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Corso Ercole I d'Este, 44 – 44100 Ferrara

Quaderno n. 12/2005

March 2005

Waste Indicators, Economic Drivers and Environmental Efficiency: Perspectives on Delinking and Empirical Evidence for Europe

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WASTE INDICATORS, ECONOMIC DRIVERS and ENVIRONMENTAL EFFICIENCY

Perspectives on Delinking and Empirical Evidence for Europe[•]

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ABSTRACT

The paper provides a critical assessment on the environmental efficiency of economic growth, from a methodological perspective. The general framework for the decoupling analysis is first presented, with a specific focus on waste resource indicators. Current experiences of de-linking analysis are discussed and commented. The environmental Kuznets curves arena is then addressed as a natural extension of any analysis on the environmental efficiency of economic growth. Some critical issues and research suggestions are discussed. We finally provide preliminary empirical evidence on environmental Kuznets curve for waste indicators using a European countries dataset. Empirical evidence on packaging and municipal waste shows that decoupling seems to occur only on a relative basis. No significant evidence on an inverted U-shape is found for both waste indicators. Europe appears still lagging behind in reaching the critical turning point concerning the relationship between waste and consumption indicators. The lack of explicit targets referring to waste prevention at source, in addition to recovery/reuse/recycling goals, may be the primary reason behind the absence of a strong Delinking process in the case of primary waste sources. The applied panel investigation, though informative since it is focussed on a homogenous Regional area, indicates the need of further work, exploring the occurrence of delinking processes relatively to specific materials and/or focussing on specific countries.

Jel: C23, Q38, Q56

Keywords: Decoupling, Waste Indicators, Economic Drivers, Kuznets Curves, Environmental Efficiency

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[•] The work derives from, but it has not to be considered part of, a European Research Project on Methodology and indicators to measure decoupling, resource efficiency, and waste prevention. CERIS-DSE is involved through the European Topic Centre on Waste and Material Flows and is responsible of economic methodology and evaluation issues. The paper findings and opinions are sole responsibility of the authors.

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1. Introductory framework: a general framework for decoupling analysis

1.1. Driving forces, efficiency, and scale of environmental impact

The general relationship between economic driving forces, efficiency gains in the use of resources (or 'decoupling') and the scale of environmental impacts can be illustrated by referring to the IPAT model. Since its original formulation by Ehrlich (1971), the model, in different versions, has been extensively used for the analysis of global resource problems. As a description of the relationship between economic driving forces and environmental impact or pressure indicators, the model is very flexible.

In general, the model expresses total impact I (in our case, for example, the consumption of a material, or the total waste generated) as the (multiplicative) effect of population level (P),"affluence" (A) as measured by GDP per capita, and the impact per unit of economic activity, the latter taken as an indicator of the state of technology (T):

$$I = P \times A \times T$$

where:

I = Impact (e.g. waste production)

A = Affluence, i.e. GDP/P

T = Technology, i.e. I/GDP

and therefore:

$$I = P \times GDP/P \times I/GDP$$

In the traditional formulation presented above, it is an accounting identity suitable for statistical decomposition exercises, aimed at identifying the *relative* role of A, P, and T in the observed change of I over time and/or across countries. Obviously, the level of the three drivers must be suitable for the indicator of Impact/Pressure which is being analysed. By a small transformation, it can be expressed also as:

$$I/P = GDP/P \times I/GDP$$

or the Impact per capita as the result of the two drivers represented by GDP per capita and the Impact per unit of GDP.

The meaning of the Population and Affluence drivers can be easily interpreted: they drive (multiplicatively) the demand/consumption of the resources or environmental Impact/Pressure considered. As their level and growth rates are generally positive but very different in different countries and time, they 'explain' a large part of both the level and the variability of the Impact in different times and across countries/economies.

The meaning of the T variable is less immediate but critically important for both general and specific explanations of the observed Impact. Being expressed by the ratio of Impact to GDP, T is an 'intensity-of-use' measure, which represent how many unit of Impacts (e.g. natural resource consumption or emissions) are needed in the economy (national, or local, or global) in a certain year for producing one unit (i.e. one dollar) of GDP. It is therefore an indicator of 'efficiency' in the use of resources and the environment, or (if its reciprocal GDP/I is taken) an indicator of 'resource productivity' in terms of GDP. Therefore, it can be though as the most compact way for expressing the state of the technology of that economy/region at a certain point of time in terms of environmental impact. Its *change* over time (and its variability across countries) thus expresses the change (and the country variability) of the environmental efficiency, or the resource productivity, or the state of technology in terms of resource/environment use. It is actually a 'decoupling' indicator which measures to what extent the impact/pressure grows less than the economic driver.

Two main points can be highlighted.

(1) Absolute decoupling can be represented by a decrease of the variable I over time. Relative decoupling is generally defined as an environmental impact growing less than its economic-activity driver, and it is represented by a decreasing T over time. Therefore, inside the general IPAT framework the role and the limitations of decoupling analysis clearly emerges in a very simple way. Relative decoupling can be very strong (i.e. rapidly and strongly decreasing T over time) but absolute decoupling might not take place (i.e. I is increasing) because efficiency in the use of the resource or the environment is not enough to compensate for the effect of other drivers, i.e. Population and GDP per capita. But also the opposite can be true in the short run: in advanced economies there can be phases in which, with a stable Population, adverse business cycle may push down the Impact variable (absolute decoupling) because of depressed GDP growth, while T, or the Impact per unit of GDP, is increasing or not diminishing (no relative decoupling). This has been the case for some Impacts in the early years of transition in Eastern European countries and can be very important when short time series cannot allow for clearly detecting sound and stable trends of the indicators (which may be the case with waste data). All in all, the so called *'absolute' decoupling, which refers to the scale of the impact, and 'relative' decoupling, which refer to efficiency in using resources, should be always considered together in the appraisal of the evolving state-of-the-environment*.

