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Update of national and international resource use indicators

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Update of national and international resource use indicators

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Abstract

The study “Update of national and international resource use indicators” contains three main parts. In the first part central resource indicators for Germany such as Domestic Material Consumption (DMC) and Total Material Requirement (TMR) were updated until 2008. In 2008, Germany extracted 30% less used materials and 52% less unused materials compared to 1980 with a particular decrease in the extraction of soft coal. At the same time there was an increase in direct imports and exports as well as indirect flows associated with imports and exports. Altogether, domestic material consumption (DMC) decreased by 27% to 1.3 billion tonnes in 2008. Similarly, per capita domestic material consumption declined by 29% to 15.8 tonnes between 1980 and 2008. However, total material requirement (TMR) only fell by 15% in absolute terms (by 19% in per capita terms) reaching almost 2 billion tonnes in 2008. The second part of this study updates and analyses global trends relating to direct material use between 1980 and 2008. Global extraction (used and direct) and material consumption increased by 79% up to 68 billion tonnes during the investigated period. Physical trade volume increased by 158% up to 10 billion tonnes and material productivity (in regards to DMC) increased by 38%. The final part of the study identifies further research questions that will need to be addressed in order to improve the quality of selected indicators of material analysis.

Kurzbeschreibung

Die Studie „Aktualisierung von nationalen und internationalen Ressourcenkennzahlen“ umfasst 3 Teile. Im ersten Teil wurden wichtige Ressourcenkennzahlen für Deutschland wie der heimische Materialverbrauch (DMC) und der gesamte Materialinput (TMR) bis zum Jahr 2008 aktualisiert. Im Jahr 2008 wurden in Deutschland rund 30 % weniger genutzte Materialien und 52 % weniger ungenutzte Rohstoffe entnommen als noch 1980. Dabei sind vor allem die Entnahmen von fossilen Energieträgern, insbesondere von Braunkohle, rückläufig. Gleichzeitig stiegen die direkten Importe und Exporte von Deutschland ebenso wie die mit den Ein- und Ausfuhren verbundenen indirekten Materialflüsse an. Insgesamt sank der inländische Materialverbrauch (DMC) in absoluten Werten um 27 % auf rund 1,3 Milliarden Tonnen. Auch die Pro-Kopf-Werte reduzierten sich zwischen 1980 und 2008 um 29 % auf 15,8 Tonnen. Der gesamte Materialinput Deutschlands (TMR) sank hingegen nur um 15 % in absoluten Werten (pro Kopf um 19 %) und umfasste 2008 rund 2 Milliarden Tonnen. Im zweiten Teil der Studie wurden globale Trends der (direkten) Materialnutzung zwischen 1980 und 2008 erhoben und analysiert. Weltweit stiegen die genutzte Extraktion und der (direkte) Materialkonsum in diesem Zeitraum um 79 % auf rund 68 Milliarden Tonnen, das physische Handelsvolumen um 158 % auf rund 10 Milliarden Tonnen und die Materialproduktivität bezogen auf den DMC um 38 %. Im abschließenden dritten Teil der Studie wurde der weitere Forschungsbedarf identifiziert, um die einzelnen Komponenten der Materialflussanalyse zu verbessern und so zu robusteren Gesamtaussagen zu gelangen.

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1 Summary

Resource use and resource productivity have been gaining increasing attention in national and international policy in recent years. This is due to the fact that many environmental problems are either directly or indirectly linked to man's use of natural resources which has been escalating globally, particularly in recent years, exacerbating pre-existing environmental and social problems. Resource use and resource productivity have also gained the attention of economists who have identified the opportunity that these issues present for increasing the international competitiveness of economies and decreasing countries' resource dependencies. OECD countries, and in particular Germany, have made significant progress in the assessment of data and indicators of resource use and resource productivity. Nevertheless, there are still remarkable data gaps for the majority of developing countries. Thus, further empirical data on global and regional facts and trends on resource use are required to facilitate national and international comparisons and classifications. This is the aim of the present study.

This study updates central resource indicators for Germany in areas such as Domestic Material Consumption (DMC) and Total Material Requirement (TMR) until 2008. In 2008, Germany extracted 30% less used materials and 52% less unused materials compared to 1980 with a particular decrease in the extraction of soft coal. At the same time there was an increase in direct imports and exports as well as indirect flows associated with imports and exports. Altogether, domestic material consumption (DMC) decreased by 27% to 1.3 billion tonnes in 2008. Similarly, per capita domestic material consumption declined by 29% to 15.8 tonnes between 1980 and 2008. However, total material requirement (TMR) only fell by 15% in absolute terms (by 19% in per capita terms) reaching almost 2 billion tonnes in 2008. This is a significant development as TMR increased globally by 135% during the same period. Lastly, total material consumption (TMC) in Germany fell by 36% down to 1.7 billion tonnes and declined by 39% to nearly 50 tonnes per capita.

Germany reached an absolute decoupling of economic growth and material use between 1980 and 2008. This holds true in regards to domestic material consumption (DMC), total material requirement (TMR) and total material consumption (TMC). Material productivity in regards to DMC increased by 131% which is a significant increase in comparison to the global average increase of 38%. Material productivity in regards to TMR doubled, with material productivity in regards to TMC in Germany increasing by 166%.

The second part of this study updates and analyses global trends relating to direct material use between 1980 and 2008. Global extraction (used and direct) and material consumption increased by 79% up to 68 billion tonnes during the investigated period. Physical trade volume increased by 158% up to 10 billion tonnes and material productivity (in regards to DMC) increased by 38%. Material composition, extraction and consumption of non-metal minerals had the highest increase and held the highest share in global extraction and consumption in 2008. Measured in physical terms, fossil fuels, in particular petroleum continuously held the highest share in global trade. Trade in metals and incommodities made of different or undetermined materials had the highest increase in physical trade volume between 1980 and 2008.

With respect to regions, Asia shows by far the highest rates of extraction, imports and exports and material consumption. China dominated Asia's share and growth of resource use, particularly after the turn of the millennium. The global average of material consumption per capita increased from 8.5 to 10.2 tonnes between 1980 and 2008. In 2008, Australia showed the highest consumption per capita while Africa had the lowest material consumption per capita (36 versus 5 tonnes per capita and year). During the past three decades, the highest increase of DMC per capita can be observed in Asia, however its average material consumption per capita in 2008 was still below the global average (9 tonnes).

Between 1980 and 2008, global material productivity (GDP per DMC) increased by 38% which equals an annual growth rate of 1.4%. The world did not reach an absolute decoupling due to the increases of absolute material consumption. With respect to regions, material productivity in Europe and North America was highest and increased most during the investigated period while material productivity in Asia and Latin America increased only slightly. In summary, differences in material productivity increased between Europe and North America on the one side, and the other regions on the other.

This study will also analyse global trends in material extraction, trade and consumption with respect to selected parameters such as resource endowment, income or population density. Extraction and direct exports are high in resource rich countries while resource poor countries mainly import materials from the afore-mentioned countries. It should be noted that a majority of the world's population live in resource rich countries. This study also found that direct material consumption decreases as population density increases. Very densely populated countries such as Singapore and Qatar are exceptions to this rule; their average material consumption per capita was highest in 2008.

Analysis of material use by income groups found that OECD countries continuously net-imported materials during the investigated period. The results also showed that low-income countries have increasingly become net importers after the turn of the millennium and lower-middle income countries changed to net importers of materials in 2007. Non-OECD countries with high income and upper-middle income countries are net exporters of materials, the latter group increasingly supplying materials to world markets. Average material consumption per capita was highest in OECD-countries until 2007; in 2008, average material consumption in high income, non-OECD countries was even higher. Low-income countries had the lowest per capita material consumption in 2008. OECD countries increased their resource productivity (GDP per DMC) significantly and had the highest material productivity in 2008. Material productivity in low-income countries was continuously lowest but this group reached the highest increase of material productivity during the past three decades.

Material productivity was linked to the sectoral structure of the countries. The results indicated that countries with a higher share of less material intensive services in GDP generally showed higher rates of material productivity; at the same time, higher shares of material intensive agricultural sectors in GDP corresponded to lower material productivity. However, it should be noted that this link may be caused to some extent by outsourcing of material intensive sectors.

The majority of countries examined reached a relative decoupling of economic growth and (direct) material consumption between 1980 and 2008. Only a few countries, such as Germany, reached an absolute decoupling during the past three decades.

Global total material requirement (TMR) increased by 135% between 1980 and 2008. While in 1980 the USA showed the largest absolute TMR, twenty-eight years later China had surpassed the USA. This study analysed the dynamic of TMR and material productivity (GDP per TMR) in ten selected countries. This analysis found that Japan, (followed by the USA) was the most material productive country as well as that it had significantly increased its material productivity. China also increased its material productivity significantly, although it had started from a low level compared to other countries.

The summary identifies further research questions that will need to be addressed in order to improve the quality of selected indicators of material analysis. A further recommendation is that the concentration of metals and construction minerals should be further developed in regards to used material extraction methods, as well as the assessments of the amount of biomass uptake by animals (grazing). The study also found that data regarding unused extraction was generally fragmented, and therefore needs to be improved in terms of quality and quantity. This study highlights that there is no internationally standardised method to be able to consistently and sufficiently assess indirect trade flows. It is recommended that future research analyse if and how the strengths of the currently most used approaches (Life-Cycle-Assessment (LCA)-based and methodologies based on Input-Output-Analysis) can be effectively combined.

2 Introduction

Resource use and resource productivity has been gaining increasing attention in national and international policy in recent years. This is due to the fact that many environmental problems such as climate change, water scarcity, desertification or erosion, are directly or indirectly linked to the use of natural resources by humans. Furthermore, the increasing use of natural resources at the global level is exacerbating these problems. Resource use and productivity is also gaining increasing attention from an economic perspective, due to an increase in resource productivity which has been identified as a powerful strategy to increase the international competitiveness of economies and to decrease resource dependencies. Examples are the flagship initiative "Resource efficient Europe by the European Union (European Commission, 2011); the OECD-strategy "Green Growth" (OECD, 2011) or initiatives by the United Nations such as Green Economy or Green Industry (UN-EMB, 2012, UNIDO, 2011).

OECD countries, and in particular Germany, have made significant progress in the assessment of data and indicators of resource use and resource productivity. Nevertheless, there are still significant data gaps. For example, continuous data for direct material flows for all European countries are only available since 2000 (Eurostat, 2012). Germany's data on resource use have been available after reunification (UBA, 2008 and 2012). Even more fragmentary are global data on material consumption and material productivity. Existing studies which cover more than one year focus on selected regions or country groups (e.g. Estrada Calvo, 2007, Giljum et al., 2010, Dittrich et al., 2011, Schandl and West, 2010, UNEP, 2011a, Eurostat, 2011); include only one or selected years (e.g. Krausmann et al., 2008a, Bringezu and Bleischwitz, 2009, Dittrich, 2010, Steinberger et al., 1010, UNEP, 2011b) or examine either material extraction or trade (e.g. Behrens et al. 2005, Schandl and Eisenmenger, 2006, Dittrich, 2009, Dittrich and Bringezu, 2010). Thus, further empirical assessment of global and regional facts and trends on resource use are required in order to enable national and international comparisons and classifications.

This study includes three work packages in order to fill relevant German and selected data gaps.

The first work package aims to update the following resource indicators for Germany: Domestic extraction used (DEU); imports, exports and physical trade balances (PTB), domestic material consumption (DMC); unused domestic extraction (UDE); indirect flows of imports and exports as well as total material requirement (TMR) and total material consumption (TMC). These indicators complete existing knowledge on material use in Germany between 1991 and 2003/4 as assessed by the Wuppertal Institute (UBA, 2008) in the periods from 1980 to 1990 and 2004 to 2008. Results are presented in Chapter 4 of this study.

The second work package includes the key aspects of this study, presenting the main global, regional and national facts and trends on material extraction during the period from 1980 to 2008 in the areas of material trade (imports, exports and physical trade balances); import dependencies (integration into the world market); (direct) material consumption and material productivity. Furthermore, selected facts and trends are analyzed by income and level of affluence, resource endowment, population density and the structure of the respective economies. At the end, total material requirement (TMR) of all countries is assessed for 1980 and 2008 and TMR of ten selected countries are calculated in five-year-steps. Chapter 5 presents the main results.

Chapter 6 presents the results of the third work package which includes a discussion of the methods used in this study, in particular for the assessment of TMR with recommendations as to methods that could be further developed in order to improve the quality of data from TMR assessments.

3 Method and data sources

This study is based on the methodological framework of material flow accounting and analysis (MFA). MFA builds on earlier concepts of material and energy balancing, as introduced already in the 1970's. The MFA concept was developed as a response to the fact that many persistent environmental problems, such as high material and energy consumption and related negative environmental consequences (such as climate change), are determined by the overall scale of industrial metabolism rather than the toxicity of specific substances.

MFA has been a rapidly growing field of scientific and policy interest since the beginning of the 1990s, when material flow accounts were first presented at the national level. Since then major efforts have been undertaken to harmonize the various methodological approaches developed by different research teams. Today, the MFA methodology is internationally standardized, with methodological handbooks publicly available, for example from the European Statistical Office (EUROSTAT, 2007 and 2011) and the OECD (2007).

For MFA at the national level, two main boundaries for resource flows can be defined. The first is the boundary between the economy and the domestic natural environment from which raw materials are extracted. The second is the frontier to other economies with imports and exports as accounted flows.

In general, four major types of materials are considered in MFA studies. All types of materials are accounted in terms of their weight (tonnes). Thus, this study will also present data at this level of aggregation:

- Biomass (from agriculture, forestry, fishery, and hunting);
- Fossil energy carriers (coal, oil, gas, peat);
- Minerals (industrial and construction minerals); and
- Metal ores.

Used and unused as well as direct and indirect material flows are also distinguished. Used material extractions are those that enter in the economic processes while unused material extractions (such as overburden) do not. Direct material trade includes the directly traded raw materials and processed commodities, while indirect flows of trade are the materials embodied in the traded goods (also referred to as "ecological rucksacks" or "hidden flows") which are not included in the physical mass of the traded good but are required to produce the traded goods. However, it should be noted that assessments of unused extractions and indirect flows of trade are not yet standardised and a variety of questions are still the subject of scientific debate.

A large number of resource use indicators can be derived from economy-wide material flow accounts that are comprised of indicators of material inputs, material outputs, material consumption and physical trade. In this study, we will mainly use the following MFA-based indicators:

- Domestic extraction used (DEU), reflecting all raw materials extracted within the national borders of a country;
- Domestic Material Consumption (DMC), which is calculated as DE plus imports minus exports;
- Physical Trade Balance (PTB), which is calculated as imports minus exports;
- Total Material requirement (TMR) which includes used and unused extractions and direct and indirect imports
- Total material Consumption (TMC) which is TMR minus direct and indirect exports.

The compatibility of MFA with data from the System of National Accounts (SNA) enables direct comparison of material flow indicators with indicators of economic performance, such as GDP. These inter-linking indicators quantify the eco-efficiency (or material productivity) of an economic system by calculating economic output (measured in monetary units) generated per material input (in physical units), for example GDP/DMC. Material productivity indicators are thus suitable tools to monitor processes of de-linking or de-coupling of material use from economic growth.

The calculations illustrated in this study build upon the integration of two existing data bases. First, the global database on material extraction developed and maintained by SERI, which is based on international statistics, including the International Energy Agency, the Food and Agriculture Organization of the United Nations and the US and British Geological Surveys. This database is accessible in an aggregated form on the following webpage: www.materialflows.net, where a detailed technical report can also be downloaded (SERI, 2011b). Data quality varies for the different types of materials. It is generally good for the extraction of fossil fuels and metal ores, however, in some cases, estimations have to be applied regarding the concentration of metals in crude ore extraction. It can be assumed that biomass extraction for subsistence purposes are underestimated. Additionally, statistics for mineral use are poor in the majority of countries. Thus, the extraction of construction minerals was estimated as best as possible by using data of the physical production of cement and bitumen. Where no reliable data on cement and bitumen production was available, the estimations were carried out using per capita income as proxy. Thereby, 0.3 tonnes per capita and year was assumed as a minimum value of construction mineral extraction. The minimum value was derived from countries with low income and reliable available data. Conservative estimates were used in all cases, hence it can be assumed that extractions are generally underestimated rather than overestimated in this study.

Many studies were reviewed in order to assess unused extraction (see also SERI, 2011b for details). These studies highlight the detrimental impacts associated with resource extraction such as crop residues from harvesting in the agricultural and forestry sector and by-catch in the fisheries sector. The calculation of Germany's unused extraction (in TMR) also includes erosion in order to allow for comparability with existing studies on Gemany's TMR (Chapter 4). Due to the fact that data on erosion are generally not available for many countries, or when they do exist, are of poor quality, it has not been included in the calculation of TMR for the selected countries and years (Chapter 5). To allow comparability, the portion of erosion was subtracted again in Germany's TMR in the respective chapter. The quality of data for unused extraction is generally poorer than the quality of data for extraction. Only few country-specific data are available, thus many continental and global averages have been used for the assessments for this report.

As the second major data source, the global database on resource trade, developed at University of Cologne and the Wuppertal Institute in Germany – which is based on UN Comtrade data and includes global accounts of imports and exports in physical (weight) units – has been applied. All missing weight values in UN Comtrade have been filled using the global annual price for each commodity group, starting with the most differentiated level, then summarized according to the classification structure, and repeated at the next higher differentiation level up to the total sum. Values of direct trade flows of major outliers are corrected by adjusting the concerned values with regard to global prices, amount of global imports and exports and – as far as available – bilateral trade data as well as with regard to national or international sector statistics such as IEA. A more detailed methodological description is given by Dittrich (2010) and Dittrich and Bringezu (2010).

In general, UN Comtrade trade statistics are relatively good in regards to completeness, plausibility and level of differentiation, more so in recent years than in earlier years. The trade statistics for European and Latin American countries are generally good, while the trade statistics for African and Central Asian countries are rather incomplete and fragmentary.

In this study, indirect material flows associated with trade were calculated using LCA-based coefficients, multiplied with the mass of directly-traded commodities. With very few exceptions, the same coefficients were used to assess the indirect trade flows for German and global trade (UBA, 2008). The coefficients assessed for Germany are arguably one of the most differentiated and complete coefficients in the world. Germany is also one of the largest trading nations, both in monetary terms and in physical terms, exporting to and importing a wide range of commodities from all countries of the world. Therefore, it is appropriate to use the coefficients assessed for Germany in this study, in order to assess the indirect flows of imports from the other countries. Exceptions are those commodities with a very high variety of indirect flows, in particular hard coal which can be extracted from deep or from open-pit mines. Thus, the global average coefficients have been calculated for these commodities and used in this study in order to assess TMR (Dittrich et al., 2012b).

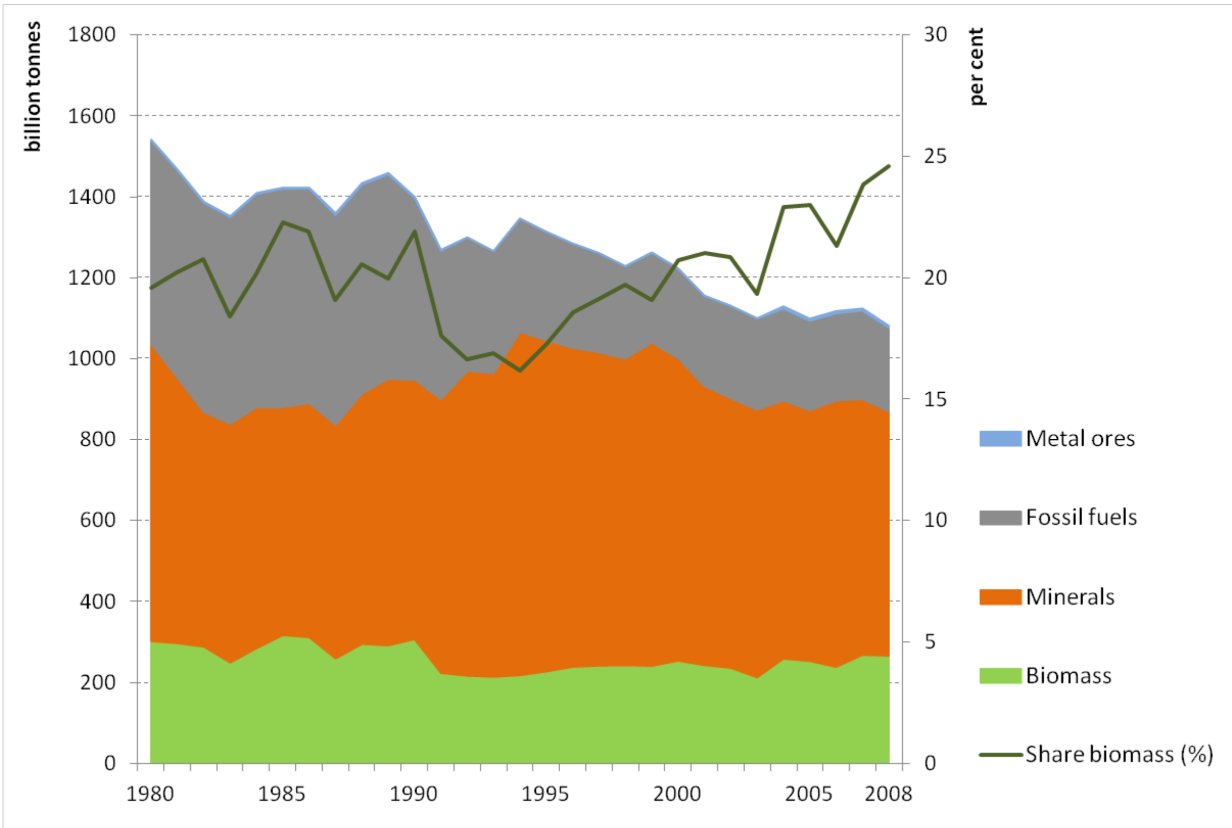
4 Resource use indicators of Germany

The first work package includes an update of Germany's major resource indicators, based on a former study „Ressourcenverbrauch von Deutschland – aktuelle Kennzahlen und Begriffsbestimmungen“ (Resource use in Germany- actual numbers and terms (UBA, 2008)). The aforementioned study examined the period between 1991 and 2004; hence this study focuses on the periods from 1980 to 1990 and 2005 to 2008. In order to maintain clarity, we have included the full period between 1980 and 2008 in the figures. The results are structured, contrasted and categorised as in the previous study. Due to space restrictions, only the most pertinent results will be discussed in this paper.

4.1 Domestic Extraction Used (DEU)

According to MFA-standards, material extraction used (DEU) includes biomass, fossil energy carries, metals and non-metal minerals. Material extraction used in (West and East) Germany declined by 30% between 1980 and 2008. Material extraction used also decreased in absolute numbers by 1.5 billion tonnes to 1.1 billion tonnes in 2008 (Fig. 1). Overall, extraction of fossil energy carriers declined significantly by 59% between 1980 and 2008 with a particular decline in hard coal (-80%) and brown coal (-55%). Petroleum also declined by 35% and natural gas by 30%. Furthermore, extraction of biomass and minerals declined by 12% and 18%respectively. In contrast, extraction of metals increased significantly by 93%, although the amount of extracted metals is rather negligible.

Fig. 1: Domestic extraction used in Germany, 1980-2008



Source: SERI, 2011

Non-metal minerals dominate used material extraction with a share of 56% in 2008. Extracted non-metal minerals are predominantly construction minerals such as sand and gravel. Biomass held a share in extraction of 21 to 25% between 1980 and 2008, with its share increasing from the 1990s.

