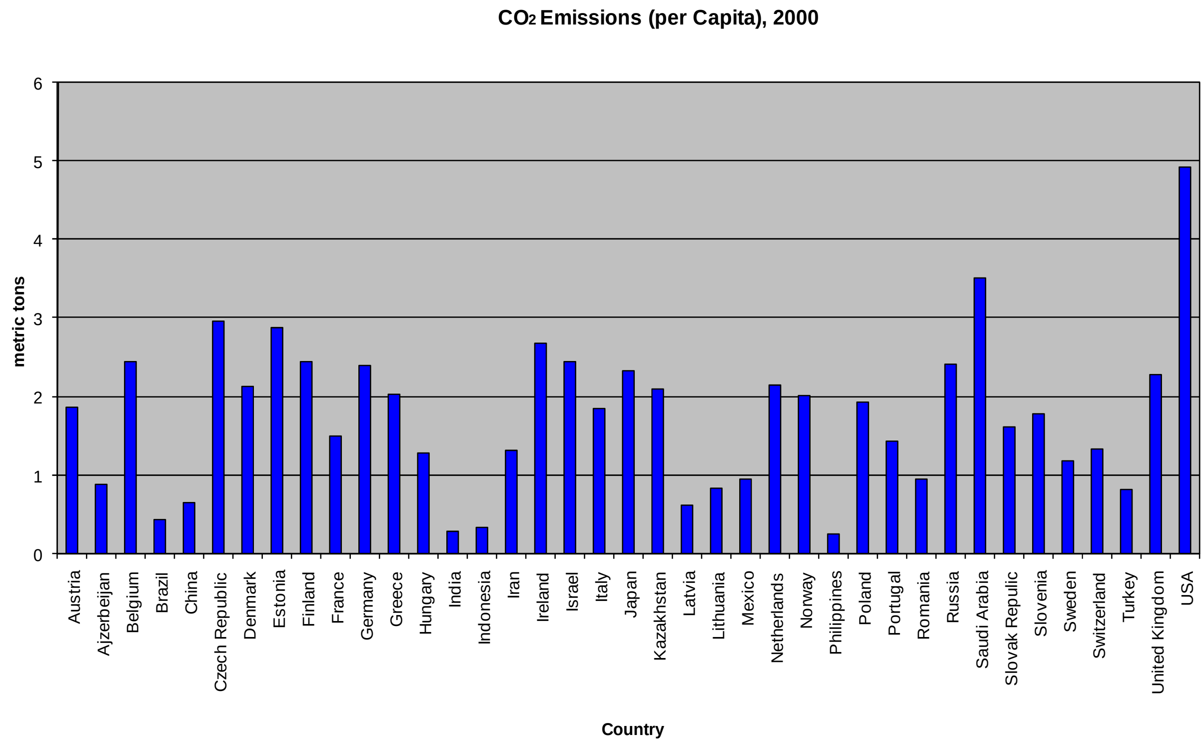
In the wake of the two oil price shocks of the 1970s – each bringing with it a quadrupling of the oil price –, the economics of exhaustible resources became an important research field (e.g. STIGLITZ, 1974; DASGUPTA/HEAL, 1979; SINN, 1981). Oil and gas are particular examples of non-renewable resources, and they are politically sensitive since the main deposits are concentrated regionally, in the case of oil in politically rather sensitive Arab countries as well as Iran and Russia. In addition, major oil producers have established OPEC, which became a powerful cartel in the 1970s when it controlled about 60% of the world market for oil. As transportation costs for oil are very small, the oil price is a true world market price since equilibrium is determined by world oil supply and global oil demand. There is considerable short-term oil price volatility in the short run, und there have been major shifts in oil prices over the medium term. Changes in market structure will affect the optimum rate of depletion of resources (KHALATBARI, 1977).

The oil and gas sector has a long history of high Schumpeterian dynamics, where analysis by ENOS (1962) suggests there is a time lag of about 11 years between invention and innovation. By implication, R&D promotion in this industry will go along with considerable time lags with respect to innovation – this is also a challenge for policy makers, who would have to apply a relatively long time horizon. As regards R&D Promotion, FURTADO (1997) found that differences in the degree of appropriability between upstream and downstream of the oil industry had a great impact on effect of R&D promotion. There are regional case studies on the dynamics of innovation in the oil and gas industry – concerning Stavanger and Aberdeen (HATAKENEKA/WESTNES/GJELSVIK/LESTER, 2006) – which show that different approaches to R&D promotion can have similar effects. It is also noteworthy that the energy sector has been a leading early user of information technology (WALKER, 1986).

A rising relative price of non-renewables is often considered inevitable, since there is long-term global population growth and also high aggregate output growth since the 1990s in the world economy. The use of fossil energy sources does not only have economic issues at stake, but it is also relevant in terms of global warming issues. The Stern Report (STERN ET AL., 2006; NORDHAUS, 2006; LATIF, 2009) has raised international attention about the dynamics of the use of energy and the associated CO_2 emissions as have the policy activities and UN reports with a focus on the Kyoto Protocol. There is long term concern that high economic global growth will strongly stimulate the demand for energy and hence raise emissions. At the same time, there are also medium term concerns about the potential negative impact of oil price shocks. While higher real oil prices might be useful at encouraging a more efficient use of energy resources, there could also be inflation and unemployment problems linked to sudden rises of nominal oil prices.

As regards CO_2 emissions per capita we see a well known picture in which the United States was leading with a relatively poor performance up to 2000.

Figure 6: CO_2 Emissions



Source: WDI, 2008

As regards the consistent composite indicator (with adequate centering) a positive position is strictly defined as a favorable global position, a negative value reflects ecological weakness and to some extent lack of green innovativeness or inefficiencies in the use of energy-intensive products (as mirrored in the CO_2 per capita indicator); more and better innovations can improve the position of the composite indicator so that the main message is that green innovation dynamics matter – thus government should encourage green Schumpeterian dynamics, particularly if there are positive national or international external effects. Specialization in green knowledge-intensive industries and positive green RCAs could go along with national or international positive external effects, however, there are hardly empirical analyses available here. The aggregate indicator shows results which, of course, are somewhat different from the simple aggregation procedure; we clearly can see that careful standardization is required for consistent results.

As already mentioned, from a methodological point the weights attached to the individual components of the indicator could be determined through empirical analysis. Factor loadings are useful starting points for a valid approach. It should be emphasized that the new indicator set proposed (even disregarding the weighing issue) puts the analytical and policy focus on the issue of global sustainability in a new way. The indicator emphasizes long term opportunities and global sustainability. While this approach is only a modest contribution to the broader discussion about globalization and sustainability, it nevertheless represents analytical progress. There is little doubt that specific issues of sustainability – e.g., global warming (see appendix) – will attract particular interest from the media and the political systems. At the same time, one may emphasize that the new broad indicators developed are useful complements to existing sustainability indicators such as the global footprint from the WWF.

The indicator presented is complementary to existing sustainability indicators. However, it has two specific advantages:

- It emphasizes within the composite indicator a dynamic view, namely the Schumpeterian perspective on environmental product innovations.
- It is in line with the OECD handbook on composite indicators.

The indicator for SO_2 emissions can be easily aggregated for global emissions, while the genuine savings indicator cannot easily be aggregated if one wants to get a global sustainnability information. However, as regards the genuine savings indicator one may argue that if the population weighted global savings indicator falls below a critical level there is no global sustainability. One might argue that the global genuine savings rate – a concept which obviously does not need to focus on embedded (indirect) use of materials and energy – should reach at least 5% because otherwise there is a risk that adverse economic or ecological shocks could lead to a global genuine savings rate which is close to zero; and such a situation in turn could lead to economic and political international or national conflicts which in turn could further reduce genuine savings rates in many countries so that global sustainability seems to be impaired.

There are many further issues and aspects of the indicator discussion which can be explored in the future. One may want to include more subindicators and to also consider robustness tests, namely whether changing weights of individual subindicators seriously changes the ranking of countries in the composite index.

3.1 Strategic Views

Global warming represents a long term problem which is related mainly to the use of fossil-based energy resources. The Kyoto protocol established an international framework which – excluding the US and Australia (the latter signed the Protocol in 2008) as the only OECD countries – imposed restrictions on the industrialized countries aimed at reducing greenhouse gases by a certain percentage by 2012. EU countries have adopted an emissions trading system which establishes a certain price for CO_2 emission permits. Energy producers and energy-intensive producers will have to buy such permits unless they obtained them in the first allocation period. Firms will adjust production in a way such that the marginal costs of avoiding CO_2 emissions equals the market price of the emission permit. With a uniform price of emission permits, the marginal costs of CO_2 reduction will be equal across firms. Climate policy measures undertaken by firms or government always have opportunity costs, and the EU's approach of introducing an emission trading system (ETS) is an efficient way at achieving the politically desired reduction of CO_2 emissions; the EU has set a certain cap for the overall EU, and the individual countries have made commitments concerning the reduction of national CO_2 emissions. Analysis of economists (e.g. WARD, 2006; PEARCE, 1999; WEIMANN, 1995) have emphasized that a Pigou tax or an international emission trading system may both be considered as equivalent instruments.

From a theoretical perspective, an emission trading system seems better than a Pigou tax, namely since ETS is effectively like a flexible international Pigou tax. One may, however, raise some doubts about the effectiveness of ETS, namely to the extent that the price of emission certificates is linked to general asset market dynamics – the international banking crisis of 2007/08, which created some (downward) overshooting, has caused emission permit prices to fall drastically in 2008/09.

Germany has adopted a specific law (Law on Renewable Energy; *Erneuerbare Energie Gesetz*) which subsidizes wind energy generation and solar energy generation, both considered useful ways to reduce CO_2 emissions. This at least was emphasized by several German governments, which also pointed out that many new jobs had been created by the expansion of the solar panel industry and the production of wind mills and related software.

Taking a closer look at the economic aspects of renewable subsidization, a modified perspective is adequate. Indeed, a rather inefficient way of reducing CO_2 emissions concerns solar energy generation. In the first two trading periods which started in 2005 and 2008, German firms obtained emission permits for free. While the price of emission permits in the EU has hovered around €20 per ton, the costs of avoiding one ton of CO_2 emission through solar energy production (in Germany households producing solar power are guaranteed a price of about 50 cent per kWh while the market price is only 20 cent per kWh) is in the range of €700-1200, and wind power generation amounts to costs of €100-200 per ton of CO_2 avoided (WEIMANN, 2009, p.89). To the extent that the German government subsidizes solar power and wind power and CO_2 emissions in Germany are reduced, there is no improvement in global CO_2 emissions. The German improvement simply leads to a surplus of CO_2 emissions in Germany so that the German demand/EU demand for emissions permits reduces; the price of emission certificates will fall and energy-intensive producers in other EU countries will thus increase their emissions.

