Economic Growth for Sustainable Development[1]

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Abstract

Income had grown along with lower environmental impacts during 1991-2010 in nearly all high income countries OECD data show. Many countries reduced their environmental impacts in total. Further, more impacts were reduced in the growing consumption than production. This decoupling process evolved in the fast and slow growing countries both during upswing and slowdown. It is not because polluters were outsourced to the lower income countries or due to services as the shares of service and government expenditures in the countries' GDP have often decreased along with services in consumption while industries and construction have increased. The decoupling is explained by innovations due to the growing know-how. When the process innovations reduce materials use and environmental impacts, they save costs entailing innovation-rents and savings which are allocated as investments into the value creating product innovations expressed as income growth. The countries' performance can be explained by the demands for environmental qualities. The demands increase because the growing knowledge works and leisure time needs environmental and cultural qualities for performance. The demands generate markets for innovations aiming at material efficiency and pollution controls in production, as well as for consumption of environmental qualities, through 'natural blends' of ethical purchases, ecosystem services and cultural expressions. The present global market of such sustainable innovations exceeds USD 2,980 billion, i.e. about 4.6% of the global GDP. On the other hand, policies impede the sustainable innovations when they support rival environmentally harmful interests in sectors such as fossil fuels, agriculture, infrastructure and resource extraction, which is in excess of USD 3,053 billion. Progress can be enhanced through capacity building and abolishing support for the vested interests.

Keywords: income growth, innovations, environmental qualities, market demands, decoupling

Highlights

- Income growth along with lower environmental impacts is observed in nearly all high income countries during fast growth and slow-down.
- Cost savings due to process innovations allocated into value added product innovations generate the low-impact income growth.
- Countries' performance is due to demands for the sustainable innovations, which create markets of roughly USD 2,980 billion a year.
- Financial policy support of environmentally harmful rivals to the sustainable innovators interest exceeds USD 3,053 billion a year.

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1. Introduction

Innovating towards higher income at lower environmental impacts is at the core of sustainable development (WCED, p. 43). The material decrease per income, being an indicator of environmental impacts, is observed globally during the period 1900 – 2005 as the global annual materials use decreased 1.5 - 2 times faster in total than the average global real income growth of about 1.2% which is 1.5% per person when corrected for the population growth. This process evolved along with an increasing material share of the material intensive constructions (from 9% to 40%) and industries (from 3% to 9%) and a decreasing one for biomass and energy uses (Krausmann et al., 2009). Observations in many countries show that the environmental impacts increase at a slower pace than the income growth called the relative decoupling or decrease in total along with more income called the absolute decoupling (Fischer-Kowalski and Swilling, 2011).The decoupling rate, which is the difference between the income and materials growth rates, varies across countries and periods as 1.0 percent income growth is associated with – 0.2 to + 0.8 environmental impact growth, i.e. the absolute (-) and relative (+) decoupling. The decoupling is rarely above 1.0, i.e. more impact than income (Dittrich et al., 2012). The relative and absolute decoupling are observed across the high-income and low-income countries and for various sustainability indicators (Luken and Castellos- Silveria, 2011; EEA, 2013;PBL, 2013; Sengupta et al, 2014). Using correlations between composition of economies and environmental impacts over time, the decoupling is explained by the decreasing material-intensive, polluting agriculture and industry and increasing labor-intensive services, labeled as the Green Kuznets curve (Grossman and Krueger, 1991). However, other studies only partially support this view point (e.g. Bruijn et al, 1999; Stern, 2004). High correlations are also observed between the impact reduction and policies (e.g. Dasgupta et al, 2006) and cleaner technologies (Bertinelli et al, 2012). Correlations can indicate relevant factors, rarely mechanisms. This paper shows that there is no direct link between the income growth and environmental impacts, but mechanisms of innovations as argued in the trailblazing studies on the growth and environment (Kuipers and Nentjes, 1973, Rosenberg, 1973, Solow 1973, Weitzman, 1977).

The starting point is the environmentalist argument about environmental impacts function of population (Ehrlich and Holdren, 1971). This argument is expanded into the IPAT model, then refined into coefficients (Chertow, 2001):

$$I = P \cdot A \cdot T. \quad (1)$$

$$I = P \cdot {}^{a}/_{p} \cdot {}^{m}/_{a} \cdot {}^{i}/_{m} \quad (2)$$

Environmental impacts, *I*, are results of population, *P*, affluence, *A*, and technology, *T*, also considered as interaction (Alcott, 2010). The term ${}^{I}/_{(P \cdot {}^{a}/_{p})}$ expresses the decoupling of environmental impacts and economic values as result of the materials use per value ${}^{m}/_{a}$, and environmental profiles of the materials use ${}^{i}/_{m}$. Values are composed of factors materials, capital, labor resources, expressed as income, product or expenditures; many add knowledge as a resource. This paper addresses solely labor and materials. For convenience, new factors combinations that generate income, are called considered or "doing things differently" as expressed by Schumpeter (1939, 1989:59). Policies are comprehended as tacit and formal institutional actions aiming to influence these combinations. Environmental profiles are expressed as materials consumption, pollution, biodiversity loss and other impacts. Innovations that reduce environmental impacts are labeled as the sustainable innovations.

