Jarmo Vehmas, Jyrki Luukkanen and Jari Kaivo-oja

MATERIAL FLOWS AND ECONOMIC GROWTH

Linking analyses and environmental Kuznets curves for the EU-15 member countries in 1980-2000

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TURUN KAUPPAKORKEAKOULU
Turku School of Economics and Business Administration
FINLAND FUTURES RESEARCH CENTRE

Jarmo Vehmas
Senior Researcher
Finland Futures Research Centre, Tampere office
Turku School of Economics and Business Administration
Kuninkaankatu 34 B 31, FIN-33200 Tampere, Finland
Tel. +358 3 223 8363, +358 40 595 8578, fax +358 3 223 8363
E-mail: jarmo.vehmas@tukkk.fi

Jyrki Luukkanen
Academy Research Fellow
Finland Futures Research Centre, Tampere office
Turku School of Economics and Business Administration
Kuninkaankatu 34 B 31, FIN-33200 Tampere, Finland
Tel. +358 3 223 8363, +358 50 337 0710, fax +358 3 223 8363
E-mail: jyrki.luukkanen@tukkk.fi

Jari Kaivo-oja
Research Manager
Finland Futures Research Centre, Turku office
Turku School of Economics and Business Administration
Rehtorinpellonkatu 3, FIN-20500 Turku, Finland
Tel. +358 2 4814 526, +358 50 502 7030, fax +358 2 481 4630
E-mail: jari.kaivo-oja@tukkk.fi

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CONTENTS

ABSTRACT

De-linking or decoupling environmental impacts from economic growth has become an important element in the scientific debate on economic growth versus the environment. In addition to this debate, the political importance of the so-called linking issue necessitates some empirical tests for assessing whether environmental stress has moved into a desired direction or not. The aim of this article is to present a theoretical framework including new concepts for describing the linking process and related environmental Kuznets curve hypothesis, and provide an empirical analysis for operationalizing the framework. In the empirical analysis, aggregated direct material flow data for the European Union member countries is used as a proxy for environmental stress. The compatibility between the most important indicator of economic growth, GDP, and different material flow indicators is also discussed. The linking issue and environmental Kuznets curves are analysed during the time period 1980-2000.

Keywords: material flows, decoupling, de-linking, environmental policy, environmental Kuznets curve

TIIVISTELMÄ

Ympäristöongelmien riippuvuus taloudellisesta kasvusta on noussut keskeiseen asemaan talouden ja ympäristön suhdetta koskevassa tieteellisessä keskustelussa. Tämän lisäksi niin sanotulla irtikytkennällä (decoupling; de-linking) on ympäristöpoliittista merkitystä, jonka vuoksi tarvitaan uusia menetelmiä, joiden avulla voidaan arvioida ympäristön tilan muutoksen suuntaa. Tämän julkaisun tarkoituksena on esitellä teoreettinen viitekehys ja käsitteistö, jotka jäsentävät talouden kasvun ja ympäristöongelmien suhdetta uudella tavalla ja kuvaavat entistä paremmin irtikytkentää ja siihen liittyvää Kuznets-käyrähypoteesia. Empiirisessä osassa viitekehys operationalisoidaan käyttämällä aggregoituja materiaalivirta-indikaattoreita Euroopan Unionin jäsenmaiden tarkasteluun. Lisäksi pohditaan materiaalivirtaindikaattoreiden ja taloudellisten indikaattoreiden kuten bkt:n yhteensopivuutta. Irtikytkentää ja Kuznets-käyriä tarkastellaan vuosien 1980 ja 2000 välisellä ajanjaksolla.

Avainsanat: materiaalivirrat, irtikytkentä, ympäristöpolitiikka, ympäristövaikutusten Kuznets-käyrä

1. INTRODUCTION

A policy framework for sustainable resource management (SRM) is required both to guarantee the materials and energy supply of the EU economy and to safeguard the natural resource basis of a modern society also in the future. Many environmental changes are brought about by human-induced material flows. Material flow analysis is considered as an important part of the European SRM framework (e.g. Bringezu *et al*, 2002).

De-linking or decoupling environmental impacts from economic growth, as well as the environmental Kuznets curve (EKC) hypothesis dealing with this phenomenon, have become important elements in the scientific debate on economic growth versus the environment since these concepts were introduced in the early 1990s (e.g. Yandle *et al*, 2002). However, many authors still refer to the early stage of development in the theoretical EKC framework (e.g. de Bruyn, 2000; Magnani, 2001; Yandle *et al*, 2002).

Beside the scientific debate, the political importance of the linking process of environmental stress and economic growth necessitates some testing to observe whether environmental stress moves into a desired direction or not. For this purpose, we present a theoretical framework and an empirical study where we observe what kind of a linking process is going on in the European Union member countries when aggregated material flows are considered. The linking process may be a part of some kind of a transition process in the EU-15 member countries. Transition can be defined as a gradual continuous process of societal change where the structural character of a society transforms (Martens and Rotmans, 2002, p. 3). It is possible to consider material use and related material flows as a structural element in the industrialized countries.

2. INDICATORS OF MATERIAL FLOW AND ECONOMIC GROWTH

Aggregated material flows can be considered as a comprehensive indicator describing environmental stress, or at least a proxy for it. The connection between aggregated material flows and environmental impacts is an important question. One proposed method for taking the environmental impacts better into account is weighting the material flows on the basis of e.g. environmental impact assessment (EIA) of different types of materials. Another possibility is to use the exergy measure to assess the qualitative differences of materials (Malaska et al 1991). These methods offer several possibilities, but they are, however, not in the scope of this paper.

Beyond the environmental impacts related to different materials, the aggregated material flow indicators have two types of problems which arise especially from the perspective of the linking analysis. The first one is the question of data availability, especially publicly accessible data on hidden flows. For example, the generally available time series data set used in the analysis provided here (Eurostat 2002), includes only direct material flows, so unused, indirect or other hidden material flows are not included. However, hidden flows are usually considered as very significant in the rapidly evolving material flow accounting (MFA) literature (see e.g. Eurostat 2001; Bringezu & Schütz, 2001a; Bringezu, 2003; Hinterberger *et al*, 2003). Currently, a lot of work is carried out in the European Environment Agency in collaboration with the Wuppertal Institute in order to estimate the hidden flows (cf. Bringezu and Schütz, 2001a; 2001b). For a comprehensive and largely acknowledged framework for different categories and types of aggregated material flow indicators, a methodological guide is available (see Eurostat, 2001).

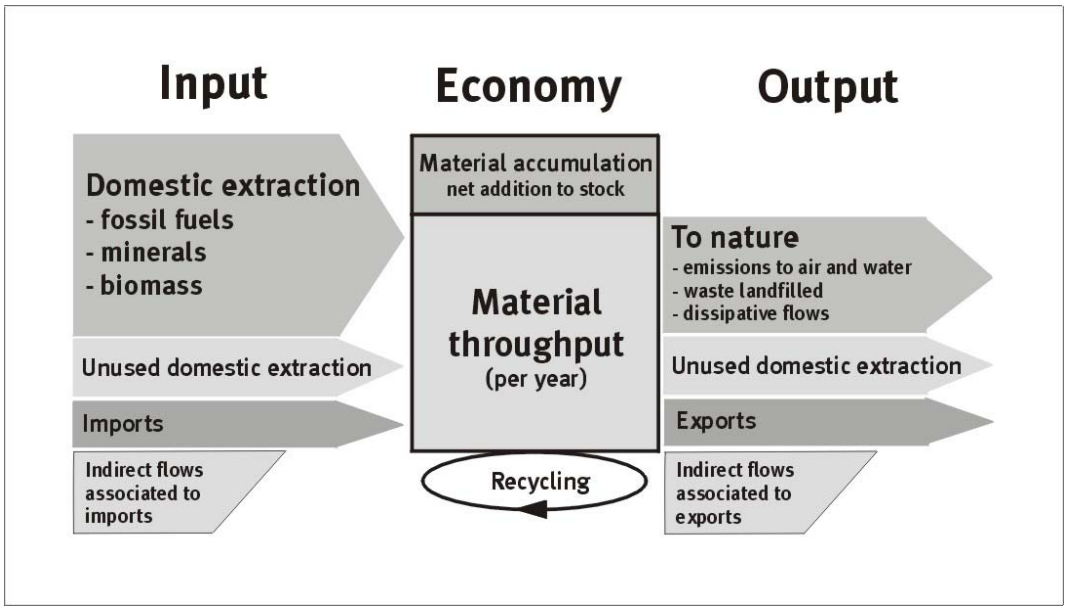

Figure 1. *General scheme for economy-wide material flow accounting. Source: Eurostat, 2001.*