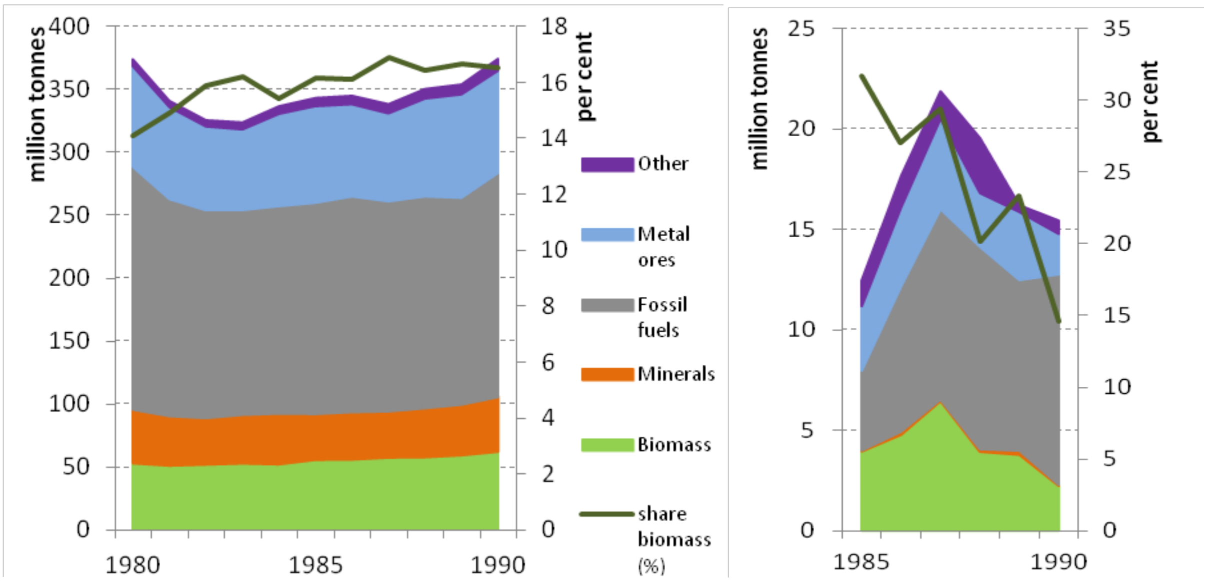
In 1980, only four countries extracted more materials than Germany; this had changed by 2008 to ten countries with China, USA, India, Brazil, Russia, Australia, Indonesia, Mexico, Canada and Iran extracting more than Germany.

4.2 Imports, exports and physical trade balances

The trade data for West Germany (BRD) was of a high standard between 1980 and 1990, in contrast, East German (DDR) data was only first collated from 1985, resulting in very fragmented physical trade data, correspondingly, the quality of results for East Germany prior to unification are clearly not as rigorous as those for West Germany.

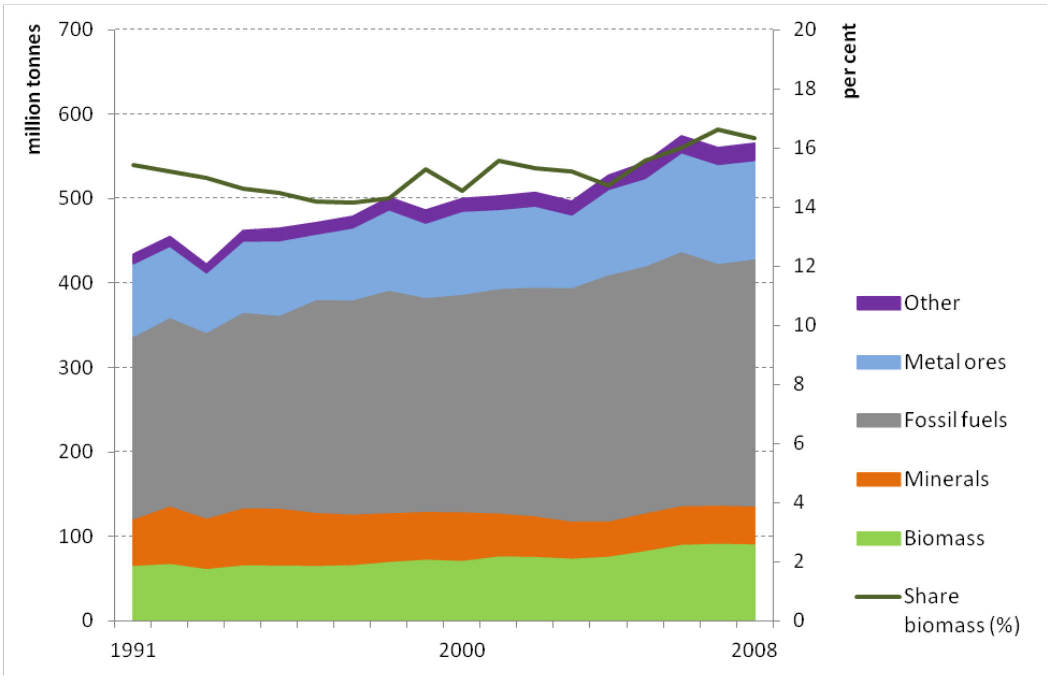
Imports (in physical terms) into West Germany, in particular imports of fossil fuels, declined during the second oil crises at the beginning of the 1980's (Fig. 2). However, imports in physical terms increased again from 1983. In 1990, Germany imported around 375 million tonnes of materials, almost the same amount as it was ten years prior. Imports into West Germany surpassed imports into East Germany by a factor of almost twenty. It should be noted again that the quality of physical trade data for East Germany is limited. In 1990, imports for both West and East Germany were dominated by fossil fuels which held a share in total imports of 48% and 68%, respectively. In the same year, the share of biomass in total imports was 17% in West Germany and 15% in East Germany.

Fig. 2: Imports of West (left) and East (right) Germany, 1980/1985-1990



Source: Dittrich, 2011, based on UNComtrade

Fig. 3: Imports of Germany, 1991-2008



Source: Dittrich, 2011, based on UNComtrade

After reunification, imports increased continuously, from 434 million tonnes in 1991 up to 565 million tonnes in 2008 (+30%). Thereby, imports of biomass, fossil fuels and metals increased on average by almost 35% and imports of other products (manufactured products made from different materials) rose by 83%. In contrast, imports of non-metal minerals declined (-18%). Biomass has continuously held a share in total imports of between 14 to 17%.

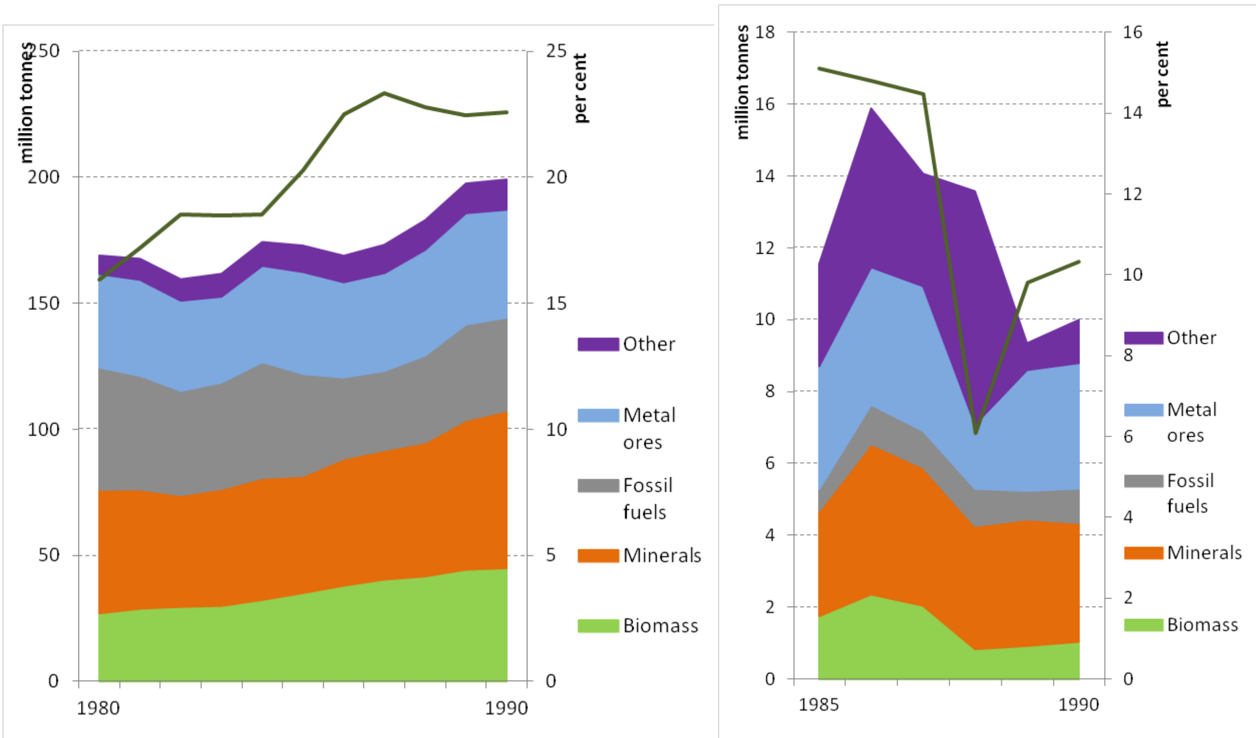
In 2008, Germany was the fourth largest importer of materials after the USA, China and Japan.

West Germany's exports in physical terms increased to almost 200 million tonnes (+18%) between 1980 and 1990. In contrast to imports, West and East German exports were more dispersed in regards to their material composition (Fig. 4). West German exports exceeded those of East Germany by a factor of twenty. The share of biomass in total exports for West Germany increased from 16% in 1980 to 23% in 1990.

After reunification, German exports increased by 142 million tonnes up to 353 million tonnes in 2008. Thus physical exports increased more than imports (+67% vs. +30%) with an increase in exports of all material groups. Exports of fossil fuels and other products increased while exports of minerals increased less quickly. Biomass held a share in total exports between 25 and 28.5% between 1991 and 2008.

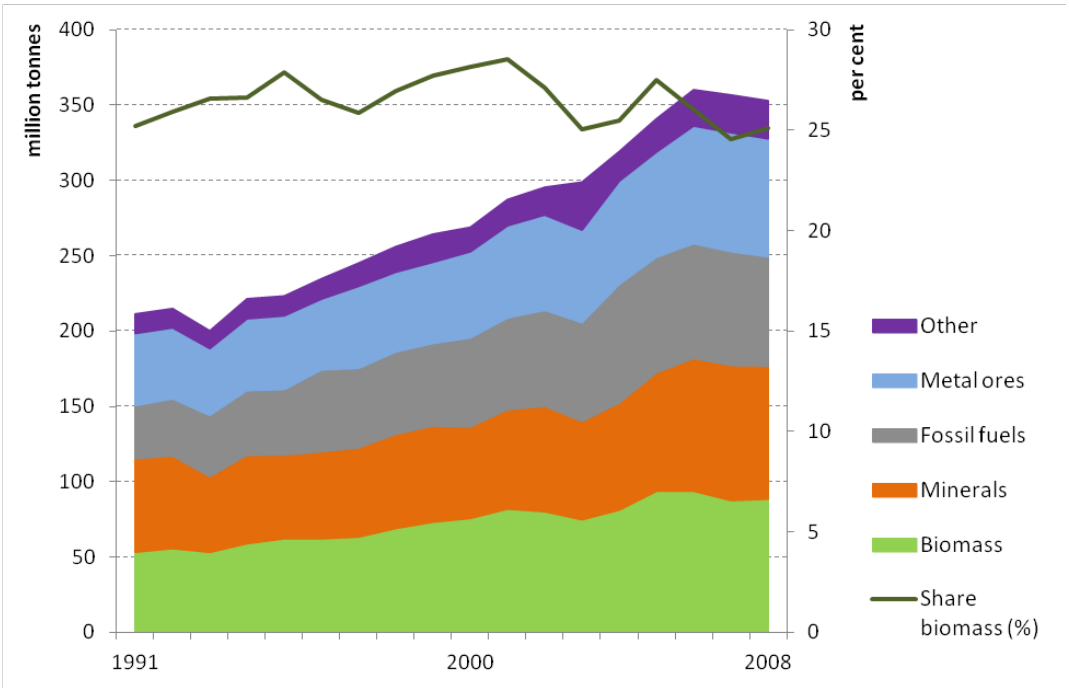
Germany was the ninth largest exporter of materials in 2008. This is largely due to the fact that Germany exports non-metal minerals (in particular for construction) to neighbouring countries such as the Netherlands and Switzerland.

Fig. 4: Exports of West (left) and East (right) Germany, 1980/1985-1990



Source: Dittrich, 2011, based on UNComtrade

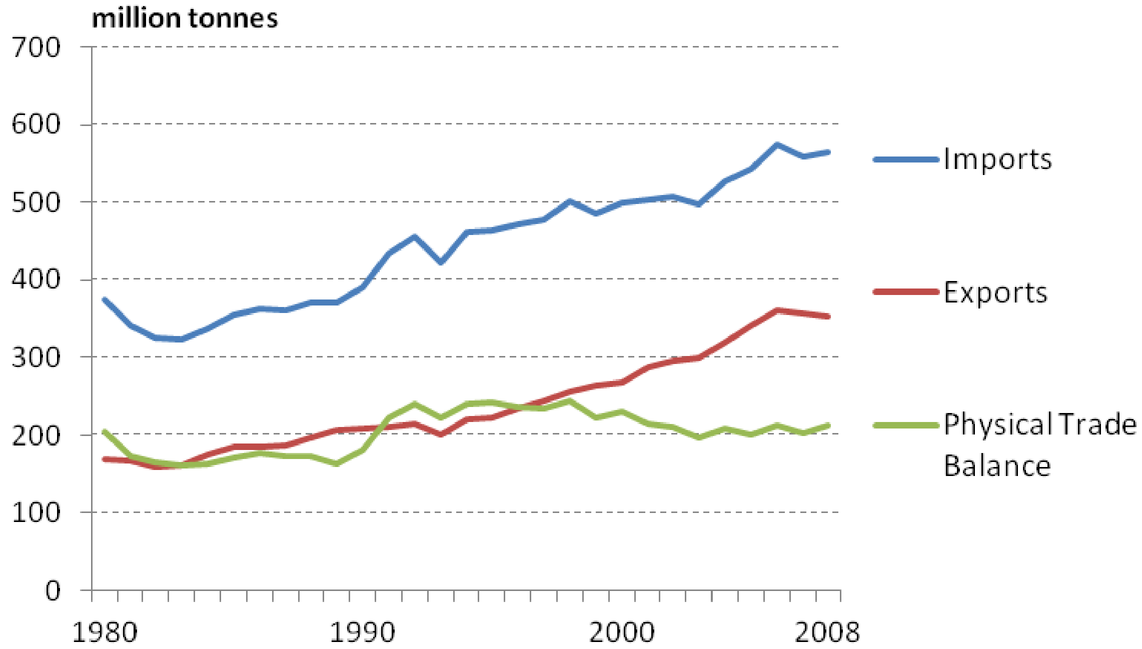
Fig. 5: Exports of Germany, 1991-2008



Source: Dittrich, 2011, based on UNComtrade

In summary, Germany imported 212 million tonnes of materials in 2008 (Fig. 6). After reunification, Germany's physical trade balance declined slightly (a decrease of 5% since 1991). In 2008, Germany was the fifth largest net importer of materials after Japan, China, USA and South Korea.

Fig. 6: Imports, exports and physical trade balances of Germany at a glance, 1980-2008



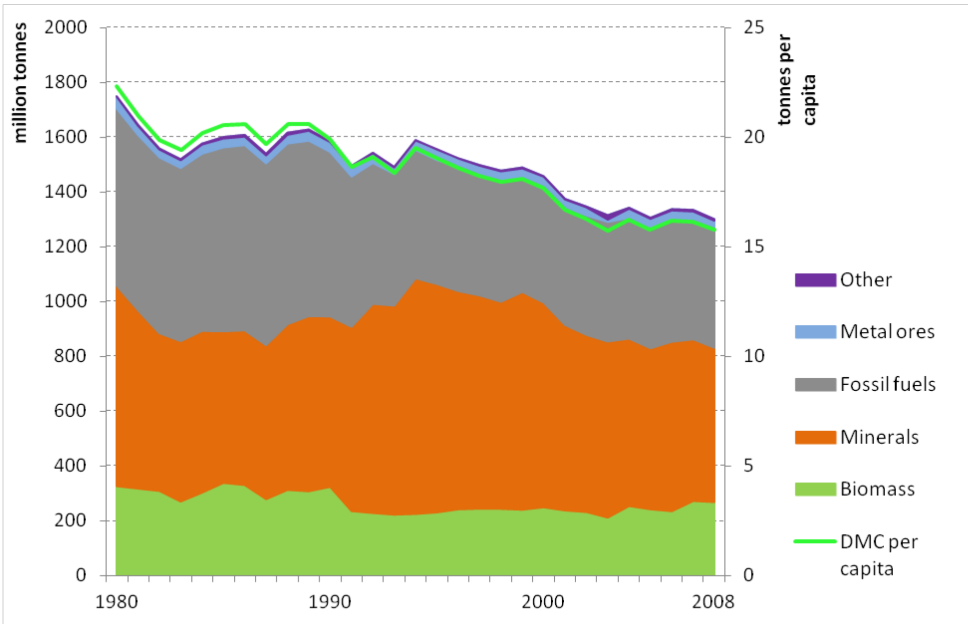
Source: Dittrich, 2011, based on UNComtrade; before 1990 imports and exports of West and East Germany are summed.

4.3 Domestic Material Consumption (DMC)

Domestic material consumption (DMC) is the sum of material extraction plus physical imports minus physical exports. Between 1980 and 2008 Germany's DMC declined by 453 million tonnes to 1,294 million tonnes in 2008, a decrease of 27% (Fig. 7). DMC per capita declined from 22.3 to 15.8 tonnes (-29%) during the same period. In 2008, minerals held the highest share in DMC (43%), followed by fossil fuels (33%) while the share of biomass in DMC was around 21%.

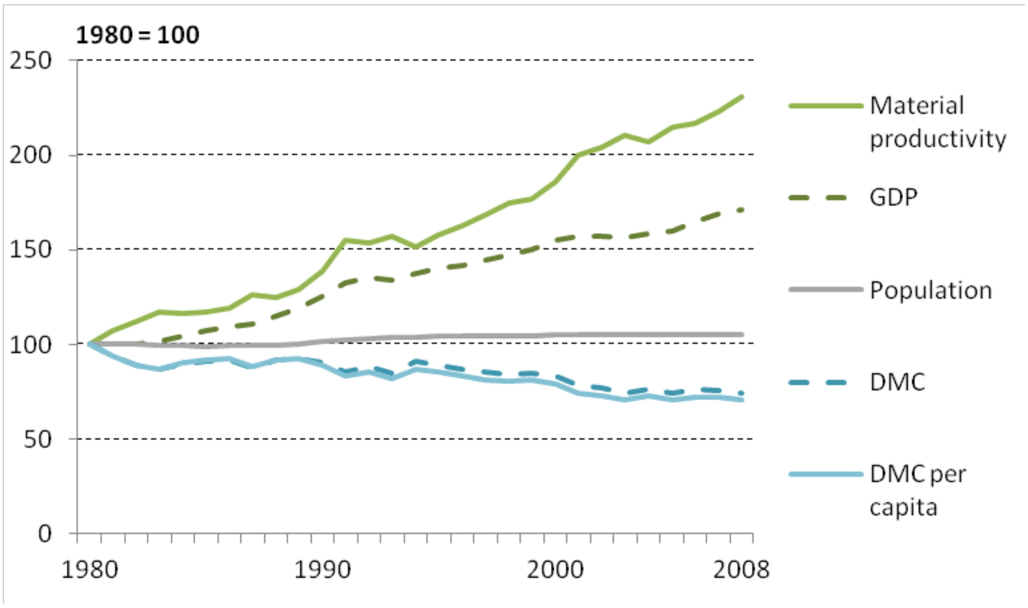
In 2008, Germany's DMC was the eighth largest in the world and 47th in the world in regards to DMC per capita.

Fig. 7: DMC of Germany, absolute and per capita, 1980-2008



Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011b

Fig. 8: Change of DMC, GDP, Population and material productivity (GDP per DMC) in Germany, 1980 - 2008



Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011b

Germany reached a decoupling of economic growth and (direct) material consumption (Fig. 8) between 1980 and 2008. Material productivity (GDP per DMC) increased by 131% which equals a yearly growth rate of 4.7%. Thus, improvements in material productivity in Germany were better than the global average of 38% between 1980 and 2008, equating to a yearly growth rate of 1.3%.

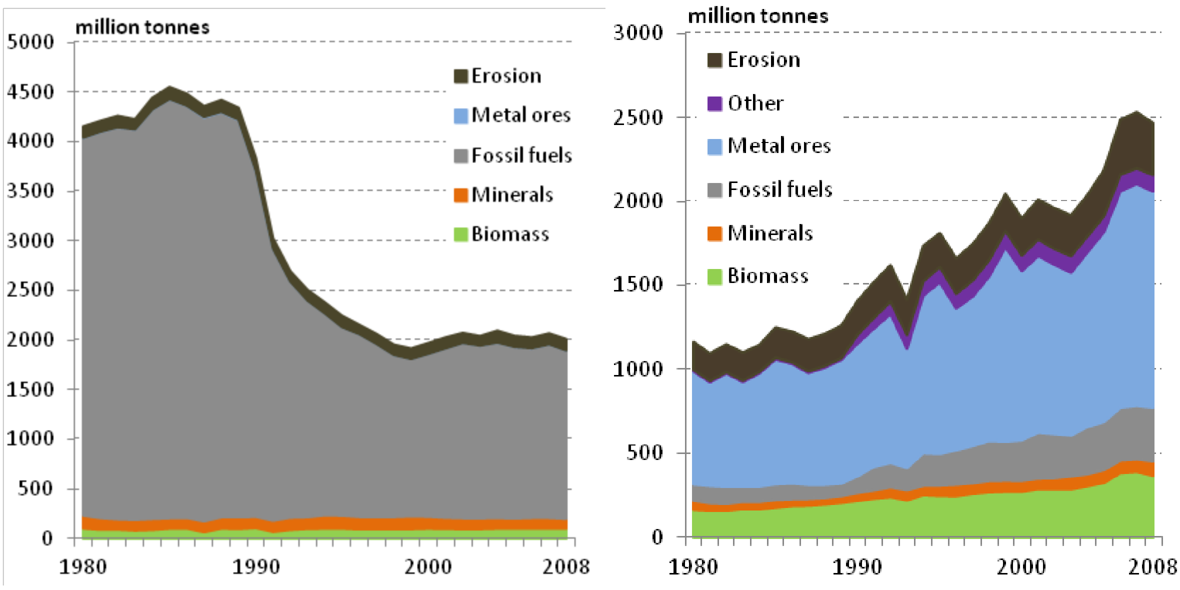
4.4 Total Material Requirement (TMR)

Total Material Requirement (TMR) is the sum of used and unused material extraction as well as direct and indirect physical imports. In the following, unused extraction and indirect imports are presented first, and then Germany's TMR will be analysed.

In Germany, unused extraction is dominated by fossil fuels, in particular by soft coal which alone is responsible for almost 86% of unused extraction in 2008 (Fig. 9). In this same timeframe, unused extraction in Germany dropped by 52% mainly due to a decline in soft coal extraction (from 4.1 to 2.0 billion tonnes).

Material flows associated with trade are only available for West Germany but not for East Germany due to the reasons mentioned previously. Contrary to the results for direct imports, material flows associated with metal imports dominated indirect imports. It should be noted that these indirect flows consist of different material such as fossil fuels or minerals in order to produce the imported metals (see also Chapter 6). Altogether, indirect flows of imports increased from 1.16 billion tonnes in 1980 (West Germany) to 2.46 billion tonnes in 2008, an increase of 112% overall for Germany. At the same time, the average indirect flows per imported tonne of material increased from 3.1 to 4.3 tonnes.