The decoupling is subject to three types of innovations. It can be the labor for materials substitution, which generates labor-intensive activities called service. The second type is lower material use at any level of labor. These process innovations are cost-saving if the engineering is cost-effective (Rosegger, 1980; Leeuwen, 1989). The third type is the labor addition to materials

called value addition. These product innovations are due to the creative labor called know-how (Helpman, 2004). The materials additions rarely add value, aside specialties, but can impede the value addition (Sachs and Warner, 2001), unless more know-how is involved (Stijns, 2005).

The decoupling in the high-income countries is assessed in section 2. It is explained in section 3. This is followed by assessment of drivers for sustainable innovations in section 4, the markets and barriers in sections 5 and 6. The paper ends with conclusions in section 7.

2. Decoupling

In this paper, the income and environmental impacts are assessed with the OECD statistical data (www.stats.oecd.org/). This data covers 34 high-income countries. In 2010, their total GDP was more than 59% of nearly USD 65 (€ 50) trillion global GDP of 192 United Nations members and their consumption per person exceeded the environmental carrying capacity as measured with the ecological footprint (Global Footprint Network, 2014). This statistics is used because covers a wider range of environmental impacts data than the World Bank (data.worldbank.org) and a larger total GDP than the European Union statistics (ec.europe.eu/eurostat), which are the major international open source databases. The countries' GDP and private consumption value in constant USD_{2005} are used. The annual growth is calculated. The GDP is the sum of the private consumption value, i.e. all household expenditures, private investments including constructions, and government expenditures. The environmental impacts of the GDP compared to the private consumption value indicate the difference between the impacts of consumption and the impacts of production including that of the government. The period 1991-2010 is considered. This period covers economic expansion in the OECD countries during 1990s, saturation during early 2000s and slump after 2008.While some data is missing, the earlier data is deficient. Standard deviations of the growth rates are calculated to assess trends. The standard deviation below the average is assumed as a trend.

Several environmental impact indicators are used. The materials consumption growth is assessed in two ways. First is the materials requirement, i.e. the domestic material consumption including the imports minus the exports, plus materials consumed for these imports in the exporting countries. This shows the material footprint but double counting of the materials consumption in trades between countries is not avoided in these statistics (Bringezu, 2010). Second is the domestic materials consumption growth with the imports minus exports but without the material footprint of the exporting countries. The greenhouse gases measured in the carbon dioxide equivalents indicate impacts on the climate. The emission of nitrous oxides (NOx) in tons indicates acidification and health impacts. The biodiversity data is scarce in all statistics. This impact is indicated by the number of persons per hectare forest, which indicates only the direct human pressures on biodiversity albeit imperfectly. However, better statistically measured indicators for the biodiversity impacts are not found. The generated waste indicates squandering. The fresh water abstraction indicates water abstraction and pollution however, this data is deficient in all statistics. It is assumed that measurements of the impacts are reliable and presented well in the statistics.

The annual average GDP and private consumption value growth reflect the population and income changes. During the period 1991 – 2010, the OECD trend was the growth of annual average population by 0.63% and GDP by 1.49%, whereas the private consumption value has grown by 2.42% a year though fluctuated. The population had grown in all OECD countries nearly continuously, except in Estonia and Hungary. The GDP and private consumption value had grown on an annual average in all OECD countries, albeit recession in some years. The private consumption value had grown faster than GDP in all OECD countries, except in Germany, Luxemburg and Slovenia. The value growth of industries and construction, shares of

services and government expenditures in GDP and research and development expenditures are assessed aiming at explanation of the decoupling trends. The number of countries with the absolute and relative decoupling is presented. All basic data are in the Appendix.