However, for the purposes of this article, suitable data on direct material flows only has been available. As noted above, Eurostat (2002) has recently published a database of aggregated indicators of direct material flows, which covers the European Union member countries for the years 1980-2000. The data includes the following direct material flow indicators:

- Domestic extraction (DE): all biomass, fossil fuels and minerals extracted for use in a country.
- Direct material input (DMI): domestic extraction plus all imported materials.
- Domestic material consumption (DMC): direct material input minus all exported materials.
- Physical trade balance (PTB): all imported materials minus all exported materials; i.e. net imports or net trade.

The second problem of aggregated material flow data relates to the compatibility of economic indicators and material flow indicators. For example, while direct material input (DMI) includes domestic extraction (DE) and imported materials and domestic material consumption (DMC) includes domestic extraction (DE) plus imported materials minus exported materials, none of them treats imports and exports with the same logic as the gross domestic product (GDP), the most commonly used economic indicator in linking and EKC analyses. From the end-use perspective, GDP is defined as follows:

$$GDP = C + G + I + (E - M)$$

where C = private consumption, G = public consumption, I = capital accumulation, E = exports and M = imports. Thus, the trade balance in GDP is defined differently from the trade balance in the material flow terms. The problem of this incompatibility has been detected in the MFA literature (cf. Mäenpää and Juutinen, 2000; Schandl and Schulz, 2000; European Environment Agency, 2003) but on the other hand, it has not been widely discussed in the context of linking and EKC analyses. Some recent linking and EKC analyses on material flows have been carried out without reference to this problem (e.g. Seppälä *et al*, 2001; Eurostat, 2002).

Although data on exported and imported material flows are available, a “GDP-equivalent” indicator for material flows (such as DE + exports – imports) cannot be constructed because domestic extraction (DE) in many cases includes exported materials and hence it is possible that exports will face the problem of double counting. In other words, aggregated material flow indicators are not compatible with the SNA system.

How to overcome this problem of incompatibility? Mäenpää and Juutinen (2000, p. 12) have pointed out that in an opening economy, both imports and exports tend to increase, but in the long run foreign trade will balance towards a situation where exports and imports compensate each other. Thus, the value of the term (E – M) in the GDP formula approaches the value of zero. This gives some reason to use domestic extraction (DE) as a rough estimate for a “GDP-equivalent” indicator of aggregated material flows, by assuming that physical trade balance (PTB) = 0. In this article, however, we carry out the linking and EKC analysis using direct material input (DMI) against GDP and DMI/GDP as an indicator of material intensity of production. In comparison, we make the analyses also with domestic material consumption (DMC), but against public and private consumption (PPC) instead of GDP because we consider DMC/PPC as a better estimate for material intensity of consumption than DMC/GDP. It is reasonable to use DMI against GDP and DMC against PPC, because GDP is always larger than PPC and DMI is always larger than DMC in open economies. Moreover, material intensity should not depend on the choice of production side or consumption side when measured at the global level.

In many empirical studies dealing with the EKC hypothesis, the environmental point of view has been dealt with by using per capita figures of environmental stress in the vertical axis and

GDP per capita figures in the horizontal axis. However, environmental stress per capita decreases with population growth, although the total environmental stress stays constant - or even increases, but at a slower rate than population growth. Thus, the results may be misleading from the environmental perspective. For this reason, we carry out two types of EKC analyses mentioned above and both of them with absolute material flow values and per capita values, and we also take a look at differences in the results.

3. A THEORETICAL ANALYSIS FOR THE LINKING ANALYSIS

In absolute terms, the linking process refers to the relationship between environmental stress trend and economic growth trend during a certain time period. In the previous literature, de Bruyn and Opschoor (1997) have defined five stages of the linking process, which is usually called as N-shaped curve. If the last stage of re-linking does not take place, one may speak about a genuine inverted U-shaped curve or environmental Kuznets curve (Panayotou, 1993, Seppälä *et al*, 2001).

The concept of de-linking refers to a situation where aggregate economic activity increases but environmental stress (ES) decreases during the same time period. De Bruyn (2000, p. 62) has separated two forms of de-linking in a growing economy: weak and strong de-linking. For de-linking to be called weak, the ES intensity must fall. Hence, using the difference (Δ) between the values of environmental intensities at two time moments, a sufficient condition for weak de-linking is

$$\Delta(ES/GDP) < 0$$

Weak de-linking implies that the ES intensity of the GDP decreases over time. However, environmental stress can still increase, but at a lower rate than the growth of the economy. For de-linking to be called strong, environmental stress must decrease over time (de Bruyn, 2000, p. 62). This strong de-linking rule implies in difference terms that

$$\Delta ES < 0$$

Some supporters of economic growth have argued that such transformation processes are enhanced by economic growth, and hence ΔES is a non-positive function of ΔGDP. This idea has been labelled as the “environmental Kuznets curve (EKC) hypothesis” (e.g. Panayotou, 1993; Grossman and Krueger, 1995; Rothman and de Bruyn, 1998; Borghesi, 1999). The EKC hypothesis states that economic growth first increases environmental stress, but at a certain level of income, environmental stress starts to decrease endogenously or “automatically”, e.g. through positive income elasticity for environmental goods, technological progress and shifts towards less environmentally intensive activities such as service sectors. The recent literature concerning the EKC hypothesis suggests that there may also be other factors determining the emergence of a downward sloping segment in the EKC than GDP or GDP per capita (e.g. de Bruyn, 2000; Magnani, 2001). However, identifying these factors and their effects is not an easy task. Strictly speaking, the existence of an inverted U-shaped EKC does not tell anything about the reasons for decreasing environmental stress.

Assuming that the EKC hypothesis holds, there are still doubts if the observed improvements in environmental efficiency can be extrapolated into the future. There may come a time, or income level, where weak or strong de-linking conditions do not hold any more because the possibilities for improving environmental efficiencies may have a technological (e.g. thermodynamic) or economic upper limit. From that point onward, the economic growth component may become more dominant and ES and GDP will be re-linked again, at least until further technical, social, political or other innovation breakthroughs. This prediction is called the re-linking hypothesis (de Bruyn and Opschoor, 1997). It can be defined as the empirical validation of a process in which ES intensity has been stabilized or starts to rise again, thus in difference terms

$$\Delta(ES/GDP) \geq 0$$

This situation can be termed as weak re-linking, and it implies that the ES intensity of the GDP increases over time. In this situation, environmental stress can still decrease, but only in the case of a decreasing economy. For re-linking to be called strong, environmental stress must increase over time. Thus, strong re-linking rule implies in difference terms that

$$\Delta ES \geq 0$$

The de-linking and re-linking issue deals with change in GDP (ΔGDP), change in environmental stress (ΔES) and change in the environmental intensity of GDP, Δ(ES/GDP). To define all possible combinations of different changes, the variables will be put in a system of coordinates (Fig. 2) where the vertical axis represents GDP and the horizontal axis represents environmental stress (ES); i.e. their absolute values in a selected base year. Thus, a constant relationship between ES and GDP (ES/GDP) can be drawn and chosen as the third axis. With these three axes we can define six different degrees of the de-linking and re-linking process, based on the changes in the three variables ΔES, ΔGDP and Δ(ES/GDP) from their base year values during the studied period.