Fig. 9: Unused extraction (left) and indirect imports (right) for Germany, 1980-2008



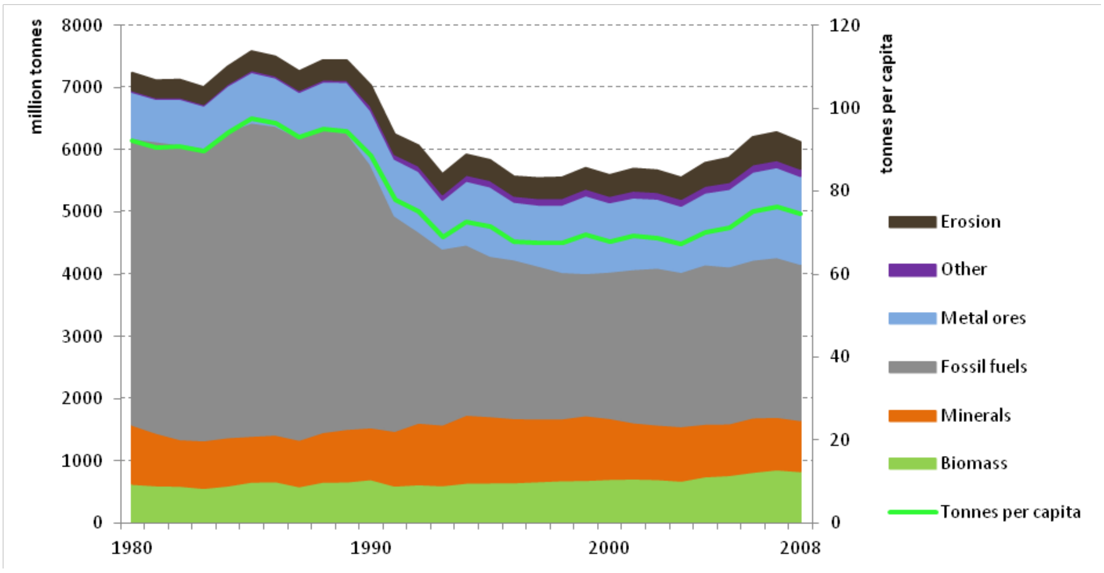
Sources: extraction: SERI, 2011, trade: Dittrich, 2011; please note the figures for 1980 – 1990 relate to West Germany only.

Between 1980 and 2008, the TMR for Germany decreased by 15% down to 6.117 billion tonnes (Fig. 10). Germany's TMR was dominated by fossil fuels although they declined during the 28 years (-45%). Metals held the second highest share in TMR due to the indirect flows of imported metals.

Germany had the second largest TMR in the world after the USA in 1980 and the fifth largest in 2008, after China, the USA, Australia and India.

TMR per capita also declined from 92.3 tonnes in 1980 to 74.5 tonnes in 2005 (-19%).

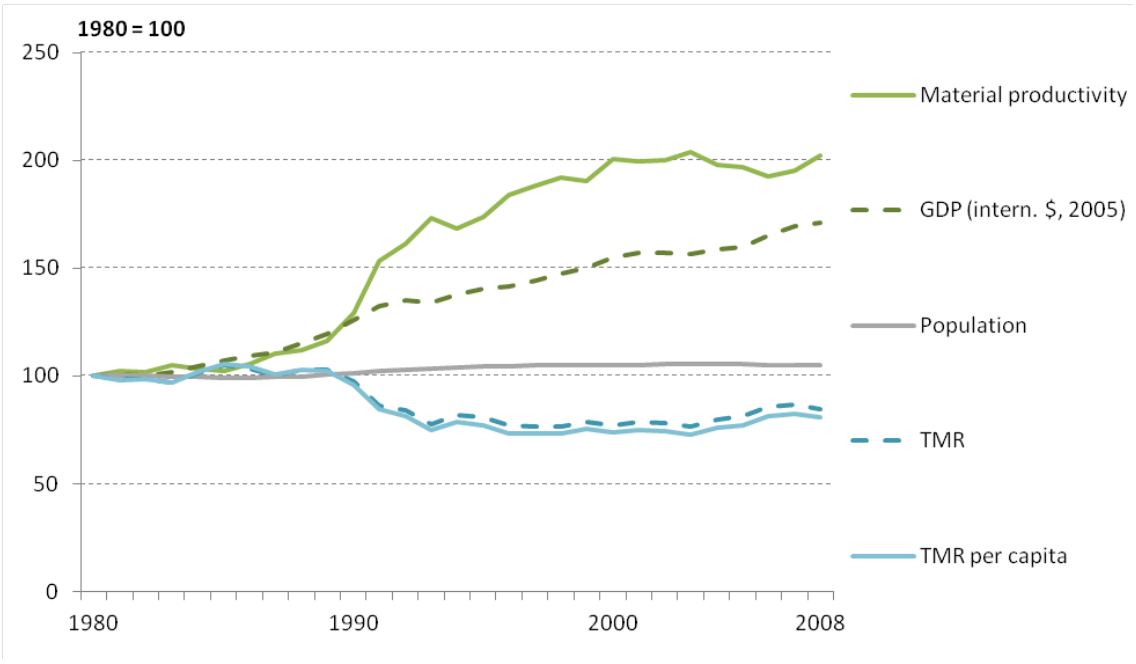
Fig. 10: TMR of Germany, 1980-2008



Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011b

The declining TMR combined with the increasing GDP resulted in a doubling of material productivity between 1980 and 2008 measured in GDP per TMR (Fig. 11). The main increase in material productivity can be observed in the first years of reunification while material productivity stagnated in the 1980s and after 1995.

Fig. 11: Change of TMR, GDP, population and material productivity (GDP per TMR) for Germany, 1980-2008

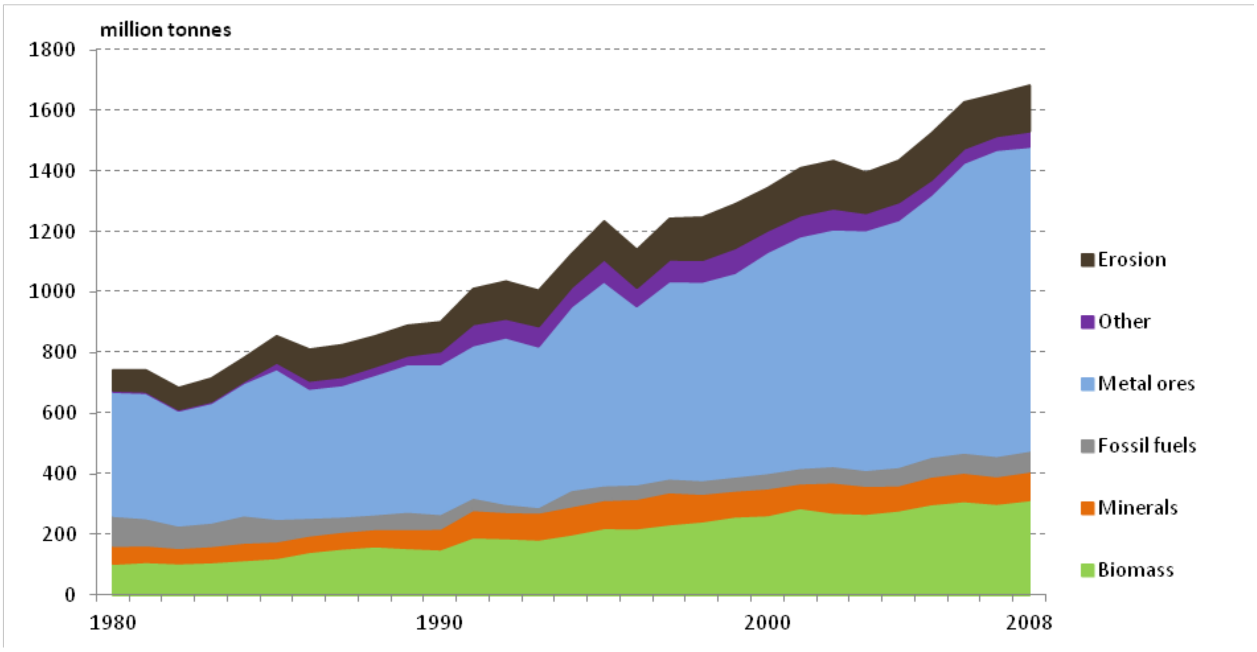


Source: Dittrich, 2011, SERI, 2011, World Bank, 2011b

4.5 Total Material Consumption (TMC)

Total Material Consumption is calculated as TMR minus direct and indirect exports. The indirect flows associated with Germany's exports increased by 126% to 1.7 billion tonnes between 1980 and 2008 (Fig. 12). Indirect flows of metal exports dominated the indirect flows of exports. Contrary to the results for Germany's imports, the average relation of direct and indirect exports decreased from 4.4 tonnes indirect flows per tonne directly exported material in 1980 to 3.2 tonne per tonne in 2008. This decrease is mainly caused by changes in the structure of exports. For example, the export of several commodities that are associated with higher indirect material flows, such as soft and hard coal as well as zinc, declined or increased only slightly (in case of iron and steel) while exports of several commodities that are linked to rather lower indirect material flows increased more. It can be assumed that improvements of material efficient production also contributed to the decreasing average of materials associated with exports. However, it is difficult to measure their respective shares.

Fig. 12: Indirect flows associated with exports, 1980-2008

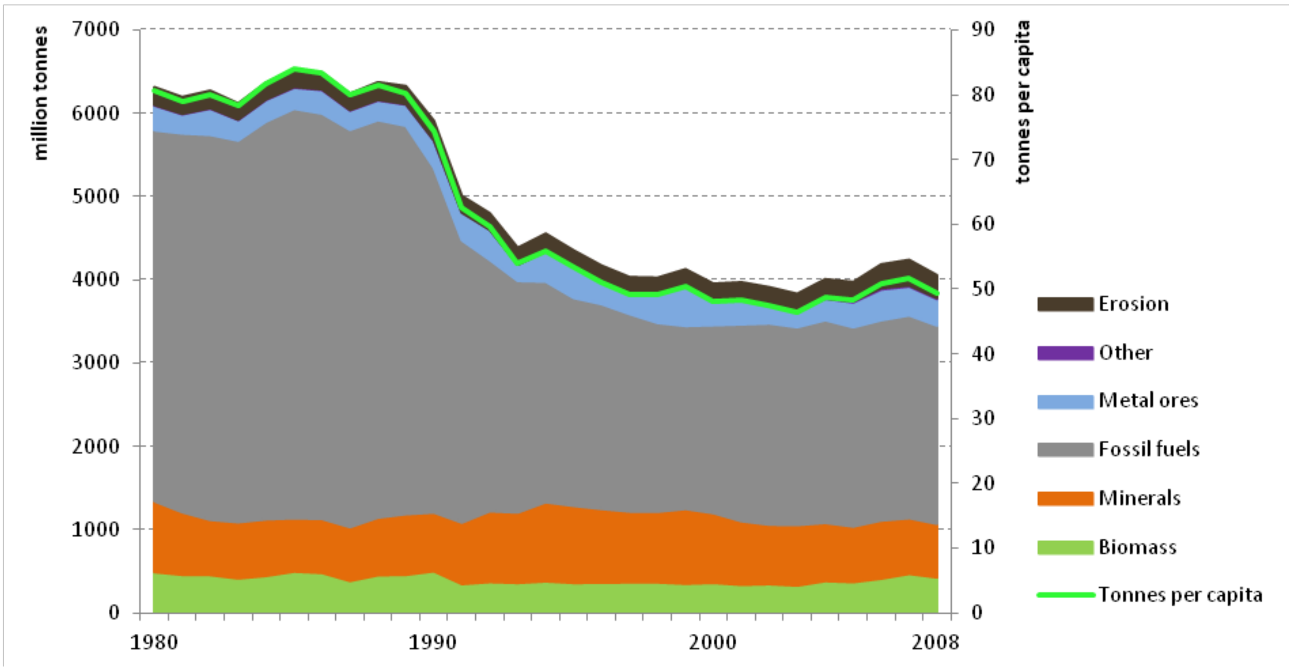


Source: Dittrich, 2011

TMC for Germany declined from 6,310 million tonnes to 4,061 million tonnes between 1980 and 2008 (-36%). As was observed in TMR, fossil fuels also held the highest share in TMC and dominated dynamic of TMC (Fig. 13). However, contrary to the results of TMR, metals are rather negligible in TMC.

TMC per capita reduced from 80.6 tonnes in 1980 to 49.5 tonnes in 2008 (-39%).

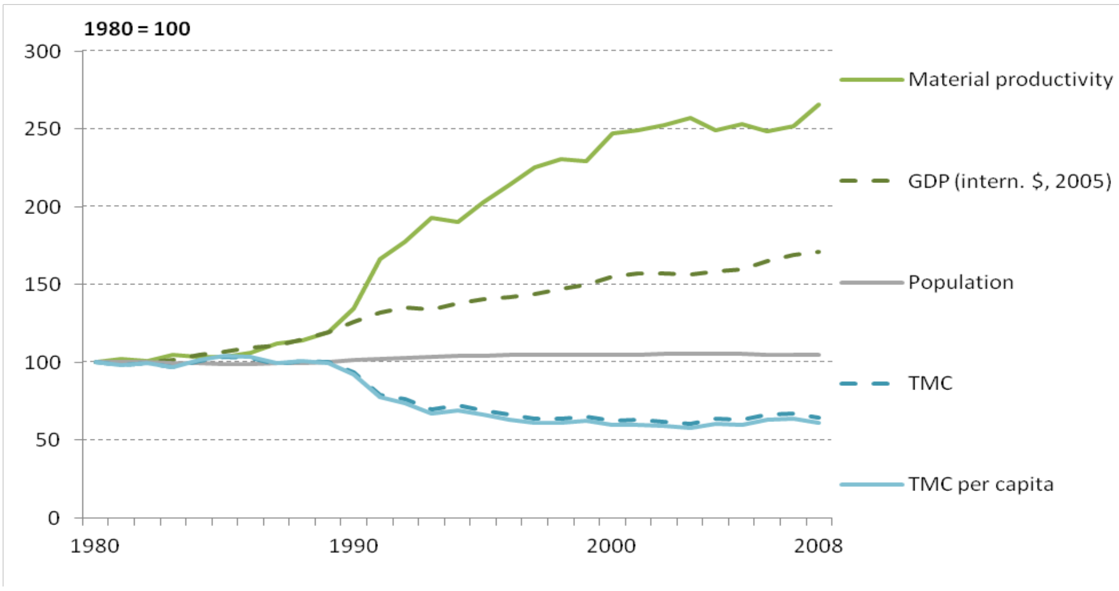
Fig. 13: TMC absolute and per capita for Germany, 1980-2008



Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011b

Material productivity (GDP per TMC) increased by 166% between 1980 and 2008 (Fig. 14) as a consequence of declining TMC and growing GDP. The decline of soft coal extraction in particular after reunification was predominantly responsible for the increases of material productivity measured in GDP per TMC. Thus, an absolute decoupling can be observed in Germany during the past three decades.

Fig. 14: Change of TMC, GDP, population and material productivity (GDP per TMC) in Germany, 1980-2008



Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011b

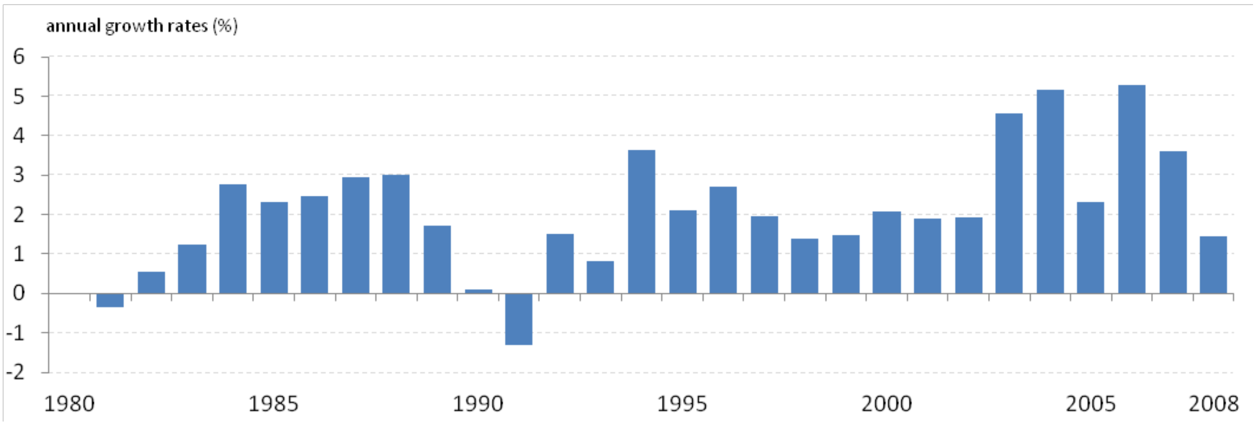
5 Global trends in material use

This part of the study provides an overview of global facts and trends regarding material use between 1980 and 2008, outlining the spatial-temporal dynamics of used material extraction, direct physical trade, material consumption (DMC) and material productivity (GDP per DMC). These dynamics are analysed by material categories as well as by regions. In addition, they are also examined with regards to income, level of affluence (HDI), resource endowment, population density and the sectoral structure of the economy. Due to limited space, only the key outcomes are presented in this chapter.

5.1 Extraction

Global material extraction rose from almost 38 billion tonnes to more than 68 billion tonnes (+79%) between 1980 and 2008. In this period, material extraction decreased only in two years: 1981 in the context of the second oil crisis and 1991 as a consequence of the collapse of the former Soviet Union (Fig. 15). Between 1980 and 2002 material extraction increased yearly at an average of 1.7%, increasing thereafter on average by 3.7%, mainly due to high growth rates of material extraction in China.

Fig. 15: Yearly growth rates of global extraction, 1980-2008



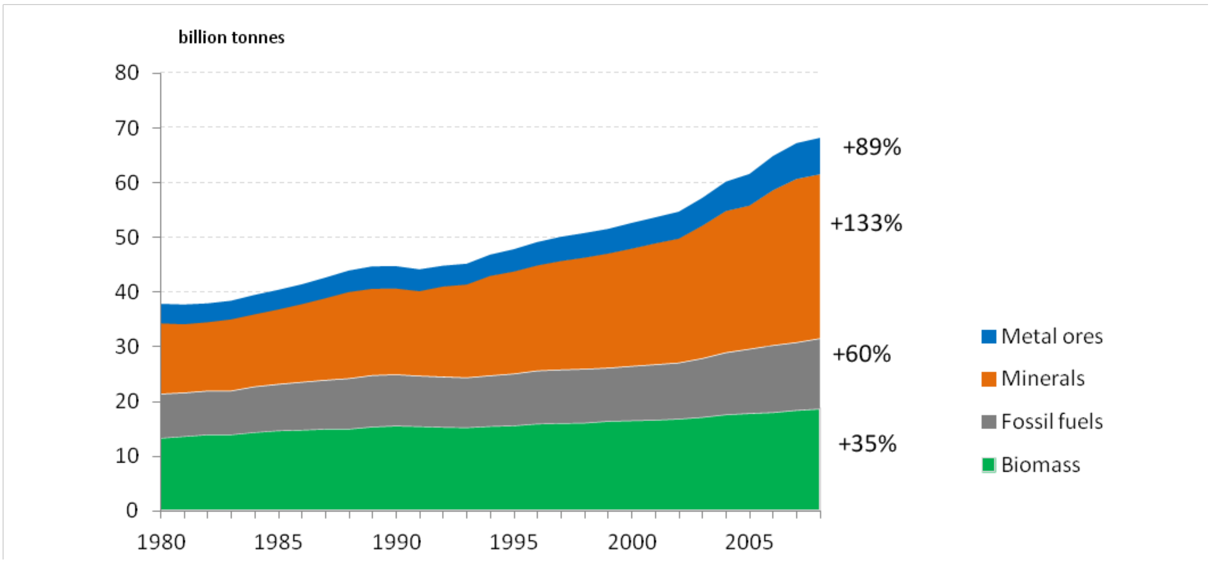
Source: SERI, 2011

With regard to material composition, global extraction of biomass, minerals metals as well as fossil fuels increased between 1980 and 2008 (Fig. 16). Thereby, extraction of biomass and fossil fuels increased under the global average (+ 35% and +60%, respectively) while extraction of metals and minerals rose over average (89% and +133%, respectively). Thus, the share of non-renewable materials in global extraction increased from 64.5% in 1980 to 72.4% in 2008, while the share of biomass decreased from 35.5 to 27.6% during the same period.

In 2008, minerals dominated global material extraction with a share of 44% with mainly sand and gravel being extracted (77% of extracted minerals). Fossil fuels held a share of almost 19% of global material extractions, in particular hard coal (45% of extracted fossil fuels), petroleum (28%) and natural gas (17%). Ten per cent of global extractions were metals, in particular iron (34% of extracted metals), followed by copper (29%) and gold (8%). Extraction of biomass consisted mainly of feed (47% of extracted biomass in 2008), plant based food (36%) and products from forestry (12%) in 2008.

The remaining biomass extraction (5%) is constituted by fish catches and other biomass. It should be noted that under MFA accounting methods that the “Feed” category only includes materials that are used exclusively for fodder. Plants that are used both as food and feed are assigned to the category “food”. Thus, the share of feed in biomass extraction is underestimated.

Fig. 16: Global material extraction by material composition, 1980-2008



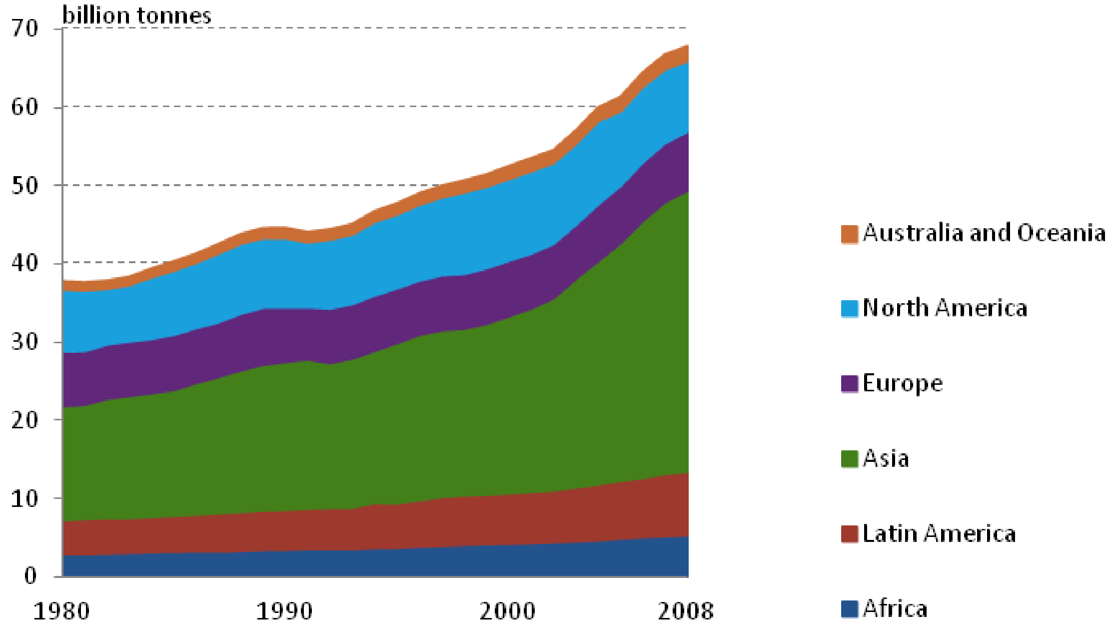
Source: Dittrich et al., 2012a

The majority of materials extracted in the period between 1980 and 2008 (Fig. 17[1]) were from Asia. Asia also had the largest increase in material extraction in Asia with an increase of 147% during the investigated period. Extraction also increased in Latin America, Africa and Australia (including Oceania) over the global average (+88%, +85% and +85%, respectively) while they increased under global average in North America and Europe (+13% and +6%). Thus, Asia’s share in global extraction grew from 38% in 1980 to 53% in 2008, while Europe’s share declined from 19% to 11% during the same period.