The results are that the population growth impedes decoupling, which confirms the original environmentalist argument. Most OECD countries, however, increased the GDP and private consumption values at a higher rate than the population growth and reduced nearly all environmental impacts much faster than the GDP growth. The impacts reduction compensated the population growth and income growth in nearly all countries, opposite to the IPAT model. Since the cross-countries correlations between the economic and most environmental indicators are low and the standard deviations of the growth rates are large, which indicates strong annual fluctuation, any explanation based on the correlations is dubious. It puzzles about how studies found significant correlations (only the forest areas had steadily increased). Table 1 presents the number of OECD countries that have reached the relative and absolute decoupling during the period 1991-2010. The environmental impact indicators are shown horizontally, the annual GDP and private consumption value vertically and countries with the GDP and private consumption increase above the OECD averages are specified as the high economic performers.

Table 1 Number of countries that decoupled the annual growth of environmental impacts and GDP respectively private consumption growth during 1991-2010

Rel. is relative, Abs. is absolute, Decoup. is decoupling	n	GDP decoupling			Consumption decoupling[1]		Decoupling of the high economic performers[2]		
		Rel.	Abs.	% of all (abs.)	Dec-oup.	% of all	Dec-oup.	Of it Abs.	% these (abs.)
Materials requirement[3]	34	13	7	59 (21)	22	65	11	4	69 (25)
Dom. Materials Cons.	34	18	9	79 (26)	31	91	12	2	75 (13)
Greenhouse gases	34	17	14	91 (41)	33	97	15	6	94 (38)
NOx emissions	33	5	28	100 (82)	33	100	14	10	88 (63)
Forestry area [3]	34	21	12	100 (35)	33	97	16	7	100 (44)
Waste generation	33	17	7	73 (21)	26	79	13	2	87 (13)
Freshwater abstracted[3]	24	7	14	88 (58)	22	92	12	8	100 (67)

www.stats.oecd.org/

[1] number of countries with the absolute decoupling is the same as for the GDP

[2] Environmental impacts to GDP for 16 high economic performers, though for the Waste generation - 15 countries and for the Freshwater abstraction - 12 countries because of deficient data

[3] Several data during the period 1990 - 1995 are missing

Nearly all OECD countries had attained the relative decoupling with respect to all environmental impact indicators. Less widespread is the absolute decoupling across these countries and the annual average reduction of the total environmental impact is modest because usually below 1% a year. This impact reduction was seldom above 3% annual average during 1991 - 2010, which would reduce the impacts by half during this period. More countries had decoupled impacts from their private consumption value than the decoupling from their GDP and the decoupling rates were generally higher. This finding suggests that the households reduced the total environmental impacts faster than producers together with government. These are results across the countries and impacts.

There are differences between the impacts and countries. Total nitrous oxides were reduced in 25 out of 33 countries, freshwater abstraction in 14 out of 24 and greenhouse gasses in 14 out of 34 countries but only one third of the OECD countries reduced pressures on biodiversity, and only one quarter reduced waste and materials consumption. Most of the 16 high economic performers reduced total nitrous oxides emissions, water abstraction and pressure on biodiversity, possibly because they could afford these changes. Ten countries reduced in total

nearly all impacts: France, Italy, and Japan (all but freshwater abstraction data is missing for France), Belgium, Czech Republic, Germany and United Kingdom (all except waste), Denmark and Hungary (all except materials), Greece (all except greenhouse gasses). Three of ten high environmental performers were also high economic performers: Czech Republic, Greece, and the United Kingdom. High economic performance and impacts reduction across the environmental indicators can go along.

The decoupling in production cannot be attributed to the de-industrialization. The share of service in GDP decreased in 21 out of 28 countries and the government expenditures in 16 out of 34 countries, whereas the industries have grown above the GDP growth in 31 out of 34 countries and constructions in 23 out of 30 countries (some countries data is absent). A re-industrialization is observed. Moreover, five of ten high environmental performers experienced the industries growth and five construction growth, seven experienced the decreasing share of services in GDP and four a lower government expenditures share in GDP. The high environmental performance cannot be explained by the growing environmental policy as the share of environmental taxes in all taxes and in GDP had decreased in 8 out of ten environmentally highly performing countries. Research and development could play a role as all ten environmentally highly performing countries enlarged these efforts, 5 of them above the OECD average. The finding is that the environmental impacts are not directly linked to the income growth and rarely to changes in the countries' economic structure.

Fast growth of the private consumption value does not preclude the fast environmental impacts reduction. Data per capita is used because these exclude the population growth. This data is specified for 21 fast growers, i.e. countries whose private consumption value exceeded the OECD average per capita, and 13 slow growers. In addition, the periods of economic upswing 1991 - 2001 and slow-down 2002 – 2010 are specified, i.e. when the average OECD growth was 2.9% and 1.9% a year. All fast growers reached the relative or absolute decoupling except for material requirements in two countries, which could be caused by double counting. Differences between the fast and slow income growers percent wise in total are small across the impact indicators; the fast income growers reduced the materials requirements and forestry faster than the slower growers, but slower with respect to other impact indicators. During the economic upswing, more countries increased the environmental impacts compared to the period of slow-down though differences across the impact were small.