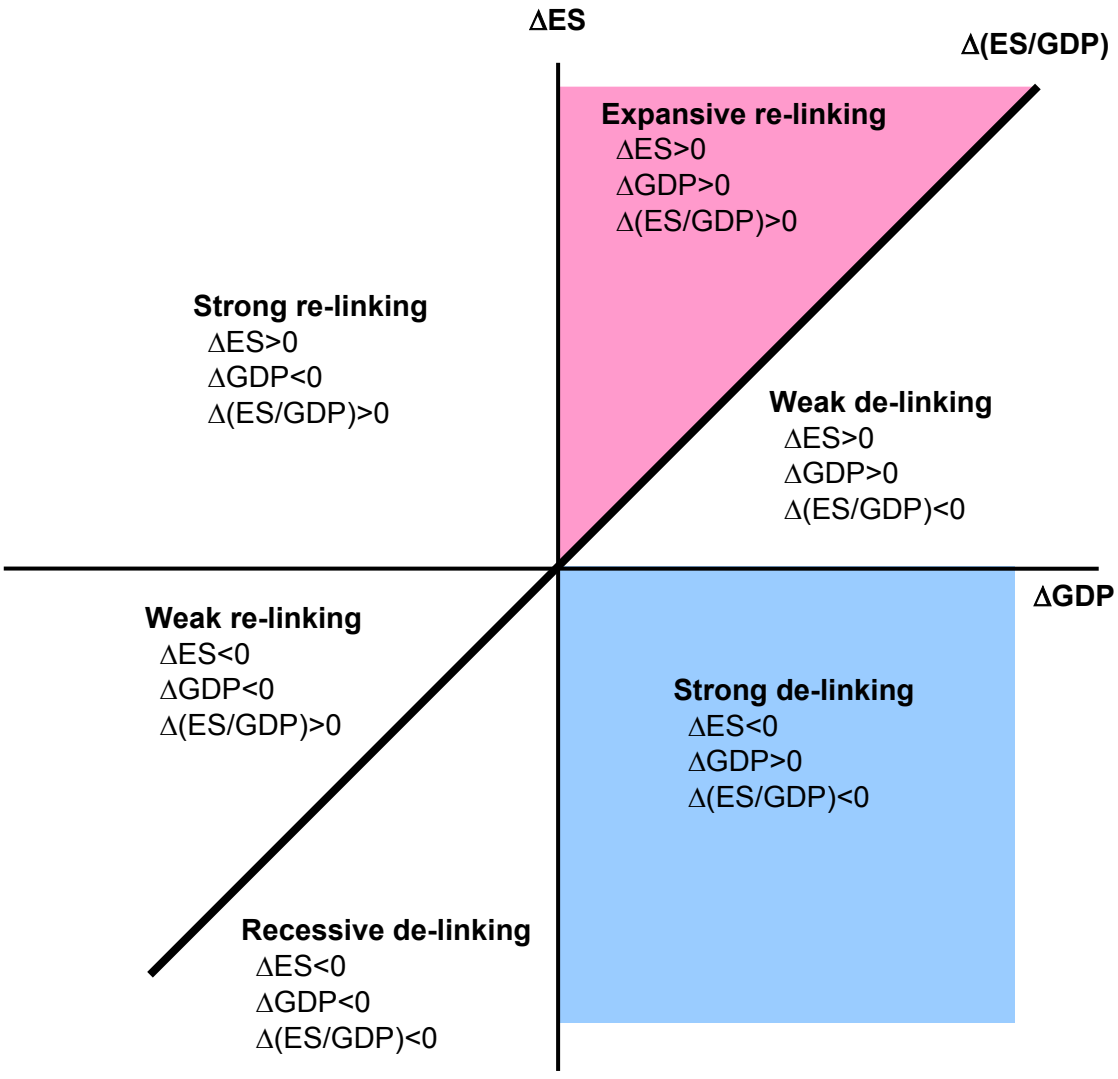

Figure 2. *Degrees of the linking process.*

The area above the line Δ(ES/GDP) in Fig. 2 represents re-linking and the area below the line represents de-linking. For both de-linking and re-linking, three different degrees can be defined and conceptualized according to the direction of change in each of the three variables (GDP, ES and ES/GDP) after a selected base year.

The area where change in GDP is positive, change in ES negative, and change in ES/GDP negative, can be defined as **strong de-linking**. In practice, strong de-linking means that economic growth is achieved by more efficient technology with decreasing environmental stress. The area with positive changes in both GDP and ES but negative change in ES/GDP can be defined as **weak de-linking**, by following the rules by de Bruyn (2000). In practice, weak de-linking means that despite efficiency improvements, environmental stress increases within GDP growth. The third area of de-linking, where changes in all variables (GDP, ES and ES/GDP) are negative, can be defined as **recessive de-linking**. In this case, negative change in GDP causes also negative change in environmental stress, but also efficiency improvements take place at the same time. This is a new concept, because de Bruyn (2000) and others have left out the possibility for decreasing GDP.

The area above the ES/GDP line in Fig. 2 represents re-linking, and three different degrees can be defined like in the case of de-linking. In relation to the analysis by de Bruyn (2000), three new concepts also emerge here. The area where the change of GDP is negative, change in environmental stress (ES) is positive, and change in ES/GDP is positive, can be defined as **strong re-linking**. Here environmental stress increases despite of decreasing economy, because of increasing environmental intensity of the GDP. The area with negative changes in GDP and ES but a positive change in ES/GDP, can be defined as **weak re-linking**. Here environmental stress decreases due to decreasing GDP, although environmental intensity increases. The third area, where changes both in GDP and ES are positive and change in ES/GDP is positive, can be conceptualized as **expansive re-linking.** In practice, economic growth is performed by more inefficient technology with increasing environmental stress.

It is obvious that the empirical results of de-linking and re-linking analysis gives different results depending on the indicator of environmental stress (or a proxy of it) chosen – such as energy consumption, material flows, discharge emissions to air, water and soil, and wastes, etc. This is well demonstrated in the surveys of empirical EKC studies (e.g. Ekins, 1997; Borghesi, 1999; de Bruyn, 2000; Yandle et al, 2002). A logical conclusion from this is that sustainability policy cannot be based on the analysis of a single indicator only; the analyses and policies must be issue-focused instead and detailed enough instead.

The above presented degrees of de-linking and re-linking indicate also a differentiation of weak and strong EKCs on the basis of the condition for weak and strong de-linking. Thus, a **weak environmental Kuznets curve** can be drawn with environmental intensity of the economy (e.g. ES/GDP) in the vertical axis. A **strong environmental Kuznets curve** can then be drawn with environmental stress (ES) or environmental stress per capita in the vertical axis. In both cases, the usual choice of GDP per capita, or another per capita indicator on economic activity, can be made for the horizontal axis. Regardless of the difference between weak and strong EKC, a possible empirical support for the EKC hypothesis can be interpreted in different ways (cf. de Bruyn, 2000, p. 5; Magnani, 2001). The shape of the EKC can stem from economic growth, from environmental policy, or from some other factor(s). This very important issue is, however, out of the scope of this article.