(2) The IPAT framework is an accounting model useful for attributing a relative role to economic and technological drivers but it is neither a true behavioural model nor a deterministic model. This is also the case with decoupling indicators, which cannot be considered an explanation but, instead, should themselves be "explained". The IPAT framework actually takes the drivers as separate and *independent* variables in an arbitrary way. In the medium-to-long run dynamics of economic systems, *each* of the drivers as well as the impact/pressure indicators can depend the one from each other. For example, population dynamics (P) depends on GDP per capita to some extent (and vice versa), the state of Technology of an economy depends on GDP (and vice versa), and so on. Therefore, the IPAT frameworks and the estimated role of different drivers are only the starting points for a deeper economic analysis. In this regard, also the so-called 'Environmental Kuznets Curve' (EKC) is a heuristic empirical regularity. In its general formulation, the EKC is an empirical relationship between two drivers of the IPAT model, i.e. between the T or I/GDP (efficiency or decoupling indicator) and the level of GDP or GDP per capita. It is expected to show the extent to which the efficiency in the use of resources changes at different level of economic development. In particular, based on empirical observation over time series and cross-country data, it is expected that T is increasing at low levels of GDP/P, then it should achieve a peak at intermediate levels of GDP/P, and then it is should decrease (i.e. there is decoupling) at high levels of GDP/P. But it can just be an empirical regularity and then it may explain little. Furthermore, it could support the *wrong deterministic suggestion* by which economic development automatically drives to environmental efficiency and then it is the ultimate and only solution to reduce environmental impact. But we have seen that GDP or GDP/P growth also implies a 'scale effect' on I, the Impact/Pressure variable. A decreasing requirement of Impact and or Pressure per unit of GDP (or more specific economic drivers) is obviously suggesting that *something positive is taking place but is ask for an explanation, which can be found in the working of markets (prices), technologies, and policies*.

1.2. Evidence on increasing efficiency in the use of resources and the environment

Growing evidence suggests that advanced economic systems operate with a decreasing intensity of energy and materials per unit of output. For energy and materials, these trends can be observed over the very long run. Phases of emerging scarcity of "productive" natural resources stimulated significant demand and supply responses that, at the cost of economic turbulence and difficult adjustments, ultimately entailed extensive efficiency gains in the use of resources. The historical regularity of these processes suggested the idea that resource-use efficiency and de-materialisation are the result of technological innovation which responds to scarcity 'revealed' by resource prices and, in the absence of resource markets, by public policies.

In countries of earlier industrialisation, energy consumption per unit of GDP is already decreasing since the end of 19th century (United Kingdom) or since the 1920s and 1930s (United States, Germany and France). During and after the 1970s, these trends spread to all the advanced countries and to some less developed countries. Shocks on energy and commodity prices of the 1970s stimulated energy efficiency, resource saving and innovation policies (Rosenberg 1994, Martin 1990). A huge amount of evidence is available on decreasing energy intensity since then. In Germany, for example, real GDP increased by 50% from 1970 to the early 1990s while energy consumption remained nearly constant.

Similar developments took place in the case of industrial materials. In the mineral and metal sector, for example, where metals with increasing and decreasing intensity of use (ratio of consumption to GDP) usually tend to coexist, the 1970s represented a break point and a declining intensity of use tended to generalise to almost all the metals (Labson and Cropton, 1993). Even in this case structural change, with a significant delocalisation of traditional heavy industries to emerging countries, and technological innovation worked together (Tilton 1991).

In general, the factors behind macro-level decoupling between economic growth and resources can be: (a) market factors, i.e. change in relative prices of basic commodities; (b) technological innovation at the macro and micro level, including structural changes of the sectoral composition of the economy and 'industry migration'; (c) public policies. The three can be dynamically interrelated.

However, the actual working of these mechanisms is rather complicated and leaves rooms for uncertainties on interpretation of decoupling/efficiency process. For example, the above-mentioned evidence suggest that resource price shocks of the 1970s have been the main cause of developments towards 'dematerialisation', a 'lighter' economic structure, and the intensification of R&D and innovation (OECD 1992). However, other analyses claim that energy and material price shocks have played a marginal role in the observed changes (Abramowitz 1991; Toman 1993). Actually, in the enormous amount of works on energy prices and efficiency produced during the last 30 years, we cannot find definitive conclusions about the role of price mechanisms.

Lagged effects and interactions concerning prices, policies, and technological innovations can partly explain the uncertainties in interpretation. The attainment of a higher energy and material efficiency typically calls for investment in capital goods. Therefore the adjustment to a relative price change may result very sluggish and even very efficient technologies already available can be introduced slowly.

Public policies have had also a significant role in filtering the effects of international price shocks, supporting technological changes, and, on the negative side, subsidising energy- and material-intensive sectors. Fiscal instruments have been widely used and, in the industrial countries, energy products are the target of an array of taxes. Although they often reflect tax revenue objectives, these instruments are aimed at energy saving, energy efficiency and the change of sources mix.

