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Waste prevention, waste management and landfill policies effectiveness

Outline of a quantitative analysis at European level

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Context
The Topic Centre has prepared this working paper for the European Environment Agency (EEA) under its work programme as a contribution to the EEA's work on policy analysis and assessment.

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1. Introduction

We outline the possibility to perform an analysis of waste production and waste management options aimed at assessing decoupling trends with respect to socio-economic drivers and eventually policy effectiveness using panel econometric techniques at the European level.
We assume that the observed (ex post) decoupling between economic drivers and waste production represents the best empirical indicator of actual waste prevention. By econometric analysis, the factors explaining decoupling/prevention can be tested empirically, including the effects of policies. We also include the outline of an analysis on the determinants of the main waste management options (landfill, incineration, recycling). As emerged in the above framework, production and management are interrelated elements of a waste system, and consequently the empirical model has to take this into account by specifying, where feasible, causal links and cross-relationships. The empirical model we proposed here has the primary aim of being consistent with the main objectives of the landfill directive, that is waste diversion from landfills, both in general and for specific waste flows; and waste prevention (feedback on the amount of waste produced either in absolute amount or in terms of 'relative decoupling' from main economic drivers).
We provide a framework for empirical analysis which has the objective of offering a general approach for such analyses. Given that the data availability, at European and even national level, is increasing year by year with respect to quality and quantity of data, the reasoning will also specifically revolve around a possible implementation of the model using current available data. More in detail, current availability of data could be sufficient to perform such a panel based investigation at the level of around 25 European countries for 10 years (1995-2004), which would be an original contribution to the research project, with an high value added both regarding the literature on delinking and EKC, wherein waste analyses are very rare, and with respect to environmental policy effectiveness, rarely assessed on an extensive quantitative basis. Then, in outlining the proposal, and with the aim of suggesting an additional country based high value research direction, we also refer to a recent work on delinking and waste policy assessment which exploits APAT Italian provincial and regional data over 1996-2004 (Mazzanti, Montini and Zoboli, 2006a). As suggested by Mazzanti and Zoboli (2005), higher value added evidence appears to emerge from both/either case studies on sufficiency homogenous regional areas, like Europe, and/or nationally based case studies which allows greater heterogeneity by focusing on within country, regional or provincial trends for economic, waste and other drivers[1]. This confirms what

[1] In fact, it has to be remembered that econometric analyses provide an assessment of relationships which refer to the "average" unit in the observed sample. The more the countries are homogeneous, the more the statistical output is valuable in terms of economic and policy value. Cross country analysis on large and heterogeneous sets of countries are often difficult to interpret. We underline the need to place equal importance on economic and statistical significance of results. Works with unbalanced weights on either economic or statistical elements are frequent and of little help, mainly to policy evaluation research. See Ziliak and Mckloskey (2004) on the importance of both "economic and statistical robustness" of quantitative outcomes.
There are ways of quantitatively addressing this heterogeneity. The superiority of the rather complex heterogeneous panel data models is also questioned. Baltagi et al. (2002) claim: "Depending on the extent of cross sectional heterogeneity in parameters, researchers may prefer these heterogeneous estimators to the

List and Gallet (2002) asserted in their study on US which exploits state-level data, providing specific for the US on a vector of pollutants. The analyses we here attempt to set and suggest go towards this research direction.

We point out that the primary statistical objective in setting up the database is to fill a panel of 25 countries and 10 years, with as many explanatory factors as possible. Missing values are to be dealt with using the methods discussed. If a variable considered crucial should present non random missing values (concentrated in a few eastern European countries, for example) a trade off arises between the choices of losing countries (statistical units) or the variable itself for the analysis. We believe that only in exceptional cases the choice should favour the loss of countries, and the pros concerning economic/policy significance and the cons on the side of statistical robustness of panel investigations. As a second best, but still sound option in both economic and quantitative terms, an analysis on EU25 countries could be chosen in the end[2]. Then, when available (at the beginning of 2007), data for 2005 could be easily included.