4. RESULTS FROM THE LINKING ANALYSIS

Table 1 describes the linking process for material flows as measured by direct material input (DMI) and GDP per capita in the EU-15 countries. In the columns of ∆(DMI/GDP), ∆DMI and ∆DMI per capita, the color of the cell indicates the degree of the linking process. Blue refers to strong de-linking, white to weak de-linking, and red to expansive re-linking. Strong and weak re-linking as well as recessive de-linking are lacking, because the linking analysis in Table 1 deals with changes in two ten years periods and one twenty years period, and GDP has been clearly growing during this long periods.

When the whole period 1980-2000 is considered in absolute material flow figures, the general trend in the EU is weak de-linking, i.e. increasing material flow (DMI), increasing GDP and clearly decreasing material intensity of production (DMI/GDP). There are only two exceptions from the general EU trend. In Germany material flows have slightly decreased between the years 1980 and 2000, and thus the German trend is strong de-linking. In Greece, the material intensity of production has slightly increased and thus the Greek trend is expansive re-linking. In many countries, a remarkable decrease in material intensity from the 1980 value has not been able to restrict the increase in aggregated material flows measured by DMI. In Ireland, despite of an over 50 % decrease in material intensity, the material flow has increased over 30 % from the 1980 value between the years 1980 and 2000. This is due to very fast economic growth, the Irish GDP in 2000 was more than 2.5 times larger than in 1980 while the average growth in the EU has been around 40 % from the 1980 GDP value during the same time period.

Between the years 1980 and 1990, the general EU trend was weak de-linking. Denmark and the Netherlands had expansive re-linking with large increase in DMI figures. Only Germany has strong de-linking, but a very modest one – the decrease in material flows measured by DMI between the years 1980 and 1990 was only 0.2 % from the 1980 value. Between the years 1990 and 2000, the general EU trend turns slightly into strong de-linking. In the 1990s, many countries continued weak de-linking. From expansive re-linking, Denmark turned to weak de-linking and the Netherlands to strong de-linking. On the other hand, Belgium and Portugal turned from strong de-linking to slightly expansive re-linking.

The linking trends of large EU member countries such as Germany, France, the UK and Italy, tends to dominate the general EU trend, i.e. weak de-linking in the 1980s, strong de-linking in the 1990s and weak de-linking during the whole research period 1980-2000. However, the variation between different member countries is quite large from strong de-linking to expansive re-linking. This suggests a need for benchmarking policies and incentives for advancing sustainability in the EU.

Table 1. *Changes in GDP per capita, direct material input (DMI) per GDP, DMI and DMI per capita in the European Union, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

	ΔGDP per capita (% of 1980 value)			Δ(DMI/GDP) (% of 1980 value)			ΔDMI (% of 1980 value)			ΔDMI per capita (% of 1980 value)		
	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000
Austria	20.8	22.2	43.0	-14.5	-9.3	-23.7	5.7	11.4	17.1	3.3	5.7	9.0
Belgium[1]	20.3	25.5	45.9	-1.8	0.6	-1.1	13.7	27.4	41.1	16.5	24.0	40.5
Denmark	21.8	29.5	51.3	4.2	-22.9	-18.7	27.3	0.8	28.1	26.9	-3.9	23.0
Finland	30.9	24.5	55.4	-14.5	-17.4	-31.9	16.8	-2.1	14.7	11.9	-6.1	5.9
France	19.9	18.8	38.7	-19.0	-13.3	-32.3	2.3	0.4	2.7	-2.8	-3.2	-6.0
Germany	18.1	8.3	26.4	-16.7	-9.0	-25.7	-0.2	-1.2	-1.5	-1.6	-4.4	-6.1
Greece	10.3	22.8	33.1	-0.2	5.0	4.8	16.0	36.8	52.8	10.1	29.4	39.5
Ireland	36.6	122.9	159.5	-23.5	-31.2	-54.7	7.8	23.4	31.2	4.6	13.0	17.6
Italy	23.8	17.7	41.5	-15.6	-9.2	-24.8	5.0	3.7	8.8	4.5	1.9	6.4
Netherlands	14.4	28.3	42.7	2.1	-30.2	-28.1	23.5	-8.0	15.5	16.9	-14.2	2.6
Portugal	29.5	27.5	57.0	-15.5	5.1	-10.4	10.8	33.3	44.1	9.4	31.3	40.7
Spain	29.3	32.3	61.6	-8.6	-1.0	-9.6	22.7	31.4	54.2	18.1	27.9	46.0
Sweden	18.5	14.9	33.4	-13.8	-9.8	-23.7	5.2	3.5	8.7	2.1	-0.3	1.8
United Kingdom	26.3	20.5	46.8	-12.5	-16.1	-28.6	13.0	-1.8	11.3	10.6	-5.7	4.9
EU-15	21.6	19.0	40.6	-15.6	-13.9	-29.5	5.3	-0.3	5.0	2.6	-3.5	-0.9

[1]Luxembourg included in the figures of Belgium.

The situation changes in some countries when changes in DMI per capita values are considered instead of changes in absolute DMI values presented above (see Table 1). When the whole period 1980-2000 is considered, EU as a whole and France "shift" to strong de-linking instead of weak de-linking. The same happens to France in both shorter periods as well, and for Denmark and for Sweden between the years 1990 and 2000. In general, DMI per capita figures give somewhat better results than absolute DMI figures because the increasing population counterbalances the increase of material flows.

Table 2 describes the linking process for material flows measured by domestic material consumption (DMC), and public and private consumption (PPC) in the EU-15 countries. Again, in the columns of Δ(DMC/PPC), ΔDMC and ΔDMC per capita, the color of the cell indicates the degree of the linking process. As in Table 1, also here blue refers to strong de-linking, white to weak de-linking, and red to expansive re-linking. Strong and weak re-linking as well as recessive de-linking are lacking because public and private consumption (PPC) has been clearly growing in the EU member countries during the relatively long time periods.

With this combination of indicators for material flows and economic performance, the general trend in the EU has been strong de-linking during the whole research period 1980-2000. The EU member countries fall into two groups. To the strong de-linking group belong France, Germany, the Netherlands, Sweden and the United Kingdom. To the weak de-linking group belong Austria, Belgium, Denmark, Finland, Greece, Ireland, Italy, Portugal, and Spain.

Between the years 1980 and 1990, weak de-linking; i.e. growing PPC and growing DMC but decreasing material intensity of consumption (DMC/PPC), was the general EU trend. Only three countries reached strong de-linking in the 1980's, i.e. France, Germany and Sweden, all with a very modest decrease in domestic material consumption between the years 1980 and 1990. Denmark and the Netherlands showed expansive re-linking during the same period with over 20 per cent increase in DMC from the 1980 value. Between the years 1990 and 2000 the general EU trend turned to strong de-linking, with a modest decrease in domestic material consumption. France, Germany and Sweden continued their strong de-linking trends from the 1980s, and several countries such as Belgium, Finland, Italy and the UK turned from weak to strong de-linking. Denmark and the Netherlands even shifted very clearly from expansive re-linking to strong de-linking. Austria, Ireland, and Spain continued weak de-linking, but Greece and Portugal turned with large increases in domestic material consumption from weak de-linking to expansive re-linking in the 1990s.

The analysis considering the whole research period provides better looking results, when domestic material consumption (DMC) per capita is used instead of pure DMC figures. The general EU trend between the years 1980 and 2000 shifts from weak to strong de-linking, and the same happens to four member countries: Austria, Belgium, Finland and Italy. All these countries had quite modest increase in pure DMC figures between the years 1980 and 2000, and population growth in these countries results a modest decrease in per capita DMC figures. For example, in Finland a 7.6 per cent increase of DMC in 1980-2000 equals a 0.6 per cent decrease in DMC per capita. Between the years 1980 and 1990, Austria and Ireland turn from weak to strong de-linking if DMC per capita is used instead of DMC. The period 1990-2000 remains quite similar, not depending on the choice of DMC or DMC per capita. Only Austria turns from weak to strong de-linking if per capita figures are used instead of pure DMC values.