Nearly all OECD countries decoupled the income and environmental impacts growth, though less well in biodiversity and waste while many reduced the impacts in total. Consumers decrease impacts faster than producers, particularly when the consumption growth is moderate compared to the production. The impacts are reduced across the high and low GDP and private consumption value growth though there are large differences between countries. The moderate economic growth rates as measured by the GDP and private consumption value evolve along with the decreasing environmental impacts across nearly all indicators.

3. Explanation of the decoupling

How to explain reduction of environmental impacts in nearly all high income countries whose economies have been moderately growing and re-industrialized during the period 1990 – 2010 ? The environmentalist argumentation is that environmental impacts are not reduced but they are outsourced from the high income and environmental standards countries to those with the lower income and standards. The train of thought is that the intensive use of natural resources causes resource scarcities entailing higher materials prices and industrial pollution trigger stricter policy standards, which cause higher production costs in the material-intensive and polluting industries. These industries emigrate to the lower income and standards countries from where products are

exported to the high income and standard countries. This arguments, however, rarely hold. Firstly, the real prices of natural resources were fluctuating but decreasing as a trend two hundred years ago (Mill, (1848), 1985) and throughout the last century until 1960s (Dasgupta and Heal, 1979). This trend is explained by the backstop technologies, meaning substitution for the technologies whose marginal costs are below the resource prices (Nordhaus, 1973). The forecast that the material prices would increase from the 1960s onwards due to the high income growth (Slade, 1982) is not confirmed by observations of the decreasing trend after the 1980s (Ahrens and Sharma, 1997; Krautkraemer, 2005). The policies could have been relevant for the NOx reduction in several countries, but several impacts are reduced before the policies emerged, e.g. materials and greenhouse gases, whereas others the impacts within the policies domain are hardly reduced, e.g. biodiversity, waste generation. Secondly, the outsourcing thesis is also disputable with regard to the market and labor costs. These costs are considered to be more decisive factors for investments allocations than policies (e.g. Smarzynska and Wei, 2001; Copeland and Scott Taylor, 2003; Hanna, 2010). Thirdly, the international trade is mainly between the OECD countries because they host material-intensive industries; the decoupling of the material requirements and GDP growth underpins this.

Innovations are more important. The first type of innovation is labor for materials substitutions. This was relevant during 1950s and 1960s when the services turnover including government expenditures had grown annually 1.5 - 2.0% faster than the GDP growth in the high income countries and somewhat slower thereafter until saturation at about 75% of the GDP in the 1980s (U.S. Department of Commerce, 1996). From the 1990s, however, this share had stabilized or decreased in the high–income countries along with lower environmental impacts. Moreover, the environmental impacts decreased particularly in consumption. This evolved along with stabilized or decreased share of the services consumption in total consumption in the high income countries. The latter is indicated by the household expenditures measured in constant $€_{2005}$ prices in the European Union during the period 1995 – 2012, it is during a few years of expansion and slump (earlier data is not available). The annual household expenditures are divided into the material-intensive products and labor-intensive services though all involve some labor and materials. The consumption of products covers: (1) Food and non-alcoholic beverages, (2) Alcoholic beverages, tobacco and drugs, (3) Clothing and footwear, (4) Housing, water, electricity, gas and other fuels, (5) Furnishing, household equipment and routine household maintenance, (6) Health, (7) Transport. The consumption of services covers: (8) Communication, (9) Recreation and culture, (10) Education, (11) Restaurants and hotels, (12) Miscellaneous goods and services. The services were about 33% of the total household consumption in the European Union (compared to 35% in the United States and 27% in Japan using the European statistics; the World Bank data cover somewhat different categories but they are less comprehensive). Although the consumption of services had increased in the European Union because all household expenditures had grown by 1.1% annual average its share had decreased by 0.04% annual average. The labor for materials substitution was relevant for the decoupling in the high income countries during a few decades of the last century but is hardly relevant now, though this kind of innovations can be important in the low income and emerging economies.