traditional pooled homogenous parameter estimators […] underlying the poolability of the data is the assumption of homogeneity of the parameters across states" […] "Our results show that when the data is used to estimate heterogeneous models across states, individual estimates offer the worst out-of-sample forecasts. Admittedly, this is another case study using US data, but it does add to the evidence that simplicity and parsimony in model estimation offer better forecasts" (p.376-381). Thus, added value may be found in the usual "homogenous panel analysis", but concerning national/regional datasets. Summing up, the primary analysis here presented as suggested, focusing on 25 EU countries, is consistent with this view. We note that separately focusing on, say, EU15 and newcomers could undermine, given the availability of time observations, the robustness of results. Data constraints thus always to be taken into account in quantity and quality terms. Other ways are to focus on large cross country datasets but distinguishing relative homogenous areas (Mazzanti, Musolesi and Zoboli, 2006; or focusing on single country analysis exploiting disaggregated geographical or sectoral data (Mazzanti, Montini and Zoboli, 2006a,b). As an example, it is worth noting that EUROSTAT Regional waste statistics data potentially provide waste production data at the level of EU Regions (more than 300) for 10 years. The patchy distribution of data and the many missing values prevent from carrying out this high value analysis.

[2] We do not suggest instead separate analyses on EU15 and newcomers. Though relevant, statistical evidence would be lower. The EU15 analysis could possess a sufficient, but not good, level of statistical robustness.

2. A short survey of recent studies and methodological issues of delinking and Environmental Kuznets Curves for waste

2.1. Defining a proper use of delinking and EKC analyses

Indicators of 'decoupling' or 'delinking' are becoming increasingly popular in detecting and measuring improvements in environmental/resource efficiency with respect to economic activity. Extensive research on decoupling indicators for reporting and policy-evaluation purposes is being carried out by the OECD (OECD, 2002). Various decoupling or resource-efficiency indicators are included in the European Environment Agency's state-of-the-environment reports (EEA, 2003a,b,c). A few European countries started to include delinking-type indicators in official reports on environmental performance (DEFRA, 2003).

Research on delinking and Environmental Kuznets Curves (EKC)[3] for materials and waste is less developed compared to air pollution and GHG emissions. Although recent works, in particular those by the Wuppertal Institute (Bringezu et al., 2003), produced extensive evidence on material intensity indicators, the still limited research results for the waste sector may be a serious problem in a policy perspective. The EU policy 'thematic strategies' on both resources and waste entail the reference to 'absolute' and 'relative' delinking indicators (European Commission, 2003a,b)The relationships between 'delinking' and EKC approaches, and some of their limitations can be discussed within the framework of a simple IPAT model. IPAT defines total impact (I, i.e. atmospheric emissions or waste production) as the (multiplicative) result of the impacts of population level (P), 'affluence' (A) measured by GDP per capita, and the impact per unit of economic activity (i.e. I/GDP) representing the 'technology' of the system (T), thus I=P•A•T. This is an accounting identity suited to decomposition exercises aimed at identifying the relative role of A, P, and T for the observed change of I over time and/or across countries.

While the meaning of P and A as drivers of I is clear, the exact meaning of T requires some further explanation. It is an indicator of 'intensity' and measures how many units of Impact (natural resource consumption) are required by an economic system to 'produce one unit (one dollar) of GDP. As a technical coefficient representing the 'resource-use efficiency' of the system (or if reciprocal GDP/I is considered, 'resource productivity' in terms of GDP), it is the most aggregated way of representing the average 'state of the technology' of an economy *in terms of* the Impact variable. Changes in T, for a given GDP, reflect a combination of shifts towards sectors with a different resource intensity (from manufacturing to services) and the adoption/diffusion in a given economic structure, of techniques with different resource requirements (inter-fuel substitution in