There are, however, some arguments for a modified and low subsidization of wind energy generation and solar energy generation. Two specific elements are required:

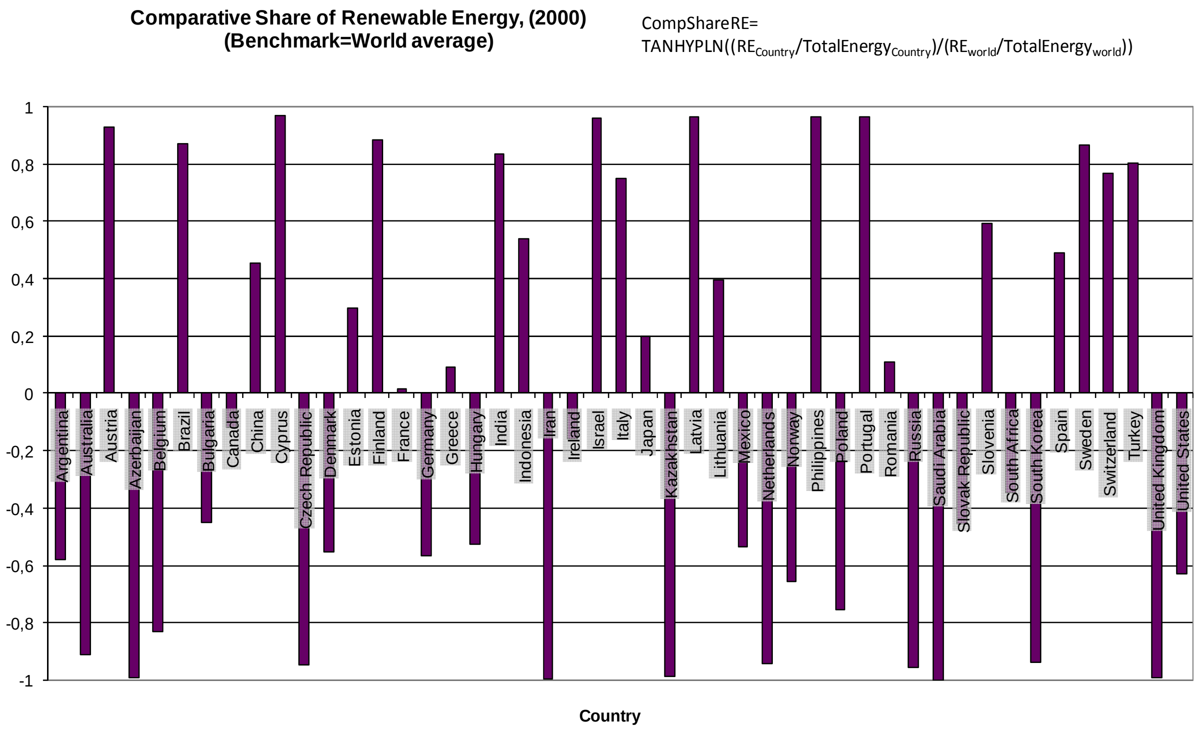
- Subsidies should only refer to projects based on new technologies; thus innovations in energy-related fields would be subsidized – and this is useful to the extent that there positive external effects.
- Static and dynamic scale economies could also be an argument for subsidizing wind energy and solar energy. To exploit such economies of scale in a world economy in which product innovations fetch a Schumpeterian premium price can be a useful way to obtain rents in international markets. The more people switch to CO_2-free energy sources – which partly might reflect prestige effects on the demand side – in an ever growing number of countries, the higher the potential rents which can be appropriated through first-mover advantages.

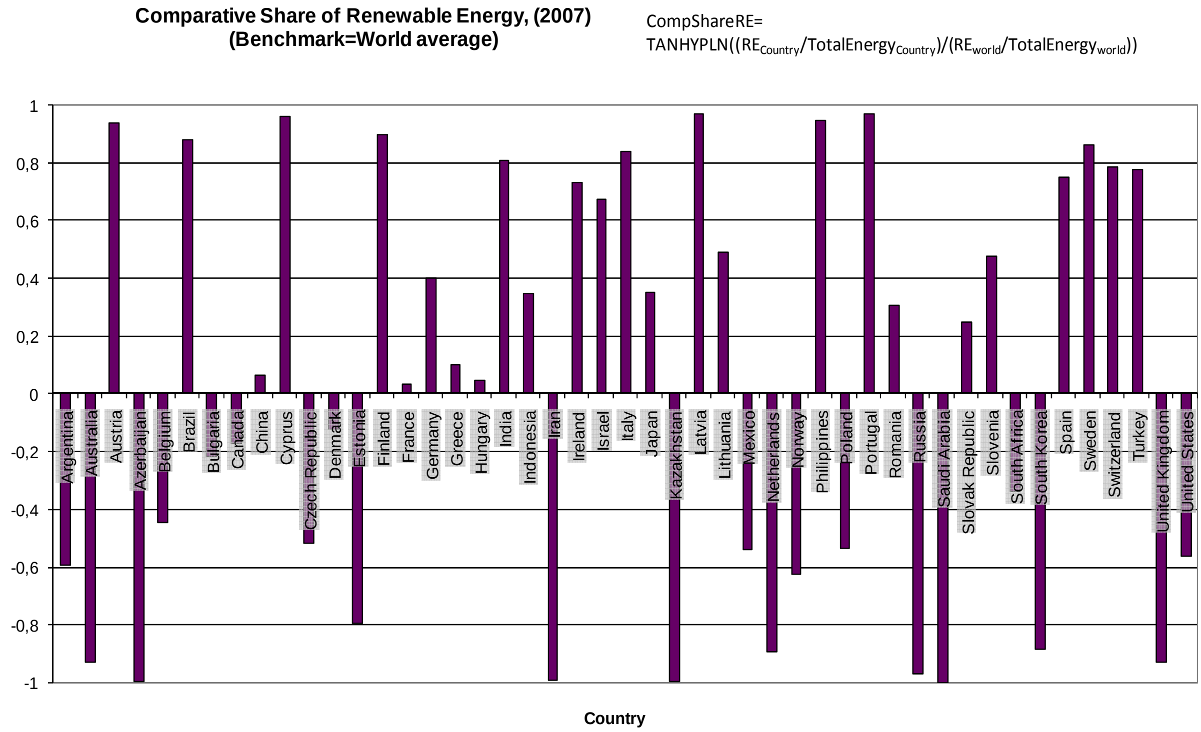
From an empirical perspective, one should like to know how important static and dynamic scale economies as well as positive external effects of innovations are. Since the global warming problem refers to CO_2 emissions and other greenhouse gases in a worldwide perspective, it is not efficient to reduce emissions of greenhouse gases in particular countries through particular national subsidies. A global approach to establishing an ETS would be useful. However, one may emphasize that stabilization of financial markets should be achieved first since otherwise a very high volatility of certificate prices is to be expected; future markets for such certificates also should be developed carefully and it is not obvious such markets necessarily will be in the US; the EU has a certain advantage here as the EU has taken a lead in the trading of emission certificates. There are policy pitfalls which one should avoid in setting up ETS; e.g the German government has largely exempted the most energy-intensive sectors in the first allocation period – those sectors would normally have rather big opportunities to achieve cuts in energy intensity and CO_2 emissions, respectively;

KLEPPER/PETERSON (2006) have calculated that the welfare loss of emission trading could have been 0,7% of GDP in the first German National Allocation Plan while in reality the welfare amounted to 2,5% of GDP.

Government incentives on renewables could be a useful element of environmental modernization. As regards the share of renewable in the use of energy generation the following tables show that there are large differences across countries. Following the general approach presented here – with the world average set at zero (and the indicator normalized in a way that it falls in the range 0,1) – we can see that there are some countries which are positively specialized in renewable energy: Austria, Brazil, Finland India, Italy, Latvia, Philippines, Portugal, Sweden, Switzerland and Turkey have positive indicators. It is noteworthy, that the position of Azerbaijan, Iran, Kazakstan, Netherlands, Russia and the UK are clearly negative. Comparing 2000 and 2006 the worsening position of China is remarkable, at the same time the UK has slightly and Germany has strongly improved its respective position. There is no doubt that countries such as Russia and China could do much better in the field of renewable provided that government encourages innovative firms and innovations in the renewable sector on a broader scale.

Figure 7: Normalized Indicator on the Share of Renewables in Selected Countries: 2000 vs. 2007





Source: IEA Database, EIIW calculations

3.2 Basic Reflections on Constructing a Comprehensive Composite Indicator

In the following analysis, a composite indicator measuring global sustainability in energy consumption is presented. In the first step, the influence of different partial indicators on the composite indicator is discussed by analysing sets of composite indicators with fixed identical weights. In the second step, the weights are allowed to be flexible/different and are estimated using factor analysis. Building on the insights gained in these two steps, a specific composite indicator is developed.

However, to begin with, the partial indicators will be introduced and it will be argued in how far they differ from the standard approaches in the literature. Additionally, the modes in which the partial indicators are transformed into centralized and normalized versions are presented.

Points of Departure: Revealed Comparative Advantage

There is a long history of using the revealed comparative advantage (RCA) as an indicator of international competitiveness, which can also be an indicator for assessing the specialization in green environmental goods. The standard Balassa indicator considers the sectoral export-import ratio (x/j) of sector i relative to the total export-import ratio (X/J) and concludes that an indicator above unity stands for international competitiveness in the respective sector. It is useful to take logarithms so that one can calculate ln(x/j)/ln(X/J): If the indicator exceeds zero, there is a positive successful specialization, if the indicator is negative, the country has a comparative disadvantage. Minor deviations from zero – both positive and negative – will normally be considered as a result of random shocks (to have a positively significant sectoral specialization, a critical threshold value has to be exceeded).

Since this indicator takes existing goods and services into account, there is a natural bias against product innovations, particularly in new fields; innovative countries that have many export products that stand at the beginning of the product cycle, will typically only export a few goods at relatively high prices – only after a few starting years will exports grow strongly. Foreign direct investment might also somewhat distort the picture, namely to the extent that multinational companies could relocate production of green products to foreign countries. To the extent that foreign subsidiaries become major exporters over time, – a typical case in manufacturing industry in many countries – the technological strength of an economy with high cumulated foreign direct investment outflows might contribute to a relatively weak RCA position, as a considerable share of imports is from subsidiaries abroad.

A slight modification of the Balassa RCA indicator is based on BALASSA (1965) and BORBÉLY (2006): The modified RCA indicator for export data (MRCA) is defined as:

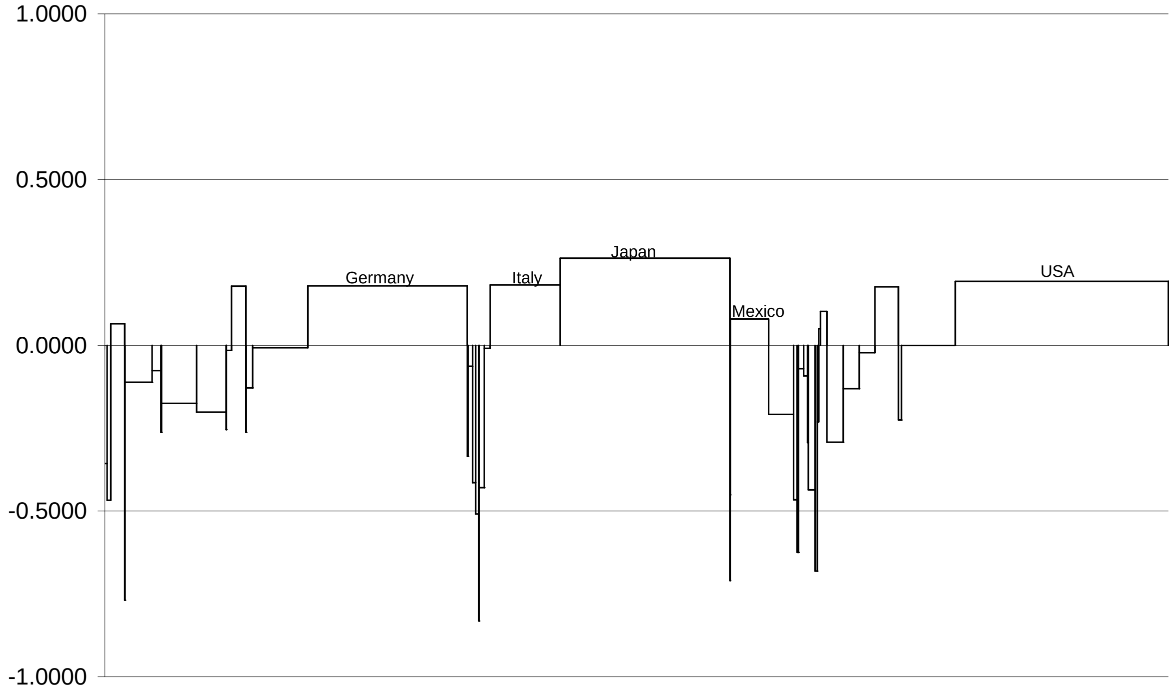
$$MRCA_{c,j} = \text{tanhyp}\left(\ln\left(\frac{x_{c,j}}{\sum_{j=1}^{n} x_{c,j}}\right) - \ln\left(\frac{x_{I,j}}{\sum_{j=1}^{n} x_{I,j}}\right)\right)$$

In this context, the index uses data for exports and calculates the ratio of the export share of a sector – in this case, the sector of environmental green goods – in one country to the export share of that sector in a reference market (e.g. EU27 or the world market). In most cases, it is adequate to use a reference market with a homogenous institutional set-up, such as the EU27 market; an alternative is the world market, which stands for a more heterogeneous institutional setting than the EU27. The selected countries make up most of the world market (about 80%), but not the whole world economy. Therefore, for practical purposes, – e.g. avoiding the problem of missing data - we have decided that the reference market used is the market consisting of the countries observed in the analysis.