Table 2. *Changes in public and private consumption (PPC), PPC per capita, domestic material consumption (DMC) per PPC, DMC and DMC per capita in the European Union, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

	ΔPPC per capita (% of 1980 value)			Δ(DMC/PPC) (% of 1980 value)			ΔDMC (% of 1980 value)			ΔDMC per capita (% of 1980 value)		
	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000	1980-1990	1990-2000	1980-2000
Austria	23.4	26.5	49.9	-19.7	-16.9	-36.6	1.4	0.7	2.1	-0.9	-4.0	-4.9
Belgium[1]	14.4	22.5	36.9	-8.4	-21.5	-29.8	6.2	-5.6	0.6	4.8	-8.7	-3.9
Denmark	12.2	23.1	35.3	8.0	-34.0	-26.0	21.6	-17.2	4.3	21.1	-21.0	0.1
Finland	32.3	20.5	52.8	-14.8	-20.1	-35.0	17.5	-9.9	7.6	12.7	-13.3	-0.6
France	20.3	19.6	40.0	-21.4	-15.9	-37.3	-0.4	-3.6	-4.0	-5.4	-6.8	-12.2
Germany	14.5	12.2	26.7	-15.9	-15.6	-31.5	-2.3	-6.6	-8.9	-3.7	-9.5	-13.2
Greece	21.8	22.9	44.7	-15.2	9.8	-5.4	8.9	41.1	50.0	3.4	33.6	37.0
Ireland	14.6	61.6	76.3	-13.0	-24.1	-37.1	2.8	20.8	23.6	-0.3	11.1	10.8
Italy	28.1	19.6	47.7	-19.8	-13.6	-33.4	3.2	-2.6	0.6	2.7	-4.3	-1.6
Netherlands	5.4	25.2	30.6	7.8	-43.8	-36.0	20.1	-26.0	-5.9	13.6	-30.0	-16.4
Portugal	28.2	33.6	61.9	-17.9	1.9	-15.9	6.7	32.7	39.4	5.3	30.7	36.1
Spain	27.7	31.1	58.9	-7.7	-3.8	-11.5	22.5	25.9	48.4	18.0	22.6	40.6
Sweden	13.9	15.0	28.9	-16.1	-14.5	-30.6	-1.5	-3.0	-4.5	-4.4	-6.2	-10.6
United Kingdom	29.5	23.9	53.4	-15.1	-24.0	-39.1	12.3	-13.3	-1.0	9.9	-16.5	-6.6
EU-15	21.2	20.2	41.4	-15.6	-15.8	-31.5	4.9	-2.2	2.7	2.2	-5.3	-3.1

[1]Luxembourg included in the figures of Belgium.

When the analysis with DMI (and DMI per capita) and GDP per capita is compared to the analysis with DMC (and DMC per capita) and PPC per capita, some significant differences reveal themselves. Let's view the results from the whole research period 1980-2000 from this perspective with absolute changes in material flows. Generally speaking, the results with DMC and PPC are clearly better from the environmental point of view than the results with DMI and GDP figures. With DMC and PPC, five countries (France, Germany, the Netherlands, Sweden and the UK) had strong de-linking, while only Germany had strong de-linking with DMI and GDP. With per capita figures, strong de-linking has occurred even in nine countries in the case of DMC and PPC, but in two countries only in the case of DMI and GDP. The Mediterranean countries Greece, Portugal and Spain have large increase in both material flow indicators with only small differences, while in many other countries such as Belgium and Denmark the difference is quite large.

5. RESULTS FROM THE EKC ANALYSIS

The de- and re-linking analysis gives a broad overall picture of the economic growth from the point of view of ecological sustainability. The results from this analysis would already allow the drawing up of some policy implications for the EU. However, in order to better understand the policy situation, the analysis must be deepened and made more comprehensive. There is a need to find bottlenecks and provide more quantitative information about the effects behind the de- and re-linking processes. A first step into this direction can be taken by analyzing the environmental Kuznets curves (EKC) for the EU member countries.

As mentioned above, a weak and strong version of the EKC can be differentiated. Fig. 3 and Fig. 4 present the weak EKC for the EU as a whole using the two different variable sets mentioned above: direct material input (DMI) per capita and GDP per capita in Fig. 3 and domestic material consumption (DMC) per capita and public and private consumption (PPC) per capita in Fig. 4.

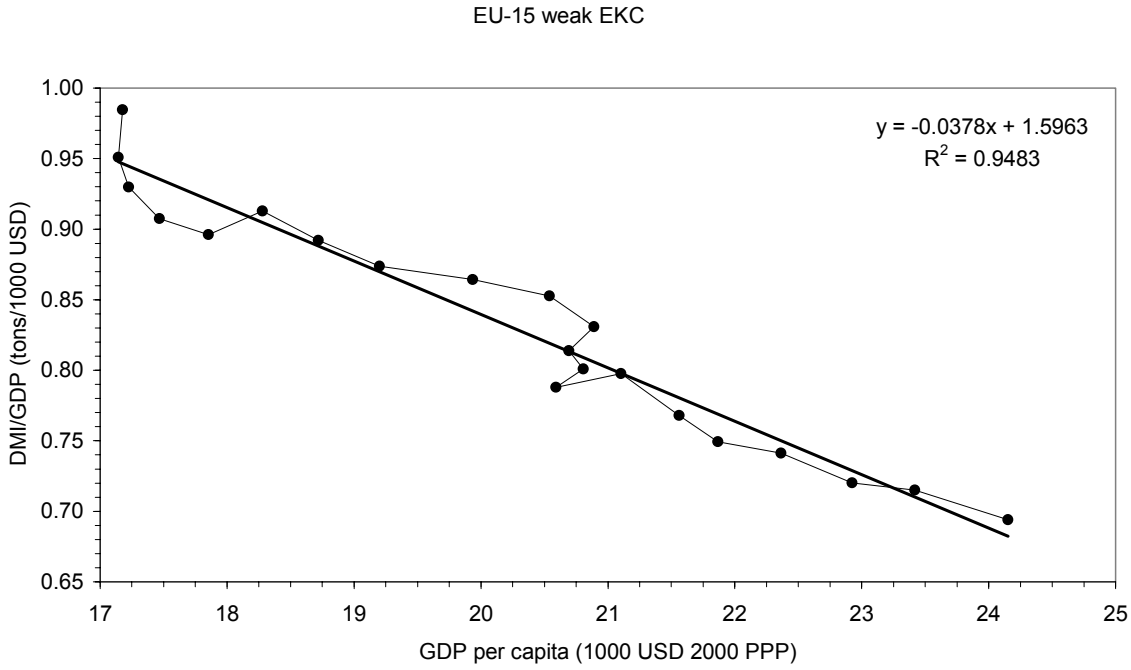

Figure 3. *Weak environmental Kuznets curve for direct material input (DMI) and GDP in the EU as a whole, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