Extraction per capita varied among the continents between 5.7 tonnes in Africa and 53.3 tonnes in Australia (including Oceania). In Asia, the average extraction per capita was 8.7 tonnes, in Europe 12.7 tonnes, in Latin America 14.3 tonnes and in North America 26.7 tonnes. Between 1980 and 2008, material extraction per capita increased most in Asia (+64%), followed by Australia (including Oceania, +20%) and Latin America (+18%) while in Europe, Africa and North America, material per capita extraction declined (-1%, -9% and -15%, respectively).

[1] Regional assignation according to UN Statistics Division (2012) except Russia which was assigned to Asia instead of Europe.

Fig. 17: Extractions by continent, 1980-2008

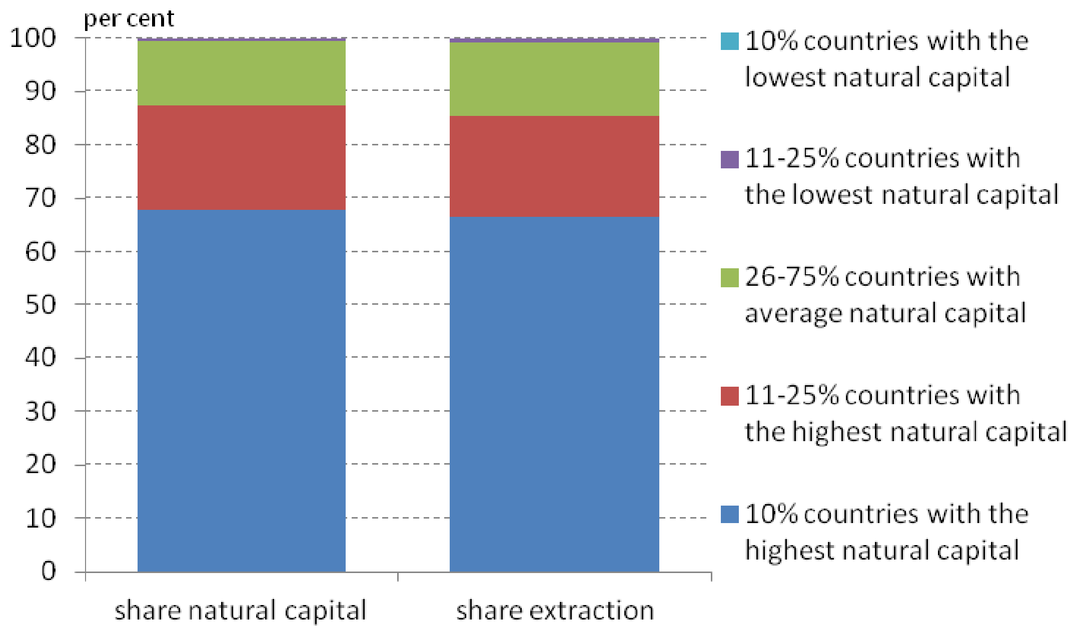


Source: Dittrich et al., 2012a

Extraction is driven by different factors. At this point, the link to resource endowment should be highlighted. Very few quantifications of resource endowment are available which allow comparisons between countries globally. However, one of the most comprehensive quantifications is the assessment of natural wealth undertaken by the World Bank (2006 and 2011). The World Bank estimated natural wealth in monetary terms (US$ in 2005) based on cropland, pasture land, used and unused forests, protected areas, deposits of petroleum, natural gas, coal, minerals and other natural resources. Estimates are available for the years 1995, 2000 and 2005, each including 120 to 146 countries.

In general, resource rich countries extract more materials than resource poor countries. The statistical correlation between natural capital and the amount of material extraction is high (correlation coefficient according to Spearman (rs) is higher than 0.92 in each of the years). This result is hardly surprising, but remarkable is the concord between both: in 2005, for example, the fifteen most resource rich countries (which are the 10% most resource rich countries) owned 68% of global natural wealth and extracted 67% of global extraction (Fig. 18). The following 16 to 37 resource richest countries (11 to 25% most resource rich countries) possessed 19% of global natural capital and also comprised 19% of global extraction. On the other hand, the 15 most resource poor countries (10% most resource poor countries) owned 0.03% of global natural wealth and extracted 0.12% of global material extraction; the following 16 – 37 resource poor countries possessed 0.6% of global natural wealth and extracted 0.8% of global extraction.

Fig. 18: Country groups according their share in global natural wealth and global material extraction, 2005

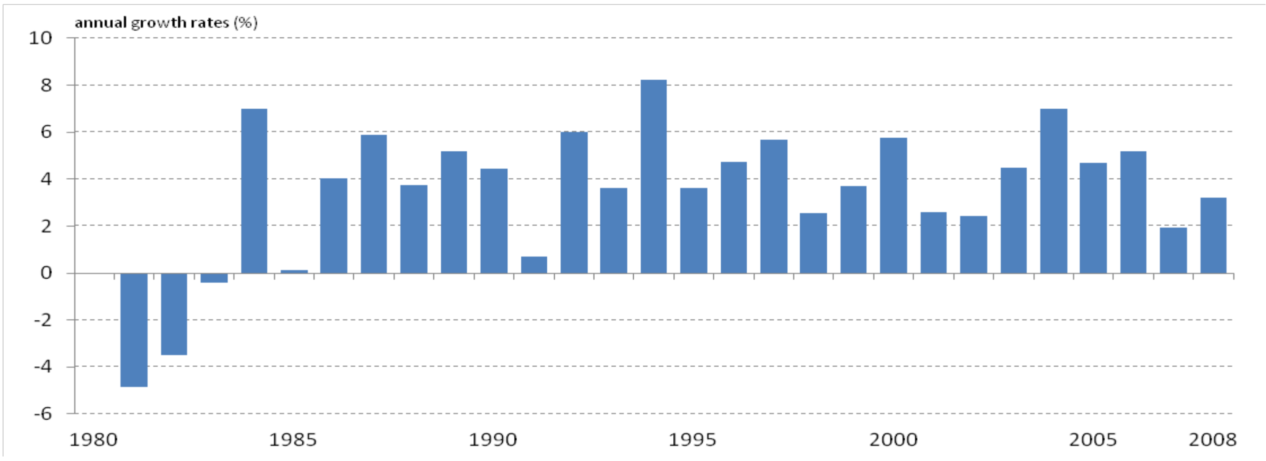


Sources: SERI, 2011; World Bank, 2011a

5.2 Global physical trade

The physical volume of global trade, measured by imports, increased by 158% from 3.97 billion tonnes in 1980 to 10.26 billion tonnes in 2008. Physical trade volume decreased between 1980 and 1983 due to the second oil crisis, increasing continuously thereafter with a yearly average of 2.44% (Fig. 19).

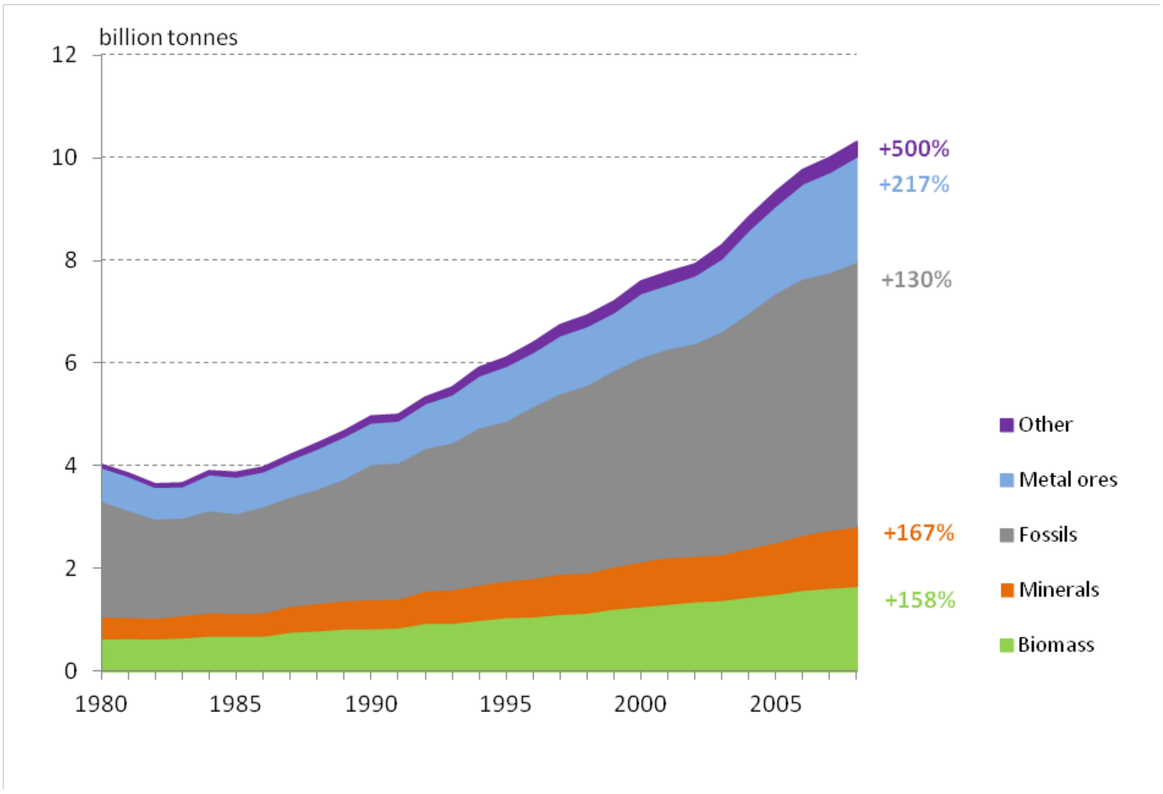
Fig. 19: Growth rates of global trade in physical terms, 1980-2008



Source: Dittrich, 2011

In physical terms, global trade is dominated by fossil fuels. Nevertheless, trade with fossil fuels increased under global average (+130%) between 1980 and 2008 resulting in a decline of the share of fossil fuels in global trade from 55.9% (1980) to 50.1% (2008, Fig. 20). Petroleum is the dominant traded commodity (58% of traded fossil fuels in 2008), followed by coal (19% of traded fossil fuels) and natural gas (15%). Almost 2.05 billion tonnes of metals, including commodities predominantly made out of metals, were traded in 2008 (1980: 647 million tonnes, +217%). Metals held the second highest share in global physical trade with 20% in 2008 (1980: 16%). Trade in metals is dominated by iron ores and concentrates as well as steel (2008: 68% of traded metals), followed by commodities predominantly made out of metals (20%). In 2008, 1.66 billion tonnes biomass were traded, including commodities predominantly made out of biomass such as paper (1980: 641 million tonnes, +158%). The share of biomass in global trade has been constantly around 16% during the investigated 28 years. Within the group of traded biomass, trade with food, in particular cereals, dominated with 43% of total trade with biomass in 2008, followed by products made out of biomass (24%) and timber (17%). 1.16 billion tonnes non-metal minerals were traded in 2008 (1980: 436 million tonnes, +167%), in particular construction minerals (34% of traded non-metal minerals in 2008). Construction minerals are mainly traded between neighbouring countries such as Indonesia and Singapore or Germany and the Netherlands. The group "other" consists of commodities which are not dominated by one material group or which cannot be specified by their material composition such as "antiques". Physical volume of other materials is negligible with 285 million tonnes in 2008 (1980: 47 million tonnes), nevertheless they increased highest during the investigated period (+500%).

Fig. 20: Global trade by material composition, 1980-2008

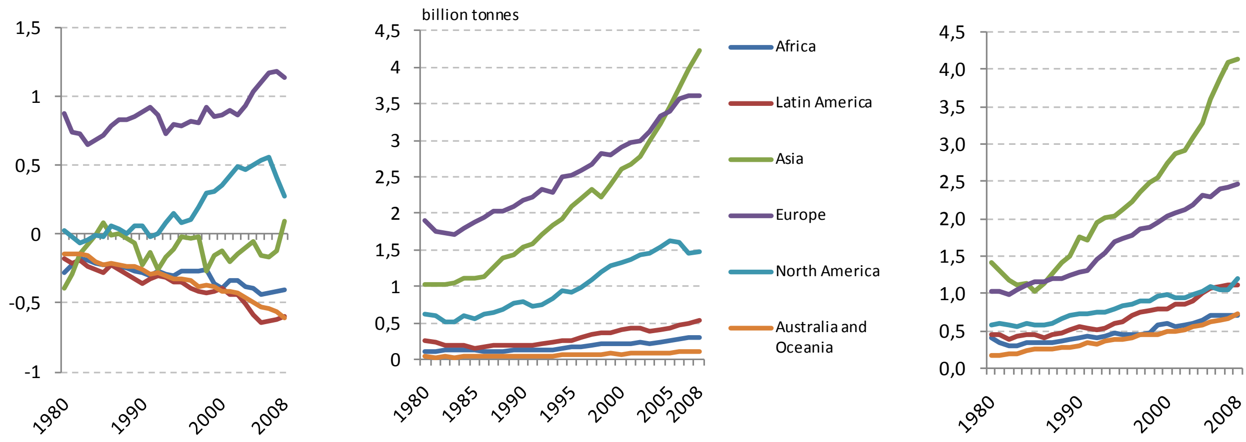


Source: Dittrich et al., 2012a

Imports as well as exports of all continents increased between 1980 and 2008, although with different growth rates (Fig. 21). With regard to exports, it can be observed that all Asian countries together exported most materials in nearly all years (2008: 40% of global exports), followed by European countries (2008: 24% of global exports). It should be noted that Asian countries mainly exported to non-Asian countries while European countries predominantly exported to other European countries. European countries together also dominated global imports until 2004.

However, since 2005 Asian countries' imports together exceed those of European countries. During the investigated period, Europe has net-imported by far the most materials while Latin America, Australia (including Oceania) and Africa increasingly net-export materials. North America was a net-importer in physical terms until the mid 1980s. From 1990 it changed to the second largest net-importer of materials. In spite of high amounts of imports and exports, Asia has the most balanced physical trade balance had in most years in the timeframe examined.

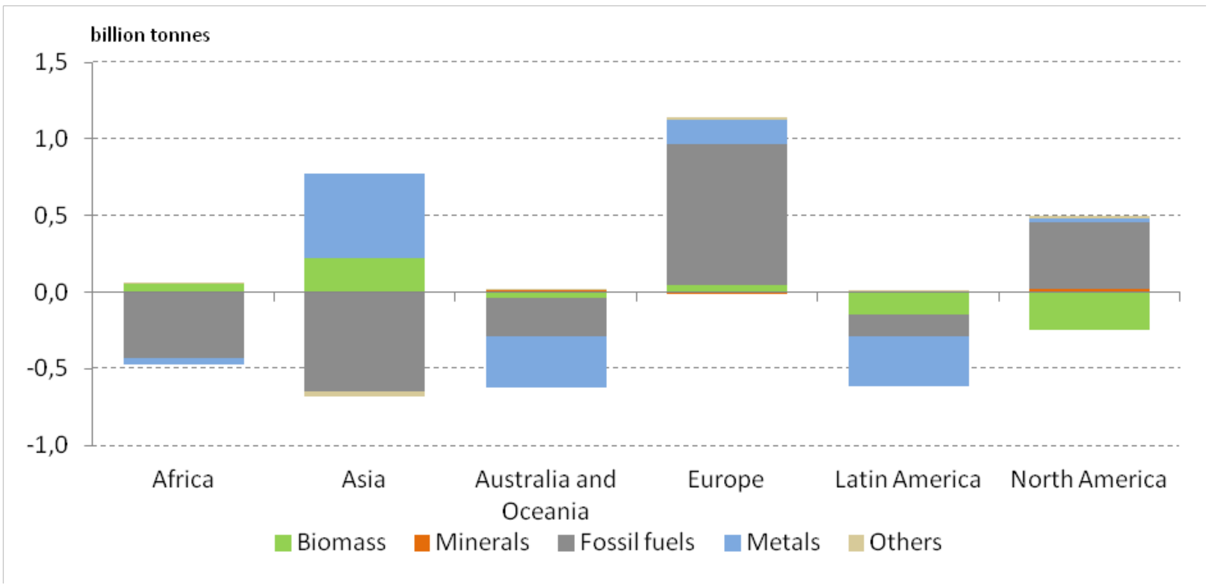
Fig. 21: Physical exports (left), imports (center) and trade balances (right) by continents



Source: Dittrich, 2011

The physical trade balances of most of the continents are dominated by fossil fuels, followed by metals and biomass (Fig. 22). In 2008, African countries supplied large amounts of fossil fuels and metals, while importing biomass. Asia was largest importer of metals and biomass and the largest exporter of fossil fuels. Australia (including Oceania) exported all material categories besides minerals and other products. In contrast, Europe imported all material categories besides minerals in 2008. North America was the largest supplier of biomass, followed by Latin America which was also the second largest exporter of metals.

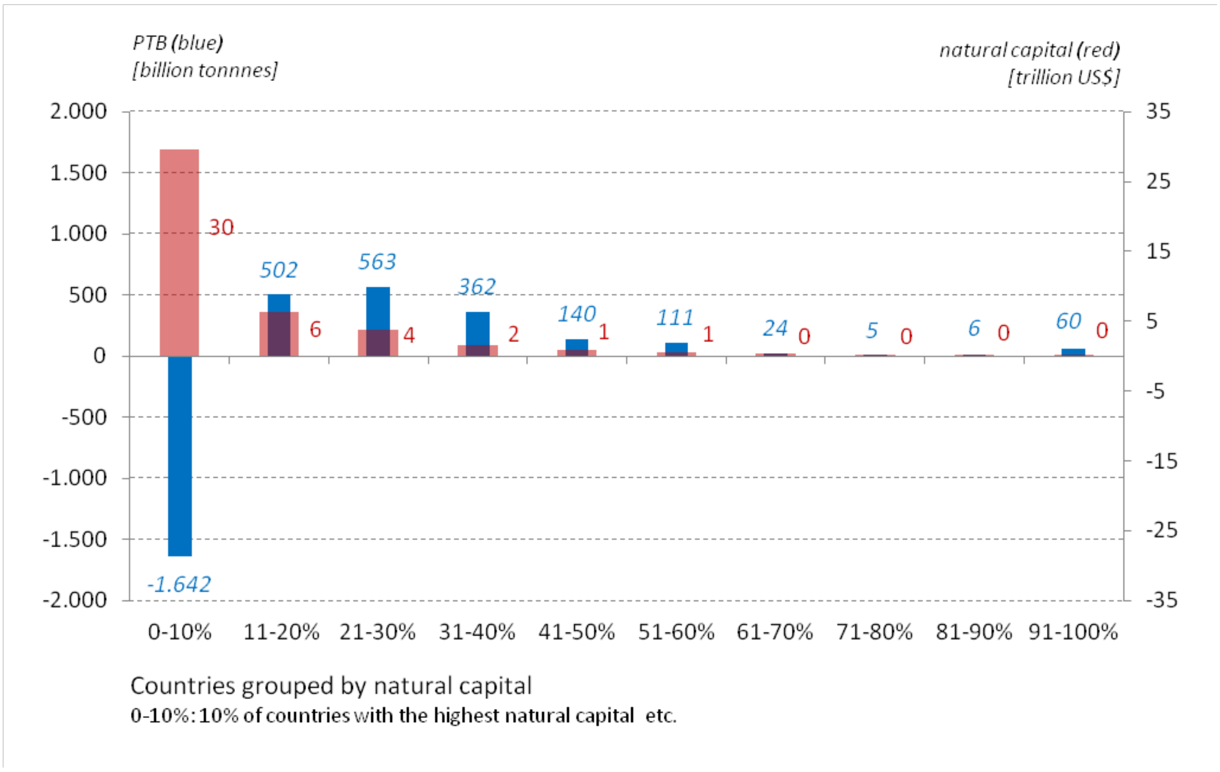
Fig. 22: Physical trade balances of the continents by material categories, 2008



Source: Dittrich, 2011

As explained above with regard to extractions, the World Bank natural capital assessment has been used to analyse the trade flows of countries with high natural capital compared to countries with low natural capital. The results show a high correlation between natural capital and physical exports; that is, the higher the natural capital of a country, the higher the physical exports (rs=0.85 in 2005). Less, but still significantly linked are natural capital and physical trade balances (rs=0.66 in 2005) as long as the net-importing countries of China, the USA and Japan are excluded. In 2005, the fifteen countries with the highest natural capital (10% most resource rich countries) which own 68% of global natural capital, together exported 1.64 billion tonnes – including USA, China and India (Fig. 23). When all other countries were arranged into groups according to their natural capital endowments (11 – 20% of the most resource rich countries, etc.) results show that all other country groups are net-importers of materials. Altogether, the ten percent of the world's most resource poor countries imported almost 60 million tonnes.

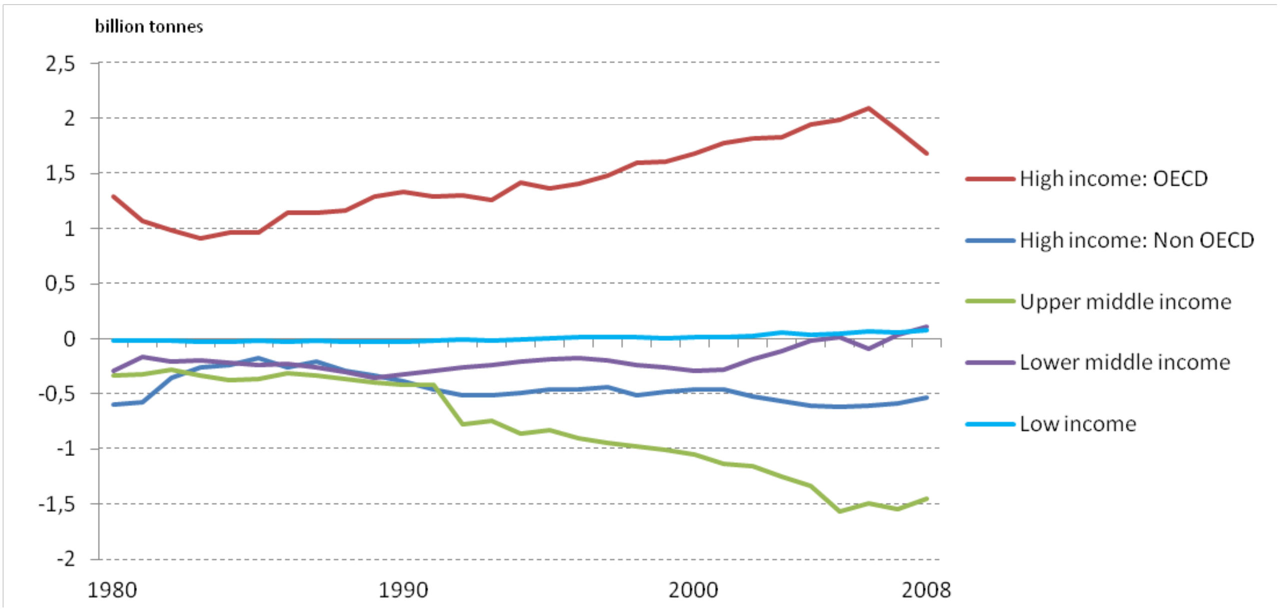
Fig. 23: Physical trade balance and natural capital by country groups according to their natural capital, 2005



Sources: Dittrich, 2011, World Bank, 2011a

In regards to country incomes, it has been observed that OECD countries together have been importing the most materials in all of the investigated years (Fig. 24). In contrast, non-OECD countries with high incomes are resource exporters, in particular due to the oil-exporting countries. Countries with upper-middle incomes such as Russia, Brazil and South Africa, supplied the most materials in physical terms during the investigated period. Countries with lower-middle incomes changed from supplier to importer in physical terms due to China. Low income countries net-exported materials until 1994; thereafter they imported materials, in particular biomass (food, see also Dittrich, 2010).