Furthermore, it is important to mention that the modified RCA indicator, as presented above, allows to be applied to a much broader range of data than just export data. While it is possible to use the indicator for the relative position of macroeconomic data, such as labor or patents, in the present case, it is also applied to the share of renewable energy production in countries instead of the export data – the idea is to consider the relative renewables position of a given country: The resulting RCA-indicator (SoRRCA) gives the relative position of one country, regarding renewable energy production in comparison with the share of renewable energy production in the reference market, which in this case is the total world market. It can be shown that for this case, the results will not be influenced much by either the world market or the market consisting of all observed countries.

In addition to the traditional and modified RCA indicators, as introduced by BALASSA (1965) and BORBELY (2006), respectively, we also test for volume-weighted RCAs. In this case, the modified RCAs (MRCAs) are calculated and multiplied by the countries' share of exports in relation to world exports, resulting in the volume-weighted RCA VolRCA (The results are the same if absolute exports are used instead of export shares.). The results for the year 2000 are shown in the figure below. Here, the basic idea is not only to look at the relative sectoral export position for various countries, but to emphasize that a country whose green sector has a positive specialization in green export goods adds more to the global environmental problem solving, the higher the absolute volume of green exports. From this perspective, large countries with a high positive green export specialization stand for a particularly favorable performance.

Figure 8: Volume-weighted RCAs for the Year 2000



The figure shows that the indicator modified in such a way allows for discrimination between those countries which are leading in weighted green RCAs, and those that fall behind, either in absolute volume or in green specialization. Leading countries, like Germany, Italy, Japan, Mexico or the USA, not only export a high volume of environmental goods, but also hold a significant advantage compared to the other countries. In contrast to that group of countries, the countries that show a comparative disadvantage can be divided into a group that has a green export advantage but a small export volume; and into a group that has a relatively high volume but no strong comparative advantage. The latter countries are mostly larger countries that are major international suppliers of green goods, but compared to their other industries, the environmental goods do not play a very important role. These countries have a potential to become future leaders in the area and a more detailed analysis of the countries and the dynamics would allow an insight into the way comparative advantages and growing sectoral leadership positions are established – an issue left for future research.

Standardization

All indicators, except MRCA or SoRRCA, are neither centralized around zero nor have they clearly defined finite and symmetrical boundaries, especially not in the same way as the RCA indicators, whose results lie in the interval [-1, 1]. If the intention is, therefore, to combine the partial indicators additively, as will be done in the present approach, it is necessary to ensure that the indicators are concentrated around zero and that their values do not exceed the above stated interval. Furthermore, it is necessary to ensure that the best possible result is +1 and the worst possible result is equivalent to -1.

Centralization is easily achieved by calculating the mean for an indicator and subtracting it from the individual indicator value. Alternatively, a given average (like the world average) can be taken and used as an approximate mean. The resulting indicator ensures that the number of countries with a negative value is equal to the number with positive values.

The problem in this context is the temporal stability of the calculated means. If the means do not stay relatively constant over time, a problem arises, where a positive or negative position does not depend so much on the values of a single country but mostly on the values of other countries.

It can be shown that, while the means of the genuine savings rate and the CO_2 output remain mostly on the same level, the mean of the total exports is monotonically rising. This will be a problem, especially in the construction of the volume weighted RCA indicator, VolRCA.

Even if the VolRCA indicator is inherently relative in nature, this effect solely takes the absolute volume into account, neglecting the sectoral structure; nonetheless, this trade-off is necessary to combine export-volumes and sectoral advantages, and until now, no alternative approach is known that could take care of this trade-off.

The second part of the standardization process is the normalization of the data. It is possible to take different approaches. The most common one is to divide the indicator values by the range given by the difference between the maximum and the minimum value. This approach is also the one that is implemented in this analysis. In the table below it is referred to as "normalized (linear)".

An alternative is the "normalized (arctan)" approach. Here, the centralized data is normalized using the function $f(x)=2/\pi \arctan(x)$. A useful effect of this approach is the fact that the result is not influenced by very large or very small outliers. Furthermore, the basis of the calculation stays the same and does not differ with the respective data used. Using the arctan-functional form also means to work with a functional form that is relatively steep for small values. Therefore, the results are very often nearing unity or minus 1, and it is very hard to discriminate between them. Additionally, the arctan-function is skewed and will lead to skewed results, which means that distances between values are no longer relatively constant. The linear approach will be used in the following chapters, considering both of the alternative approaches.

Fixed Weights vs. Free Weights

The following table provides the partial indicators used in the following analysis. As only linearly normalized variables will be used, only those are mentioned.

Figure 9: Partial Indicators Used

Partial Indicator	Abbreviation
MRCA	(1)
MRCA*Exports (centralized+normalized; Volume Weighted) : VolRCA	(3)
Genuine Savings Rate (centralized+normalized(linear)	(7)
CO_2 Generation (centralized+normalized(linear))	(9)
Share of Renewables	(A)
SoRRCA (normalized, centralized)	(B)

The composite indicators that will be constructed and discussed below all have the form:

$$\text{CompositeIndicator} = \sum_{i=1}^{n} w_i \text{PartialIndicator}_i \tag{1}$$

It is assumed in the following section that all weights are identical.

$$w_i = w_j = \frac{1}{n} \quad \forall i, j = 1, \dots, n \tag{2}$$

By contrast, in a later section, where the weights are estimated, it is generally true that weights differ:

$$w_i \neq w_j \quad \forall i \neq j = 1, \dots, n \tag{3}$$

In this context it is discussed, whether situations arise where two or more weights are identical.

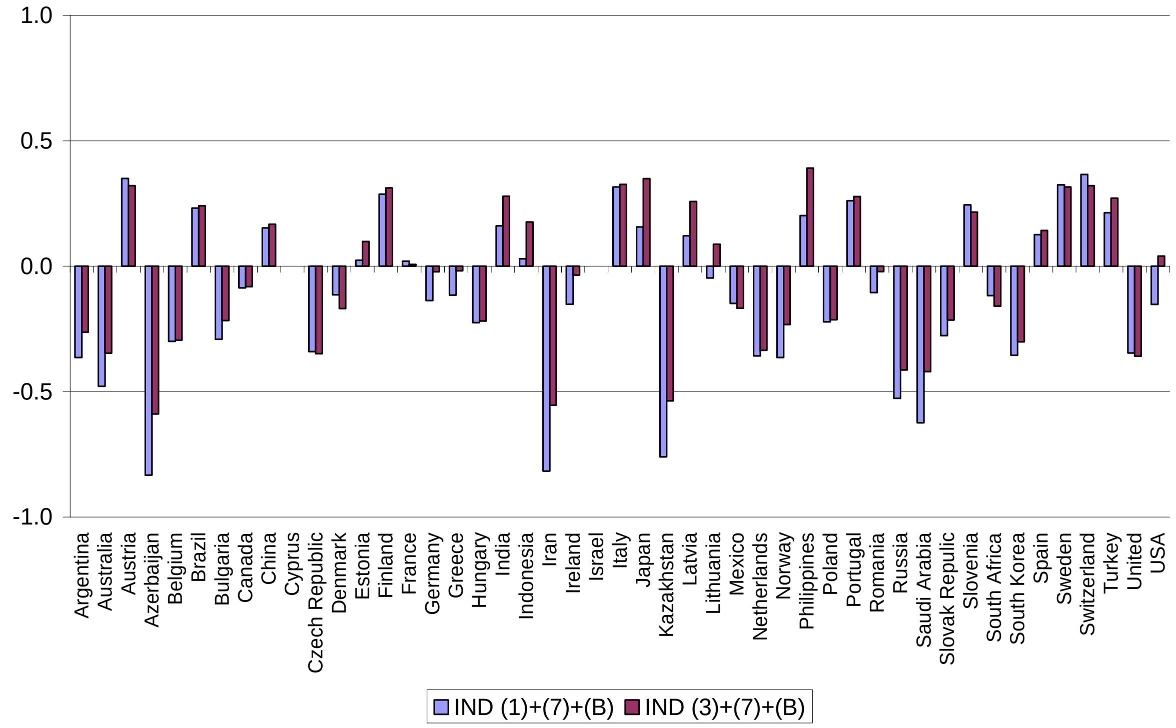
Fixed Weights

The following three figures show a composite indicator that is constructed from the partial indicators for the genuine savings rate, the SoRRCA (Share of Renewables RCA) and in the first case the MRCA and in the second case the VolRCA, for the years 2000, 2006 and 2007.

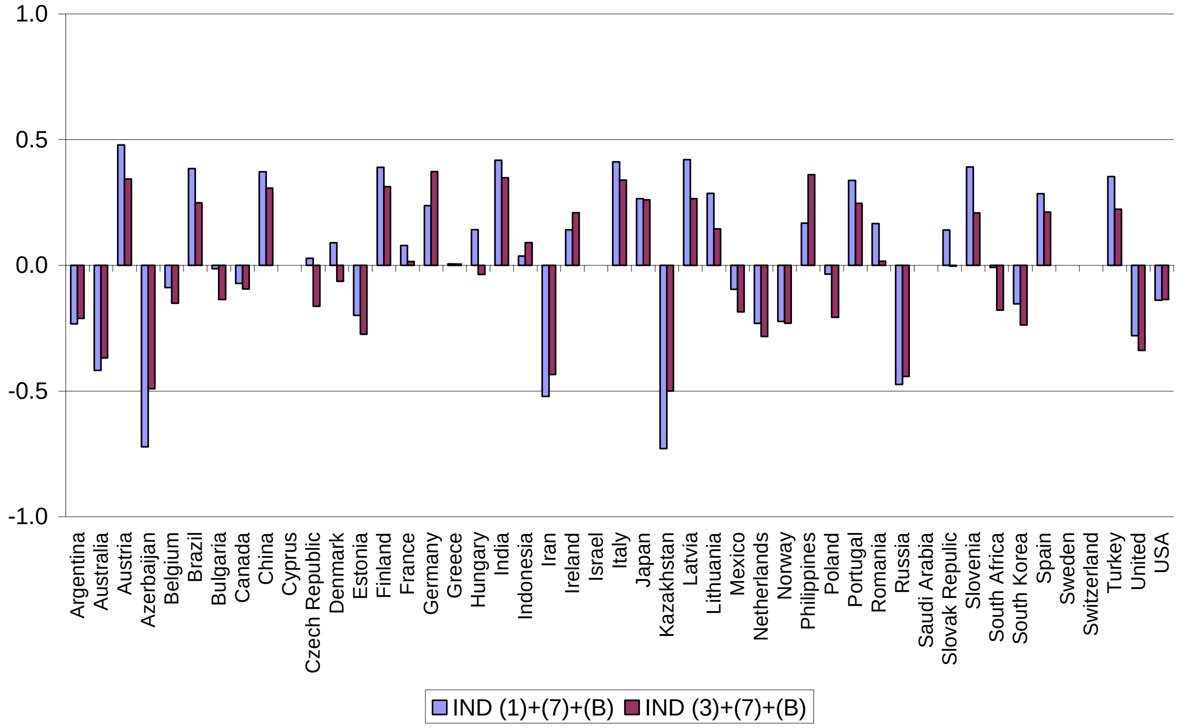
The basic of the following 3 tables is to highlight to which extend there is a difference between our "ideal" preferred composite indicator consisting of (3), (7), (9), (A), (B) namely compared two alternative indicators.