[3] For recent surveys on the varied areas of application of the EKC hypothesis see Lekakis and Kousis (2001), Dinda (2004), Stern (2004), Copeland and Taylor (2004), Mazzanti and Zoboli (2005), Cole (2003), Dasgupta et al (2002), Ekins (1997).

manufacturing). If T decreases over time, there is a gain in environmental efficiency or resource productivity, and T can be directly examined in the delinking analysis. T is the main 'control variable' in the system. In a cross-country setting, the interpretation of T is less clear cut, but delinking can emerge again as a negative relationship between I and the level of GDP or GDP/P.
Within an IPAT framework, three aspects of 'delinking analysis' and 'EKC analysis' emerge.
First, delinking analysis or observation of T on its own may produce ambiguous results. Decrease in the variable I over time is commonly defined as 'absolute decoupling', even though it is not a delinking process as it says nothing about the role of economic drivers. An environmental Impact that is slower growing (or slowly diminishing) than the economic drivers, i.e. a decrease of T, is generally described as 'relative delinking'. Thus, 'relative delinking' could be strong, while 'absolute delinking' might not occur (i.e. if I is stable or increasing) if the increasing efficiency is not sufficient to compensate for the 'scale effect' of other drivers[4].
Second, a delinking process, i.e. a decreasing T, suggests that the economy is more efficient, but offers no explanations of what is driving this process. In its basic accounting formulation, the IPAT framework implicitly assumes that the drivers are all independent variables. However, the evidence on the dynamics of economic systems suggests that *each* driver, as well as the Impact, may be reciprocally interdependent through a network of direct/indirect causations. For example, the evidence suggests that population dynamics (P) depend on GDP per capita (A), and *vice versa* to some extent. Similar relationships or inverse-causation effects are also relevant for T. Theory and evidence suggest that, in general, T can depend on GDP or GDP/P, and *vice versa*, if T refers to a key resource such as energy. In addition there is a relationship between changes in the dynamics among P and I and T (Zoboli, 1996). For example, in a dynamic setting, I can be a driver of T as the emergence of natural resource/environmental scarcity stimulates invention, innovation, and diffusion of more efficient technologies through market mechanisms (changes in relative prices) and policy actions, including price- and quantity-based 'economic instruments'. The re-discovery of the Hicksian 'induced innovation' hypothesis represents the attempt to capture the channels through which I influences T, while models including 'endogenous technological change' capture some influences of both I and GDP on T. In fact, improvements in T for a specific I can also stem from general techno-economic changes, e.g. 'dematerialisation' associated with ICT diffusion, which are not captured by resource-specific 'induced innovation' mechanisms and can vary widely for given levels of GDP/P depending on the different innovativeness of similar countries. Then, a decrease in T can be related to micro and macro non-deterministic processes also involving dynamic feedbacks, for which economics proposes an open set of interpretations.
Third, EKC analysis addresses one/two of the above relationships, i.e. between I and GDP or between T and GDP/P. It examines 'benefits' and 'costs'. Even though it may highlight empirical regularities that are of heuristic value, it does not provide satisfactory economic explanations.

[4] A general note. In the EKC framework, we refer to absolute delinking as a situation characterised by a negative relationship (a negative elasticity) between environmental and economic variables. Relative delinking is a positive but lower than one elasticity. No delinking is associated with a positive and ≥1 elasticity. Absolute delinking only implies waste prevention as such (if the environmental indicator is waste generation).