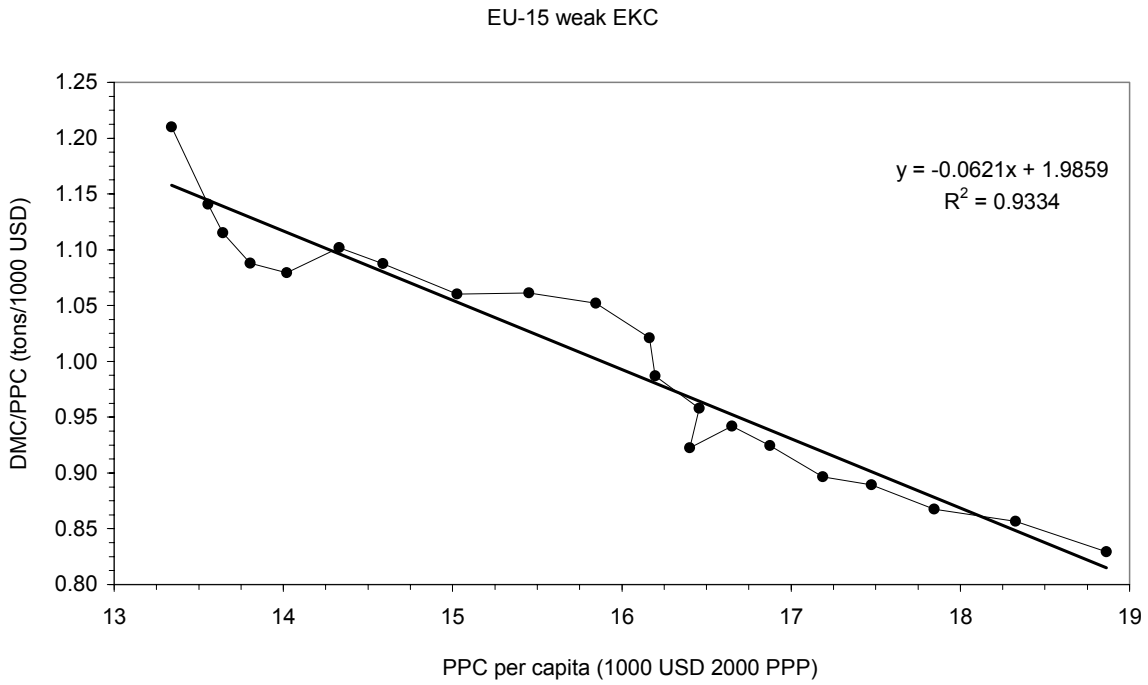

Figure. 4. *Weak environmental Kuznets curve for domestic material consumption (DMC) and public and private consumption (PPC) in the EU as a whole, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

The comparison of Fig. 3 and Fig. 4 shows that the material intensity of DMC/PPC is slightly higher than DMI/GDP. In addition to the fact, that GDP is larger than PPC, direct material input (which includes domestic extraction added by imports) is larger than DMC (which includes DMI subtracted by exports). In the EU as a whole, the volume of material imports clearly exceeds the volume of material exports. This is the situation in almost all EU member countries, only in a few countries such as Greece, Sweden and the United Kingdom, material imports and exports measured in weight are roughly at the same level (Eurostat, 2002).

Generally speaking, Fig. 3 and Fig. 4 show that the EU as a whole seems to already be on the right hand side of the inverted U-shaped EKC. The development paths in different countries, however, are not similar. With both variable sets, a continuous decreasing trend can be identified in many EU member countries such as Austria, Finland, France, Germany, Ireland, Italy and the UK. Moreover, the recession in the early 1990s, as well as the fast economic growth in the late 1980s, caused some interference in the development path. During some years in the early 1990s, many countries faced a decreasing GDP per capita and usually the material intensity also kept decreasing. After the recession, material intensity in some countries temporarily increased, and this development causes interference in the weak EKCs in the EU as a whole as well as in many member countries such as Finland and Sweden in the years 1991-95. Some countries such as Belgium, Denmark and the Netherlands, the shape of the weak EKC is close to the inverted U-shape, i.e. material intensity has first increased in the early 1980s and started decreasing not until the late 1980s or early 1990s. On the contrary, the Mediterranean countries Greece, Portugal and Spain have had more or less increasing trends in material intensity of production. However, the general downward trend in the EU seems to be quite continuous, because there are only a few exceptions in the yearly decreasing material intensity.

Fig. 5 shows the strong EKC for the EU as a whole using direct material input (DMI) per capita and GDP per capita, and Fig. 6 shows the strong EKC for the EU with domestic material consumption (DMC) per capita and public and private consumption (PPC) per capita.

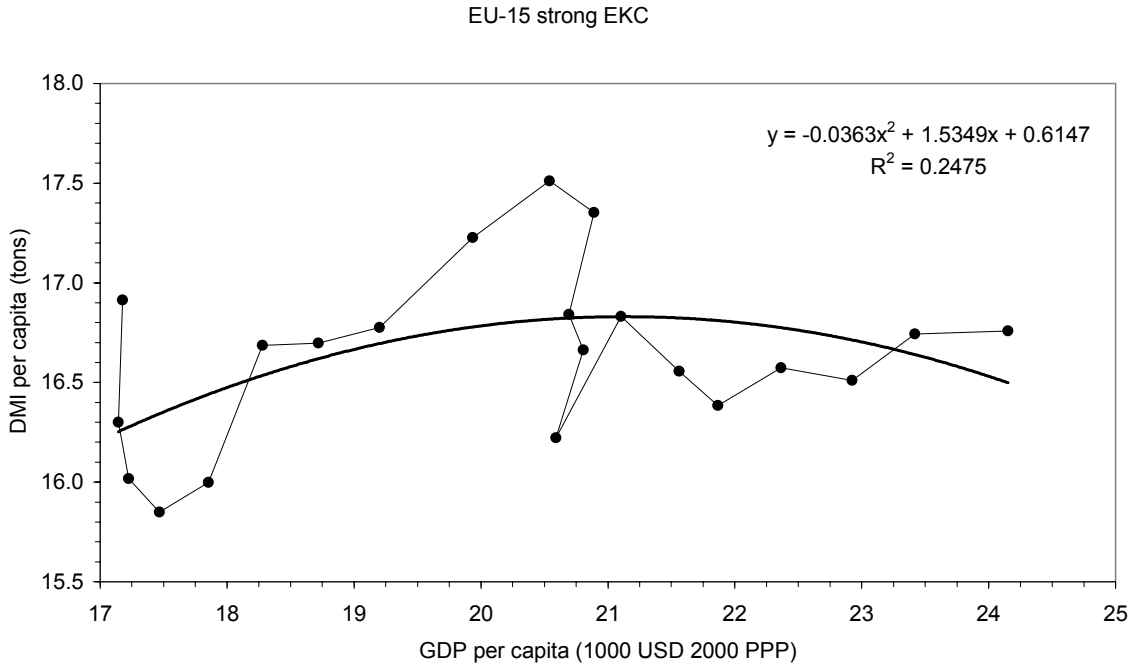

Figure 5. *Strong environmental Kuznets curve for gross material product (GMP) per capita and GDP per capita in the EU, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