2. Materials and waste in the institutional reports on decoupling

2.1. OECD decoupling indicators

OECD recently published a document titled "Indicators to measure decoupling of environmental pressure from economic growth" (OECD, 2002), which contains a very comprehending analysis of decoupling

indicators for a great number of environmental issues. The purpose of the analysis was also one of highlighting the factors that have contributed to the reduction (or to the increase) of environmental pressure.
In the OECD analysis, decoupling indicators are integrated into the framework of the Driving-Pressure-State-Impact-Response model, and, more specifically, they refer to the link between indicators of pressure and that expressing driving forces, which are the two first elements of the scheme. These indicators are distinguished in two main categories: economy-wide indicators expressing trends for decoupling at national level, and indicators designed for specific sectors. The environmental issues covered are climate change, air pollution, water quality, waste management, material use and natural resources.
For the waste sector, the decoupling indicators designed and calculated by OECD are four:

- Municipal waste going to final disposal (MWFD) versus private final consumption (PFC)
- Amount of glass not collected for recycling versus PFC
- Amount of paper/cardboard not recycled versus GDP
- Waste generated by manufacturing industry versus manufacturing value-added

In the analysis, waste appears in three different contexts. First of all, decoupling is measured for municipal waste, in connection to final consumption as driving force (first two indicators). This is because municipal waste implies a significant environmental pressure, depending on how it is managed (landfill disposal or incineration).
The third indicator is a measure of resource efficiency, and it is in particular referred to the depletion of forests. The amount of not recycled paper does not express a pressure on the environment, but it indirectly measures progress made towards a sustainable use of natural resources. This objective passes necessarily through recycling and re-use of materials. Waste should in fact be viewed and analysed in this double perspective: one related to its bad impact on the environment, which is especially associated to waste management and treatment, and the other reflecting resources depletion and resource intensity in production and consumption included in the concept of waste.
For the first indicator, the OECD survey shows that in OECD countries, there has been a relative decoupling of waste going to final disposal from private consumption since 1995. The amount of waste increased by 5%, whereas PCF by 15%. Some European countries also recorded an absolute decoupling.
We note that the approach is consumption-based rather than GDP-based. Private final consumption is considered to be the most relevant factor affecting the production of municipal solid waste, and for this reason it has been chosen as denominator of the ratio. In order to understand cause-effect chain of events moving decoupling indicators, OECD also proposes a decomposition of this first indicator in intermediate indicators, as follows:

Primary Indicator = Intermediate indicator 1 * Intermediate indicator 2

In general, this step helps to distinguish among all the variables influencing decoupling changes over time. The decomposition proposed in this particular case allows distinguishing between total amount of municipal waste generated (MW) and the fraction going to final disposal:

Amount of waste going to final disposal (MWFD)/Private final consumption (PFC)= MWFD/MW * MW/PFC

This simple level of disaggregation makes it possible to appreciate that the final level of this decoupling indicator is determined by three main factors: the total amount of waste generated, the percentage not recycled, and the amount of final consumption. Thanks to this distinction, it is possible to understand what is the real driver for decoupling, and this assessment can be used also to evaluate policy effects especially for waste management and recycling policies.

The analysis of data of 21 OECD Member countries show that the portion of waste going to final disposal decreased over time of about 65 to 62% during 1995-98. This decline is though the responsible for decoupling for a number of the countries considered.

Another meaningful decomposition proposed and calculated by OECD is the following:

Amount of waste going to final disposal (MWFD)/Population (POP)= MWFD/PCF*PCF/POP

Population is another important issue contributing both to the generation of municipal waste and to the amount of private final consumption. The examination of changes these ratios over time of makes it possible to understand how much of the decoupling effect (where it occurs) is determined by changes in population (scale) or in consumption per capita or in production of waste going to disposal per unit of consumption.

Changes over time can also be considered by referring to the decoupling factor, which is defined as follows:

(EP/DF) n/(EP/DF)n-1

where EP = environmental pressure

DF = driving force

n = year of reference

Decoupling occurs when decoupling factor value is between 0 and 1. Decoupling factors can be used in addition or in alternative to graphs showing time-series of both environmental pressures (MW or MWFD) and driving forces (final consumption or population).

The second decoupling indicator proposed is the amount of glass collected for recycling versus PFC. This is a ratio showing recycling propensity and it can be employed to measure improvements over time of separate collection of waste. In fact, it can be also used to perform "distance to target" in order to assess the achievement of policy goals concerning recycling and recovery of materials, whereas existing. Between materials recyclables, OECD selected glass because of the availability of data, but it is also possible to compose similar decoupling indicators for other and more damaging materials.

The third indicator takes account of recycling, but the context of application is that of resource use in the forestry sector. In this area, it is difficult to define a more appropriate indicator showing environmental pressure on forests versus an economic variable. A possibility could be that of considering biodiversity loss per volume of production, but this is unlike due to lack of data. The amount of paper and paperboard potentially ending up for final disposal per unit of GDP is instead taken as a measure of the growing demand for those goods, and it can be interpreted as a "proxy" for the pressure on forests. No decomposition is proposed in that case, but two "context indicator", providing information about the sustainability of the management of the resource base, accompanies the decoupling indicator.