Recall that the EKC hypothesis is that the concentration/emission of a pollutant first increases with the economic driver, as a 'scale effect' prevails, then starts to decrease more or less proportionally, and thus de-links from income due to a steady improvement in T. More specifically, it predicts that 'environmental income elasticity' decreases monotonically with income, and that its sign eventually changes from positive to negative thus defining a turning point for an inverted-U shaped relationship. Here, we do not address the different meanings of the various formulations of the EKC hypothesis, which range from a relationship between I and GDP to a relationship between T (I/GDP) and GDP/P, but note that if the relationship is between I and GDP, the EKC provides the same information as the analysis of T. Furthermore, if I and GDP show an EKC, then there should also be one between T and GDP because, with some exceptions, both P and GDP are generally increasing over the long run, and delinking must have occurred at some level of GDP. However, in the case of an EKC between T and GDP or GDP/P, it is not necessarily the case that there is also one between I and GDP, because GDP and P might have pushed I more than the 'relative decoupling', i.e. decreasing T, was able to compensate for. This is what occurs in the case of global CO_2 emissions over the very long run. When relying on GDP or GDP/P as the only explanatory variable, EKC suffers from the shortcomings highlighted above for delinking analysis, but with an additional risk. The existence of an EKC could be deterministically misleading in suggesting that rapid growth towards high levels of GDP/P *automatically* produces greater environmental efficiency, i.e. 'absolute' or 'relative' delinking, and thus can be the 'best policy strategy' to reduce environmental Impact. However, from the IPAT framework, it is clear that GDP, or GDP/P growth, by itself implies a 'scale effect' on I, i.e. a growth in Impact at each level of T (and P).

2.2. Estimating Environmental Kuznets Curves: Key issues

The EKC framework extends the basic decoupling reasoning, modelling a multivariate analysis of the environment-income relationship[5]. We refer to the EKC framework as the field of analysis that, based on no predefined theoretical model but rooted in Kuznets' seminal work, empirically studies whether or not, for pollutants and other environmental indicators, an inverted-U shaped curve can be observed. This implies that along a first stage of economic development (growth) the elasticity of the environmental pressure indicator with regard the selected economic driver is positive (higher than one, lower than one, or unitary: relative delinking is proven by a lower than one elasticity); then, if a "peak" is observed (a turning point, TP[6]) at some level of income, this elasticity turns into a negative one. Then, it is worth assessing both at which pace absolute delinking is occurring and, extremely important, if the hypothesis of an N shape (the relationship returning positive at higher levels of income) is rejected or is a likely possibility.

[5] We suggest that the EKC framework, under certain circumstances, is a necessary step in the most simple decoupling analysis. Multivariate investigations add robustness to the results. However, the potential weaknesses of the EKC analysis will be highlighted.

[6] It is clear that the occurrence of a TP does not assure sustainability. In fact, the environmental indicator may present different values for the same income level. Thus, policy objectives should be relevant even if observe an EKC path, aiming at (i) reducing the environmental pressure at the TP income level and (ii) tunnelling through the "BAU EKC", that is modifying the elasticity values, especially in the first increasing part of the income-environment relationship.

Although EKC does not rely on a specific economic model, many theoretical assumptions, on both the consumption and production sides, are implicitly tested within the empirical context of EKC. 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' we find a composition effect concerning GDP economic activities, a technological effect, a preference-drive effect (environment being a normal/luxury good), and a market-instruments driven effect (which is integrated within the wider policy effect). Copeland and Taylor (2004) presents a model where sources with (trade, capital accumulations sectoral composition), increasing returns to abatement, and income / threshold policy effects are defined as main explanations (drivers) for EKC dynamics.

Thus, in knowing the benefits of an EKC multivariate econometric-based analysis, we must be fully aware of the costs, and try to find pragmatic ways to mitigate them. This involves identifying the main deficiencies and weaknesses of EKC.

We need to pay particular attention to deriving policy implications. EKC studies use different environmental indexes (absolute, per capita, output based, input based, per unit of GDP) and there is no consensus about which indicators should be used. However, different measures produce different implications and are open to different interpretations. For example, using per capita measures for the OECD countries would produce few problems, and absolute measures could be avoided, if we measure intensity on the vertical axis the presence of a lower bound implies that total emissions are growing at the same rate as income in a sort of 'steady state' equilibrium. Thus, the vertical and horizontal axes measures must be compatible. There is also no consensus about the type and number of explanatory factors that can be introduced as potential drivers of environmental performance. Some studies use only income variables; others include several socio-economic variables with the (correct) aim of extending the conceptual setting behind the EKC empirics (Harbaugh et al., 2002); while a few include policy drivers (Markandya et al., 2006). The choice obviously depends on data availability and research objectives.