The relative and absolute decoupling across nearly all high income countries and indicators during the last few decades is driven by know-how about the cost-saving materials reduction and about the value addition to products, it is argued in this paper. These types of innovations are linked. The cost-saving materials reduction in production and consumption decreases environmental impacts. This kind of process innovations generates innovation-rents and savings that are allocated as investments into the value creating labor, which generates higher value products and services expressed as the income growth. This economic circulation explains the quasi-autonomous reduction of environmental impacts along with income growth in

the slow and fast growing countries. This explanation has an empirical basis. The materials saving innovations entailing numerous adaptations during decades, in some cases for centuries, are observed for capital goods in production (Rosenberg, 1982) and utensils in consumption (Petrovsky, 1994). In result, the material-intensity of product life cycles decreased throughout the last half century measured in materials use per unit cost, which is illustrated on the national levels, in businesses and by product cases (Larson, 1986; Herman, et al. 1989; Tilton, 1991; Wright, 1997). When the cost-savings due to the materials reduction exceed the costs involved in these innovations and adaptations, the innovation-rents or savings are allocated into know-how for value creation. This know-how has grown during last decades being expressed by the so called creative industries and media. This is observed as the globally growing number of knowledge workers measured statistically by the science and engineering indicators, as well as by the media and communication business growth. The decoupling in this train of thought is due to the labor productivity in know-how compared to labor productivity in material processing, formally:

$$I/(P \cdot a/p) = m/a \cdot i/m = fa[L_k/L_m] \qquad (3)$$

Herewith, $L_k$is productivity of the know-how labor, L_m productivity of the materials processing labor, and a vector that relates the know-how to the environmental impacts reduction in the specific contexts of countries or businesses.

The global scale of the innovation-rents and savings allocation is assessed indirectly because sales of the material resources saving activities are unavailable. The GDP trend in the real USD_{2005} and the materials use trend in tons in the OECD during 2000 – 2010 are compared using World Bank data (earlier data is incomplete). This period of time includes the recession after the financial crash in 2008 when the assets augmented during 2000s are largely lost, which implies that the average GDP growth in that period was mainly due to value creation in the real economy. The GDP trend, corrected for the labour cost changes, is compared to the materials use trend from the year 2000 on. The additional GDP to materials trends indicates the volume of allocated innovation-rents and savings. The total innovation-rents and savings allocation in the OECD was annual average USD 4,789 (€ 3,684) billion; they increased from USD 337 (€ 259) billion in 2001 to USD 11,146 (€ 8,574) billion in 2010. Since the OECD covers about 59% of the global GDP of USD 64,548 (€ 49,652) billion in 2010, the global allocation is an annual average of USD 8,160 (€ 6,698) billion if the OECD reflects the global allocation trend. It is about 12.6% of the global GDP in 2010, which is a sufficiently large allocation to explain the decoupling of income and environmental impacts.

The decoupling of income growth and environmental impacts from 1950s to 1970s in the high income countries can be explained by the service growth in production and consumption. The more recent decoupling across countries and impact indicators can be explained by quasi-autonomous generation of innovation-rents and savings due to know-how about the cost-saving materials reduction and allocation into know-how about the value creation. Capacity building in knowledge, engineering, design, arts and suchlike foster this process. The differences in decoupling between countries and impacts refer to the growing market and policy demands for environmental qualities, which induces the sustainable innovations.

4. Induced sustainable innovations

The growing demands for environmental qualities are observed as high willingness to pay for good environment, preferences for ethical products, citizenship on the environmental issues, membership of environmental groups and so on. These market demands are reflected in the policy demands albeit imperfectly and with time-lags (Stern, 2000; Krozer, 2008; Viñuales,

2013). The driving force for these market demands is the growth of knowledge workers such as artists, scientists, engineers, educators, managers, policymakers and other experts and craftsmen. Their number enlarged throughout the last century from a tiny group of specialists to a quarter of all waged and non-waged labor in the present high income countries (Drucker, 1993), while the low income countries are catching up. Their interest in environmental qualities is not solely for personal reasons; the personal preferences for good environment are found across societies. The knowledge workers have also professional interests in good environment. The knowledge work performs when cultural diversity enables social interactions (Cooke and Morgan, 2002; Florida, 2002). The interactions require the context of spaciousness, tranquility and beauty, which is found rural areas and recreated in cities as parks, squares, campuses and other public spaces of high environmental qualities. These demands also grow because leisure needs environmental qualities. Leisure has grown as the income growth enabled shorter work time along with longer life time. Compounded for 20 years between 1990 and 2010, the leisure time had increased on an average per person by 20% and the real average income per person by nearly 100% in the OECD countries. More leisure time and even more income enabled people to spend on environmental qualities for leisure.