Figure 10: Indicators Showing the Influence of the Standard RCA Indicator vs. the Volume-Weighted RCA Indicator

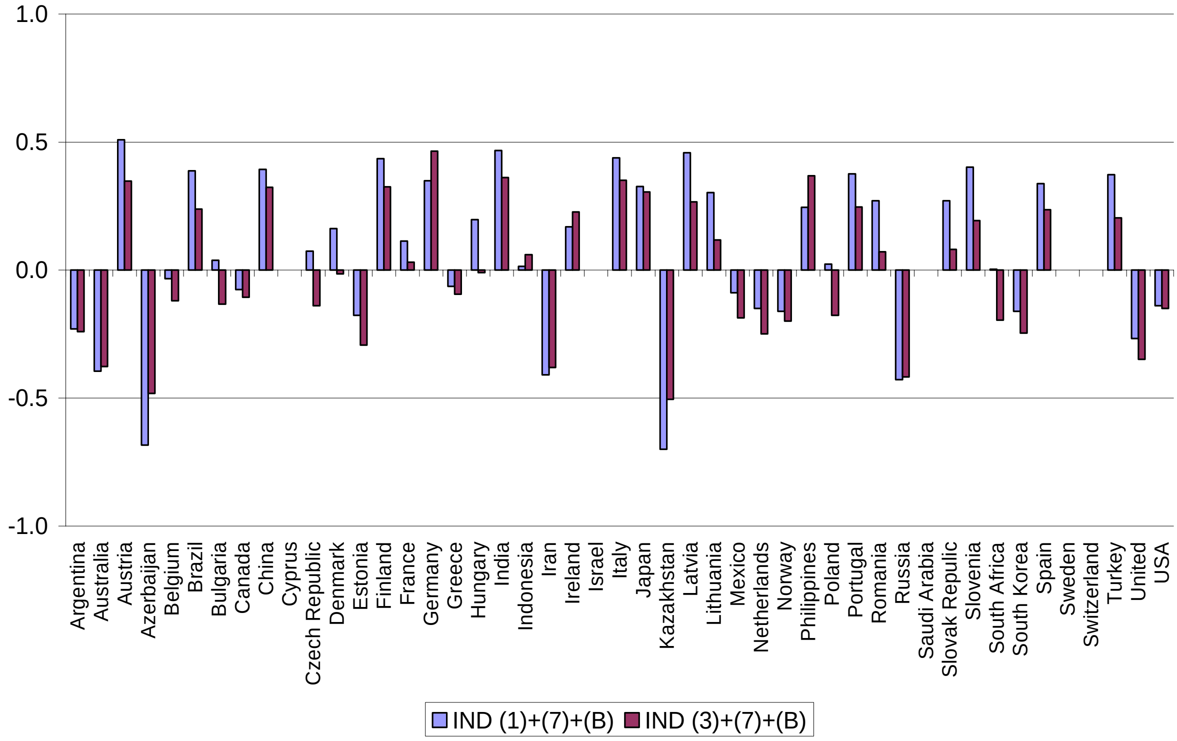
2000:



2006:


1.0
0.5
0.0
-0.5
-1.0
Argentina
Australia
Austria
Azerbaijan
Belgium
Brazil
Bulgaria
Canada
China
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Kazakhstan
Latvia
Lithuania
Mexico
Netherlands
Norway
Philippines
Poland
Portugal
Romania
Russia
Saudi Arabia
Slovak Repulic
Slovenia
South Africa
South Korea
Spain
Sweden
Switzerland
Turkey
United
USA
IND (1)+(7)+(B)
IND (3)+(7)+(B)

2007:


1.0
0.5
0.0
-0.5
-1.0
Argentina
Australia
Austria
Azerbaijan
Belgium
Brazil
Bulgaria
Canada
China
Cyprus
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
India
Indonesia
Iran
Ireland
Israel
Italy
Japan
Kazakhstan
Latvia
Lithuania
Mexico
Netherlands
Norway
Philippines
Poland
Portugal
Romania
Russia
Saudi Arabia
Slovak Repulic
Slovenia
South Africa
South Korea
Spain
Sweden
Switzerland
Turkey
United
USA
IND (1)+(7)+(B)
IND (3)+(7)+(B)

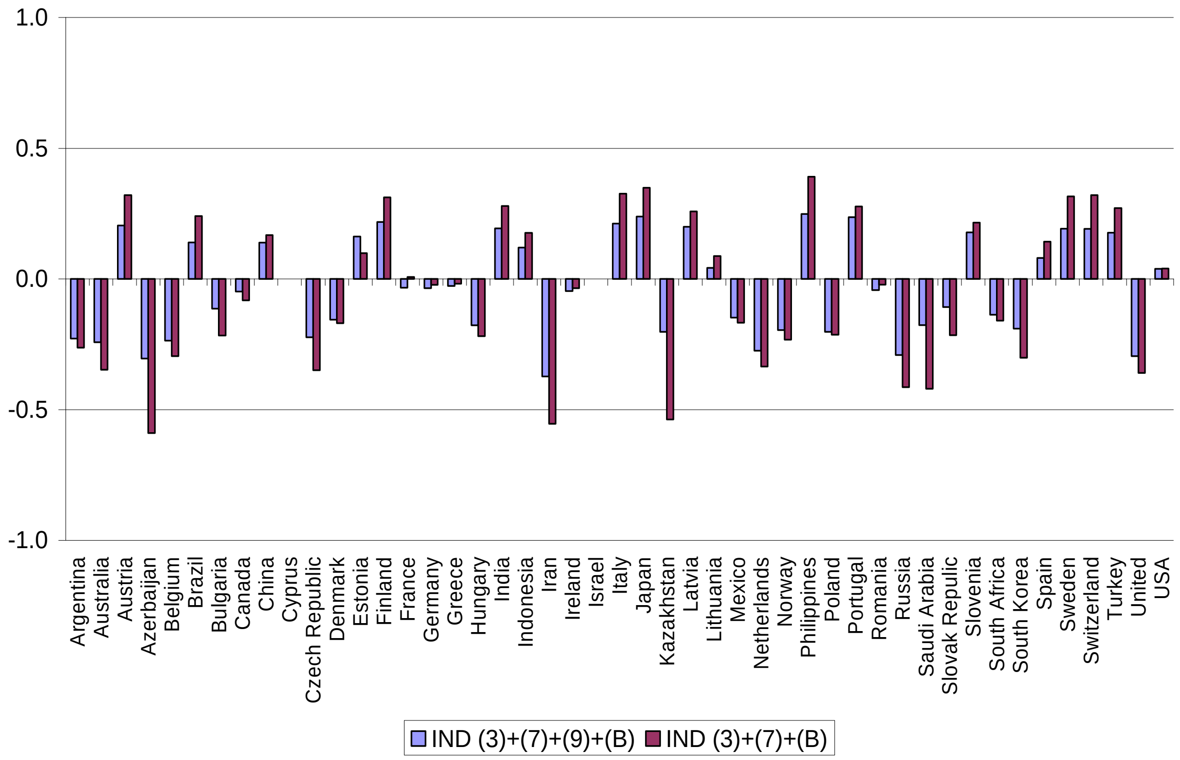
The first insight gained from the figures above is that in most cases both indicators point in the same direction, meaning that if the first one indicates a comparative advantage, the second one does so as well. Furthermore, it seems that the second one is somewhat less harshly accentuated. Additionally, in the area were the first indicator is insignificantly close to zero, the second one gives a clear indication as to whether an advantage is present or not. The last fact that is worth mentioning is that, over time, the indicators stay mostly similar. While this does not influence the decision concerning the choice of the export RCA, it is, nonetheless, worth mentioning as it shows that not only the composite indicators both stay stable, but also that there has been rather few dynamics in the last years concerning sustainability in the majority of countries.

Conclusively, it can be said that both partial indicators can be used for the creation of a composite indicator, as there is no discernable difference between the effects the two have. We decide in favor of the VolRCA since it discriminates best between advantages and disadvantages and, as it will be shown in the following sections, using the VolRCA will result in better weights when they are allowed to deviate from each other (across subindicators).

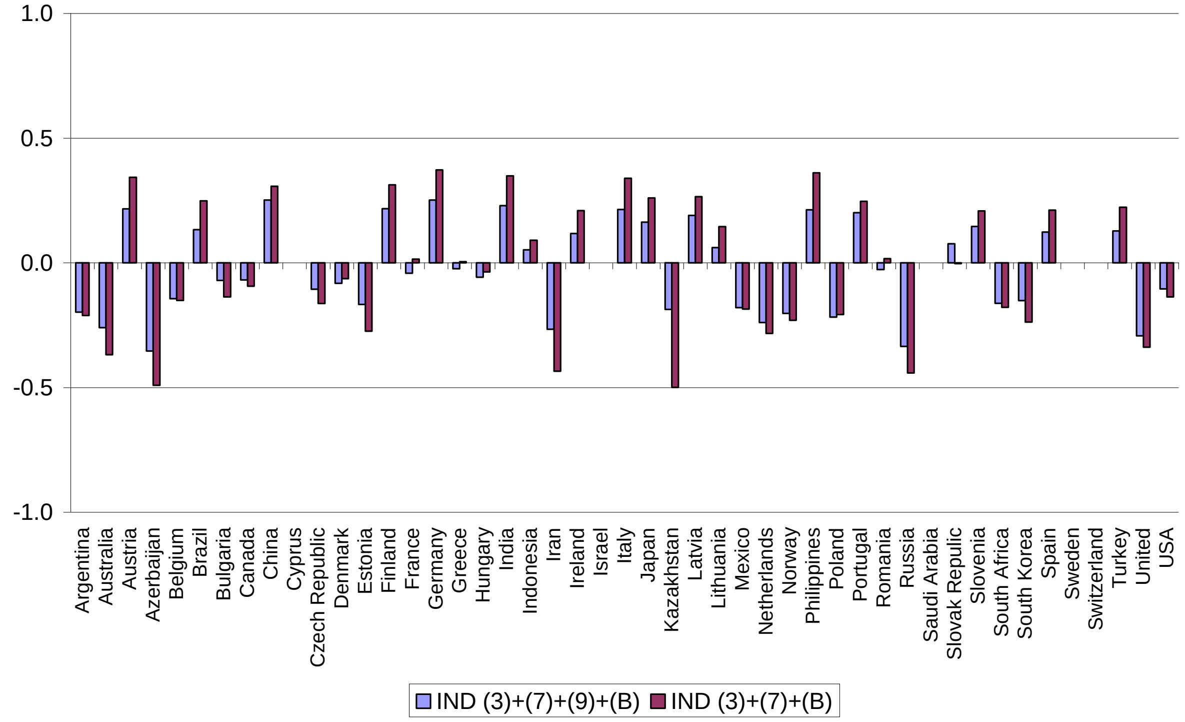
Following the same procedure as above, a composite indicator constructed from the partial indicators of the VolRCA, the genuine savings rate and the SoRRCA are compared to an indicator additionally containing the CO_2 output indicator.