The nature, quality and availability of data are crucial issues. The first wave of the EKC literature includes a large majority of contributions focused on the analysis of cross-country datasets, generally taken from official OECD and World Bank sources. However, the quality of macro data for some regions (non OECD countries) has been questioned, and even the use of panel datasets does not allow specific country-level coefficients for the income-environment relationship to be calculated. The key fact here is that there are many different relationships that can apply to different categories of countries. In other words, the policy relevance of world-wide cross country analyses is limited. Future research, as we highlight in the conclusions to this paper, should focus on delinking analysis that exploits datasets which include environmental and economic indicators at provincial/regional level (at European/national level). It follows that the value added from studies based on national/regional datasets will be higher than from those based on international datasets[7]. The more micro-based (regionally/locally disaggregated) the evidence, the better it is for statistical and policy aims.

We would argue that the research lines providing the most value added are, as the literature we review below highlights: the comparison of parametric and non parametric models which test the relevance of functional forms (and within the parametric world of homogenous and heterogeneous panel specifications); and, not necessarily separate from the former empirical studies of national cases disaggregated at regional level. One emerging result is that, irrespective of their statistical robustness, for most environmental pressures, large cross country datasets do not provide sound outcomes because different EKC shapes may be associated with different units of the sample under analysis. More interesting results, and richer in terms of economic and policy relevant interpretations, may stem from databases of homogenous sets of countries or, perhaps even better, national cases. The EKC may ultimately turn out to be country specific.

We refer to Ekins (1997), Dinda (2004, 2005), Stern at al. (1996), Stern (2003, 2004), Managi (2005), for critical surveys of the literature on delinking and environmental Kuznets curve, which has overwhelmingly analysed air and water emissions, mainly CO2, with a limited focus on waste streams. We may say that among EKC studies, waste is the lowest level in the ranking, less investigated even than issues like deforestation, biodiversity.

Thus, there are still few EKC analyses aimed at analysing the relation between waste and material flows and economic drivers. Some studies are even not aimed at identifying the occurrence of delinking, but focus on waste determinants as such. Policy effectiveness analyses are also scarce, for the same reasons, if compared to air emission related policies.

As noted by Karousakis (2006), most evidence on the determinants of waste generation is based on US microeconomic studies carried out at community level. Johnstone e Labonne (2004) present an overview of studies dealing with microeconomic individual or household data, manly on the US environment: income-elasticities of waste generation is estimated in a range between 0.05 to 0.55, thus inelastic. They note that a microeconomic based study is problematic since it often relies on case studies and small datasets.

In our framework, this inelastic relationship may mean that a relative delinking is present, though no signal of a reversal appears. Concerning the intrinsic macroeconomic EKC framework, some evidence is first presented in the international report which gave birth to the EKC literature (World Bank, 1992; Shafik and Bandyopadhyay, 1992): exploiting cross country regression analysis of data from the eighties, no evidence was found of delinking processes concerning waste. The elasticity is positive and equal to 0.38, showing actually a relative delinking trend. Recent reports like the UK DEFRA (DEFRA; 2003) present the positive elasticity of waste generation to income as a primary policy concern: as long as CO2, which nevertheless is associated to some evidence of a turning point in some recent studies, waste generation seems still to be characterised by a strict

[7] Bimonte (2002) makes this point in exploiting a cross sectional dataset of European countries on the area devoted to nature conservation and national parks. Other OECD countries are dropped for reasons of data commensurability and homogeneity. For emissions, the problem is less severe, though it remains true that value added in statistical and policy terms is higher when focusing on more homogenous cross country or within country datasets.

relationship between economic drivers and the environmental pressure. Both the literature on the determinants of waste production and the EKC literature converge to a point: to date, macroeconomic evidence on this relationship is still very scarce. There is plenty of room for providing new evidence on the determinants of waste generation, possibly at regional and national level rather than at international level. Policy implications deriving from international cross country studies are weaker, since elasticities value, in order to be informative for policy makers, must be calculated at the more decentralised level as possible. In this paper we pursue this task, encouraging research on this line. Macroeconomic analysis at a relatively decentralised level may be the good compromise and the best choice between microeconomic based studies, difficult to generalise, and macroeconomic investigations based on cross country based aggregated datasets, whose results are difficult to interpret since they provide average figures/estimates.