The traditional demands for environmental qualities address environmental impacts caused by production, such as scarcity of material resources, impacts on health and safety of citizens, pollution and waste etc. These production-oriented demands, usually formulated by policies, invoked businesses presently called 'Cleantech' (Copenhagen Cleantech Cluster, 2012). Several impacts could be reduced by Cleantech, such as some greenhouse gases, NOx, waste, water abstraction but materials reduction, less CO_2 and more forestry also need different types of businesses. The emerging market demands address the consumptive purposes, such as care about biodiversity. These invoke large businesses. An example is the international tourism service, which has grown from about nil arrivals and sales in the early 1950s to more than 800 million arrivals and nearly USD 1,100 (€ 850) billion sales in 2010, as measured by the World Bank and World Tourist Organisation. The consumptive uses of environmental qualities grow into blends of cultures and nature, called further the 'natural blends'. These are man-made, privately owned attributes of the collective environmental qualities; a way of appropriation of common goods. For convenience, the natural blends are divided into three markets. First, where the products reflect attributes of environmental quality, for instance the 'natural materials', 'organic food', 'green banks'. The second, expresses interactions with environmental qualities, e.g. visits to nature parks, birds watching, tree-hugging. The third, where the market re-creates environmental qualities in the cultural expressions of media, crafts, science education and so on. All these markets generate businesses that drive sustainable innovations.

The market volumes due to the traditional and emerging demands are assessed based on escalation of the present expenditures on technologies instead of willingness to pay which indicates social conventions rather than marketable demands (Kahneman and Knetsch 1992). These expenditures indicate sales opportunities of the sustainable innovators if they outperform the present technologies. The global markets of material resources, pollution reduction, ethical consumption, ecosystem services and cultural attributes are assessed. The traditional markets of material resources and pollution reduction are assessed with statistical data. The emerging markets of ethical consumption, ecosystem services and cultural attributes are scaled up cases. Tourism is excluded to avoid double counting, which implies that the markets of natural blends are underestimated. The estimates are crude, aiming to indicate order of magnitude. These are expressed in USD, Euro a year and the percentage of the global GDP in 2010.

5. Markets of Sustainable Innovations

The material-reducing innovations mentioned above evolve largely independent of the demands for environmental qualities. The land use for extraction and cultivation of the natural resources, however is sensitive to the demands because various interests claim land. Data on technologies and costs of the land use is not available. Hence, the market of sustainable innovation is assessed indirectly using the World Bank data on the adjusted savings of natural resource depletion, it is comparison of the annual natural resources depletion to their reserves in monetary terms. Although this data reflects expectations about the future value of natural resource, which are imperfect, the enlarging savings indicate progress in exploration, development and extraction of material resources. Another limitation of this data is that it covers only a short period from 2004 to 2012. It includes the financial crisis in 2008 when the estimates are largely adapted. A prudent estimate is during 2004 – 2008 when the annual average increase of the savings was USD 1,063 (€ 818) billion. It was 1.65% of the global GDP in 2010.

The second market refers to the capital and operational costs of controlling pollution and hazards. Since the global statistical data on these expenditures is not available and the OECD data is unreliable because much data is missing (e.g. Australia, Canada, Japan and United States) or deficient, (e.g. Mexico) the European Union data on 28 member states is used. It covers the period 2002 – 2010. The annual average pollution control costs were USD 280 (€ 216) billion, i.e. 1.48% of the European Union GDP, fluctuating from 1.4% to 1.6% (Georgescu and Cabeça, 2010 found 1.8% for 25 member states in 2006). Although the pollution control costs as percentage of GDP vary from 0.5% to 2.5% across countries, fluctuate in time and depend on definitions, this European Union data is useful for the global scaling up because it includes the high income and low income countries. Using 28.5% average European Union GDP in the global GDP, this global market is about USD 973 (€ 748) billion a year, i.e. about 1.48% of the global GDP in 2010.

The ethical consumption represents purchases and uses of products and services that are certificated for good working condition, trade relation, environmental and health performance and so on. Herewith, solely the consumer markets are covered. Business is excluded to avoid double counting with materials saving and pollution control, which causes underestimation of this market. Statistical data on the consumer ethical expenditures is available for the United Kingdom. This covers purchases of foods and drinks, home related products, traveling and transport, personal care products, community expenditures and money. In the year 2011 about £ 989 (€ 1251 or USD 1627) was spent per average household, or 3.1% of all expenditures per person. The expenditures had grown during 2002 - 2011 on average by 4.7% a year. A higher share and growth were observed in the foods in many countries (Bunte et al, 2010). A prudent estimate of the ethical consumption expenditure is 2% of all in the OECD countries and 1% in the non-OECD countries. Given the disposable consumers' incomes in 2010 of USD 27.1 trillion respectively € 11.7 trillion, the ethical consumption market was about USD 658 (€ 506) billion. It was about 1.02% of the global GDP in 2010.