The last decoupling indicator for waste suggested by OECD focuses on manufacturing processes, and it is strictly related to the concept of resource efficiency, the amount of waste generated by manufacturing industry versus manufacturing value added can in fact be interpreted as a partial measure of their resource

efficiency or productivity. The available data shows that no decoupling has occurred during the period 1990-97. No decomposition is proposed, although it is straightforward that the main factors influencing it are the overall industrial structure and the presence of clean and material-saving production processes and technologies. As for the choice of the denominator, it seem appropriate to use value added, because it is the main driving force behind manufacturing production of waste.
OECD work on decoupling environmental indicators (DEI) underlies the idea that decoupling indicators can be used to determine whether countries are "on track towards sustainable developments".

2.2. DEFRA Sustainable Consumption and Production Indicators

The second experience here considered is the report recently proposed by the British Department of Environment, Food and Rural Affairs (DEFRA/DTI, 2003). The U.K. Government is planning a long-term policy strategy heading for decoupling economic growth from environmental degradation and resource use in both production and consumption, for promoting the increase in material productivity and energy efficiency. In this context, DEFRA developed a package of indicators with the double purpose to measure past trends and to evaluate improvements over time.
First of all, the conceptual framework of DEFRA report directly comes from OECD assessment presented above. Decoupling indicators are in fact divided in three categories: economy-wide, parameters for resource use and sector-specific ones.
The first category displays indicators showing direct pressures on the environment (as in the OECD work) and among others, it comprehends the measure of household waste not recycled versus Final Consumption Expenditure. In DEFRA consultation paper it is proposed to employ, in conjunction to this one, another indicator showing commercial and industrial waste risings, in order to monitor the total amount of waste generated, from both sides of consumption and production. Due to lack of data, no comparison between the two waste streams was possible.
Indicators of resource use do not include waste but among the sectors related to sustainable consumption and production, a specific attention is given to households. The indicator for waste to be included in this category is however the same that the one used for the economy-wide evaluation. Decoupling indicators are presented as a line chart displaying household consumption expenditure growth rate from 1990 to 2001 in conjunction with waste not recycled, water consumption, GHG emissions and energy consumption. Those trends all show a relative decoupling.
For the buildings of indicators, in this phase DEFRA work closely depended on data availability. Actually a preference was given to organize and adapt existing indicators rather than to create new way to measure and monitor decoupling. In addition, their vision deeply reflected OECD approach on decoupling. The practical construction of decoupling indicators for waste was particularly affected from a lack of data availability, and that was probably the main reason preventing the usage of more analytical indicators. Also for what concerns the choice of driving forces to explain waste, they follow a consumption-based approach, instead of a GDP-based, according to OECD vision. The main difference is that DEFRA interprets decoupling indicators as a possible mean of evaluating policy effectiveness.

3. From Decoupling to the Environmental Kuznets Curve arena

The natural extension of the decoupling analysis based on the examination of correlation for pairs of variables is the Environmental Kuznets Curve (EKC) type of analysis. The EKC hypothesis is shortly that for many pollutants, an inverted U-shaped relationships between per capita income and pollution is documented;

concentration of a certain pollutant first increases with income/production, reflecting a scale effect, then start to decease more or less proportionally, de-linking from income. More specifically, the hypothesis predicts that the "environmental income elasticity" decreases monotonically with income, and that it eventually changes its sign from positive to negative thus defining a turning point for the inverted U-shaped relationship. The hypothesis does not originally stems directly from a theoretical model, but it has followed a conceptual intuition, though recent contributions have started showing the extent to which the Environmental Kuznets hypothesis may be included in formalised economic models[1].

EKC will be commented referring to the extensive literature developed over the last decade [2]. The focus is twofold: first, one aim is suggesting that the EKC framework is, under certain circumstances, a necessary step forward the simpler decupling analysis. Then, the weaknesses of the EKC empirical analysis will be commented. Building on that, we will finally provide preliminary empirical evidence on waste, an issue not addressed so far given an intrinsic lack of data in the European environment. In a simple decoupling analysis, policy issues enter in a qualitative way, as a complementary analysis of correlation indexes and trends. When a quantitative analysis of policies is deemed possible (when the framework is sufficiently defined in terms of variable interactions and the boundaries of the system are circumscribed), the EKC setting offers more robust ways of testing the ex post effectiveness of, say, waste policies. Waste policies are a sensitive and crucial issue since the EKC literature seems to share the view that waste indicators generally increase with income or other economic drivers (Cole, 2003, Borghesi, 1999)[3]. Relative decoupling could nevertheless be present. Empirical evidence has been scarce so far.

The EKC framework extends the basic decoupling reasoning, offering the possibility of modelling a multivariate analysis of the environment-income relationship. We refer to the EKC framework as the field of analysis which empirically studies, without a defined theoretical model in mind, but rooting on Kuznets seminal work and, whether or not an inverted U-shape curve is observed for pollutants and other environmental indicators. Even if EKC does not rely on a specific economic model, many theoretical assumptions, on the consumption and production sides, are implicitly tested within the EKC empirical context[4]. The main economic hypothesis revolving around the EKC setting are: (i) among the "negative effects" of income increase, we find a typical scale effect, and (ii) among the "positive effects" a composition effect concerning GDP economic activities, a technological effect, a preference-drive effect (environment being a normal/luxury good), a market-instruments driven effect (which is integrated with the wider policy effect).

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[1] See for example Andreoni and Levinson (2001) and Chimeli and Braden (2005).

[2] The reader may found a good critical survey in recent contributions by Stern (2004) and Dinda (2004).

[3] Rothman (1998) argues that relative or absolute delinking are more difficult to occur when we tackle "consumption-based" measures, such as CO_2 and waste, for which impacts are relatively easy to externalise or costly to control, rather than production based processes.