Figure 11: Indicators Showing the Influence of the CO_2 indicator

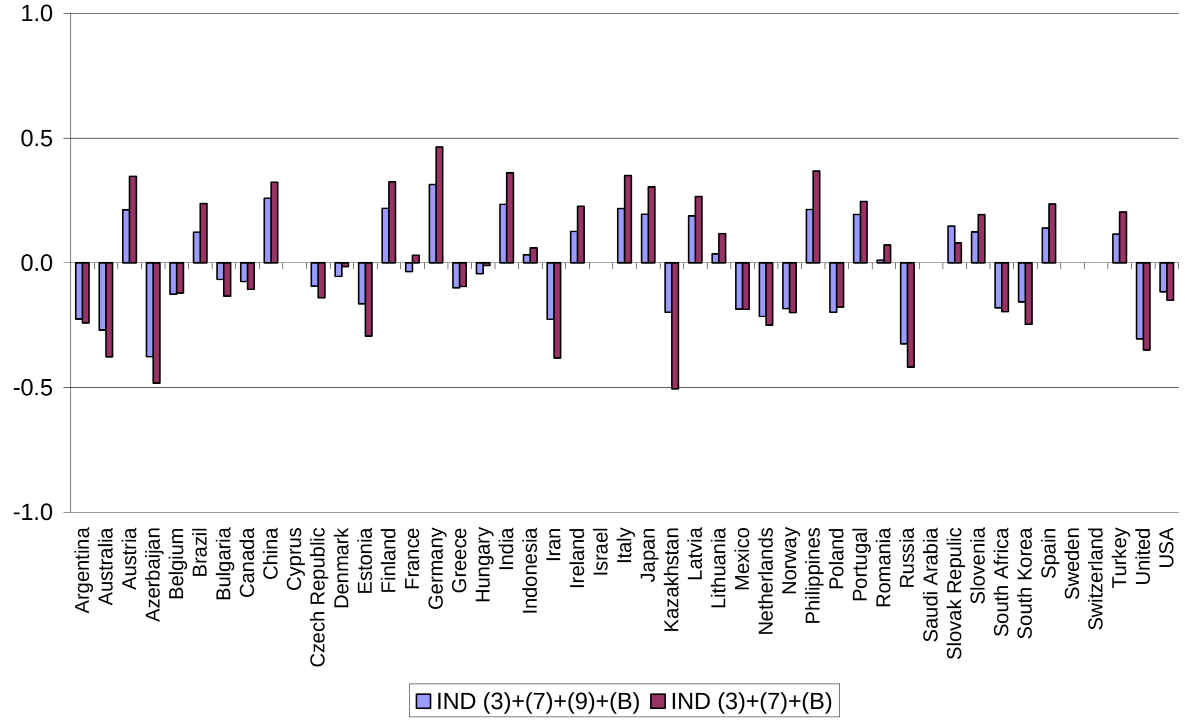
2000:



2006:



2007:



In almost all cases, the indicator without the CO_2 emissions is more accentuated than the indicator including them. Combined with the effect that, as shown below, inclusion of the CO_2 emissions indicator leads to redundancy problems in the composite indicator, it is prudent to abstain from using the CO_2 emissions indicator. Similar to the first three figures, the two composite indicators compared here stay relatively stable over time, and in the rare occasions where the results change, at least the relations of the two indicators to each other are kept.

Finally, in the third part of this analysis, the influence of the share of renewable energy production in the energy mix of the countries is observed. Here, the composite indicator is calculated from the VolRCA and the genuine savings rate. Additionally, the three cases of no inclusion of the share of renewable energy, the absolute share of renewable energy and the SoRRCA are considered.

3.3 Weights from Factor Analysis

In the following part, the weights are no longer fixed to the number of partial indicators used. Instead, a factor analytical approach is used to estimate the values for the weights.

Factor Analysis is a mathematical method from the field of dimension reducing algorithms. The goal is to start from a row of observations for different indicators and estimate weights for aggregation of the indicators into one or more composite indicators. The number of resulting composite indicators will be less than the number of indicators to begin with. The method also offers decision support on how many indicators will result from the process. In contrast to the traditional application of the factor analysis, the number of resulting indicators in this case is fixed, but not the number of resulting eigenvalues exceeding given bounds.

Nevertheless, the eigenvalues play an essential role in constructing the composite indicator. In traditional factor analysis, the desired result would be for one eigenvalue to dominate all other eigenvalues. The sum over all eigenvalues equals the number of partial indicators; traditionally, the ideal result would be for the largest eigenvalue to be equal to this sum, whereas all other eigenvalues would be zero. This would be the case if all partial indicators were measuring exactly the same concept.

In constructing the present composite indicator, it is desirable to combine different concepts around the idea of sustainability. Therefore, it would be best for every partial indicator to describe a different concept. The degree to which this goal is achieved can be seen from the eigenvalues. If all eigenvalues have values near unity, it indicates that all partial indicators measure independent concepts.

This is also the way in which the final decisions on the usage of partial indicators of the preceding chapter have been reached. If more than one indicator is possible, the one that has the more evenly distributed eigenvalues for all years is chosen.

The second aspect that is used as a decision criterium is the sign of the resulting components, e.g. the resulting weights. It can be seen that the expected signs for the weights of all but the CO_2 emissions indicator are expected to be positive. This condition is, with the exception of two cases, met by the present data, so that it does not offer a reliable means to discriminate between feasible partial indicators and non-feasible ones. So, the main decision is made using the distribution of eigenvalues. Finally, the resulting components are normalized by dividing them by their sum, thus, resulting in weights summing up to unity. An overview of the resulting eigenvalues and the components, e.g. weights, is given in the appendix.

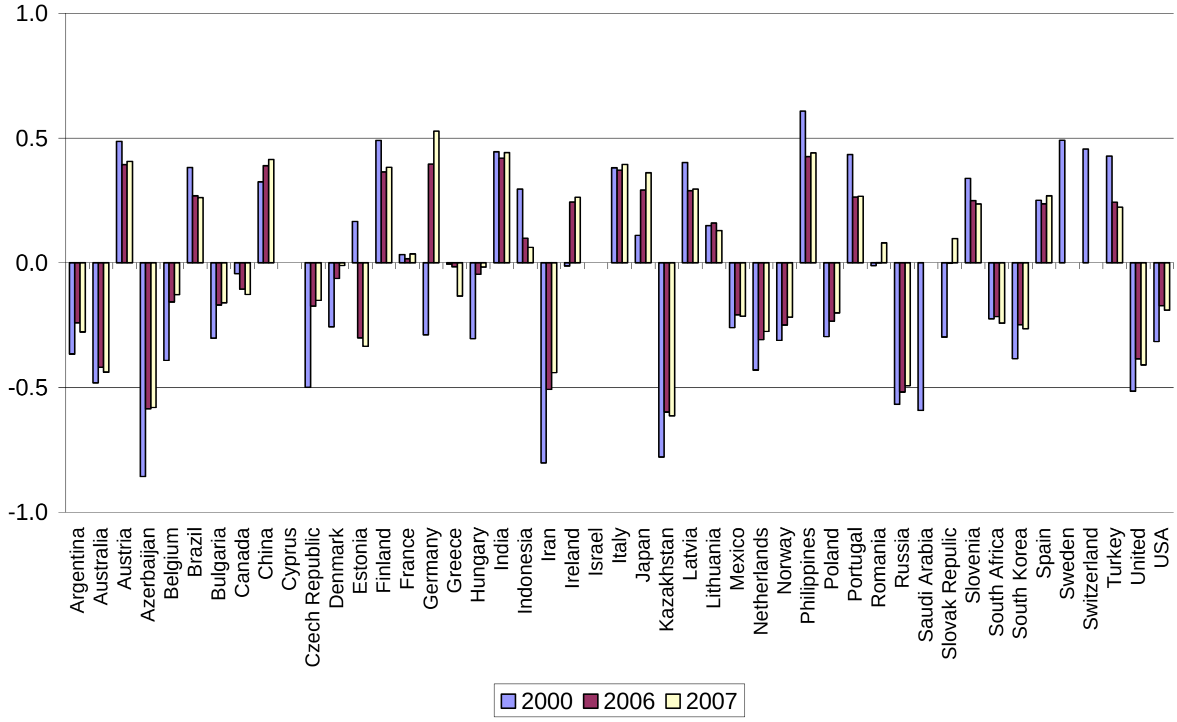
Combining the insights from this and the preceding chapter, an ideal global indicator can be motivated, which is constructed from the VolRCA, the genuine savings rate and the SoRRCA. The following figure gives a broad overview of this composite indicator for the years 2000, 2006 and 2007. A clear finding is that Austria, Brazil, Cyprus, Finland, Germany (in 2006 and 2007, not in 2000), India, Ireland, Italy, Japan, Latvia, the Philippines, Portugal, South Africa, Sweden and Switzerland have considerable positive indicators; by contrast, Australia, Azerbaijan, Iran, Kazakhstan, Russia, Saudi Arabia, the UK and – less pronounced – the USA, the Netherlands and Mexico and some other countries - have a negative performance. The countries with relatively weak indicator values for sustainability are often rather weak in terms of renewable energy; this weakness, however, can be corrected within one or two decades, provided that policymakers give adequate economic incentive and support promotion of best international practices. To the extent that countries have low per capita income, it will be useful for leading OECD countries to encourage relevant international technology transfer in a North-South direction. At the same time, successful newly industrialized countries or developing countries could also become more active in helping other countries in the South to achieve green progress.

To the extent that international technology transfer is based on the presence of multinational companies, there are considerable problems in many poor countries: these countries are often politically unstable or have generally neglected the creation of a framework that is reliable, consistent and investment-friendly. Countries in the South, eager to achieve progress in the field of sustainability, are well advised to adjust their economic system and the general economic policy strategy in an adequate way. Joint implementation in the field of CO_2-reduction could also be useful, the specific issue of raising the share of renewable energy should also be emphasized. Solar power, hydropower and wind power stand for three interesting options that are partly relevant to every country in the world economy. With more countries on the globe involved in emission certificate trading, the price of CO_2 certificates should increase in the medium-term that will stimulate expansion of renewables both in the North and in the South. While some economists have raised the issue that promotion of solar power and other renewables in the EU is doubtful, – given the EU emission cap – as it will bring about a fall of CO_2 certificates, and ultimately, no additional progress in climate stabilization. One may raise the counter argument that careful nurturing of technology-intensive renewables is a way to stimulate the global renewable industry, which is often characterized by static and dynamic economies of scale. With a rising share of renewables in the EU's energy sector, there will also be a positive effect on the terms of trade for the EU, as the price of oil and gas is bound to fall in a situation in which credible commitment of European policymakers has been given to encourage expansion of renewables in the medium-term. Sustained green technological progress could contribute to both economic growth and a more stable climate. One may also point out that the global leader in innovativeness in the information and communication technology sector, offers many examples of leading firms (including Google, Deutsche Telekom, SAP and many others) whose top management has visibly emphasized the switch to higher energy efficiency and to using a higher share of renewable energy.

Given the fact that the transatlantic banking crisis has started to destabilize many countries in the South in 2008/09, one should keep a close eye on adequate reforms in the international banking system – prospects for environmental sustainability are dim if stability in financial markets in OECD countries and elsewhere could not be restored.

There is a host of research issues ahead. One question - that can already be answered - concerns the stability of weights over time used in the construction of the comprehensive composite indicator. While the weights for every year have been calculated independently, one could get further insights if a single set of weights over all years is calculated. Considering the results shown in the table below, it is not straightforward that it is possible to calculate such a common set of weights for the available data. Making such a calculation, this results in weights with a distribution similar to those for the years 2006 and 2007.

Figure 12: EIIW-vita Global Sustainability Indicator



In 2000, the main weight in the construction of the indicator lies in the savings rate and the SoRRCA, whereas the VolRCA only plays a marginal role. By contrast, in 2006/2007, all three indicators show similar weights, with a slight dominance by the savings rate. In light of these findings, one might conclude, – based on exploitation of more data (as those are published) – that the empirical weights converge to a rather homogenous distribution. There is quite a lot of room left for conducting further research in the future. However, the basic finding emphasized here is that the variables used are very useful in a composite indicator.