Fig. 24: Physical trade balances by income groups, 1980-2008



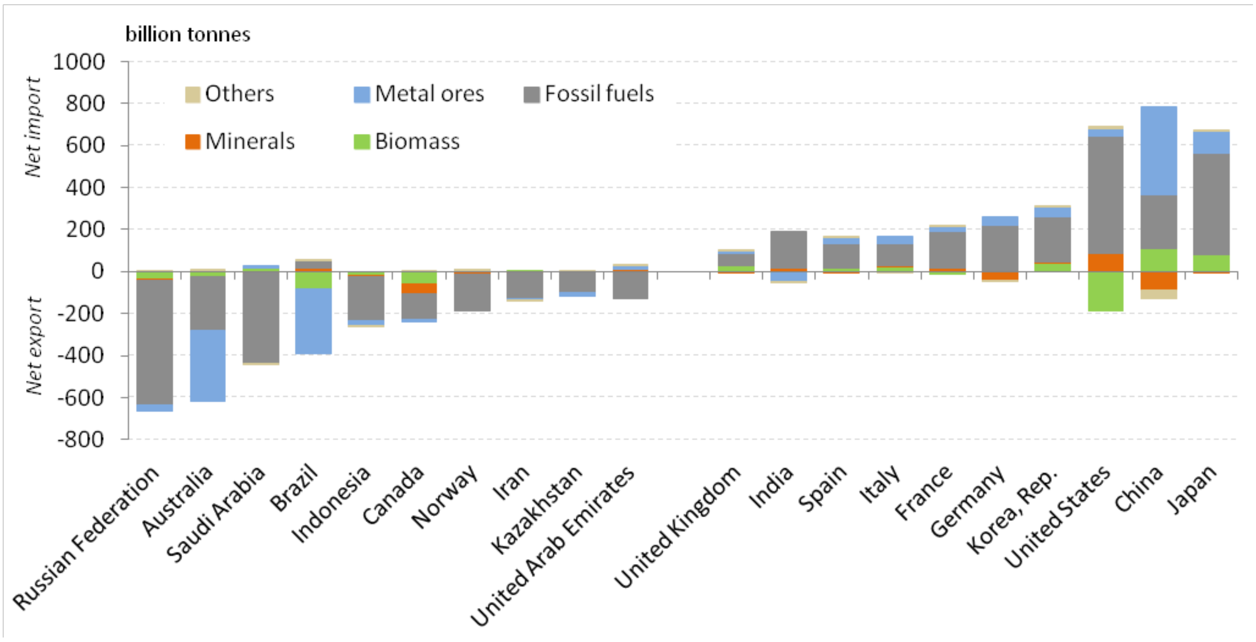
Source: Dittrich, 2011; Assignation according to World Bank, 2011a.

In the following, international trade is analyzed at the country level. Between 1980 and 2008 physical trade volume (measured as exports plus imports) increased in the majority of countries. On average, physical trade volume doubled from 61 to 121 million tonnes. Countries with decreasing trade volumes are exceptions such as Iraq or small islands such as Bahamas where trade with single commodities partly preponderated trade volumes.

Trade in physical terms was dominated by a minority of countries: in 2008, the ten countries with the highest trade volume imported and exported 95% of globally traded materials while almost 85 countries together not even imported and exported ten million tonnes of materials (less than 1%). Furthermore, the direction of net-trade of the countries is generally constant, although the amount of net imports or net exports increased. Only a few countries (14%) changed from being net importers to net exporters or vice versa, whereas more countries changed from being net suppliers to net importers. This tendency shows that increasingly less countries supply increasingly more materials to global markets (see also Dittrich, 2009 and 2010).

In 2008, the Russian Federation was the largest supplier of materials globally followed by Australia and Saudi Arabia (Fig. 25). Due to high amounts of exported coal and natural gas, the Russian Federation exported even more fossil energy than Saudi Arabia. Japan was net importing most materials, followed by China in spite of its large exports of minerals and manufactured goods. The United States was the third largest net importer and at the same time, the largest supplier of biomass in 2008.

Fig. 25: Physical trade balances of the ten largest net importer and exporter by material categories, 2008



Source: Dittrich et al., 2012a

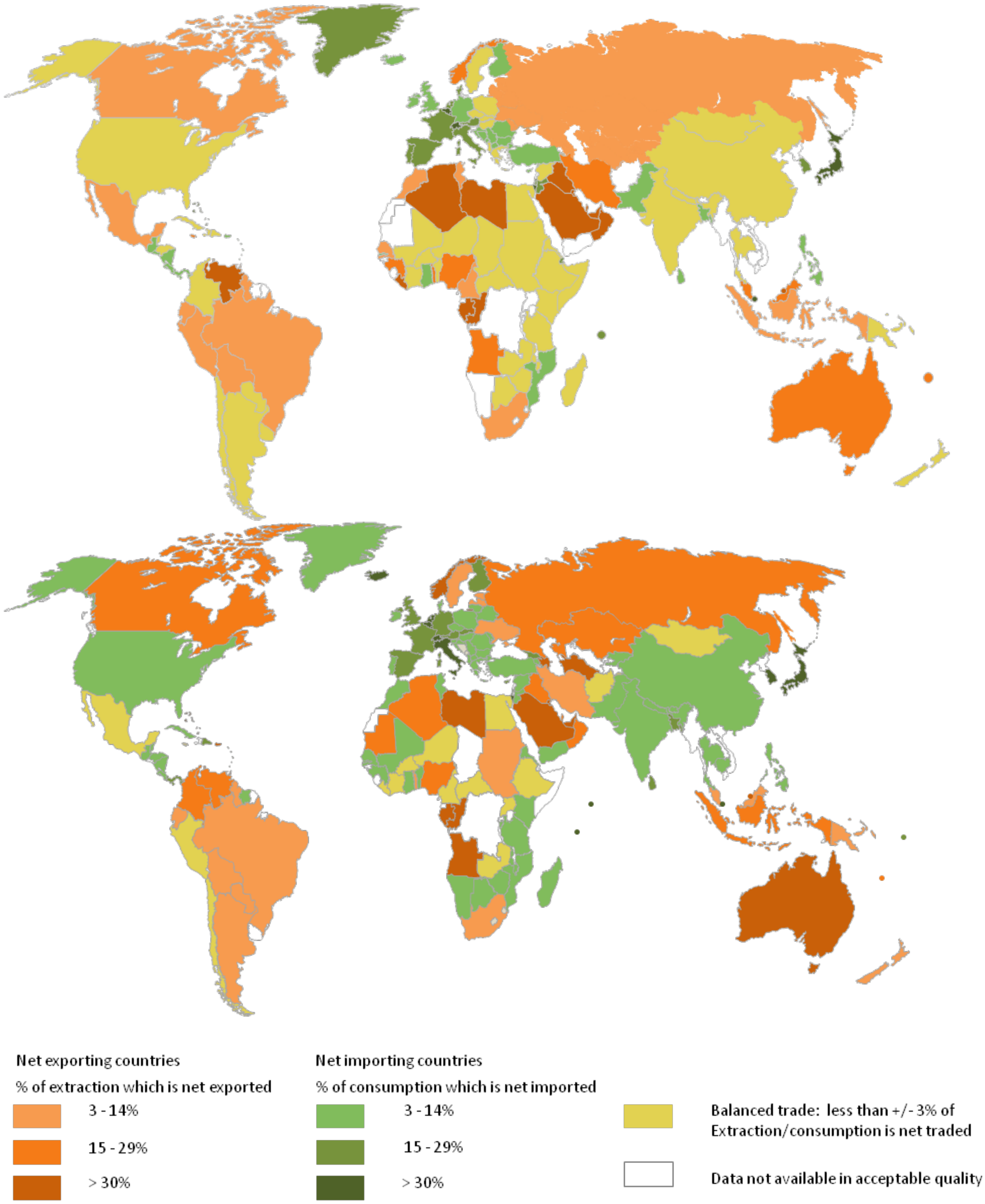
5.3 Import dependencies

Analyzing trade in regards to material extraction and consumption provides information about the import dependencies of countries. Since 1980, the number of countries that import a significant share of their material consumption has increased each year by over 3%, which was higher than the number of countries which exported a noteworthy share of their material extraction (3% and more). The relationship between both groups has also changed in the past three decades; while in 1980 55 countries imported a significant share of their consumption and 39 exported a major share of their extraction, the relationship between both countries changed to 110 versus 45 in 2008 (Fig. 26). Thus, an increasing number of countries competed for materials exported by a rather constant number of (net) exporting countries. Furthermore, import dependencies in European and Central American countries have been continuously high and increased in particular in populous emerging economies in Asia and in Africa.

5.4 Domestic Material Consumption

Global material consumption - which equals global extraction - increased by 79% up to 67.8 billion tonnes between 1980 and 2008. Material consumption increased over the global average in Asia (+115%), Africa (+89%) and Latin America (+82%) with less of an increase than global average in Australia (including Oceania, +46%), North America (+16%) and Europe (+ 9%, Fig. 27). In 2008, more than half of global material extraction was consumed in Asia (53%), 14% in North America, 13% in Europe and 11% in Latin America. Africa’s share in global consumption was around 7% and Australia‘s share only 2%.

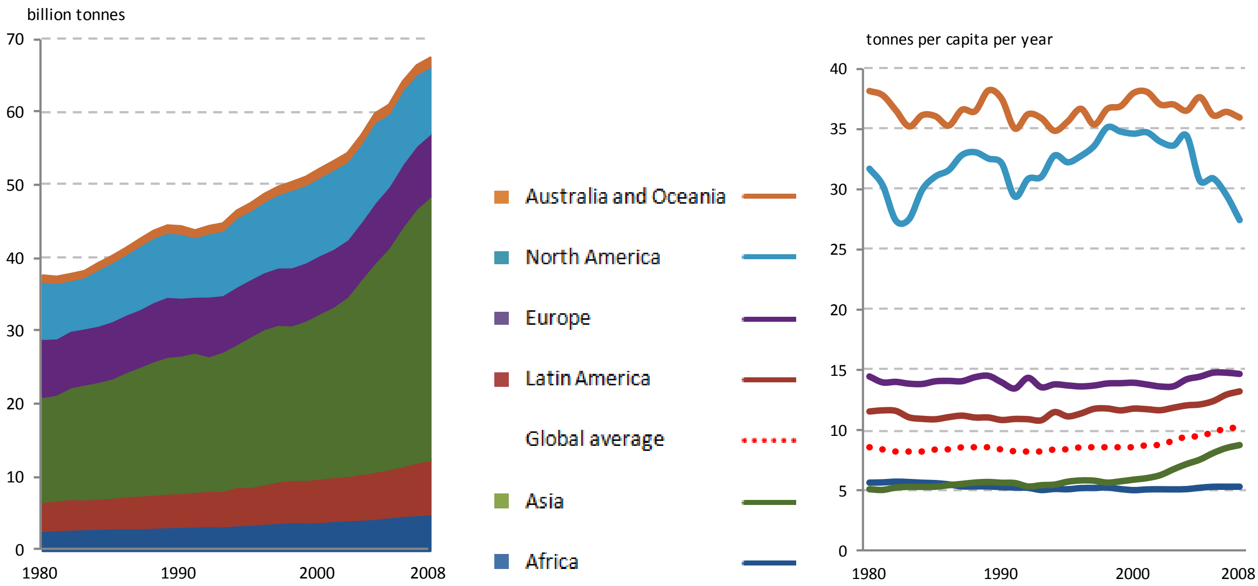
Fig. 26: Share of net trade in material consumption and extraction, 1980 (up) and 2008 (down)



Source: Dittrich et al., 2012a

The average material consumption per capita increased from 8.5 to 10.2 tonnes globally between 1980 and 2008 (+19%). In 2008, the highest material consumption per capita can be found in Australia (including Oceania) with 36 tonnes in 2008, followed by North America (27 tonnes per capita), Europe (15 tonnes per capita) and Latin America (13 tonnes per capita). In Asia and Africa, material consumption per capita in the same year, has been below the global average at 9 tonnes and 5 tonnes, respectively. While material consumption per capita decreased in Africa, Australia and North America (by -7%, -6% and -13%, respectively) between 1980 and 2008 it was relatively constant in Europe (+1%) growing/increasing in Latin America and in Asia (+15% and + 69%, respectively).

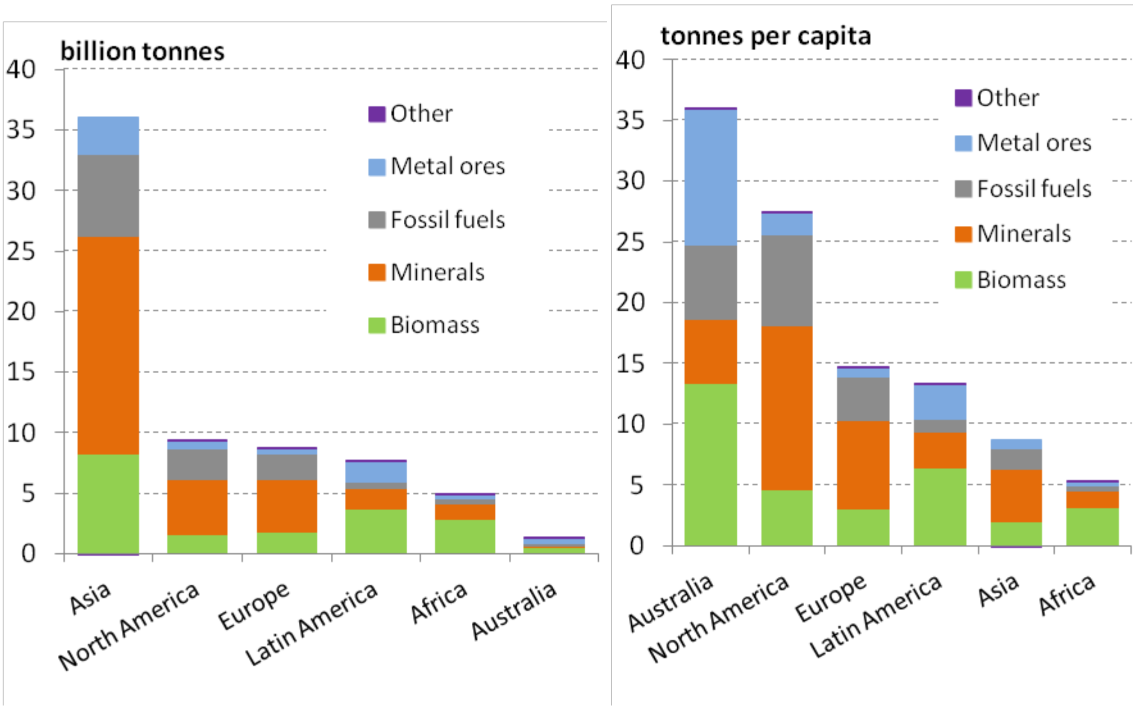
Fig. 27: DMC absolute (left) and per capita (right) by continents, 1980-2008



Source: Dittrich et al., 2012a

With regards to material composition, Asia consumed the largest share of globally extracted biomass, fossil energies, metals and minerals in 2008 (Fig. 28, left). However, in terms of per capita consumption Australia (including Oceania) consumed the most biomass and metals and North America the most fossil energy carriers and minerals (Fig. 28, right). The difference between regions with the highest per capita consumption of a material category and the region with the lowest one are remarkable. While differences in biomass consumption are rather low with a factor of seven (between Australia with the highest biomass consumption per capita and Asia with the lowest), mineral consumption varied by a factor of ten (between North America and Africa). Even higher was the difference in fossil fuel consumption by a factor of 15 (again between North America and Africa). Per capita metal consumption even varied by a factor of 35 (between Australia and Africa). However, it should be noted that in DMC, the difference between gross extraction of metals and exported (generally concentrated) metal is counted in extracting and exporting countries such as Australia and not in the consuming countries.

Fig. 28: Material consumption, absolute (left) and per capita (right) of continents by material categories, 2008

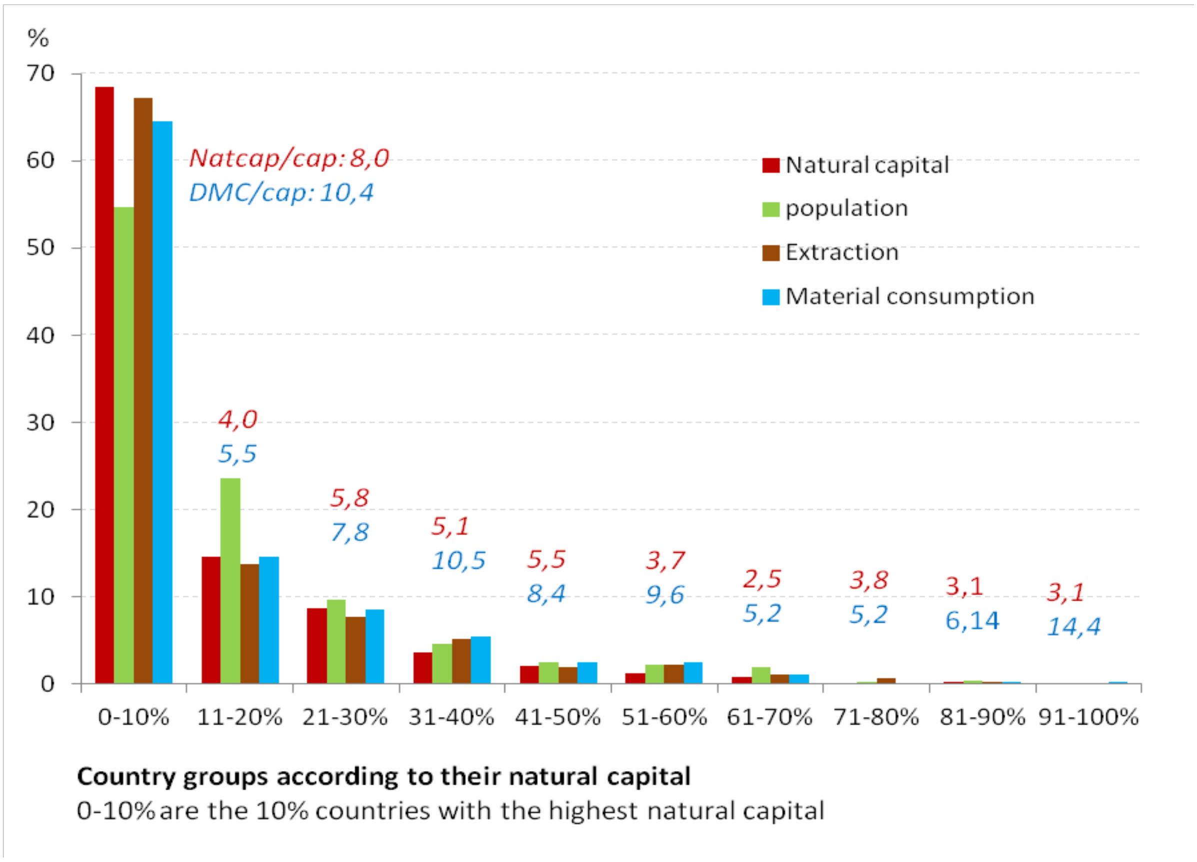


Sources: Dittrich, 2011, SERI, 2011

The relevance of natural capital was analysed above with regards to extraction. Hence, at this point, only the relationship between absolute material consumption, natural capital and population will be discussed for the most recent year (2005). Around 55% of global population lives in the 15 most resource rich countries (which are the 10% most resource rich countries owning 68% of global natural capital) consuming 65% of globally extracted materials (Fig. 29). In contrast, around 0.1% of the world's population live in the 10% of resource poorest countries which own 0.03% of global natural capital and consume 0.2% of globally extracted materials. In this group – which includes countries such as Singapore, the Seychelles, St. Lucia or the Maldives- the average per capita consumption is highest with 14.4 tonnes, but average natural capital is lowest with around 500 US$ per capita.

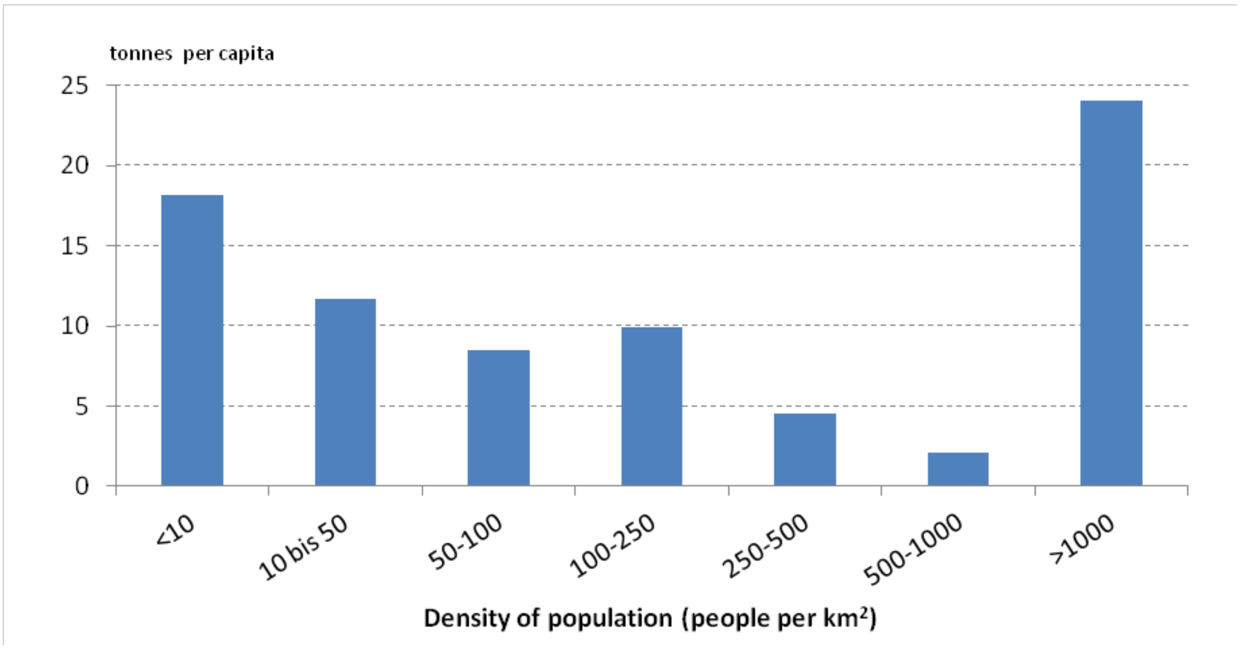
The relevance of population density in material consumption has been demonstrated by a number of authors (e.g. Krausmann et al. 2008; UNEP, 2011). These studies have demonstrated that average material consumption is lower in more densely populated regions than in more sparsely populated regions. The current study further builds on the previous analyses by including more recent data from 2008 (Fig. 30). The exceptions observed from the general trend are very densely populated countries (such as Qatar or Singapore). The general trend of increasing material consumption with increasing population density can be explained to some extent by the fact that sparsely populated countries are net exporters of materials and part of extraction associated with exports are counted as consumption in the exporting country. Densely populated countries are predominantly net importers; their DMC consists only of concentrated imports but not the upstream flows required producing their imports. Further investigation is needed in order to analyse to what extent the upstream flows would change these results.

Fig. 29: Share in global natural capital, global material consumption and global population and DMC and natural capital per capita by country groups according to their natural capital, 2005



Sources: Dittrich, 2011, SERI 2011, World Bank 2011a; Natural capital in 1.000 US$.