[4] See Kelly (2003) for a dynamic optimal-growth theoretical framework justifying the EKC model. The author finds that the EKC shape depends on the interplay between marginal costs and benefits of abatement. By assuming convexity on costs of emission controls and the environment as a normal good, the EKC is downward sloping at a given income level only if the marginal benefit of pollution control rise more than the marginal costs, but under not restrictive assumptions on parameters. Although using recent US emissions data for simulations, the study does not include waste data. See also Bratz and Kelly (2004).

The aim is thus to estimate a vector of coefficients, each linked to a single variable entering as explanatory factor of the "environmental" index under analysis, by a reduced form single equation model.

Knowing the benefits of a EKC multivariate econometric-based analysis, we have to be fully aware of the costs, then trying pragmatic ways for mitigating them. It is necessary to draw out what the main EKC deficiencies and weaknesses are. Thus, extending the reasoning to a more complex setting has, quite obviously, its costs and its benefits. We do not specifically focus on the more statistically oriented weaknesses, like (i) differences in estimated coefficients between parametric and non parametric models (Millimet et al., 2003; Baiocchi-Di Falco, 2001 and Galeotti et al., 2001); (ii) the degree of the polynomial used to proxy the environment income relationship (Borghesi, 1999; Shobee, 2004)[5]. Less technical but possible flaws are: (i) the environmental performance index investigated; (ii) the nature and quality of data; (iii) the model specifications used.

As far as the environmental performance index, we may note that careful attention should be placed on deriving policy implications. In fact, EKC studies often use different environmental index (absolute, per capita, output based, input based, per unit of GDP). A general consensus over what indicators to use does not exist. Different measures have nevertheless different implications and interpretation. For example, if a measure on per capita basis in OECD countries faces few problems of understanding, and absolute measures could be avoided, if we measure intensity in the vertical axis the presence of a lower bound implies that total emissions are growing at the same rate of income, in a sort of "steady state" equilibrium. It is obvious that the measures on the vertical and horizontal axis should be compatible to each other[6].

The nature and quality of data are crucial issues. In fact, for reasons linked to feasibility (data availability), the first wave of the EKC literature has witnessed a large majority of contributions focussing on the analysis of cross-country datasets generally taken from official OECD and World Bank sources. Another practical reason is that, being one key issue the assessment of North-South differences in EKC shapes, world datasets were needed. Nevertheless, one the one hand the quality of macro data for some regions (less developed countries) has been questioned, on the other hand the use of panel models usually prevent the researcher from calculating specific country-level coefficients for the income-environment relationship. In fact, econometric panel studies usually provide information on mean-value coefficients since they rely on the assumption of different constant terms but equal coefficients across units[7]. We note in addition that there is no consensus about the type and number of explanatory factors introduced as potential drivers of the environmental performance. Some studies use income variables only. Other studies include many socio-economic variables with the (correct) aim of extending the conceptual setting behind the EKC empirics

[5] Concerning income as driver-determinant, the problem is how specifying the functional relationship. There is no consensus on it. Some authors use second order polynomial, others have tried third and even forth order polynomials, comparing different specifications for relative robustness.

[6] Some argue that the choice over the dependant variable could depend on the issue considered. The per capita option is probably more compatible with situations where the degradation is deriving from overexploitation linked to population growth, whereas emission intensity is more compatible with scenarios with externalities caused by industries. The point is nevertheless not open to generalisation.

[7] The benefits of using "heterogeneous panel models " should be weighted against the costs of a more complex analysis. Most authors doubt on the value added of such analysis.

(Harbaugh et al., 2000); a few include policy drivers (Markandya et al., 2004). The choice obviously depends on both data availability and research objectives.

We finally observe that a higher added value is currently associated to studies based on National/regional rather than International datasets. The EKC literature, as it has developed over last years, is mostly characterised by an extensive use of international official data. Thus, added value may be found in "homogenous panel analysis", but concerning national/regional datasets, thus leading to coefficients representing average effects, but specific to homogenous environments. The relevancy for policy-making purposes is thus higher. Some authors (Vincent, 1997) have argued that the inverted U-shape EKC emerging for some pollutants in some cases could well be meaningless, if we take into consideration that it may simply reflect the forced integration of a positive relationship in developing countries with a fundamentally different link for industrialised or transitional countries. The conceptual key fact is that not a single relationship, but many different, applies to different categories of countries[8]. European countries, if compared to international datasets usually exploited for EKC analyses, may represent a homogeneous set of statistical units. Therefore, further research is needed to understand the evolution of environmental indicators with respect to income and other regionally specific factors over time, taking a country, eventually subdivided in its Regions, or a regional area, as reference.

If we add to this picture the lack of EKC analysis on waste outputs and material flows[9], the waste European framework emerges as a very fruitful environment. At this time, current waste data availability does not allow neither nationally focused studies nor EKC analysis including waste policy changes (since policies were implemented in the mid nineties). Nevertheless, some panel series for municipal and packaging waste allow carrying out a preliminary analysis for the European environment[10]. Given (i) the relative homogeneity across those countries in terms of structural characteristics, and (ii) the panel framing which helps dropping off non observed fixed factors, our results, though preliminary, could be considered robust and of policy interest for the European framework.