The market of interactions with environmental qualities refers to the ecosystem services, which conceptualizes nature as provision of services for humans. The global value of ecosystem services is estimated to be USD 16,000 to 54,000 billion a year (Constanza et al, 1997). With regard to the global $149*10^{12}$ square meter land area, of which 38% is cultivated (World Bank), the estimated value of nature is maximum USD 0.96 per square meter cultivated land. The expenditures on protection of nature on about $971*10^{9}$ square meters were about USD 8.5 billion a year in 2000s (Pearce 2007), which is USD cents 0.87 per square meter, i.e. 110 times lower. Regarding that small nature protection area and budget, payments for ecosystem services on the cultivated land are introduced to farmers, for instance in Costa Rica and Switzerland (Gómez-Baggethun, 2010) and in the natural parks (Lordkipanidze et al, 2014). If it is to be assumed that the USD cent 0.87 per square meter nature protection reflects the social valuation of ecosystem

services on all cultivated land of 56.6* 10^{12} square meters, the global market is about USD 245 (€ 188) billion or 0.38% of the global GDP in 2010.

The value of the environment for culture, a cornerstone in the environmentalist thinking in the last two centuries (Grober, 2010) is expressed as the existence value of environmental qualities. The existence value refers to the justifiable environmental qualities that lack recognized utilities (Krutilla, 1967). Entitlements for the existence values are proposed, e.g. the amenity rights (Mishan, (1968), 1993) and the quality of life (Ehrenfeld, 2008). The cultural attributes derived from such entitlements would foster creativity in work (Laszlo et al, 2012) and change management (Miller Perkins, 2012). A proxy for market value of the cultural attributes is the membership of nature and environmental organizations. The market of the cultural attributes is assessed based on 30 million members, out of which 16 million are in Europe and 14 million in the United States, and assumption that these members relate their recreation, culture, education and leisure expenditures to environmental qualities,. These expenditures are on an average 21% of the total household expenditures in Europe and 19% in the United States during 1995 - 2012 (Eurostat). Based on the average disposable income per person of USD 5,657 (€ 4,351) in the European Union and USD 8,584 (€ 6,603) in the United States this global market is about USD 42.1 (€ 32.4) billion, i.e. 0.07% of the global GDP in 2010.

The global markets of sustainable innovations are summarized in Table 2. These are added to each other because double counting is avoided. It is a minimum estimate because some markets are excluded, such as tourism. The total market volume is about USD 2,981 (€ 2,293) billion or 4.62% of the global GDP using the 2010 year data. For a comparison, the global expenditures on health were USD 7,322 billion, i.e. 10.3% of the GDP in 2010 (World Bank). The demands for environmental qualities generate large global markets.

Table 2 Global markets of sustainable innovations due to demands for environmental qualities.

Markets	Description	USD billion	Share in global GDP
Material resources	technologies for reducing material and energy use	1, 063	1.65
Pollution control	cleaner technologies for pollution reduction	973	1.51
Ethical consumption	ethical purchase and use of products and service	658	1.02
Ecosystem services	nature management with payment for services	245	0.38
Cultural attributes	cultural expression of environnemental quality	42	0.07
Total		2, 981	4.62

6. Impediments for sustainable innovators

There are also barriers of entry for the sustainable innovators related to policy entitlements given to the rival firms. When firms seek entitlements from authorities they can gain policy support for the costly and low quality supplies due to institutional deficiencies, such as corruption (Krueger, 1974). This rent-seeking behavior undermines innovations because gains are generated by the vested firm that have more financial capabilities, larger political influence and take lower risks than the innovators (Murphy et al 1993). Such barriers of entry can persist during many decades despite social and environmental harms. For instance, the monopoly entitlement was given to the gas producers for street lights with gas in the late 1800s which inhibited electric lighting for several decades despite fires caused by the gas lights (DiLorenzo, 1996). The non-monetary barriers of entry cover trade and work licenses, property rights, and so on; the monetary ones can be subsidies, tax exemptions, credit facilities, liabilities, bonds, concessions, patents and so on (Boldrin and Levine, 2004). The latter are addressed; i.e. the policy financial support.