Fig. 30: Average material consumption per capita by population density, 2008

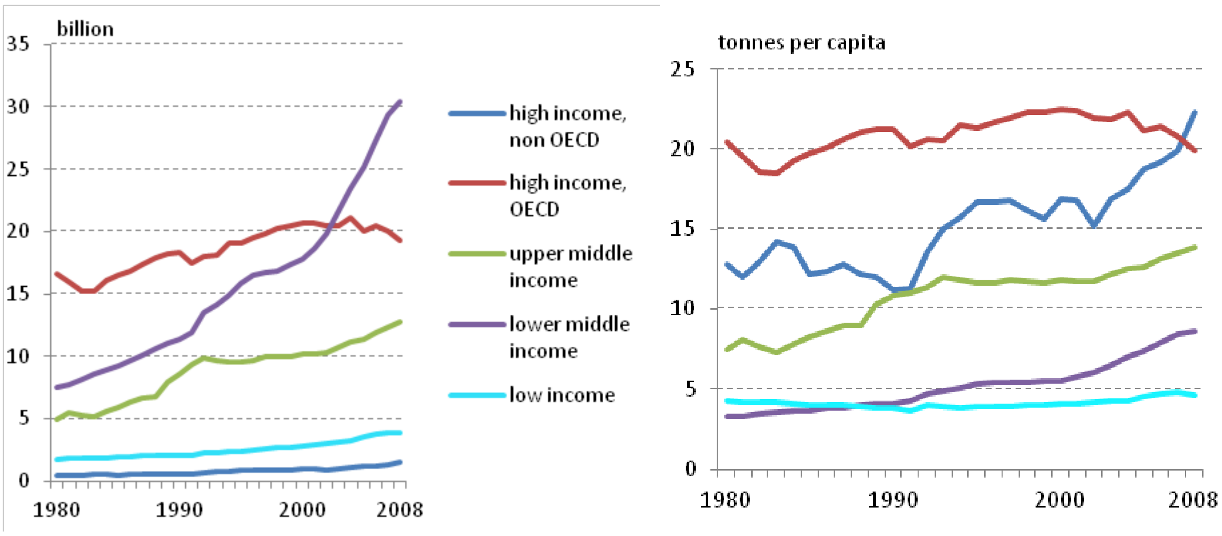


Sources: Dittrich, 2011, SERI, 2011, UN Population Division 2012

Different trends can be observed when material consumption is analysed by income group. Absolute material consumption of OECD-countries increased slightly until 2004 and decreased slightly thereafter (Fig. 31). Since 2003, lower middle-income countries (including China) together consumed more materials than OECD-countries with the former group quadrupling its material consumption between 1980 and 2008 (+304%). In the same period, non-OECD-countries with high incomes had the second highest increase in material consumption (+231%), followed by upper middle-income countries with an increase of 158%. In contrast, the absolute material consumption of low income countries only doubled during the 28 years (+117%).

Per capita material consumption has declined in OECD countries since the year 2000, although the OECD still had the world's highest per capita material consumption in 2007. Per capita material consumption in high income, non-OECD countries increased significantly and reached an average of 22.3 tonnes per capita in 2008, which is even higher than the OECD average of 19.9 tonnes per capita. The high values of material consumption per capita in high income, non-OECD countries are caused, amongst others, by the consumption of the United Arab Emirates and Qatar, and in particular by the construction of luxury artificial islands such as "the Pearl". Average per capita material consumption increased most in countries with lower-middle incomes (+162.5%) and reached 8.6 tonnes per person in 2008. In low income countries, material consumption was not only lowest world-wide with 4.6 tonnes per capita, but it also increased least between 1980 and 2008 (+9%).

Fig. 31: DMC, absolute (left) and per capita (right), by income groups, 1980-2008

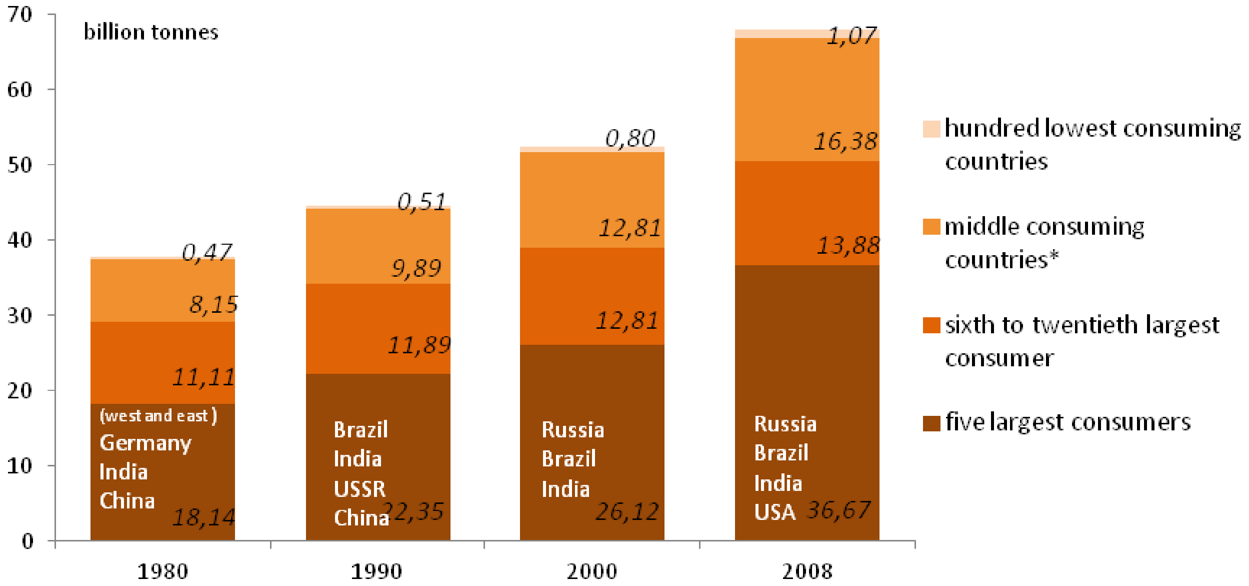


Sources: Dittrich, 2011, SERI, 2011; grouping of countries according to World Bank, 2011a.

In the following, the material consumption of countries is analyzed in absolute and in per capita terms.

Absolute material consumption is concentrated in a few countries throughout the investigated period. In 1980, the five countries with the highest absolute material consumption consumed almost half of globally extracted materials (48%, Fig. 32). The five countries were (in order of amount of absolute material consumption) the USA, the USSR, China, India and Germany (East plus West). In contrast, the one hundred countries with the lowest absolute material consumption together consumed only 1% of globally extracted materials in the same year. In 2008, the five countries with the highest absolute material consumption were (in order of absolute material consumption) China, USA, India, Brazil and Russia. These five countries consumed 54% of globally extracted materials while the one hundred countries with the lowest absolute DMC held a share of only 2% of global DMC.

Fig. 32: Absolute material consumption by material consumption of countries:



Source: Dittrich et al., 2012a

Fig. 33 shows the DMC of all countries in 2008. Fig. 34 shows the country size as share of global DMC. In absolute terms, China consumed most of the globally extracted materials. Its share in global DMC was around 28% in 2008. China was followed by the USA which held a share of only 13% in global DMC in 2008. India's absolute material consumption was the third highest in the world (7% of global DMC), followed by Brazil (4%) and Russia (3%). In the same year, Germany held a share of almost 2% of global DMC.

Average material consumption per capita in 2008 varied between 114 tonnes in Qatar and less than two tonnes in Afghanistan, Bangladesh, the Republic of Congo, Comoros or Tuvalu (Fig. 35). In general, in countries with a low per capita consumption, consumption of biomass, in particular for food, dominate. Based on empirical data of countries where data quality is comparatively good, it can be observed that per capita consumption of around 1.5 tonnes of biomass and 0.3 tonnes minerals are somehow a minimal for survival. Increasing material consumption results in growing requirements for the extraction of minerals, fossil fuels and metals in average material consumption. Consumption of metals is high in metal extracting countries such as Australia, Chile and Peru. As outlined above, this is due to the difference between gross metal extraction and concentrated metal exports of the extracting county. Consumption of biomass is predominantly high in countries with high shares of extensive, cattle-based agricultural systems such as Australia, Mongolia and Argentina. The extraordinary material consumption in Qatar is predominantly caused by construction of prestige objects such as artificial islands compared to a low population size.

In 2008, each person globally consumed an average 2.8 tonnes biomass, 1.9 tonnes fossil fuels, 1.0 tonnes metals and 4.5 tonnes minerals.

Fig. 33: Absolute material consumption of countries, 2008

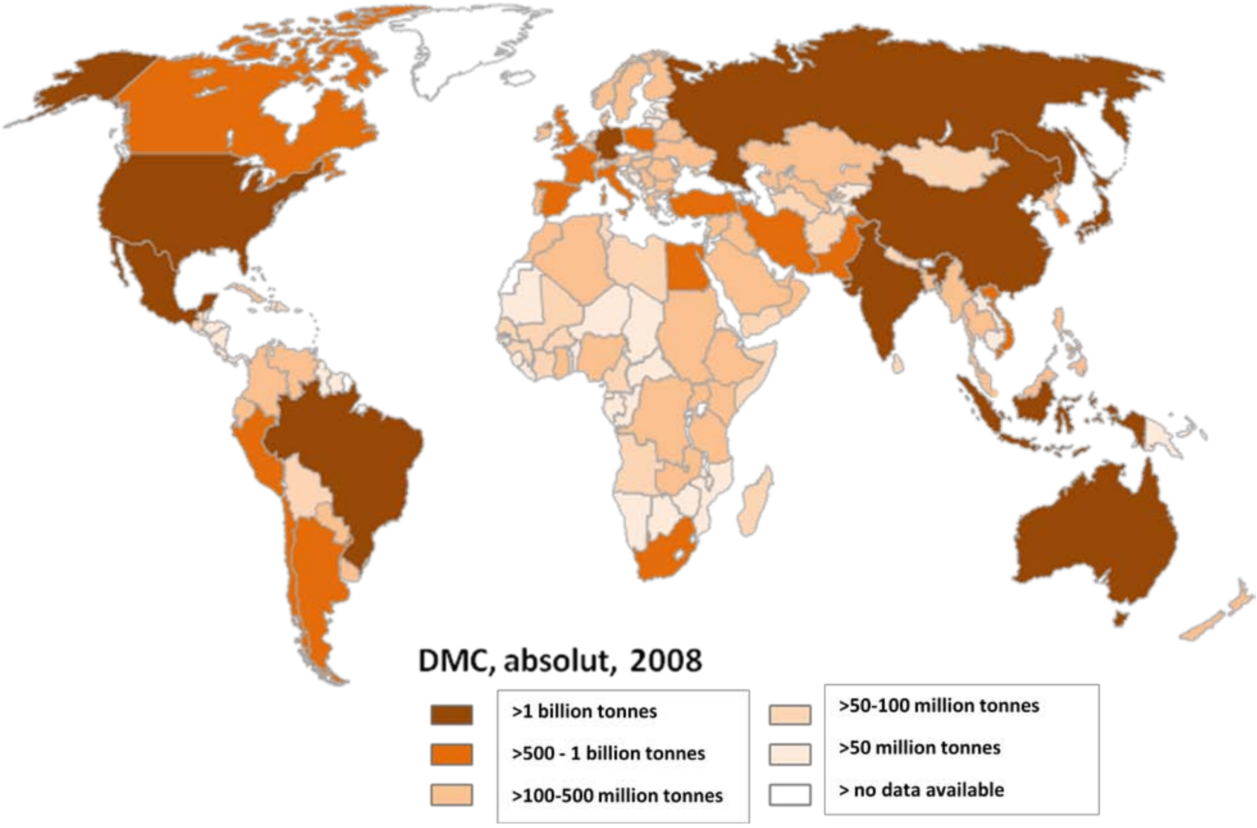
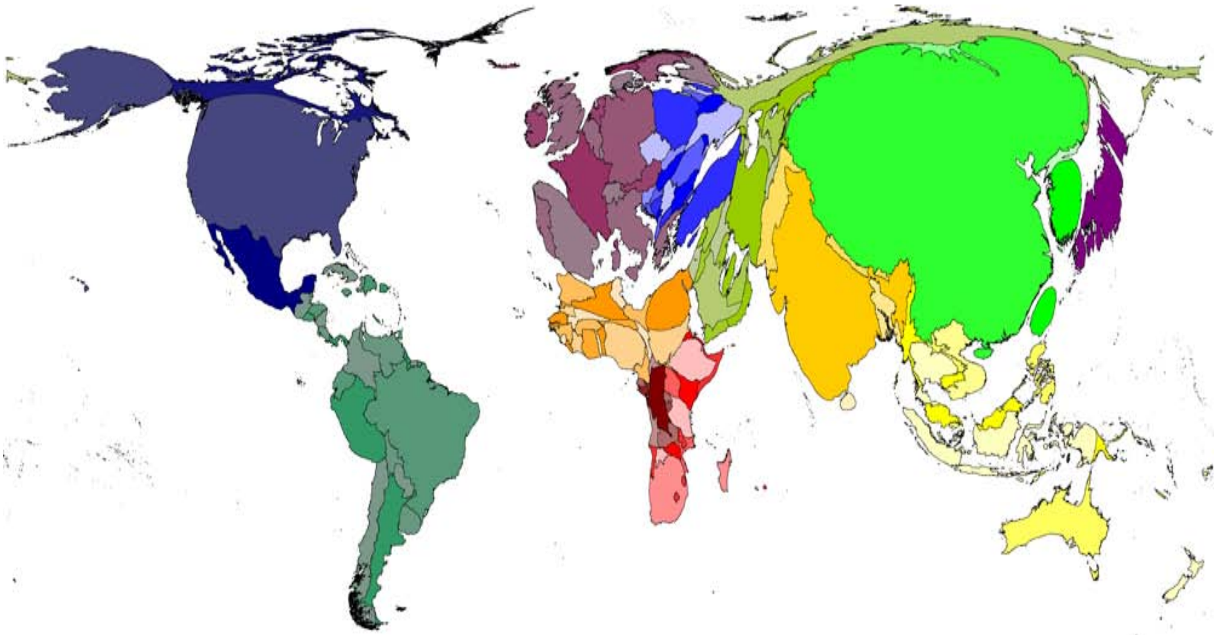
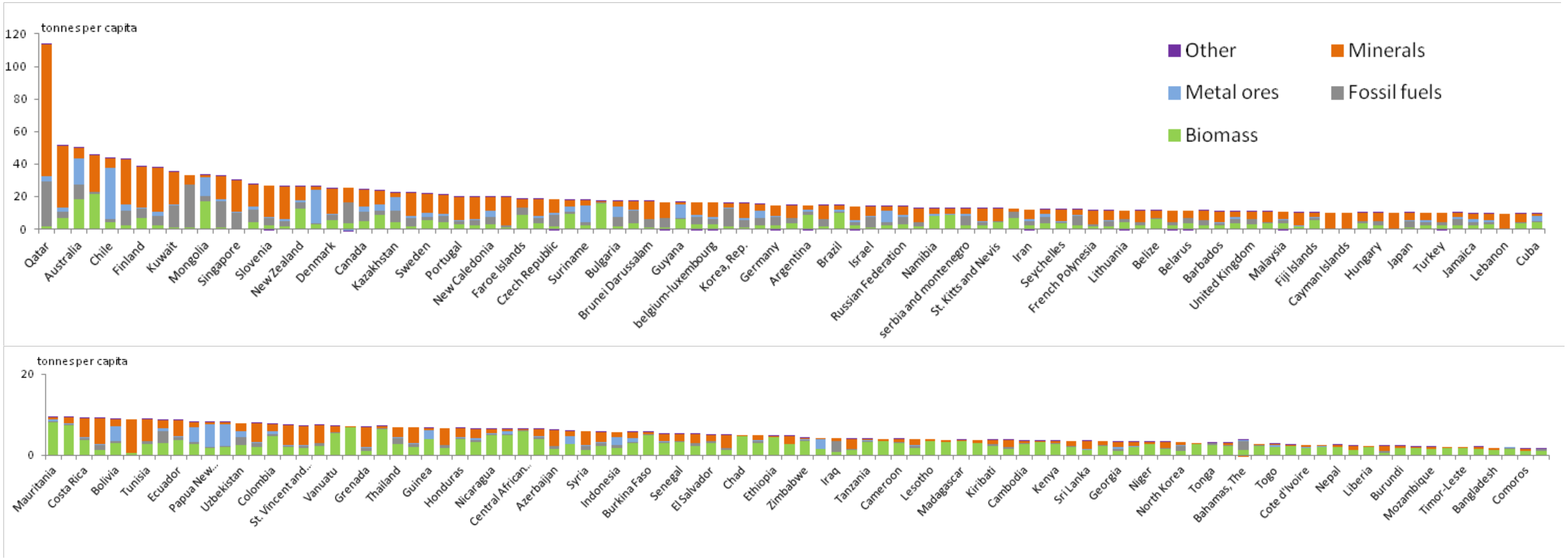


Fig. 34: Absolute material consumption of countries, country size according to share in global DMC, 2008



Source: Dittrich et al., 2012a

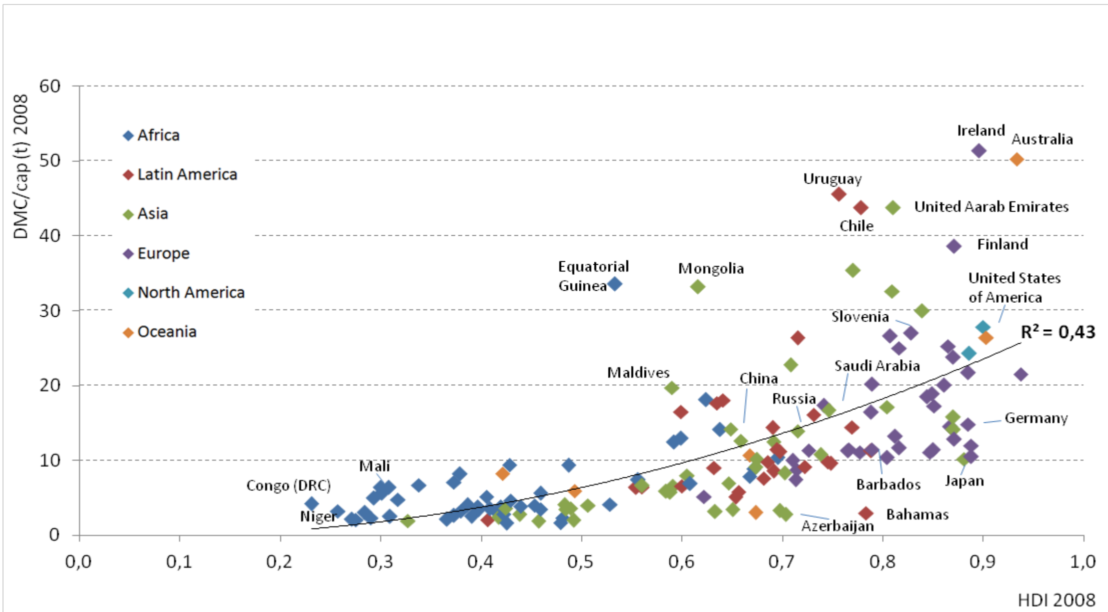
Fig. 35: Average material consumption per capita by countries and material categories, 2008



Source: Dittrich et al., 2012a

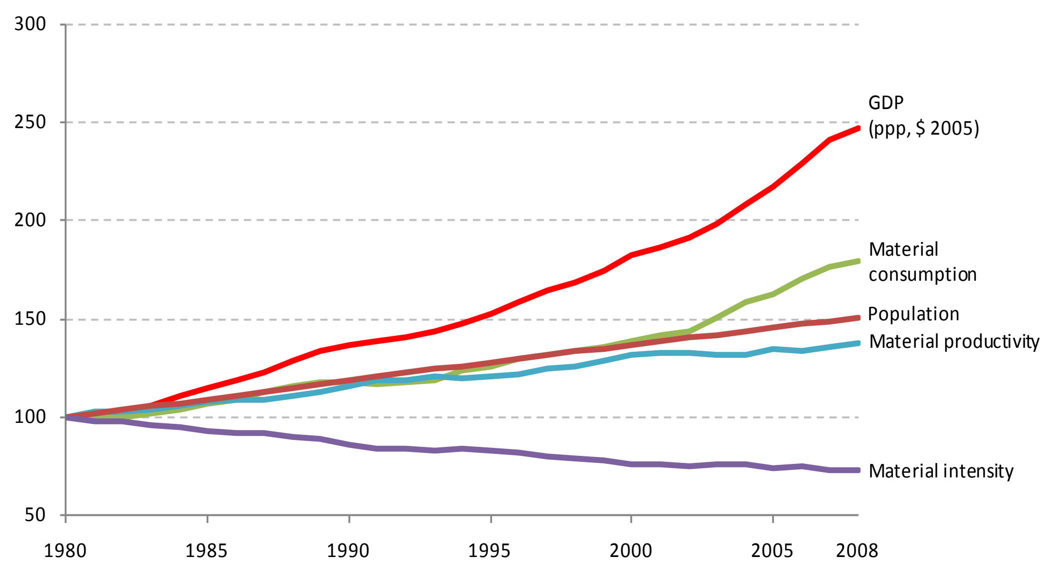
It is also important to examine the link between per capita material consumption and the level of affluence as measured in the Human Development Index (HDI). Generally, countries with a low HDI (predominantly countries in Africa and Asia) have low material consumption per capita with less than 10 tonnes (Fig. 36). Material consumption per capita in countries with a HDI higher than 0.55 was less linked in 2008; a high level of affluence went along with low (less than 15 tonnes) and also with high per capita material consumption (more than 50 tonnes). It should be noted again that the differences in DMC per capita would be lower if indirect flows of trade would be considered.

Fig. 36: HDI and material consumption per capita by countries, 2008



Source: Dittrich et al., 2012a

Fig. 37: Dynamics of GDP, DMC, population and material productivity (GDP per DMC) globally, 1980-2008



Source: Dittrich et al., 2012a

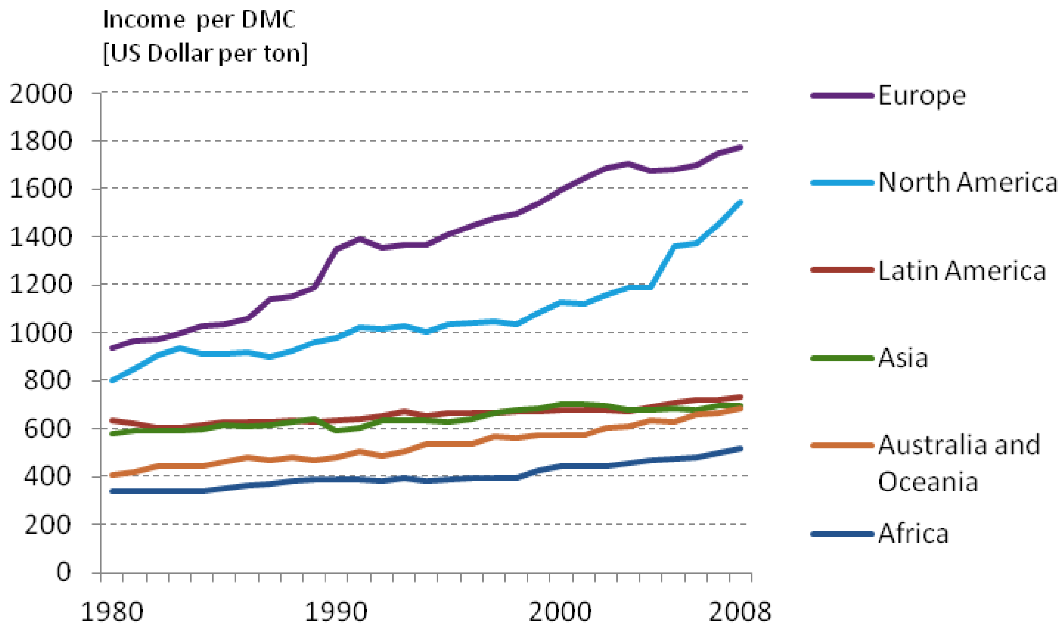
5.5 Material productivity

World gross domestic production (GDP) increased by 147% in constant terms between 1980 and 2008 with material extraction and consumption increasing by 79% in the same period. Thus, material productivity (GDP generated per unit DMC) grew by 38%, equating to an annual growth rate of 1.4% (Fig. 37). The global population reached a relative decoupling of economic growth from material extraction and consumption in the past three decades; however, they were unable to achieve an absolute decoupling due to increases in absolute material extraction and consumption.