Figure 13: Estimated Weights from Factor Analysis

	2000	2006	2007
(3)	0.01	0.29	0.30
(7)	0.50	0.39	0.38
(B)	0.50	0.32	0.31

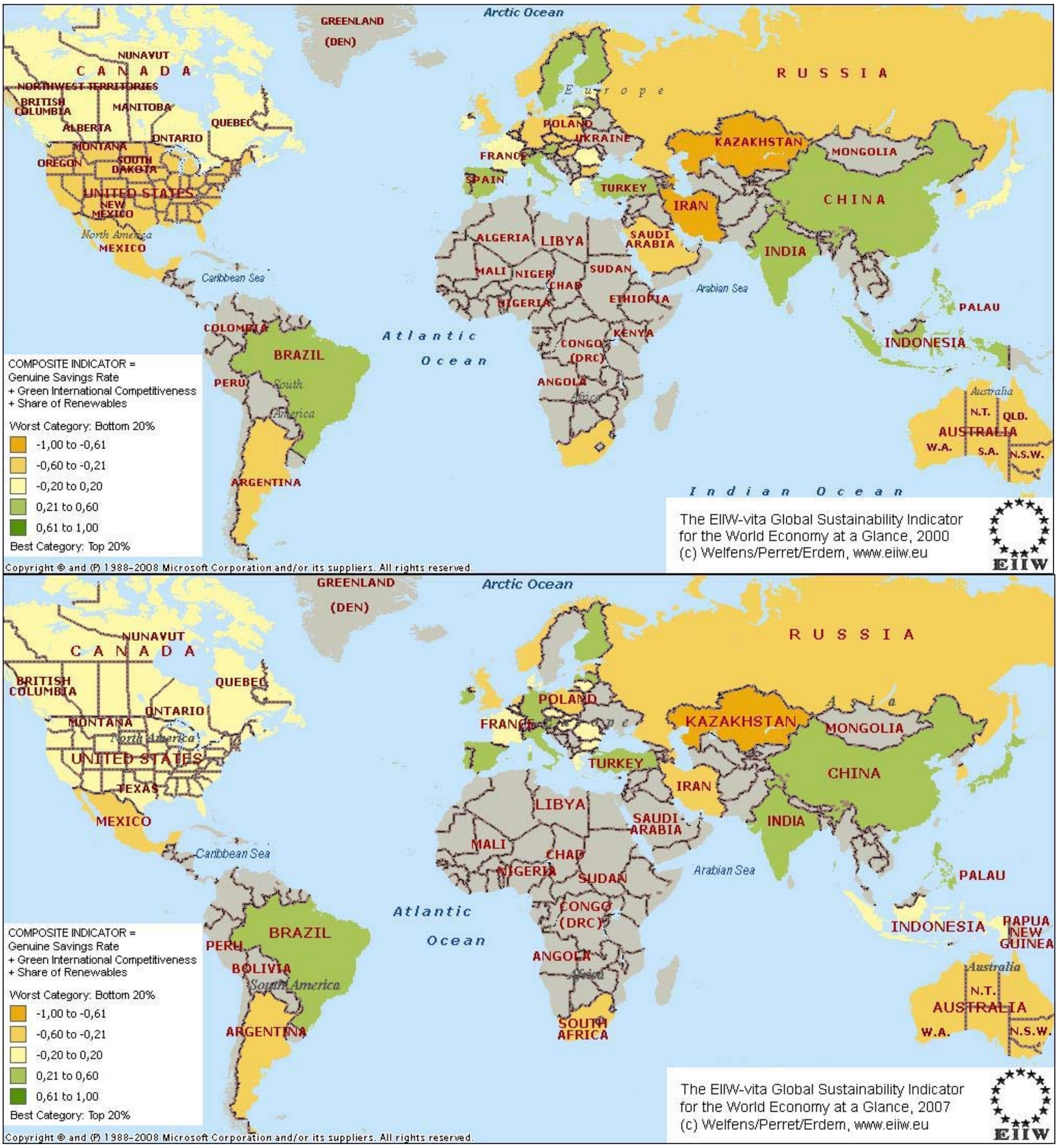
Own Calculations

With the weights derived from factor analysis we can present our summary findings in the form of two maps (with grey areas for countries with problems in data availability). There is a map for 2000 and another map for 2007 – with countries grouped in quantiles (leader group= top 20% vs. 3x 20% in the middle of the performance distribution and lowest 20% = orange). The map shows the EIIW-vita Global Sustainability Indicator for each country covered which is composed of the following subindices:

- genuine savings rate (3),
- volume-weighted green international competitiveness (7) and
- relative share of renewable in energy production (B).

Indonesia has suffered a decline in its international position in the period 2000-07 while Germany and US have improved their performance; compared to 2000, Iran in 2007 has also performed better in the composite indicator in 2007. China, India and Brazil all green, which marks the second best range in the composite indicator performance. The approach presented shifts in the analytical focus away from the traditional, narrow, perspective on greenhouse gases and puts the emphasis on a broader – and more useful – Schumpeterian economic perspective. While there is no doubt that the energy sector is important, particularly the share of renewables in energy production, a broader sustainability perspective seems to be adequate.

Figure 14: The EIIW-vita Global Sustainability Indicator



4. Policy Conclusions

There is a broad international challenge for the European countries and the global community, respectively. The energy sector has two particular traits that make it important in both an economic and a political perspective:

- Investment in the energy-producing sector is characterized by a high capital intensity and long amortization periods, so adequate long-term planning in the private and the public sectors is required. Such long term planning – including financing – is not available in the whole world economy; and the Transatlantic Banking Crisis has clearly undermined the stability of the international financial system and created serious problems for long term financing. Thus, the banking crisis is directly undermining the prospects of sustainability policies across many countries.
- Investments of energy users are also mostly long-term. Therefore, it takes time to switch to new, more energy-efficient consumption patterns. As energy generation and traffic account for almost half of global SO_2 emissions, it would be wise to not only focus on innovation in the energy sector and in energy-intensive products, but to also reconsider the topic of spatial organization of production. As long as transportation is not fully integrated into CO_2 emission certificate trading, the price of transportation is too low – negative external global warming effects are not included in market prices. This also implies that international trading patterns are often too extended. Import taxes on the weight of imported products might be a remedy to be considered by policymakers, since emissions in the transportation of goods are proportionate to the weight of the goods (actually to tonkilometers).

One key problem for the general public as well as for policymakers is the inability of simple indicators to convey a clear message about the status of the quality of environmental and economic dynamics. The traditional Systems of National Accounts does not provide a comprehensive approach which includes crucial green aspects of sustainability. The UN has considered several green satellite systems, but in reality the standard system of national accounts has effectively remained in place so that new impulses for global sustainability could almost be derived from standard macroeconomic figures. The global sustainability indicators presented are a fresh approach to move towards a better understanding of the international position of countries, and hence, for the appropriate policy options to be considered in the field of sustainability policies. International organizations, governments, the general public as well as firms could be interested in a rather simple consistent set of indicators, that convey consistent signals for achieving a higher degree of global sustainability. The proposed indicators are a modest contribution to the international debate, and they could certainly be refined in several ways. For instance, more dimensions of green economic development might be considered, and the future path of economic and ecological dynamics might be assessed by including revealed comparative advantages (or relative world patent shares) in the field of "green patenting". The new proposed indicators could be important elements of an environmental and economic compass, that suggest optimum ways for intelligent green development.

The Global Sustainability Indicator (GSI) provides broad information to firms and consumers in the respective countries and thus could encourage green innovations and new environmental friendly consumption patterns.

The GSI also encourages governments in countries eager to catch up with leading countries to provide adequate innovation incentives for firms and households, respectively. This in turn could encourage international diffusion of best practice and thereby contribute to enhanced global sustainability in the world economy.

The Copenhagen process will show to what extent policymakers and actors in the business community are able to find new international solutions and to set the right incentives for more innovations in the climate policy arena. There is no reason to be pessimistic, on the contrary, with a world-wide common interest to control global warming there is a new field that might trigger more useful international cooperation among policymakers in general, and among environmental policies, in particular. From an innovation policy perspective there is, however, some reason for pessimism in the sense that the Old Economy industries – most of them are highly energy intense – are well established and have strong links to the political system while small and medium sized innovative firms with relevant R&D activities in global climate control typically find it very difficult to get political support. Thus one should consider to impose specific taxes on non-renewable energy producers and use the proceeds to largely stimulate green innovative firms and sectors, respectively. Competition, free trade and foreign direct investment all have their role in technology diffusion, but without a critical minimum effort by the EU, Switzerland, Norway, the US, China, India, the Asian countries and many other countries it is not realistic to assume that a radical reduction of CO_2 emissions can be achieved by 2050. Emphasis should also be put on restoring stability in the financial sector and encouraging banks and other financial institutions to take a more long term view. Here it would be useful to adopt a volatility tax which would be imposed on the variance (or the coefficient of variation) of the rate of return on equity of banks (WELFENS, 2009).

It is still to be seen whether or not the Copenhagen process can deliver meaningful results in the medium-term and in the long-run. If the financial sector in OECD countries and elsewhere remains in a shaky condition, long-term financing for investment and innovation will be difficult to obtain in the marketplace. This brings us back to the initial conjecture that we need a double sustainability – in the banking sector and in the overall economy. The challenges are tough and the waters on the way to a sustainable global economic-environmental equilibrium might be rough, but the necessary instruments are known: to achieve a critical minimum of green innovation dynamics will require careful watching of standard environmental and economic statistics, but it will also be quite useful to study the results and implications of the EIIW-vita Global Sustainability Indicator.

Appendix 1: Eigenvalues and Components

Figure 15: Eigenvalues and Components

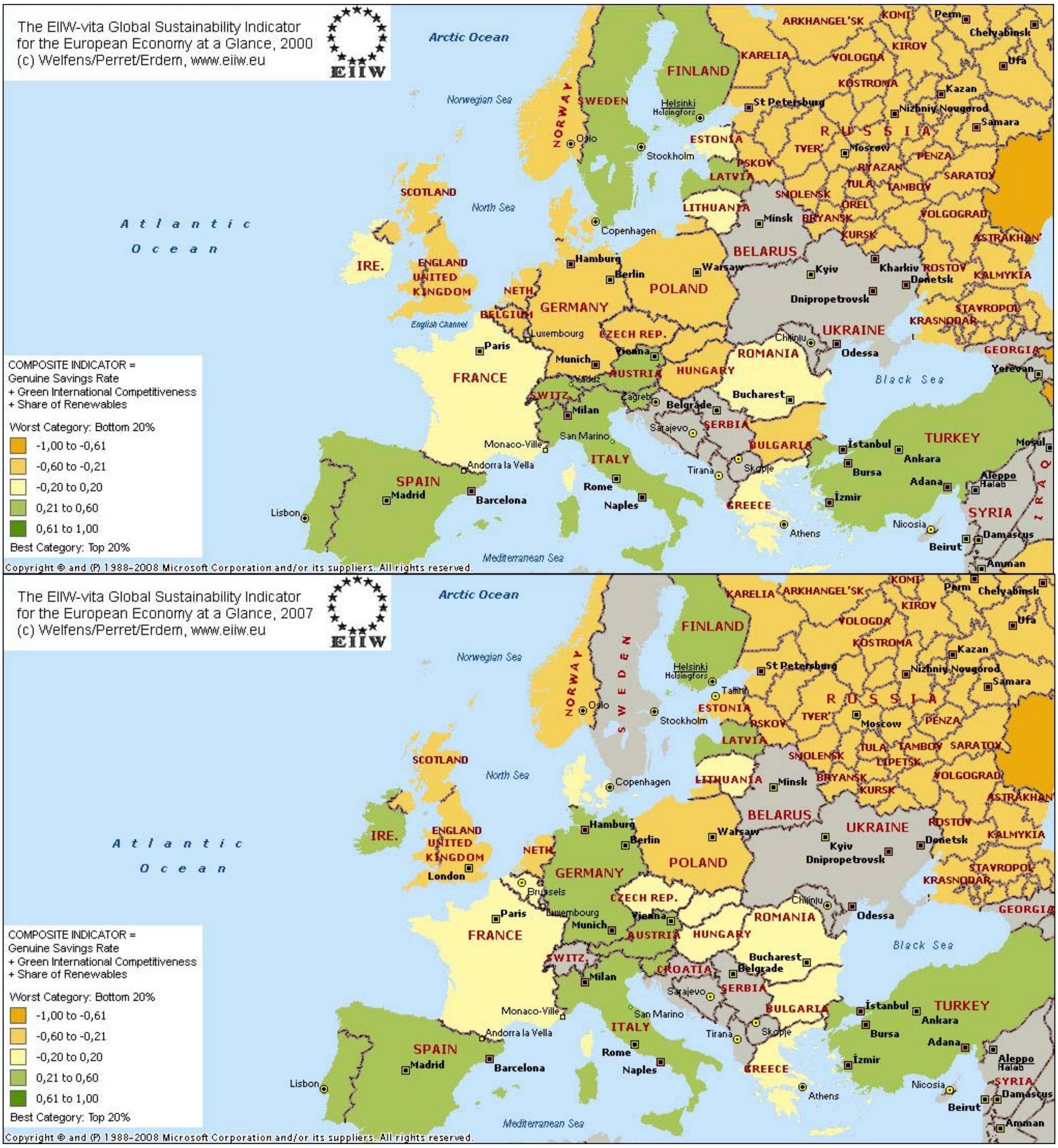
	2000											
	RCA normal						MOD RCAVOL					
	with CO2			without CO2			with CO2			without CO2		
	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA
EV1	2.151	2.252	2.427	1.516	1.602	1.786	1.682	1.856	2.033	1.014	1.283	1.432
EV2	0.520	0.969	0.796	0.484	0.969	0.792	0.996	1.044	1.008	0.986	1.006	1.000
EV3	0.328	0.451	0.449		0.429	0.422	0.323	0.777	0.636		0.711	0.568
EV4		0.328	0.328					0.323	0.323			
VolRCA	0.796	0.746	0.731	0.871	0.784	0.754	0.163	0.081	0.097	0.712	-0.148	0.015
SavingsRate	0.867	0.869	0.863	0.871	0.882	0.869	0.904	0.872	0.867	0.712	0.783	0.846
SoRRCA		0.412	0.628		0.457	0.681		0.564	0.719		0.805	0.846
CO2emissions	-0.876	-0.878	-0.868				-0.915	-0.878	-0.869			