4. Waste indicators and delinking: empirical evidence for Europe

4.1 Data and methodological issues

Empirical evidence on Delinking concerning environmental waste indicators and economic drivers is scarce. The only contribution providing results for waste we are aware of is Cole at al. (1997), who find no evidence for a turning point associated to an inverted U-shape EKC curve concerning municipal waste[11]. There is currently no evidence on both municipal and packaging waste[12]. Some authors have recently suggested that

[8] See Stern (2004) for a recent paper criticising the empirical results produced by the EKC literature so far.

[9] This obviously depends on the rarity of data and on the low quality and reliability of most waste datasets.

[10] We note that the EUROSTAT dataset sources we use are the only available for waste; reliability is nevertheless not homogenous across countries. Our evidence is thus preliminary, waiting for new and more reliable data for all countries.

[11] Cole at al. (1997), use municipal waste data for the period 1975-90 in 13 OECD countries, finding no estimated turning point, with environmental indicators (per capita municipal waste) increasing monotonically with income over the observed range. The results are affected by low quality of data.

[12] This point is also highlighted by Martin and Scott (2003), who claim that rather, increased wealth continues to demonstrate a positive relationship with waste production.

for stock pollution externalities the pollution income relationship difficultly turn into an EKC shaped curve, with pollution stocks monotonically rising with income (see Lieb, 2004, for a theoretical perspective)[13]. Another structural motivation concerning waste may be that the change in sign of the income elasticity of the environment/income function should occur at relatively lower income levels for pollutants whose production and consumption can be easily spatially separated, by exporting associated pollution or by relocating activities (Khanna and Plassmann, 2004). This seems not to be the case for primary waste flows in western countries.

Looking descriptively at available data figures, we note that growth trends for packaging, Consumption and GDP figures, homogeneously available for the whole EU15 over the period 1997-2001, show waste increases less than those of economic indicators (7,1% versus 10,1% of GDP in per capita terms). Correlations between packaging waste per capita and GDP/Household consumption per capita are respectively 0,36 and 0,46. The correlation between municipal waste per capita and Household consumption per capita is 0,74 (from 1995 to 2000, considering EU_{25}, waste increased 13,2% while consumption 14%, in per capita terms). Correlations are positive and significant. Correlation analysis is obviously just the preliminary investigation. The natural extension of the decoupling analysis based on the examination of correlation for pairs of variables is the Environmental Kuznets Curve (EKC) type of analysis.

In order to provide preliminary evidence on the shape of waste-economic drivers relationship, two waste databases are set.

As far as packaging is concerned, the current available information on packaging waste generation for EU_{15} countries (1997-2001) is exploited. Although limited in time, the panel dataset may provide preliminary evidence on the existence of Delinking and on the current shape of the EKC for this waste indicator, also omitting fixed country effect from the analysis. For municipal waste, a dataset for 28 European countries over 1995-2000 is set up. Data before 1995 were available only for some countries and often only for one year. We thus decided to set the panel matrix avoiding missing values and minimising lower quality observations[14]. Descriptively speaking, packaging waste per capita ranges from 67 to 214 tonnes: Greece is the lowest country in the ranking, while Ireland and France are at the top of the scale. The mean value is 150 tonnes. As far as municipal waste is concerned, top ranking countries are Cyprus, Norway, Iceland and Switzerland, while at the bottom we find Slovakia, Poland, Latvia and Greece. The range is between 239 and 742 tonnes, with a mean value of 488.

The first methodological problem is how specifying the functional relationship. There is no consensus on it. Some authors use second order polynomial, others have estimated third and even forth order polynomials, comparing different specifications for relative robustness. It is worth noting that neither the quadratic nor cubic function can be considered a full realistic representation of the income-environment relationship. The cubic implies that environmental degradation will tend to plus or minus infinity as income increases, the quadratic implies that environmental degradation could eventually tend to zero. The issue is thus highly unresolved. Third or forth level polynomial could also lead to N rather than U shaped curves, opening new

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[13] The stock (part) of pollution harms the environment only in the future. Thus, myopic behaviour may let stock pollution grow with income.

[14] A note on data sources: for municipal waste data derives from EUROSTAT/OECD joint questionnaire, National sources, EEA; reliability is not homogenous across countries. For Packaging, Member States report in pursuance of Directive 94/62/EC on Packaging and Packaging Waste to the DG Environment. Our evidence is thus preliminary, waiting for new and more reliable data for all countries (Eurostat, 2001).

problematic issues in understanding the income-environment phenomenon for policymaking. This N shape is justified by a non-linear effect by the scale of economic activity on the environment, which is difficulty to prove[15]. Finally, the use of the income factor only, without quadratic and cubic terms, would collapse the EKC analysis to the basic decoupling analysis. For a simple presentation of EKC with a discussion of the core hypothesis see De Bruyn et al. (1998) and Stern (2004).

The aforementioned delinking hypothesis is tested by specifying a proper reduced form usual in the EKC field (Stern, 2004). Given the panel data framework, the relative fit of fixed effect and random effect model is compared by the Hausman statistic. The general hypothesis of Delinking in the EKC environment is thus tested by estimating a regression model:

$$\log(\text{waste})= \beta_{0i} + \alpha_t + \beta_1 \text{Log}(\text{Consumption/GDP})_{it} + \beta_2 \text{ Log}(\text{Consumption/GDP})^2_{it} + \beta_3 \text{ Log}(\text{Consumption/GDP})^3_{it} + e_{it} \qquad (1)$$

Where the first two terms are intercept parameters which vary across countries and years. Different polynomial specifications are tested by including as (i) dependant variable waste per capita and waste in absolute terms, (ii) independent variables either household consumption or GDP per capita, thus testing the hypothesis of consumption as more appropriate driver for waste. In fact, recent studies (Rothman, 1998; EEA, 2003a,b) point out that for municipal and packaging waste the proper economic driver/indicator is not GDP but household consumption instead. This is a critical conceptual and statistical issue.