Material productivity in Europe was constantly higher than the other world regions between 1980 and 2008 (Fig. 38), followed by North America. In both continents, material productivity improved significantly although starting from a high level (+89% and +94%, respectively). Although starting from a lower level, material productivity also improved in Africa and Australia (+53% and +67%), while stagnating in Latin America and Asia (+15% and +21%). Altogether, the differences in material productivity between Europe and North America on the one side and the other continents on the other further increased during the past three decades.

The peak of material productivity in Europe around 1990 was caused by statistical effects due to changes in country boundaries as a consequence of the collapse of the former Soviet Union.

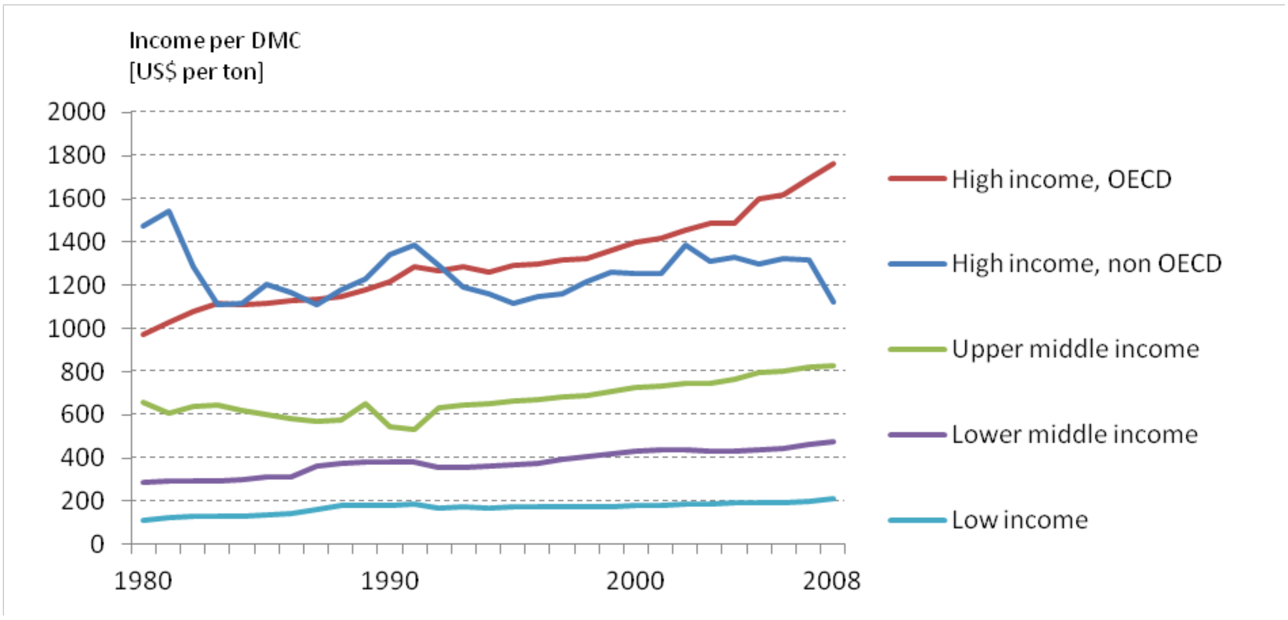
Fig. 38: Material productivity (GDP per DMC) by continents, 1980-2008



Source: Dittrich et al., 2012a; note, the former Soviet Union is excluded due to lack of income data.

Material productivity is generally higher in countries with high incomes than those with low incomes (Fig. 39). Material productivity increased in all income groups except in the non-OECD, high income countries where material productivity shrank by 24% between 1980 and 2008. Material productivity increased most in low income countries (+89%), followed by OECD countries (+81%). In 2008, the average material productivity of OECD countries exceeded those of low income countries by a factor of almost eight.

Fig. 39: Material productivity (GDP per DMC) by income groups, 1980-2008



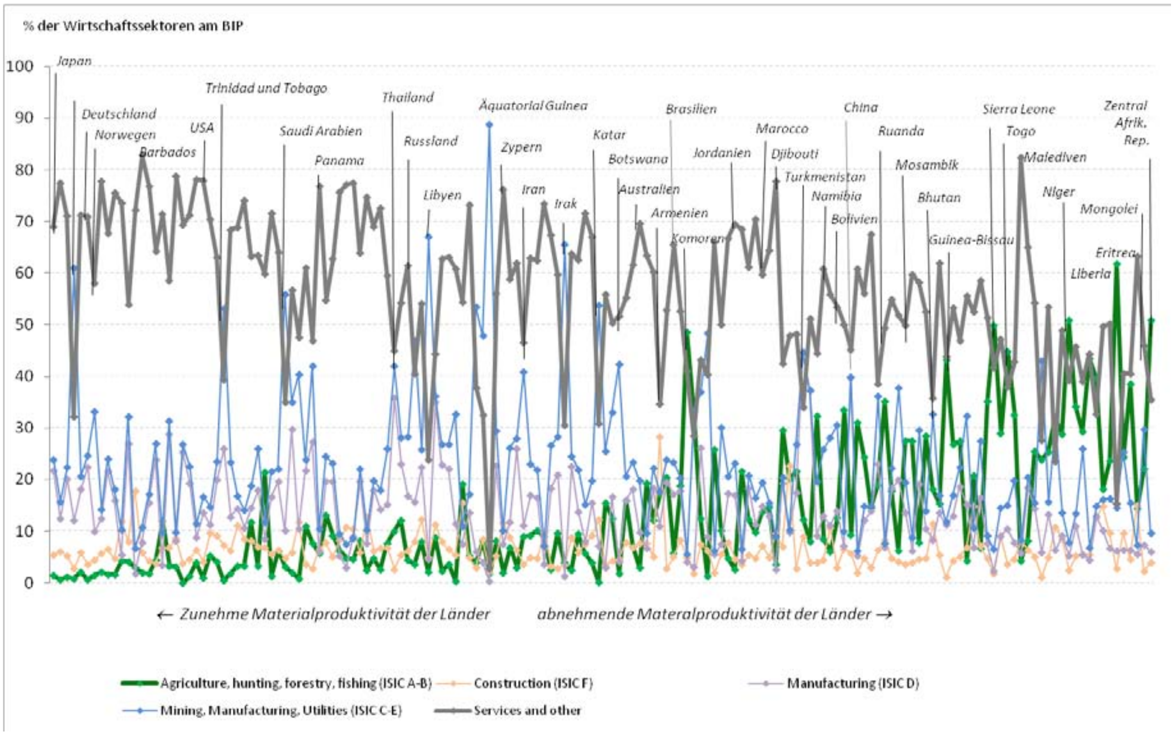
Sources: Dittrich, 2011, SERI, 2011, World Bank, 2011a

It should be noted that material productivity should only seldom be used for benchmarking and comparison between countries. Some economic sectors such as the agricultural or mining sectors (in particular the metal mining sector) are more material intensive than others such as knowledge-based or service-oriented sectors, in particular financial services or tourism. Thus, countries with higher shares of material intensive economic sectors in GDP generally show lower material productivity values than countries with higher shares of less material intensive economic sectors (Fig. 40). The figure also shows some further differentiations, e.g. oil extracting and exporting countries usually show higher material productivities than metal extracting and exporting countries.

The majority of countries examined in this study improved their material productivity between 1980 and 2008; however, the dynamics of the respective improvements varied significantly (Fig. 41). Generally, countries with higher shares of knowledge-based and service-oriented sectors in their economies (e.g. Japan, Switzerland and Germany) not only showed higher material productivity, but also improved material productivity, more so than countries with higher shares of material intensive economic sectors (e.g. Argentina, South Africa, Chile and Mali).

It is important to mention again that this increase in material productivity could be explained by the outsourcing of material intensive production. Many countries with significantly rising material productiveness also increased their net imports at the same time. It is not the focus of the present study to assess the amount and impacts of outsourcing of production, but it should be considered that assessments of material productivity based on DMC (and thus excluding indirect flows) could lead to incorrect interpretations and conclusions.

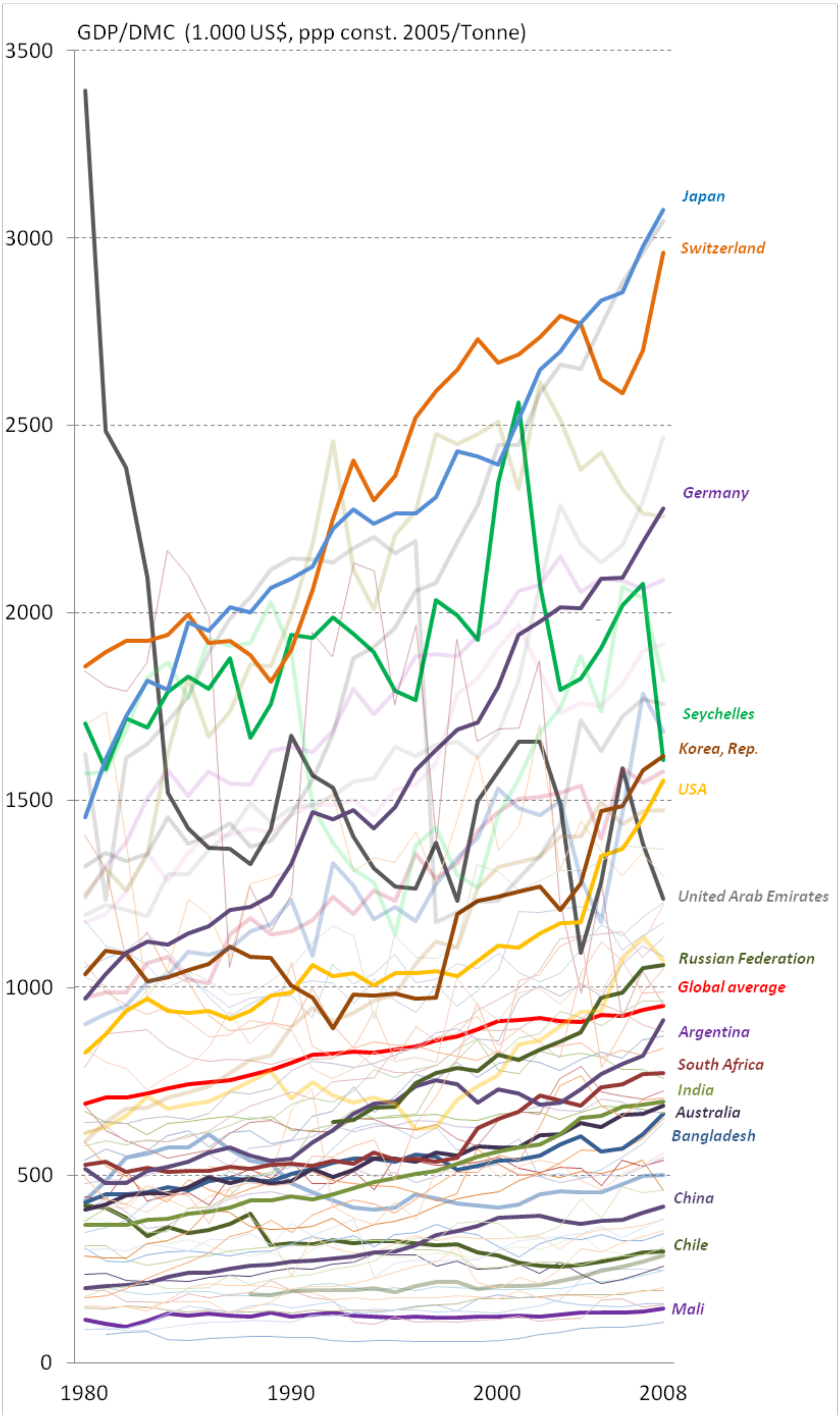
Fig. 40: Share of economic sectors in GDP of countries, ordered by material productivity, 2008



Sources: Dittrich, 2011, SERI, 2011, United Nations Statistics Division, 2012b

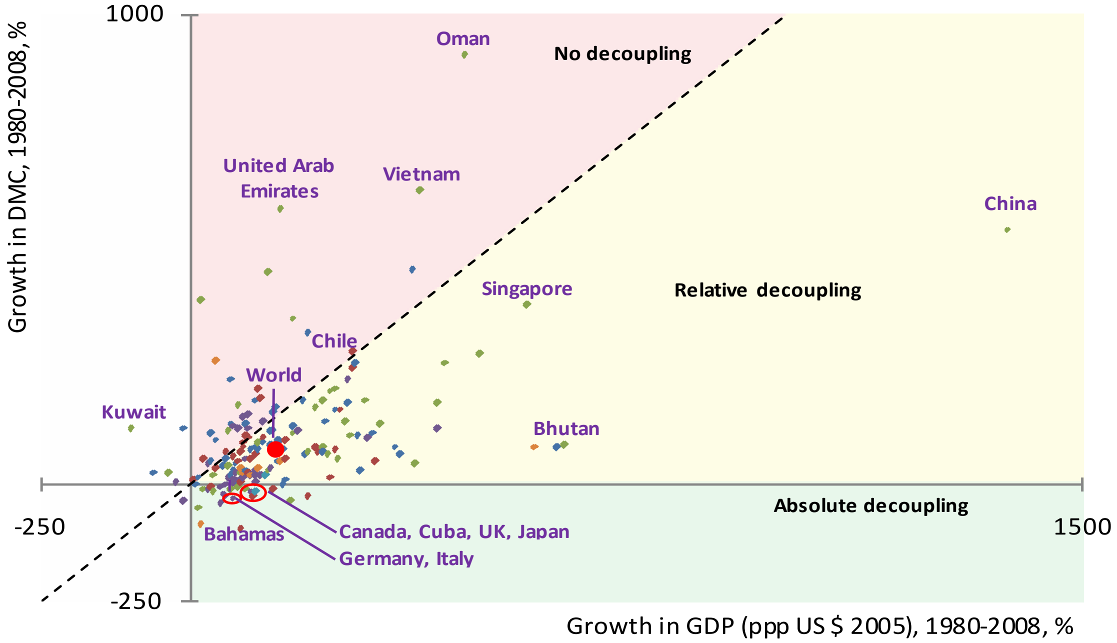
Altogether, the majority of countries in the world reached a relative decoupling between 1980 and 2008 due to the fact that they had been able to increase income faster than material consumption (Fig. 42). Some countries, for example, Germany, were able to achieve an absolute decoupling of economic growth from material consumption. Nevertheless, some countries increased material consumption faster than income, in particular oil- and metal-exporting countries such as the United Arab Emirates and Chile. In addition, a minority of countries such as Kuwait decreased both material consumption and income in the examined timeframe.

Fig. 41: Dynamics of material productivity of all countries between 1980 and 2008



Source: Dittrich et al., 2012a

Fig. 42: Growth of GDP and material productivity (GDP per DMC) of all countries, 1980-2008



Source: Dittrich et al., 2012a

5.6 Selected assessments of TMR globally

Finally, the indicator Total Material Requirements (TMR) will be estimated for selected years and countries based on the updated assessments of direct flows (presented above) using existing methods and data for the estimations of unused extraction and indirect flows of trade. Firstly the TMR of all countries globally will be presented for the years 1980 and 2008; secondly the dynamics of the TMR for ten selected countries will be examined between 1980 and 2008 in five-year-intervals. The ten countries are Brazil, China (1985 – 2008), India, Japan, Mexico, Russia (1996 – 2008), South Africa, Turkey and United States. The methodology used was outlined in Chapter 3 of this study. Further developments in these methods are discussed further in Chapter 6. At this point, it should be noted that the assessments presented in the following should be understood and interpreted as estimations of overall size but not as exact values.

TMR globally in

In 1980, Total
one million tc
United States.
countries witl

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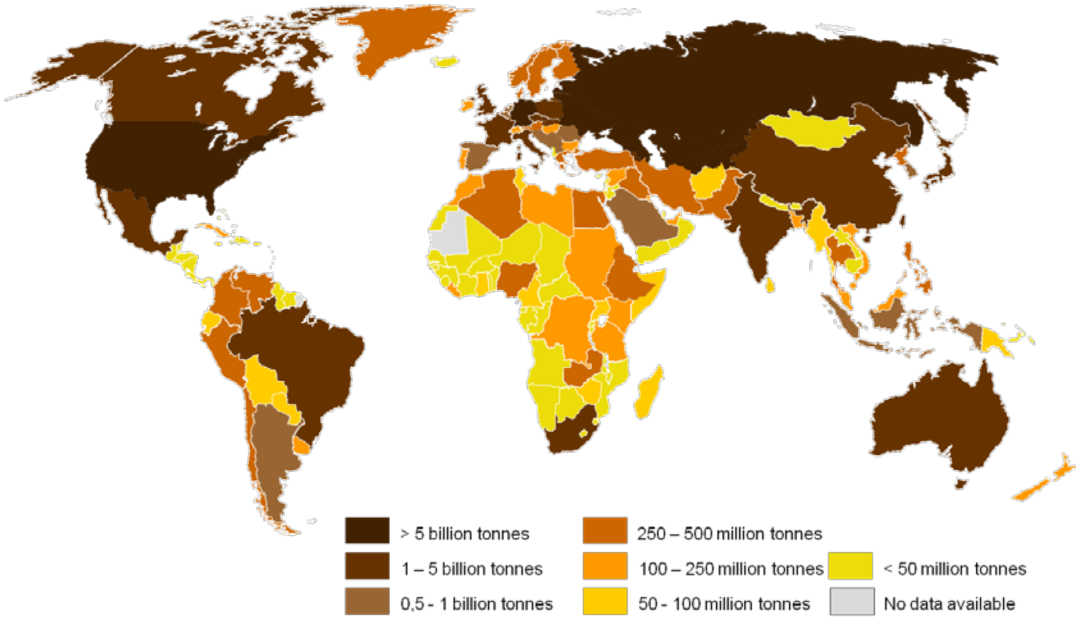
[2] Trade flows, includi
from 1980 to 2008. T

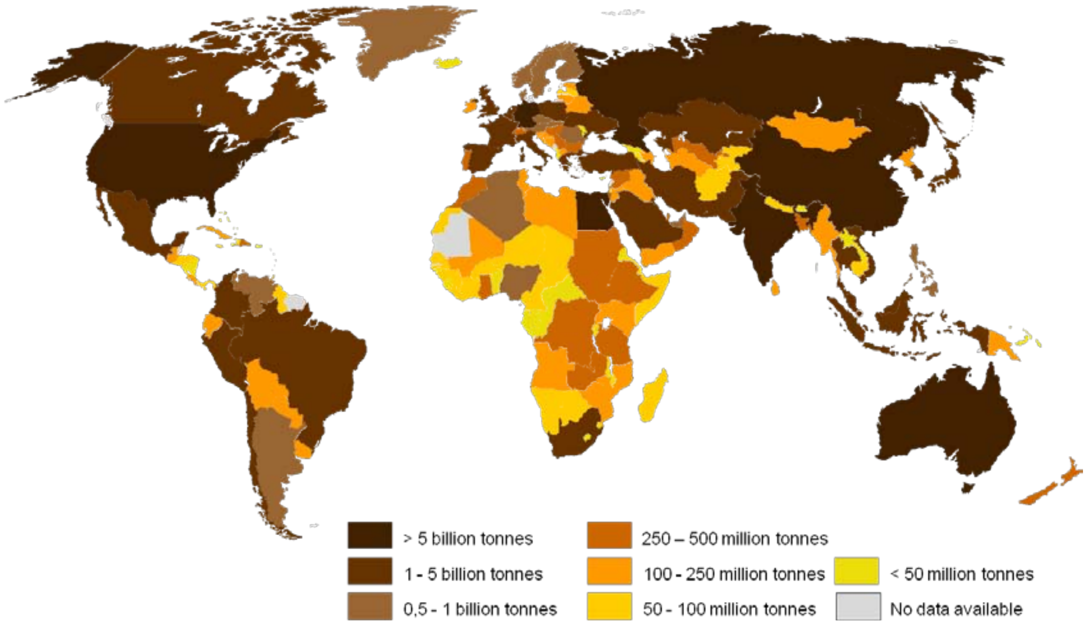
worldwide had grown by 135% (Fig. 44). Used and unused extraction grew by 85% and direct and indirect imports by 314%. As in 1980, TMR in 2008 was generally higher in countries with high populations and large economies and lower in countries with smaller populations and small economies.

Fig. 43: TMR, absolute, 1980



Sources: Dittrich, 2011, SERI, 2011; Note, Germany: East and West.

Fig. 44: TMR, absolute, 2008



Sources: Dittrich, 2011, SERI, 2011

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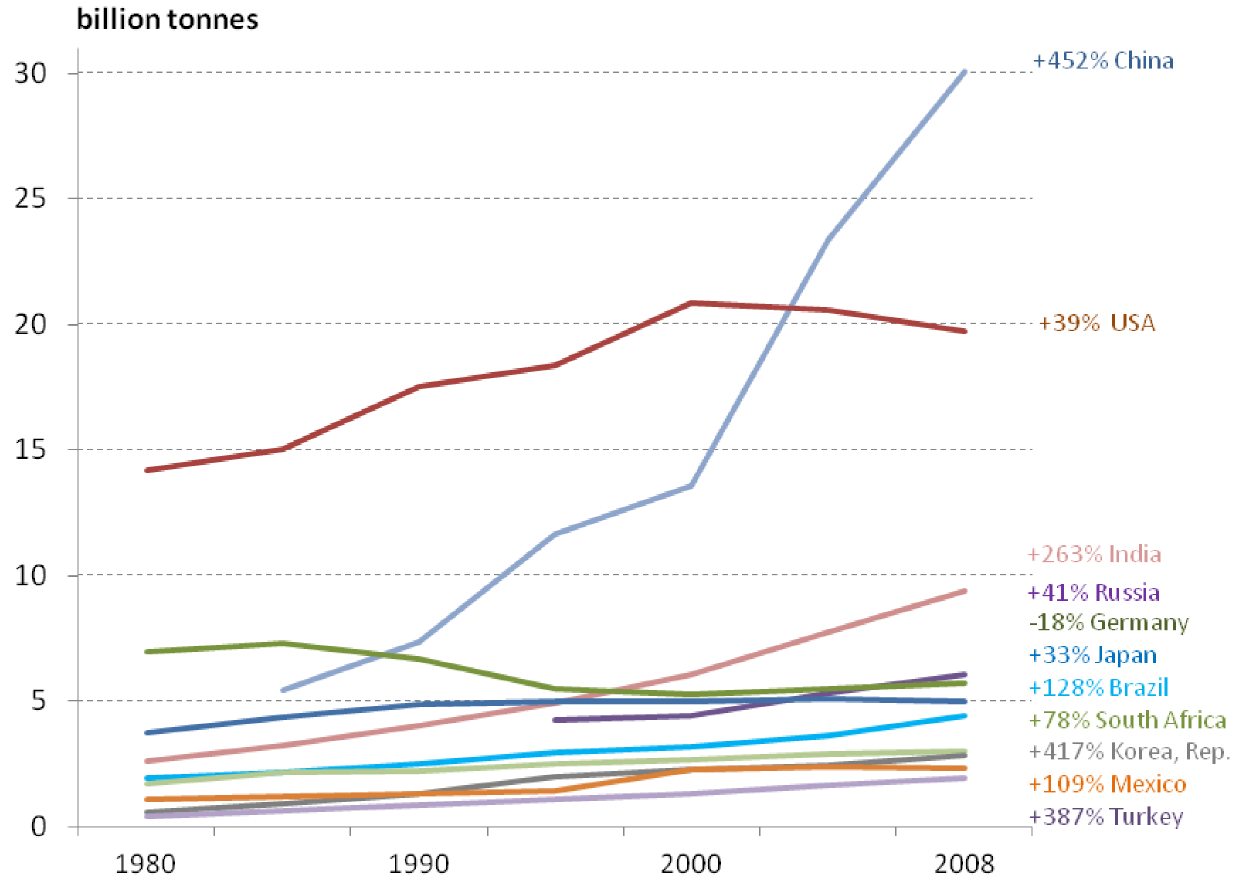
trade flows have clearly resulted in one of the categories used for the coloring of the maps. The estimation of the increase of global TMR includes only known trade flows.