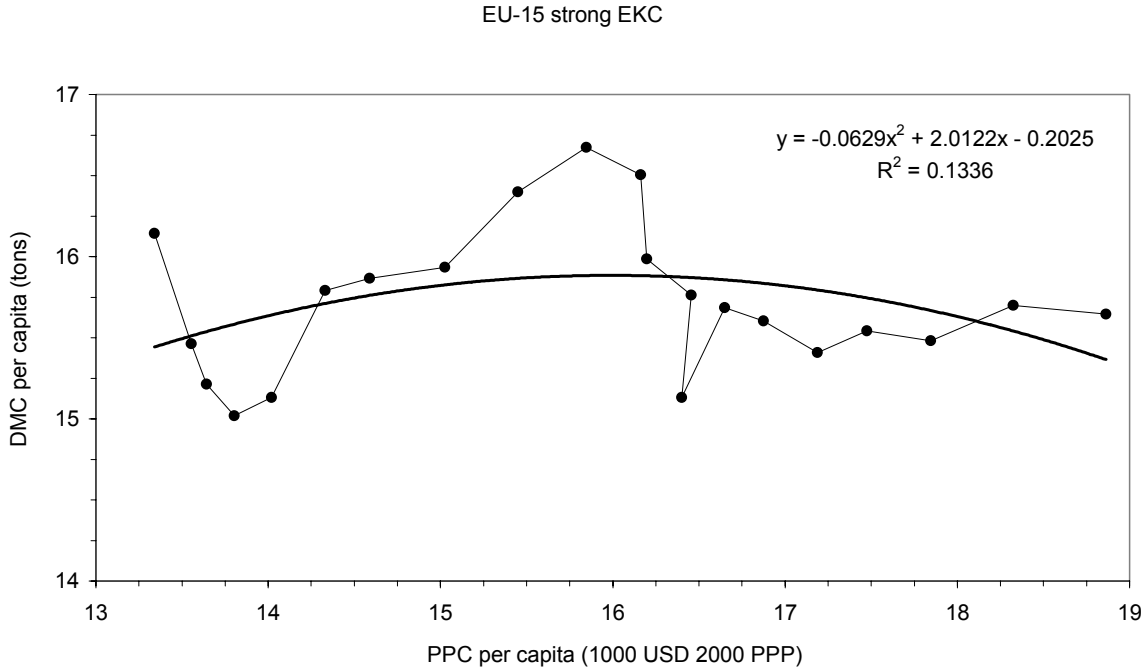

Figure 6. *Strong environmental Kuznets curve for domestic material consumption (DMC) per capita and public and private consumption (PPC) per capita in the EU, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

The general trend of direct material input (DMI) per capita in the EU was weak de-linking in the analysis presented above. Fig. 5 and Fig. 6 indicate that the EU has been turning to the right hand side of the inverted U-shaped EKC, but in the late 1990s the decreasing trend in

absolute material flows has stagnated and even turned to increase again. The situation is somewhat similar with both indicator sets used in the analysis.

Relatively good examples of an inverted U-shaped EKC in the case of DMI per capita include the Netherlands (Fig. 7) and Germany (Fig. 8) and in the case of DMC per capita Denmark (Fig. 9) and the United Kingdom (Fig. 10).

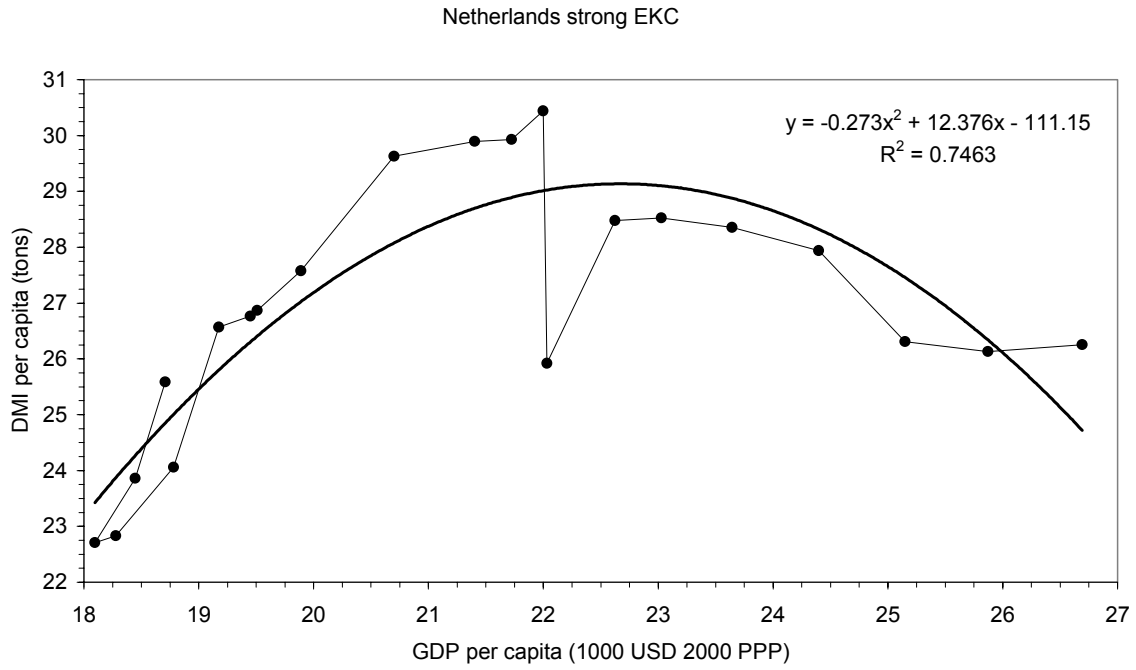

Figure 7. *Strong environmental Kuznets curve for direct material input (DMI) per capita and GDP per capita in the Netherlands, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

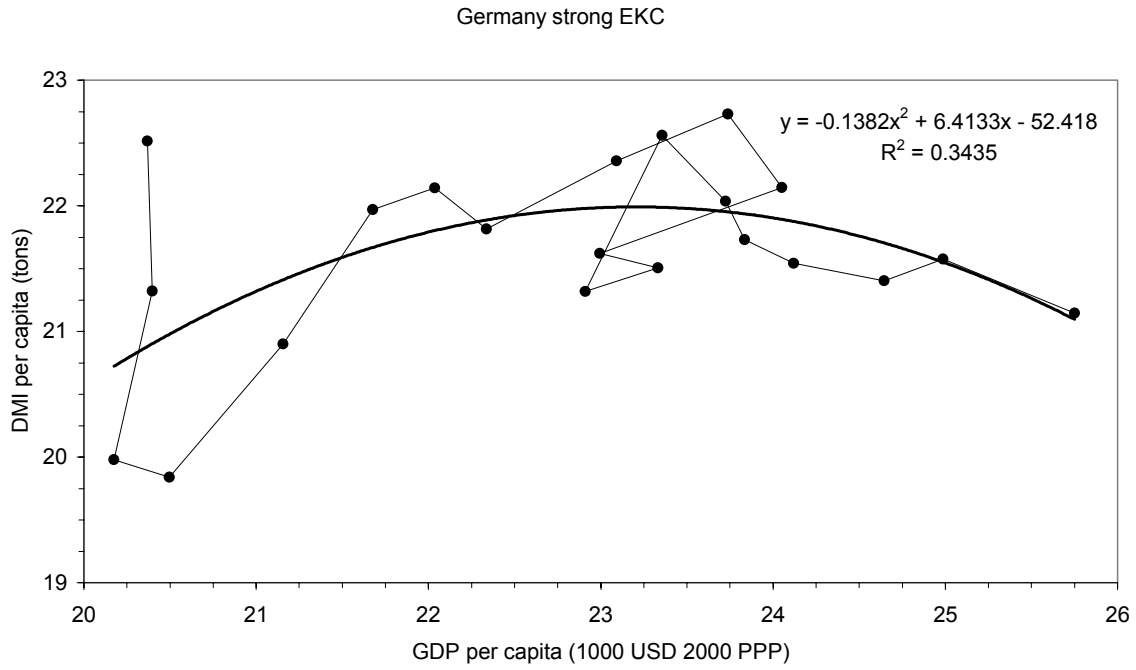

Figure 8. *Strong environmental Kuznets curve for direct material input (DMI) per capita and GDP per capita in Germany, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