Then, Cole et al. (1997) find no evidence for an inverted U-shape EKC curve concerning municipal waste. They use municipal waste data for the period 1975-90 in 13 OECD countries, finding no turning point, with environmental indicators (per capita municipal waste) monotonically increasing with income over the observed range. Leigh (2004) presents evidence for EKC concerning a waste/consumption indicator deriving from the environmental sustainability indexes (ESI). The analysis faces two potential problems: data only exists for 2001-2002 and the index is based on a comparative rather than on an absolute scale. Wang et al. (1998) also find evidence in favour of a negative elasticity, by focussing on US stock of hazardous waste as environmental impact indicator and exploiting a county-based cross sectional dataset[8]. The nature of the pollution effect (stock/flow, hazardous/non-hazardous) seems to matter: non-hazardous and flow externalities appear to be less likely associated with a negative elasticity, even in industrialised countries. Recent work is nevertheless emerging for waste, though always limited by data availability. A macroeconomic based study by Johnstone and Labonne (2004) uses a panel database of solid waste in OECD to provide evidence on the economic and demographic determinants of generation rates of household solid waste, regressed over consumption expenditures, urbanization and population density. With respect to economic activity and population density, the results are largely consistent with results found in previous studies: they find positive elasticities, but lower than one, in a range from 0.15 to 0.69, evidence of relative delinking. Population density is also positively related to waste generated, while a negative effect is found for population age[9].

Karousakis (2006) also focuses on municipal solid waste generation for OECD countries. She presents evidence both on the determinants of waste generation and the driving forces behind the proportion of paper/glass recycled, and the proportion of waste landfilled. A panel database from

[8] Regarding waste, Gawande et al. (2000) present an interesting analysis which shows that migration patterns of workers are influenced by proximity to hazardous waste sites, after a certain threshold of income. The level of income affecting the migration decision is the same observed for the observed hazardous waste EKC relationship: thus internal migration (as well as trade flows) may be a latent contributing factor to the observed EKC, adding new insights on the ancillary factors correlated to the environment-income dynamic along the development path

[9] A previous similar study is by Beede and Bloom (1995) who use cross section data for 36 countries finding an elasticity of MSW with respect to income of 0.34 and with respect to population of 1.04. When using time series data for the US (1970-1988), income elasticity is 0.88 while population is not significant as driver.

30 OECD countries over 1980-2000 (four periods of data, thus there are 120 observations) is exploited. Although not explicitly dealing with EKC, it shows that MSW increases monotonically with income, with an elasticity around 0.42-0.45. Urbanisation exerts an even stronger effect on waste generation, while population density is not significant, as the policy index[10]. This is one of the first studies to explicitly deal with the drivers of waste management and disposal options, in addition to waste generation. Though extensions are relevant, we argue that as far sustainability arguments and waste related policies are concerned, the investigation of the relationship between waste and its economic and non economic drivers is of primary relevance. The generation of waste is the more relevant environmental pressure indicator; more waste means more disposals, management and policy costs. Reduction at source is in fact indicated without ambiguity as the first step of the waste hierarchy, while some doubts are now cast on the relative costs and benefits of recovery options and landfilling options. The added value of recovery, which includes incineration, and recycling opportunities, including composting, are to be demonstrated case by case, compared to (new) landfills with energy recovery and long run full cost potentially internalised (Pearce, 2004; Diikgraaf and Vollebergh, 2004). The amount of waste generated depends on structural features of processes and products at industrial and distribution nodes. This is the level at which waste policies probably exert the most visible cost, but it is also the level where policies are thought to be most effective in tacking the issue. Policies at the level of waste management and disposal difficulty exert incentives backward to the source, and act on the basis of an exogenous flow of waste, correlated to consumption level and to the qualitative and quantities "waste" features of materials used to product and to package goods.