Thus, for each combination of the dependant and independent variable listed above, I estimate different specifications, including: the linear regressors only (Delinking baseline case), linear and squared terms (EKC most usual case), and finally a specification with linear, squared and cubic terms.

4.2 Empirical evidence

Summing up and commenting results (tab.1-2), it is worth noting that, according to our ex ante expectations; the economic driver which better fits with both waste indicators is household consumption. Regressions concerning GDP are less robust in terms of both coefficient significance and coefficient signs, and they are not presented. This is a first result testing a crucial hypothesis, which is relevant for future applied studies on waste issues.

Moving to regressions exploiting consumption as driver, cubic forms do appear to perform worse than linear and squared forms, in terms of plausibility and economic significance of coefficients (Ziliak and McCloskey, 2004). I point out that the N-shape form has been raised as a theoretically possible case mainly for emission externalities; in addition, moving to the N-shape test is maybe more meaningful for externalities which have already presented a turning point in the squared specification.

The results for packaging waste are the followings. First, the basic specification with the linear term only shows a significant and positive coefficient for consumption. The Hausman test favours the random effect model: elasticities with respect to consumption are respectively 0,78 for the random effect and 0,90 for the

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[15] Shobee (2004) suggests a third order polynomial specification as more realistic relationship between environmental degradation and per capita income. This supports the credence of a logistic shape, wherein environmental degradation first accelerates, then decelerates, and finally falls. Marginal environmental degradation is thus not modelled as constant. The issue still remains highly unresolved, with the EKC hypothesis relying mainly on empirical evidence. The theoretical foundations of the EKC are still not assessed, though some contributions have emerged (Andreoni and Levinson, 2001).

fixed effect model. Since the linear specification tests Delinking by using econometric evidence instead of simple correlation analysis, we may observe that a “relative Delinking” evidence emerges.
Secondly, the non-linear form also shows a positive and significant coefficient for the linear term, and a positive, but highly not significant squared term. The elasticity value is 0,89, in the fixed effect model, for both the basic case and when correcting for heteroskedasticity. Further, adding time effects to the baseline specification does not affect those results: the estimated elasticity is 0,85. Nevertheless, all these elasticities are not different from one: also relative Delinking is questioned. Finally, using absolute waste as indicator does not change results (absolute waste and waste per capita present a correlation of 0,35). No estimated turning points arise.
Additional statistical points are worth mentioning. Estimated autocorrelation across specifications lie in a range between 0,2 and 0,4. Given those values and the limited number of years, this should not represent a serious problem Nevertheless, and maybe counter-intuitively, the Hausman test signals a better fit for the random model: results are only slightly different, with elasticities less than one, and non significant squared terms.
The analysis suggests that the first phase of the Packaging waste policy (most National policies started being operative in 1996-1997, though some were still operative in the early nineties, like Germany) has probably being effective in increasing environmental efficiency (slight relative Delinking), although no evidence appears to support an inverted U-shape EKC curve. This is confirming a shared statement, mostly qualitative, on the effectiveness of the first wave of packaging waste policies. More effort is then needed to reverse the environmental-economic relationship.
As far as municipal waste is concerned, the econometric analysis on the available 28 western and eastern European countries is robust and significant only for the base linear case. Elasticities for the fixed effect and random effect models are respectively 0,35 and 0,24. The fragility of this regression analysis may depend on the lower quality/reliability of eastern European country data. In fact, considering only the subset of 18 western countries, EKC regressions (tab.2) show that: (i) in the linear case, elasticity is 0,60; (ii) in the squared term regression, positive and negative signs are respectively associated to the linear and the non linear consumption factors; statistical significance is nevertheless associated only to the linear, with estimated elasticity at 0,83. As for packaging, results do not change when correcting for heteroskedasticity and adding time effects. The cubic relationship is again not plausible looking at signs and coefficient levels. In all regressions, the Hausman test here favours the fixed effect model.
Summing up, the analysis on municipal waste does not show evidence of a bell shaped curve and of a turning point, suggesting only a relative Delinking path. The squared specification presents a negative sign on the non-linear term, which never overcomes the statistical threshold (the t ratio is 1,172 for the regression corrected for heteroskedasticity). Further adding time period effects, the squared term coefficient shows a t ratio of –1,54.
The need of further investigation using larger and, more important, longer datasets, is confirmed by a final exercise, after dropping off two small “outliers” countries like Malta and Iceland, thus reducing the sample to 16 countries. The two-terms non-linear regression shows both significant terms: the estimated turning point is around the per capita consumption of a country like Greece. In this case, even the N-shape curve emerges, looking at signs (-,+,-), although all terms are statistically not significant. The EKC non-stability concerning results when different factors change, shown by Harbaugh et al. (2000), is an issue we have to deal with. It opens the way to more detailed analyses at country level using material specific and regional-

based dataset. To our knowledge, the availability and reliability of this type of databases for waste flows is currently very limited, if any.