	2006											
	RCA normal						MOD RCAVOL					
	with CO2			without CO2			with CO2			without CO2		
	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA
EV1	1.701	1.791	2.004	1.378	1.441	1.621	1.621	1.519	1.730	1.236	1.243	1.387
EV2	0.693	0.942	0.794	0.622	0.939	0.759	0.759	1.112	0.998	0.764	1.071	0.937
EV3	0.605	0.677	0.629		0.620	0.620	0.620	0.708	0.682		0.686	0.676
EV4		0.590	0.573					0.662	0.590			
VolRCA	0.782	0.738	0.721	0.830	0.785	0.771	0.771	0.434	0.407	0.786	0.726	0.590
SavingsRate	0.743	0.715	0.679	0.830	0.803	0.756	0.756	0.757	0.704	0.786	0.821	0.795
SoRRCA		-0.430	0.684		0.425	0.675	0.675	0.454	0.708		0.207	0.638
CO2emission	-0.733	-0.742	-0.745					-0.743	-0.753			

	2007											
	RCA normal						MOD RCAVOL					
	with CO2			without CO2			with CO2			without CO2		
	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA	without SoR	with SoR	with SoRRCA
EV1	1.635	1.743	1.974	1.386	1.468	1.667	1.439	1.502	1733.000	1.279	1.288	1.458
EV2	0.760	0.927	0.808	0.614	0.918	0.722	0.883	1.109	0.987	0.721	1.053	0.897
EV3	0.605	0.727	0.621		0.614	0.611	0.678	0.732	0.679		0.658	0.645
EV4		0.603	0.598					0.658	0.601			
VolRCA	0.785	0.742	0.725	0.832	0.792	0.776	0.664	0.521	0.482	0.800	0.750	0.633
SavingsRate	0.746	0.705	0.679	0.832	0.789	0.755	0.780	0.753	0.707	0.800	0.826	0.798
SoRRCA		0.472	0.716		0.467	0.703		0.434	0.717		0.211	0.649
CO2emission	-0.679	-0.687	-0.690				-0.624	-0.689	-0.698			

Appendix 2: Europe 2000 and 2007

Figure 16: EIIW-vita Indicator for Europe



Appendix 3: List of Environmental Products

Description	HS
Vacuum pumps	841410
Compressors of a kind used in refrigerating equipment	841430
Air compressors mounted on a wheeled chassis for towing	841440
Other air or gas compressors or hoods	841480
Parts for air or gas compressors, fans or hoods	841490
Filtering or purifying machinery and apparatus for gases	842139
Parts for filtering or purifying machinery	842199
Limestone flux	252100
Slaked (hydrated) lime	252220
Magnesium hydroxide and peroxide Activated earths	281610
Filtering or purifying machinery and apparatus for gases	842139
Parts for filtering or purifying machinery	842199
Filtering or purifying machinery and apparatus for gases	842139
Parts for filtering or purifying machinery	842199
Other glass fibre products	701990
Machinery for liquefying air or other gases	841960
Other machinery, for treatment of materials by change of Temperature	841989
Filtering or purifying machinery and apparatus for gases	842139
Parts for filtering or purifying machinery	842199
Other furnaces, ovens, incinerators, non-electric	841780
Filtering or purifying machinery and apparatus for gases	842139
Parts for filtering or purifying machinery	842199
Industrial or laboratory electric resistance furnaces	851410
Industrial or laboratory induction or dielectric furnaces	851420
Other industrial or laboratory electric furnaces and ovens	851430
Parts, industrial or laboratory electric furnaces	851490
Parts for sprayers for powders or liquids	842490
Compressors of a kind used in refrigerating equipment	841430
Air compressors mounted on a wheeled chassis for towing	841440
Other air or gas compressors or hoods	841480
Parts for air or gas compressors, fans or hoods	841490
Limestone flux	252100
Slaked (hydrated) lime	252220
Chlorine	280110
Sodium hydroxide solid	281511
Sodium hydroxide in aqueous solution	281512
Magnesium hydroxide and peroxide	281610
Aluminium hydroxide	281830
Manganese dioxide	282010
Manganese oxides (other)	282090
Lead monoxide	282410

Sodium sulphites	283210
Other sulphites	283220
Phosphinates or phosphonates	283510
Phosphates of mono or disodium	283522
Phosphates of trisodium	283523
Phosphates of potassium	283524
Calcium hydrogenOrthophosphate	283525
Other phosphates of calcium	283526
Other phosphates (excl. polyphosphates)	283529
Activated carbon	380210
Water filtering or purifying machinery and apparatus	842121
Other machinery for purifying liquids	842129
Parts for filtering or purifying machinery	842199
Other centrifuges	842119
Parts of centrifuges	842191
Water filtering or purifying machinery and apparatus	842121
Other machinery for purifying liquids	842129
Parts for filtering or purifying machinery	842199
Other articles of plastic	392690
Water filtering or purifying machinery and apparatus	842121
Other machinery for purifying liquids	842129
Parts for filtering or purifying machinery	842199
Woven pile and chenille fabrics of other textile materials	580190
Tanks, vats, etc. > 300 1	730900
Tanks, drums, etc. > 50 1 < 300 1	731010
Cans < 50 1, closed by soldering or crimping	731021
Other cans < 50 1	731029
Hydraulic turbines	841011
	841012
	841013
Parts for hydraulic turbines	841090
Other furnaces, ovens, incinerators, non-electric	841780
Weighing machines capacity < 30 kg	842381
Weighing machines capacity > 30 kg < 5 000 kg	842382
Parts for sprayers for powders or liquids	842490
Industrial or laboratory electric resistance furnaces	851410
Industrial or laboratory induction or dielectric furnaces	851420
Other industrial or laboratory electric furnaces and ovens	851430
Parts, industrial or laboratory electric furnaces	851430
Cast articles of cast iron	732510
Positive displacement pumps, hand operated	841320
Other reciprocating positive displacement pumps	841350
Other rotary positive displacement pumps	841360
Other centrifugal pumps	841370
Other pumps	841381
Valves, pressure reducing	848110
Valves, check	848130
Valves, safety	848140
Other taps, cocks, valves, etc.	848180

Instruments for measuring the flow or level of liquids	902610
Instruments for measuring or checking pressure	902620
Other articles of cement, concrete	681099
Other articles of lead	780600
Other electric space heating and soil heating apparatus	851629
Lasers Vitrification equipment	901320
Household or toilet articles of plastic	392490
Brooms, hand	960310
Brushes as parts of machines, appliances	960350
Mechanical floor sweepers Trash bin liners (plastic)	960390
Polypropylene sheeting, etc.	392020
Machinery to clean, dry bottles, etc.	842220
Other mixing or kneading machines for earth, stone, sand, etc.	847439
Other machines for mixing/grinding, etc.	847982
Other machines, nes, having individual functions	847989
Other furnaces, ovens, incinerators, non-electric	841780
Parts of furnaces, non-electric	841790
Industrial or laboratory electric resistance furnaces	851410
Industrial or laboratory induction or dielectric furnaces	851420
Other industrial or laboratory electric furnaces and ovens	851430
Parts, industrial or laboratory electric furnaces	851490
Cleaning~up	851629
Other electric space heating and soil heating apparatus	901320
Other electrical machines and apparatus with one function	854389
Parts for spark-ignition internal combustion piston engines	840991
Parts for diesel or semi-diesel engines	840999
Silencers and exhaust pipes, motor vehicles	870892
Thermometers, pyrometers, liquid filled	902511
Other thermometers, pyrometers	902519
Hydrometers, barometers, hygrometers, etc.	902580
Other instruments for measuring liquids or gases	902680
Parts of instruments for measuring, checking liquids or gases	902690
Instruments for analysing gas or smoke	902710
Chromatographs, etc.	902720
Spectrometers, etc.	902730
Exposure meters	902740
Other instruments using optical radiation	902750
Other instruments for physical or chemical analysis	902780
Parts for instruments, incl. microtomes	902790
Ionising radiation measuring or detecting instruments	903010
Other optical instruments	903149
Other measuring or checking instruments	903180
Manostats	903220
Hydraulic/pneumatic automatic regulating, controlling instruments	903281
Other automatic regulating, controlling instruments Auto emissions testers Noise measuring equipment	903289
Thermostats	903210
Peat replacements {e.g. bark)	284700

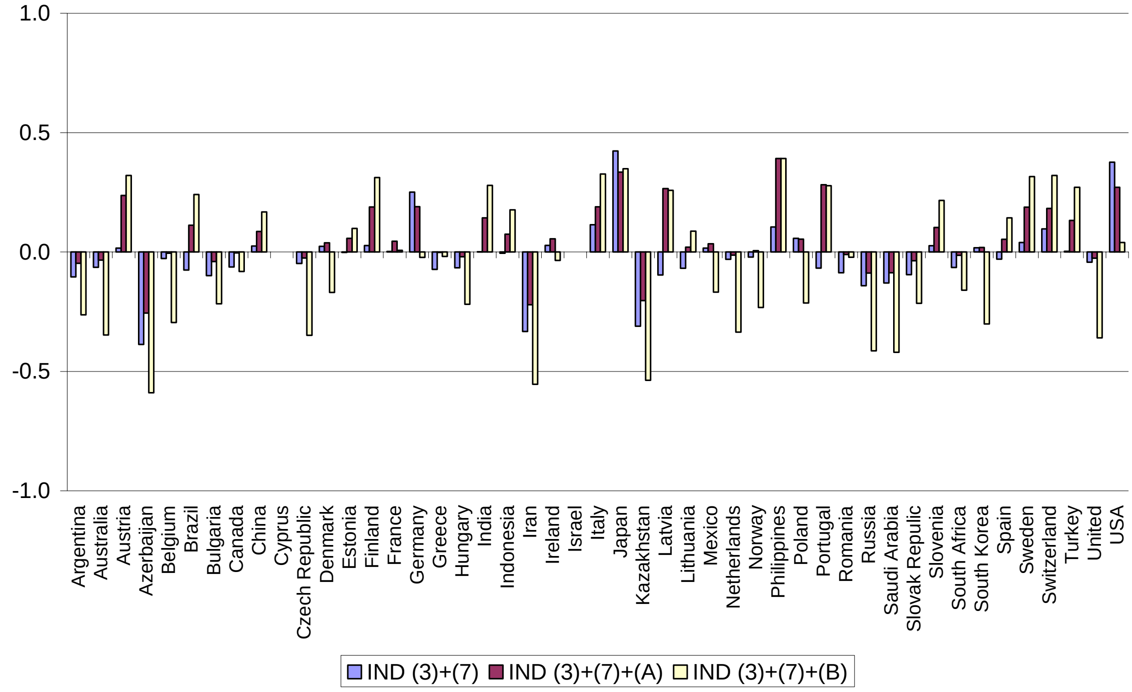
Paints and varnishes, in aqueous medium, acrylic or vinyl	320910
Other paints and varnishes, in aqueous medium	320990
Chlorine	280110
Waters, including natural or artificial mineral water	220100
Distilled and conductivity water	285100
Ion exchangers (polymer)	391400
Instantaneous gas water heaters	841911
Other instantaneous or storage water heaters, non-electric	841919
Photosensitive semiconductor devices, including solar cells	854140
Methanol	290511
Multiple walled insulating units of glass	700800
Other glass fibre products*	701990
Heat exchange units	841950
Parts for heat exchange equipment	841990
Fluorescent lamps, hot cathode	853931
Gas supply, production and calibrating meters	902810
Liquid supply, production and calibrating meters	902820
Thermostats*	903210