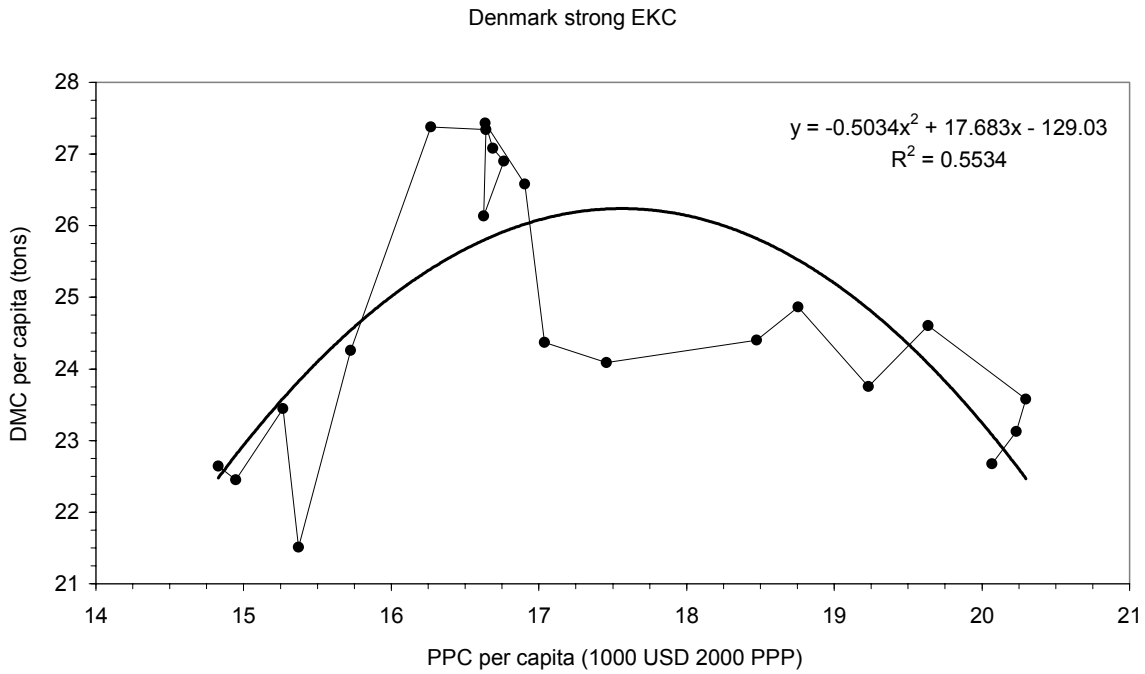

Figure 9. *Strong environmental Kuznets curve for domestic material consumption (DMC) per capita and public and private consumption (PPC) per capita in Denmark, 1980-2000. Data sources: Eurostat, 2002, OECD, 2002.*

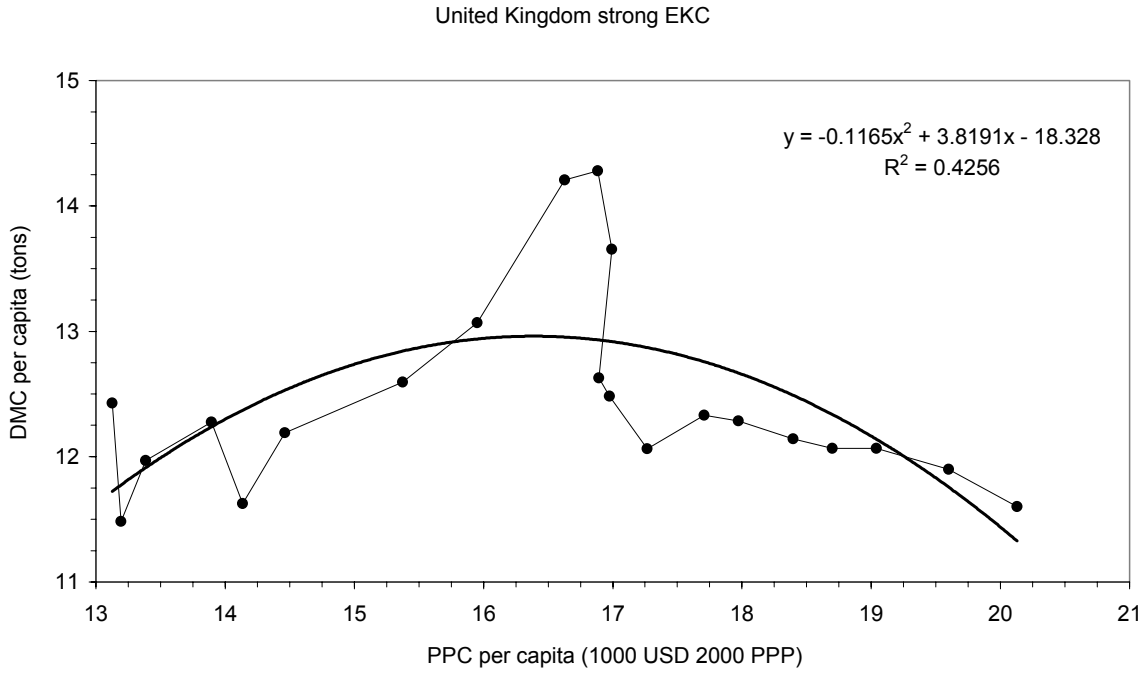

Figure 10. *Strong environmental Kuznets curve for domestic material consumption (DMC) per capita and public and private consumption (PPC) per capita in the United Kingdom, 1980-2000. Data sources: Eurostat, 2002 and OECD, 2002.*

Some EU member countries show an increasing trend in material flows also in the 1990s. Examples of such countries include Austria, Belgium and the Mediterranean countries.

6. DISCUSSION

In this article, we have presented some new concepts and definitions for the de-linking and re-linking as well as environmental Kuznets curve (EKC) theory. In previous literature the concepts of relative (weak) de-linking, absolute (strong) de-linking, and re-linking have been presented. In this article, we offered a more detailed conceptual definition for the different degrees of the de-linking and re-linking process and defined a weak and strong version of the EKC. The main contribution of this article is to operationalize these new concepts for the first time and analyze the linking process in the EU and its member countries.

On the basis of this study, we can note that in the European Union, a typical linking trend in the material flows seems to be weak de-linking. In the case of direct material input (DMI), only Germany showed a trend of strong de-linking. The shape of the strong EKC in this German case does not indicate that this would be a development path even for this country. Also in the case of domestic material consumption (DMC), the general EU trend between the years 1980 and 2000 has been weak de-linking. In general, the results with this indicator are somewhat more positive as with the “GDP-equivalent” direct material input (DMI). With DMC, five of the 15 EU member countries have a strong de-linking trend. With reference to the time period studied (1980-2000) it must kept in mind that material use has been increasing before the year 1980, and thus the results of the linking analysis can be quite sensitive to the choice of the base year and the time period in general. On the basis of other studies we can conclude that the de-linking has been mostly relative, i.e. the weak one, and the observed phases of strong de-linking are more or less temporary in nature.

The analysis of material flow EKCs shows that material flow intensity has decreased in all EU member countries during the period 1980-2000, and the exceptions from this trend are quite rare – they are mainly found in the Mediterranean countries, in other countries the exceptions are related to the phase after the economic recession in the early 1990s. The analysis of strong EKC shows that a few countries have a relatively clear inverted U-shaped EKC, but the decreasing trend in material flows or material flows per capita cannot be expected to be a continuous one in any country.

The minimum policy implication of the empirical findings presented in this study is that there is a need to deepen the material flow analysis at the EU level, in order to diagnose the most important bottlenecks where the improvements in material flow intensity should be enhanced by the EU.

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FINLAND FUTURES RESEARCH CENTRE

Turku School of Economics and Business Administration

Rehtorinpellonkatu 3
FIN-20500 Turku
Tel. +358 2 481 4530
Fax +358 2 481 4630

Korkeavuorenkatu 25 A 6
FIN-00130 Helsinki
Tel. +358 9 6227 0472
Fax +358 9 6227 0081

Kuninkaankatu 34 B 31
FIN-33200 Tampere
Tel. +358 3 223 8363
Fax +358 3 223 8363

E-mail: firstname.lastname@tukkk.fi

http://www.tukkk.fi/tutu

TURUN KAUPPAKORKEAKOULU
Turku School of Economics and Business Administration
FINLAND FUTURES RESEARCH CENTRE