The financial policy support is indicated insofar it is plausibly harmful to environment, rival to the sustainable innovators and well-assessable. There are tax exemptions and subsidies

for the energy production and use. This production and use is a source of land degradation and pollution. The global policy support in 2010 was about USD 1,900 (€ 1,461) billion as assessed by the International Monetary Fund (Clemens, 2013). About USD 1,600 billion of it is in support of fossil fuels including nuclear energy, which causes greenhouse gases and is rival to the sustainable innovations in energy-efficiency and renewable energy. Intensive agricultural businesses are subsidized in the European Union, United States and Japan although they are environmentally harmful when focused on the output maximization rather than social and environmental interests. The agricultural subsidies exceed in total USD 430 (€ 330) billion based on the European Union, United States and Japanese data (World watch, 2014). Reliable global assessments are not found. The tax exemptions and subsidies on foods add to the output bias but reliable estimates of the environmental harms are not found. Extraction of natural resources harms land. When the pre-existing and customary land rights are neglected because land is given by authorities to firms in concession, businesses are often exempted from liability for the local impacts if they comply with the national regulations. Local qualities degrade. Such concessions assessed in 22 emerging economies cover 9 million hectares land at a value of USD 5,190 billion (Leon et al, 2013). Assuming on an average 10% linear depreciation of these rights, the annual value of these entitlements is about USD 519 billion. Infrastructure degrades environmental qualities on-site and generates subsequent activities, which cause irreversible environmental impacts. Most infrastructure is uneconomic measured by the private costs - benefits. Hence, about 97% of the USD 2,600 billion a year global investment in infrastructure is from public funds (Dobbs et al, 2013). This public funding reduces risks of the private investors, but causes welfare losses of the uneconomic works and costs overrun (Flyvbjerg et al, 2003). A prudent guess is that 20% less policy support of infrastructure is possible with a social net benefit. It is about USD 504 billion a year. Patents are excluded because the harm to environment is unclear. The payment of royalties was about USD 250 billion in 2010 (World Bank).

The global impediments for sustainable innovations caused by the policy financial support of the vested interests are shown in the Table 3. The value is about USD 3,053 (€ 2,349) billion a year, which is about 4.73% of the global GDP. The barriers of entry to the sustainable innovators posed by the financial policy support are larger than the markets induced by the demands for environmental qualities. In general, policies impede the decoupling.

Table 3 Impediments for sustainable innovations expressed in monetary terms in 2010

Type of impediment	USD billion
Support for fossil fuels	1,600
Agricultural subsidies excluding food	430
Tax exemptions and subsidies on foods	P.M.
Concessions for resource extraction	519
Public infrastructure	504
Value of patents	P.M.
Total	3,053

7. Conclusions

Growth of income and private consumption value are compared to materials usage, greenhouse gases, NOx emissions, waste generation and pressures on biodiversity and water abstraction in the high income countries (OECD) during the period 1991 - 2010. It is found that the income and private consumption value have grown in nearly all countries along with the decreasing environmental impacts per unit of income, as well as the impact reduction in total in many countries. The impact reduction in consumption was generally faster when compared to that of production. These findings hold for the fast and slow growing economies, as well as during

economic upswing and slow-down. Several countries performed well across the environmental and economic indicators. The growth of services, changes in consumption, environmental policies and research and development are only partial explanations. Shift from industries to services was relevant during 1960s and 1970s when services grew faster than GDP but during the last few decades, the share of industries and construction in the high income countries' GDP increased and the share of the services stabilized. The policies had little influence; research and development are more important. The generic decoupling of income from environmental impacts across the OECD countries is explained as being driven by economic circulation in which the innovation-rents and savings due to the cost saving materials reduction are allocated into the value creating labor expressed as the income growth. This allocation mechanism is assessed as nearly 13% of the global GDP, which is a sufficiently large volume to underpin the decoupling of income and impacts. The decoupling evolves due to know-how albeit slowly.

Differences between the countries, the country-specific decoupling, can be related to the specific market and policy demands for environmental qualities. These demands are enlarged due to the growing knowledge work and leisure time. The markets embrace material and energy saving, pollution control, ethical purchases, ecosystem services and cultural expressions. The global market for the sustainable innovations is estimated to be about USD 2,981 (€ 2,293) billion in 2010, which is about 4.62% of the global GDP. This is excluding the international tourism. Policies cause barriers of entry to innovators. Contrary to the widespread opinion that policies foster environmental qualities, they generally impede the sustainable innovators because support the vested, environmentally harmful rivals. The global financial support of the fossil fuels, agricultural practices, wasteful infrastructure and environment degrading concessions is roughly USD 3,053 (€ 2, 349) billion in 2010, which is a minimum estimate of the barriers of entry for the sustainable innovators.

The present progress towards sustainable development is largely due to the generic quasi-autonomous innovations despite obstruction of sustainable innovators by policies. Enlargement of know-how and abolishment of the environmentally harmful policy support would enhance the sustainable innovations entailing a rapid decline of environmental impacts along with the income growth. There is reason for optimism about the global sustainable development within one generation if policies foster the sustainable innovators rather than the vested interests.

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