Appendix 4: List of Data Sources

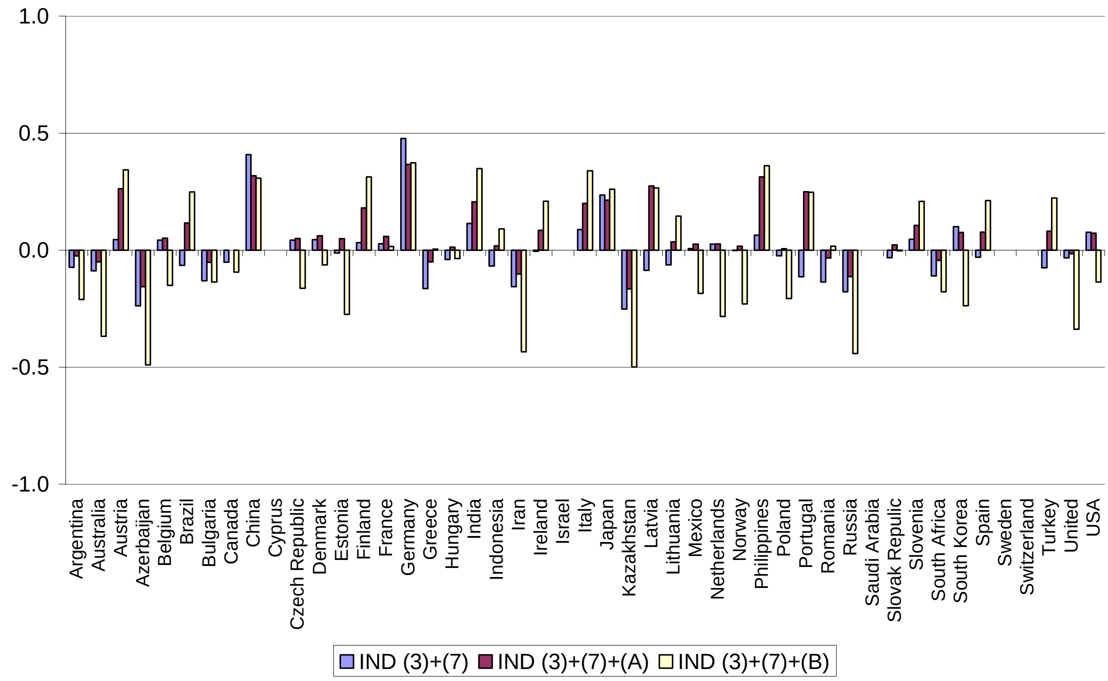
Source:	**Data:**
WITS Databank (of UN Comtrade and World Bank)	International Trade Data
World Development Indicators Online Database	National Data for GS and GDS
International Energy Agency Online Data Base	CO_2 emissions data and Share of renewables
OECD Manual for Environment Goods	List of environmental products

Appendix 5: Indicators showing the Influence the SoRRCA, respectively

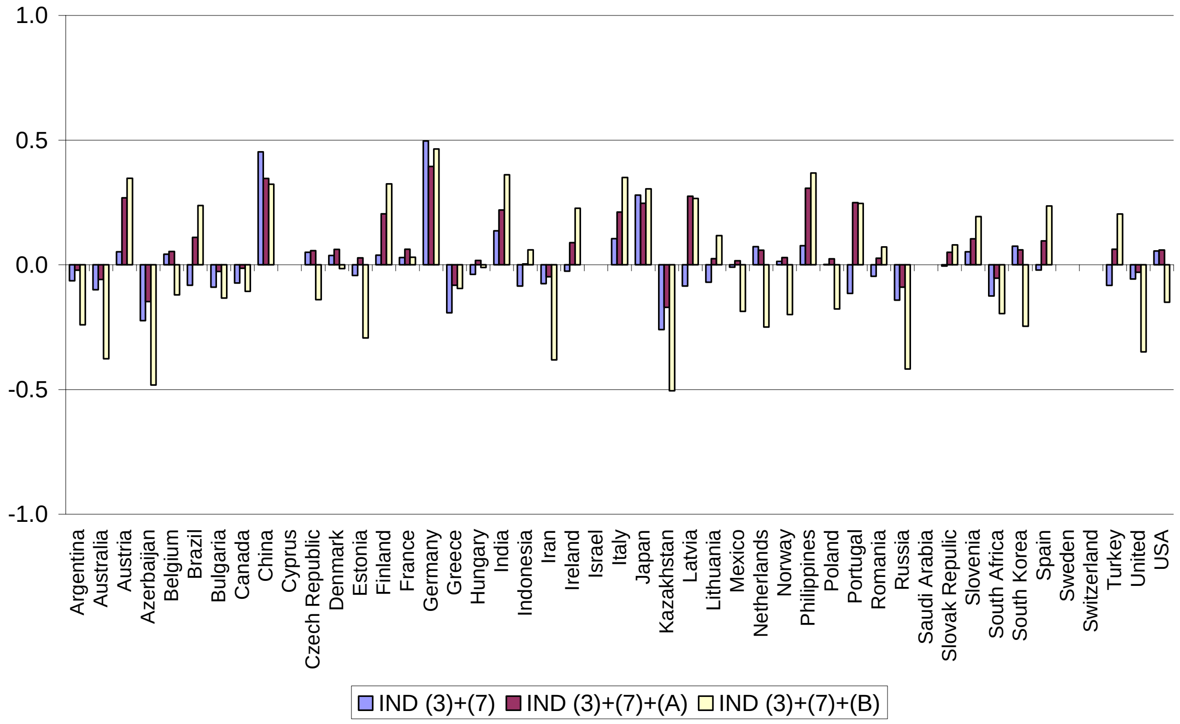
2000



2006



2007



In contrast to the first two parts, the composite indicators in this part differ rather strongly from each other. While they are still temporarily stable, in many cases it occurs that two indicators point in opposite directions or that one indicator shows neither an advantage nor a disadvantage, while the others clearly favour one of the two. It is not possible to state which indicator is more positive and which is more negatively biased.

As neither indicator shows any distinct advantage over the others, results from the tests in the case of variable weights are included. It can be seen, that only the case of either no inclusion of the share of renewable energy or the inclusion of the SoRRCA leads to consistent reliable estimates of weights. Furthermore, when the share of renewable energy is excluded from the indicator, the results for the case of flexible weights coincide with the results for the case of fixed identical weights.

Therefore, the composite indicator constructed from the VolRCA and the genuine savings rate is seen as a simple first indicator, whereas for the remainder, the case of introducing the SoRRCA is considered.

Appendix 6: Absolute CO_2 Emissions (thousand tons of carbon)

	2006	2007	2008
China	1664589	1801658,587	1922687,476
US	1568806	1594884,811	1547460,438
India	411914	445878,1672	479038,944
Russian Fed.	426729	427144,5605	435125,8403
Japan	352748	357240,8894	357534,0763
Germany	219571	212171,6012	210479,6756
Canada	148548	151776,8117	153658,9514
United Kingdom	155051	150619,0791	148818,148
South Korea	129613	137572,3905	142230,2275
Iran	127358	130348,1795	133960,6503
Italy	129314	127598,6512	125015,2981
Mexico	118950	122043,1985	124449,8597
South Africa	113085	115025,352	120520,3484
Saudi Arabia	104063	111563,2196	119373,6681
Brazil	96142	103621,3529	110832,6373
France	104495	102784,8514	103844,9818
Indonesia	90951	95007,44721	99647,71769
Other Africa	96479	97345,8269	99556,99587
Australia	101459	101086,201	96168,2528
Spain	96063	99286,1414	94468,12711
Poland	86787	87551,21704	90072,49236
Ukraine	87044	86081,10724	84447,67133
Turkey	73487	79253,20398	80207,40321
Thailand	74324	75882,95419	76817,32172
Taiwan	74371	77404,68497	75066,00612
Kazakhstan	52775	55936,18333	59015,84402
Argentina	47328	52074,73596	53821,55158
Venezuela	46799	49835,53765	52528,73085
Egypt	45491	49254,5702	52335,91825
Malaysia	51236	51554,11959	50514,61284
UAE	38060	41850,59887	47871,21725
Netherlands	45958	44901,98523	46201,51866
Pakistan	38906	42234,93692	45093,19005
Algeria	36195	39216,8782	42382,4107
Uzbekistan	31548	34473,18478	36323,15563
Belgium&Lux.	32321	31773,67704	31350,56141
Czech Rep.	31324	31523,24548	30787,66433
Greece	26287	27007,59946	27065,08835
Kuwait	23617	23464,896	25804,76189
Romania	26861	24619,85167	24403,54671
Austria	19590	19144,40926	19579,02327
Philippines	18636	19477,77719	19061,3672
Belarus	18777	18264,18022	18233,65551

Colombia	17397	17790,13996	17882,15294
Singapore	15278	16160,76728	17080,07292
Chile	16391	17278,40615	16552,5955
Portugal	16364	15991,16751	15585,04691
Finland	18189	17205,02817	15387,44049
Hungary	15721	15375,2762	15339,83635
Qatar	12598	13126,40053	13642,11905
Bulgaria	13114	13842,42338	13581,63363
Sweden	13875	13364,35734	12962,06195
Peru	10539	11694,11655	12899,94342
Denmark	14712	13479,05799	12671,7483
Turkmenistan	12028	13370,96296	12541,71536
Bangladesh	11349	11836,50792	12388,0501
Rep. of Ireland	11948	11959,47289	11624,59388
Switzerland	11407	10495,27648	11131,97475
Norway	10969	11081,45638	10906,9165
Hong Kong	10647	11049,05438	10387,50994
Slovakia	10216	10149,07825	10380,67315
Ecuador	8544	9031,029724	9392,326957
Azerbaijan	9559	8631,203791	8609,326302
New Zealand	8316	8135,067217	8338,59829
Lithuania	3870	4027,568156	4031,305761
Iceland	604	662,7754019	606,3737287
Sum of above	**7557285**	**7823175,449**	**7987781,044**

TOTAL WORLD	**8229000**	**8504526,83**	**8670866,36**

Note that the sum of all countries is less than the total world emissions for 4 reasons: 1.) fuels used in international commerce are not counted with any country but are included in the world total, 2, 3.) fossil fuels used for non-fuel purposes and the change in stocks of fossil fuels are treated slightly differently for countries than for the global average, 4.) statistical uncertainty

Source: http://cdiac.ornl.gov/

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