5. Conclusions

The paper provides a methodological perspective and a general framework for decoupling analyses, with a specific focus on waste resource indicators. Current experiences of de-linking analysis are discussed and commented. The environmental Kuznets curves arena is then addressed as a natural extension of any analysis on the environmental efficiency of economic growth. Results indicate that stronger effects are needed in order to increase the waste-oriented efficiency of economic processes. They confirm the hypothesis that concerning waste even western countries are at best experiencing a relative delinking trend, with waste indicators increasing slightly less than economic drivers. The income elasticity of primary non hazardous waste flows is likely to be or become less than one, but not negative even in wealthy countries, as proposed by the EKC suggestion.

Part of the problem may rely on the low effectiveness of waste policies implemented over the nineties (i.e. Packaging Directive). Directives targeting waste fixed targets in terms of recovery and recycling, with waste prevention at source ruled out as a possible policy objective. No country has then introduced a policy target based on prevention, even for one material. It is shared vision that waste policies were not aimed at incentiving, at least for the first period, dynamics of reduction at source and strongly innovative substitution among materials, to avoid costly structural breaks: prevention at source was ruled out and on average cost covering mechanism prevailed over pure economic incentives tools. Evaluating policies opens a new complex arena for further research where two are the critical issues: (i) the possibility to assess a policy-driven structural break over a short period of time; (ii) the choice over which policy proxies are more sound as object of analysis: main Directives/national polices, single instruments in the policy mix, indirect costs caused by policies.

It is worth noting that a panel data analysis focussing on a homogenous set of countries is associated to fewer flaws and is more policy informative, if compared to international cross section/panel analysis. The relative homogeneity, which characterises the European framework, and the European level of most waste policies, add informative value to such applied investigations even if they generate mean estimates concerning the defined sample (the income elasticity is assumed being the same in all countries at a given income level).

As far as waste packaging is concerned, the absence of de-linking specifically points the task of the second stage of the European policy is to achieve and increase Delinking from now to 2010, at least on aggregate packaging waste if not for all specific waste materials.

Many motivations may be discussed as being part of the cause of this (partial) failure in reversing the waste-consumption relationship. As stressed, one reason of this low policy effectiveness may lie around the low levels of recovery targets fixed by the first packaging Directive. In addition, no country has since then voluntarily introduced a policy target based on waste prevention at source, which did not pass as an explicit target of the 1994 Packaging Directive, though introduced and discussed as possible objective in the Directive proposal. It is shared vision that the Directive purpose was not one of incentiving, at least for the first period, dynamics of reduction at source and strongly innovative substitution among materials. The policy intervention was not primarily aimed at causing structural breaks: prevention at source was ruled out. The homogenisation of national legislations on a trade perspective was a more relevant objective; harmonised targets have nevertheless imposed a cost burden to countries, which is not distributed following economic criteria of cost efficiency. Also, the analysis of single country policies shows that on average cost covering mechanism prevailed over pure economic incentives tools as ways to achieve policy targets.

Further, the ex post effectiveness regarding the objective of waste reduction of policies such as the Landfill tax implemented in the UK is being debated. This instrument is probably too far away from waste production to exert relevant effects. For these reasons, in order to increase the probability of achieving a turning point in the waste/income relationship, a *stronger* and more spread policy effort along the productive chain is *one* of the determinants that should play a role in influencing the dynamic and the systemic interplay between environmental and economic indicators.

Further analysis concerning (i) specific packaging waste materials for Europe and/or (ii) single countries will also be worthwhile as further investigations, as soon as a sufficient set of country/material data is available: different delinking processes could arise by considering specific countries and materials. Delinking processes may occur at the level of specific materials and single countries while not observed taking regional areas as point of reference. This is matter for further research, which obviously is strongly depending on data availability at more specific levels. Nevertheless, although preliminary, the applied exercise here presented confirms the shared view that a U-inverted EKC curve is still not characterising waste in Europe, taking a regional aggregated perspective.

Table 1- EKC analysis for packaging waste

Dependent variable	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP
model	Fixed effect panel data	Random effect panel data	Fixed effect panel data	Random effect panel data	Fixed effect panel data
Constant	…	3,10***	…	3,13***	…
LogC	0,90***	0,78***	0,89***	0,76***	7,88***
$LogC^2$	…	…	0,77	0,29	5,75***
$LogC^3$	…	…	…	…	-2,72***
Turning point	…	…	No estimated turning point	No estimated turning point	No estimated turning point
N (15 countries, 5 years)	75	75	75	75	75
Model F test (Prob. value)	0.000	0.000	0.000	0.000	0.000

*** significant at 1%, ** at 5%, * at 10*, R^2 are not shown as not highly meaningful as fit measure in panel settings. C= household consumption per capita; log waste/pop is waste per capita.

Table 2- EKC analysis for municipal waste

Dependent variable	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP	LogWASTE/POP
model	Fixed effect panel data	Fixed effect panel data	Fixed effect panel data Corrected for heteroskedasticity	Fixed effect panel data	Random effect panel data
Constant	…	…	…	…	3,12***
LogC	0,60***	0,83***	0,83***	0,30	2,20***
$LogC^2$	…	-0,57 (t ratio –0,74)	-0.57 (t ratio –1,172)	0,57*	-0,57***
$LogC^3$	…	…	…	-0,14**	…
Turning point	…	No estimated turning point	No estimated turning point	No estimated turning point	Turning point
N (18 countries, 6 years)	108	108	108	108	96
Model F test (Prob. value)	0.000	0.000	0.000	0.000	0.000

*** significant at 1%, ** at 5%, * at 10*, R^2 are not shown as not highly meaningful as fit measure in panel settings. C= household consumption per capita; log waste/pop is waste per capita.

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