TMR of the ten selected countries

Total Material Requirements (TMR) in the ten selected countries increased between 1980 and 2008 (Fig. 45). The largest increase can be found in China (+452%, between 1985 and 2008), followed by South Korea (+417%) and Turkey (+387%). In this same period the Japan's TMR stagnated, in particular since 1995 (to compare: Japan's domestic material input shrank by 10% between 1995 and 2008. In the United States, TMR increased only marginally in the three decades, even decreasing after the year 2000. Amongst other reasons, this decrease was caused by a reduction in extraction, in particular of mineral extraction. Germany's TMR decreased during this period (see also chapter 4.4. The figure below excludes erosion in order to allow for comparability).

Fig. 45: Dynamics of TMR and increases of TMR of the ten selected countries, 1980-2008

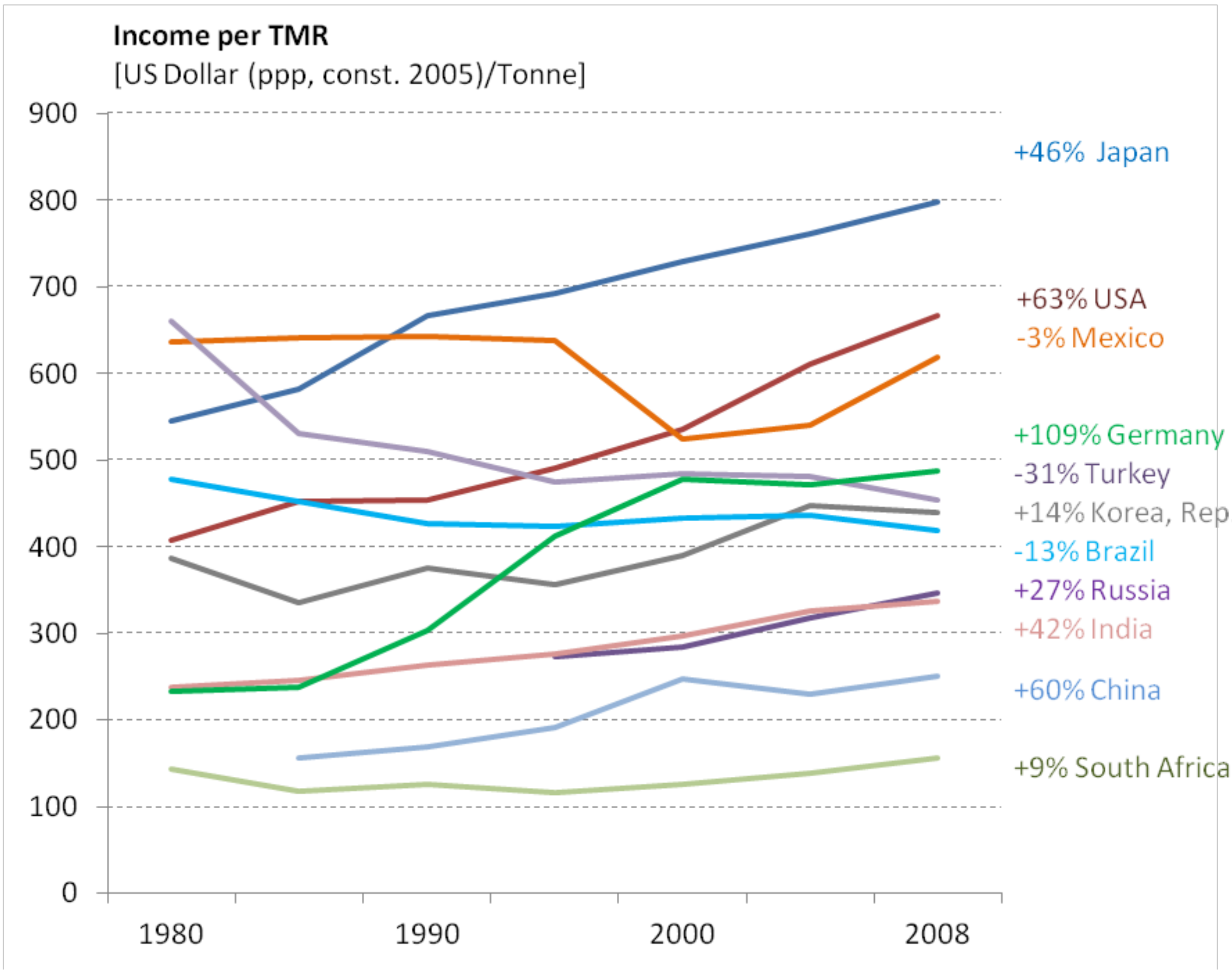


Sources: Dittrich, 2011, SERI, 2011

TMR in the selected countries (other than the Russian Federation) increased more than the DMI between 1980 and 2008, while the DMI for Japan, the USA, South Korea, Brazil, Mexico, India, South Africa and Turkey increased on average by 61%with China seeing an increase of 388% between 1985 and 2008. On average TMR grew by 85% in the selected countries and by 452% in China. In contrast, both, DMI and TMR grew by only 41% in Russia between 1996 and 2008.

Material productivity in the ten selected countries, measured as GDP per TMR, is clearly lower than material productivity measured as GDP per DMC as outlined Chapter 5.5 (Fig. 46). Furthermore, the differences in material productivity is less distinct between countries with higher shares of material intensive sectors than those with higher shares of less material intensive sectors in their economies, e.g. between Japan and South Africa. Japan's material productivity measured as GDP per DMC is four times higher than that of South Africa's; but if material productivity is measured as GDP per TMR, Japan is only 1.6 times more material productive than South Africa in 2008. These results stress the need for improving the assessments in quality and quantity of unused extractions and indirect trade flows.

Fig. 46: Material productivity of the selected countries (GDP per TMR), 1980-2008



Sources: Dittrich, 2011, SERI, 2011

6 Future research required to improve material flow accounting

The present study presented updates of selected material flow indicators for Germany between 1980 and 2008 and the first results and analyses of direct material flows for all countries worldwide in the same period. Problems in regards to data availability and quality were already partly mentioned in the methodology section of this paper (Chapter 3) in regards to the selected results for Chapters 4 and 5. Different research fields and topics for further improvements are discussed in this concluding chapter.

6.1 Material extraction

Used material extraction

As mentioned in the methodological guide of EUROSTAT, further improvements of selected material categories are required in order to improve the exactness of the assessments for economy-wide material flows (EUROSTAT, 2011a).

Biomass extraction of grazing animals (feed)

Direct extraction of plants by grazing animals (fodder) presents significant portion under the biomass category. In some developing countries, in particular in Africa, fodder makes up the largest fraction of domestic material consumption. Nevertheless, these material flows are rarely reported in national and international statistics. EUROSTAT recommends estimation methods either based on available pastoral land and their respective biomass (“supply approach”) or methods based on the number of grazing animals and their respective fodder demand (“demand approach”). Both methods are fraught with uncertainty as data on pasture land and grazing animals differ strongly in most of the countries. A reliable method to assess fodder requirements for grazing animals was introduced by Krausmann et al. (2008b). This method estimates biomass extraction by grazing animals as the difference (“grazing gap”) between the demand for fodder (calculated in a detailed demand model per farm animal category) and the available fodder in the respective country (traded in the markets and not traded feeding stuff). This method should be further refined by contrasting country specific data on fodder production in regards to demand specification of the demand of different animals in the different world regions.

Concentration of metals in ores

The production of metal raw materials is reported in detail in international statistics. Nevertheless, metal production is mainly reported as metal content and not as crude ore which is the relevant data in material flow analysis. Thus, factors based on the concentration of metals in the respective ores are used to estimate gross extraction. These factors are not yet available for many countries, therefore regional or even global average factors have to be utilised to fill this gap in data availability. Thus, further research is required in order to improve the precision and availability of country specific data on metal contents of all metal extracting countries. Furthermore, it is desirable to generate an accessible and detailed global data bases on metal content. A robust, but complex and laborious method to bridge this gap would be to systematically collect information from individual mines and mining companies, extrapolating from this data to determine national averages.

So called “coupled products” are an additional research field, because oftentimes an extracted ore contains a variety of different metals. There is currently no internationally harmonized standard to assign the gross ore to the respective metals. The most current method EUROSTAT (2011a) suggests is an assignment of gross ore according to global prices for the respective metals. Ifeu (UBA, 2012) also used a value-based allocation. The EUROSTAT and Ifeu methods suggest the use of long-term average prices (20-years) which don't include the excessive price fluctuations for some years. Thus, future research should include an improved method for these price fluctuations.

Assessment of extraction of construction minerals

The extraction of construction minerals such as chalk, gravel and sand are usually not reported in official statistics in most of the countries. Thus, estimation methods are used which are based on production data for minerals such as cement, asphalt or bitumen (EUROSTAT, 2011a).Therefore, exactness of these results are limited because demand of the variety of construction minerals is not covered completely. In Austria, assessment of construction minerals, in particular in small and medium production enterprises, have been improved in the context of a recent initiative, resulting in a significantly scaling up of construction mineral consumption (Lebensministerium et al., 2011). Thus, improvements in estimation methods for the most relevant category of construction minerals in terms of mass are required.

Unused material extractions

Unused extraction results from almost all forms of extraction of used materials, e.g. overburden in the context of mining activities or crop residues in the context of harvesting of biomass. The data quality of unused extraction is generally poor as the majority of countries average values' are extrapolated in order to estimate unused extractions. Germany is an exception due to the fact that unused extraction is published officially by statistical institutions (DESTATIS, 2011).

With regard to biomass, only very few studies are available, which focus on the relation between used and unused biomass extraction in different world regions with regards to different agricultural products (a summary is provided by Jölli and Giljum, 2005). Further research is required in order to improve knowledge about unused biomass in the different world regions and the different agricultural (and forestry related) products.

In regards to overburden, in particular overburden in the context of metal mining, only few information is available, e.g. provided by Bundesanstalt für Geologie und Rohstoffe (Kippenberger, 1999) or by the US Geological Survey. This information is not available for all countries, and when it is, it is not always up-to-date. Some actual research based on remote sensing technologies (satellite based data sets) has been undertaken by the Wuppertal Institute. The Wuppertal Institute is currently seeking to improve the quality and availability of data in this area.

6.2 International trade in materials

With regards to physical data on international trade (imports and exports), different research fields are named in the following which could improve data availability and quality for material flow analysis.

Direct trade (imports and exports)

Compared to other national and international statistics, data on international trade are relatively complete and comprehensive. Already in 1962, the United Nations started to collect trade statistics in a harmonized form which are constantly updated and further developed. UN Comtrade (the UN's trade database) is useful for material flow calculations, although EUROSTAT recommend different adjustments, e.g. comparison of selected commodities with national statistics (Eurostat, 2009 and 2011). Moreover, additional research is needed in the following mentioned areas, in particular in regards to non-EU countries where basic trade statistics are predominantly less complete and less differentiated:

1. **Completeness of reported net weight of traded commodities:** The United Nations asks the countries to include information about the net weight of all traded commodities to enable the validation of trade value information (United Nations, Department of Economic and Social Affairs, 1998). In material flow analysis the information is used to calculate physical trade, however many countries only report the net weight of their traded commodities in a piecemeal fashion. Hence, the lacking data has to be estimated. The EUROSTAT guide does not provide sufficient guidance estimation due to the fact that is is not required in European countries (which have complete and differentiated statistics). A systematic and comprehensive approach to overcome this problem was suggested by Dittrich (2010, also: Dittrich and Bringezu, 2010). The method could be further improved for selected, MFA-relevant goods such as ships and an international harmonization would be desirable.
2. **Improvement of assignation within the trade statistics:** In spite of the attempts by the UN to improve the assignations of traded goods for the respective statistical categories, many goods, in particular semi-manufactured goods such as metal concentrates or steel, could be assigned to a variety of categories within the statistics (with regard to the assessment of indirect trade in particular jewelry is relevant). This complicates cross checking and validations of trade data using the respective mirror data of the trading partner. Thus research on how to unify and simplify these assignments is desirable.
3. **Missing trade reports of countries:** Each year different countries – in particular African and Asian countries – do not report their trade statistics to the United Nations. These missing reports could be filled using trade information from their trading partners. Until now, only the BACI-data base used mirror data in order to complete global trade statistics. Nevertheless, the method used by BACI aimed at completeness of monetary values of trade statistics. It should be analyzed whether the BACI method and database is useful for MFA purposes or whether a similar method could be developed to complete global trade statistics which fulfill MFA specific requirements.

Indirect trade flows (of imports and exports)

The indirect trade flows (also named hidden flows, upstream flows, ecological rucksacks or embodied flows) compromise all materials which are required for the production of the respective traded commodity (including extraction and transport) without including the physical mass of the commodity.

Two main approaches currently exist that assess indirect flows of trade: (1) the coefficient approach which was developed by different institutions, e.g. the Wuppertal Institute. This approach multiplies the mass of the traded commodities with coefficients which reflect the material requirements during the production cycle. (2) The input-output analysis based approach which assigns material extraction to final consumption including trade based on input-output models. In this study, the coefficient approach was used to calculate TMR and TMC. Four main fields of further development can be identified:

1. **Differentiation of the coefficients according to countries of origin.** Coefficients which differentiate between countries of origin and their specific characteristics are only available for a very select amount of commodities. A comprehensive, the differences of the countries covering coefficient data set is by far not yet reached and publically available. In particular with regard to metals, but also with regard to other commodities such as coal or minerals, indirect trade flows can vary strongly between and within the country of origin. Additionally, local variations between mines as well as agricultural and forestry products should be analysed as far as possible and include variations caused by the used technologies (e.g. in small scale, labour intensive farming versus large scale energy- and machine intensive farming).
2. **Further differentiation of coefficients of manufactured goods.** Only rough estimates are available for coefficients of many semi- and manufactured goods such as machines, machine parts and chemical products, even then, these estimates are often based on global averages. Therefore, future research should enhance the quantity and quality of life-cycle assessments of (semi-) manufactured goods. Additionally, trade statistics should be further developed in order to improve the differentiation of manufactured goods (e.g. passenger cars).
3. **Further specification of coefficients according to their material substances.** Existing assessments allow the identification of traded goods which are associated with the highest indirect flows. Biotic and abiotic indirect flows and erosion can be distinguished. But a further sub-division, in particular for abiotic flows into energy and mineral related flows is clearly restricted as well as an assignation of the indirect flows from trade to its respective extraction.
4. **Systematic combination of coefficient and input-output methods**. A systematic comparison of both approaches shows the advantage of the first method in enabling the identification of the traded goods most responsible for the highest amount of indirect flows. The disadvantages of this method are, amongst others, the exclusion of built infrastructure used for trade (e.g. streets and harbours or means of transportation) as infrastructure is a large proportion of indirect flows. The input-output analysis allows the inclusion of all relevant indirect effects of an economy. Thus, further research should seek to combine the strengths of both approaches to overcome their current respective limitations.

7 References

Behrens, A., Giljum, S., Kovanda, J., Niza, S. 2007. The material basis of the global economy: Worldwide patterns of natural resource extraction and their implications for sustainable resource use policies. Ecological Economics 64 (2), 444 – 453.

Bringezu, S., Bleischwitz, R. 2009. Sustainable Resource Management. Global Trends, Visions and Policies. Sheffield, UK.

Destatis (Statistisches Bundesamt). 2011. Umweltnutzung und Wirtschaft. Bericht zu den Umweltökonomischen Gesamtrechnungen 2011. Statistisches Bundesamt, Wiesbaden.

Dittrich, M. 2009. The physical dimension of international trade, 1962 – 2005. In: Bleischwitz, R., Welfens, P.J.J., Zhang, Z.X. (Hrsg). Sustainable growth and resource productivity. Economic and global policy issues. Sheffield, UK.

Dittrich, M. 2010. Physische Handelsbilanzen. Verlagert der Norden Umweltbelastungen in den Süpden? Kölner Geographische Arbeiten 91, Köln.

Dittrich, M. 2011. Physical Trade Data Base. Heidelberg.

Dittrich, M., Bringezu, S. 2010. The physical dimension of international trade. Part 1: Direct global flows between 1962 and 2005. Ecological Economics 69, 1838 – 1847.

Dittrich, M., Giljum, S. Polzin, C., Lutter, S., Bringezu, S. 2011a. Resource Use and Resource Efficiency in Emerging Economies. Trends over the past 20 years. SERI Working Paper 12, Vienna.

Dittrich, M., Giljum, S., Polzin, C., Lobo, S. 2011b. Resource use and the role of trade of selected countries between 1980 and 2008. A pilot study on 11 countries over the past 28 years. Heidelberg.

Dittrich, M. Giljum, S., Polzin, C., Lutter, S. 2012a. Green Economies around the World? Implications of Resource Use for Development and the Environment. Vienna.

Dittrich, M., Bringezu, S., Schütz, H. 2012b. The phyiscal dimension of international trade. Part 2: Indirect global flows between 1962 and 2005. Ecological Economics, 79, 32 – 43.

European Commission, 2011: A resource-efficient Europe – Flagship initiative uder the Europe 2020 Strategy. Brussels.

EUROSTAT. 2007. Economy-wide Material Flow Accounting – "A compilation guide". By Weisz, H., Krausmann, F., Eisenmenger, N., Schütz, H., Haas, W. and A. Schaffartzik. ENV/MFA/06 (2007), Luxembourg.

EUROSTAT. 2011a. Economy-wide Material Flow Accounts (EW-MFA) - Compilation Guidelines for EUROSTAT's 2011 EW-MFA questionnaire. ENV/MFA/06 (2007), EUROSTAT, Luxembourg.

EUROSTAT. 2011b. Economy-wide material flows: European countries required more materials between 2000 and 2007. By Hass, J., Popescu, C. Eurostat, Statistics in focus, 9/2011.

EUROSTAT, 2012. Materialflussrechnung. http://appsso.eurostat.ec.europa.eu/nui/show.do [02.05.2012]

Estrade Calvo, I.A. 2007. Resource Efficienca Strategies for Developing Countries. An Analysis based on South America and its Mining Industry. Dresden.

Giljum, S., Dittrich, M. Bringezu, S., Polzin, C. Lutter, S. 2010. Resource use and resource productivity in Asia: Trends over the past 25 years. SERI Working Paper 11, Vienna.

Jölli, D., Giljum, S. 2005. Unused biomass extraction in agriculture, forestry and fishery. SERI Studies 3, Sustainable Europe Research Institute, Vienna.

Kippenberger, C. 1999. Stoffmengenflüsse und Energiebedarf bei der Gewinnung ausgewählter mineralischer Rohstoffe. Auswertende Zusammenfassung. Heft SH 10, Bundesanstalt fuer Geowissenschaften und Rohstoffe, Hannover.

Krausmann , F., Fischer-Kowalski, M., Schandl, H., Eisenmenger, N. 2008a. The global socio-metabolic transition: past and present metabolic profiles and their future trajectories. Journal of Industrial Ecology 12, 637 – 656.

Krausmann, F., Erb, K.-H., Gingrich, S., Lauk, C., Haberl, H., 2008b. Global patterns of socioeconomic biomass flows in the year 2000: a comprehensive assessment of supply, consumption and constraints. Ecological Economics 65, 471–487.

Lebensministerium (Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft), Bundesministerium für Wirtschaft, Familie und Jugend (Hrsg.): Ressourcennutzung in Österreich – Bericht 2011, Wien.

OECD, Organisation for Economic Co-operation and Development. 2007. Measuring material flows and resource productivity. The OECD guide ENV/EPOC/SE (2006)1/REV3, Environment Directorate. Paris.

OECD. Organisation for Economic Co-operation and Development. 2011. Towards Green Growth. Paris. http://www.oecd.org/dataoecd/37/34/48224539.pdf

Schandl, H., West, J. 2010. Resource use and resource efficienca in the Asia-Pacific region. Global Environmental Change 20 (4), 636 – 647.

Schandl, H., Eisenmenger, N. 2006. Regional Patterns in Global Resource extraction. Journal of Industrial Ecology, 10 (4), 133 – 147.

SERI, Sustainable Europe Research Institute. 2011a. Global Material Flow Database. 2011 Version. Available at www.materialflows.net. SERI, Vienna.

SERI, Sustainable Europe Research Institute. 2011b. Technical Report. Vienna

Steinberger, J.K., Krausmann, F., Eisenmenger, N. 2010. Global patterns of material use: a socio-economic and geophysical analysis. Ecological Economics, 69 (5), 1148 – 1158.

UBA, Umweltbundesamt. 2008. Ressourcenverbrauch von Deutschland – aktuelle Kennzahlen und Begriffsbestimmungen. Erstellung eines Glossars zum „Ressourcenbegriff“ und Berechnung von fehlenden Kennzahlen des Ressourcenverbrauchs für die weitere politische Analyse. Forschungsbericht 363 01 134, UBA-FB 001103, von H. Schütz und S. Bringezu. UBA Texte 02/08.

UBA, Umweltbundesamt. 2012. Indikatoren / Kennzahlen für den Rohstoffverbrauch im Rahmen der Nachhaltigkeitsdiskussion. Forschungskennzahl 205 93 368, UBA-FB 001563 von J. Giegrich, A. Liebich, C. Lauwigi, J. Reinhardt. UBA Texte 01/2012.

UNComtrade, 2011. Database. http://comtrade.un.org/db

United Nations, Department of Economic and Social Affairs. 1998. International Merchandise Trade Statistics. Concepts and Definitions. New York.

United Nations Population Division 2012: World Population Prospects: the 2010 Revision. http://data.un.org/ [14.04.2012]

United Nations Statistics Division, 2012a. Standard Country or Area Codes for Statistical Use. http://unstats.un.org/unsd/methods/m49/m49.htm [29.03.2012]

United Nations Statistics Division, 2012b: National Accounts Estimates of Main Aggregates; Gross Value added by kind of economic activity at constant (2005) prices – US Dollar http://data.un.org/Data.aspx?d=SNAAMA&f=grID%3a202%3bcurrID%3aUSD%3bpcFlag%3a0 [10.04.2012]

UN-EMG, United Nations, Environment Management Group. 2012. Working towards a balances and Inclusive Green Economy: A United Nations System-wide Perspective. http://www.unemg.org/Portals/27/Documents/IMG/GreenEconomy/report/GreenEconomy-Full.pdf

UNEP, United Nations Environment Programme. 2011. Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Edited by M. Fischer-Kowalski and M. Swilling. http://www.unep.org/resourcepanel/decoupling/files/pdf/Decoupling_Report_English.pdf

UNIDO, United Nations Industrial Develoment Organization. 2011. UNIDO Green Industry. Policies for Supporting Green Industry. http://www.unido.org/fileadmin/user_media/Services/Green_Industry/web_policies_green_industry.pdf

Weltbank. 2006. Where is the wealth of nations? Measuring Capital for the 21st Century. Washington.

Weltbank. 2011a. Total and per capita wealth of nations. http://data.World Bank.org [10.01.2011]

Weltbank. 2011b. Data. http://data.worldbank.org/indicator [12.10.2011]