[10] The latter two variables are instead significant in a final attempted FGLS model, both with expected negative signs.

3. Waste indicators and delinking analysis: empirical evidence

In spite of the significant policy experience of EU waste policy, there is currently no empirical evidence concerning the delinking even for major waste streams, such as municipal and packaging waste and other waste streams[11]. We here sketch some recent attempts of empirical analyses. We remark the very high value of research in this field, deriving from two separated scarcity: studies on waste production and waste disposal (delinking) trends; studies on waste and environmental policy effectiveness.

As far as Europe is concerned, Mazzanti and Zoboli (2005) find no delinking and EKC evidence exploiting municipal waste and packaging waste European panel datasets respectively from 1995 to 2000 and 1997 to 2000; estimated elasticities of waste production with respect to household consumption are close to unity. The European waste sector emerges as an area for further exploration of the EKC hypothesis. 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, the results, though preliminary, could be considered robust and of policy interest for the European framework.

Nevertheless, the survey of the literature, though developing even in the waste framework, still lacks, as noted, a more in depth investigation of driving forces taking as case study a single country over a relevant period of time. We are not aware of nationally based studies using data at regional, provincial or municipal level. We stress again that this is potentially a fruitful and more informative line of research, for the methodological reasons above noted, and even, but not least important, for motivations concerning the quality of data, as known, international waste datasets are produced by self reported data. As Johnstone and Labonne (2004) observe, OECD and EU datasets may be affected by differences in waste classifications used by different countries. Care must be taken mainly when dealing with data reported before the nineties. Thus, we may lack sufficient high quality/reliable data, in addition to problems of interpreting average elasticities stemming from panel datasets. National official datasets provide a better and more reliable environment, offering in addition the possibility of exploiting geographically disaggregated datasets. We also face the problem of data availability, which, even for OECD countries, usually begins with the mid nineties. Nevertheless, regional or provincial statistics help providing cross sectional heterogeneity and a sufficient number of observations to the panel matrix,

Regarding Italy, Concu (2000) focuses on Sardinia, exploiting cross section data on municipal waste generation for 322 municipalities: he does not find evidence supporting EKC; he finds an exponential shape for its logarithmic specification. The analysis is nevertheless limited by the cross section nature of data. As noted, we argues that though rather complex, the new research line is

[11] See European Commission, 2003a. We only have scattered pieces of evidence. Among the others, Martin and Scott (2003) claim that waste production continues to have a positive relationship with increased wealth. For the analysis of economic instruments based on ‘producer responsibility principles’ in European ELV policies see Mazzanti and Zoboli (2006b).

one exploiting panel data[12] at regional, provincial or municipal level, for assessing EKC evidence at national level. Heterogeneity may exist in EKC shapes across countries, as noted in the literature, and the heterogeneity associated with disaggregated data help producing better estimates for EKC functional forms.

New evidence from Italy using APAT data at regional and provincial level is provided by Mazzanti, Montini and Zoboli (2006a). The paper provides empirical evidence on delinking and Environmental Kuznets Curve (EKC) for municipal waste production in Italy. They analyse two very disaggregated panel datasets on Italian Regions and Provinces (1996-2004 data for the 20 regions, 2000-2004 data for the 103 provinces) to estimate the extent to which delinking between waste production and economic drivers is taking place. The empirical analysis of different specifications shows mixed evidence in favour of an EKC relationship. Evidence supporting an EKC hypothesis significantly arises at the provincial level, which presents a very high data heterogeneity. Nevertheless, the turning point is at very high levels of value added per capita (around 23,000-26,000€), which characterise a very limited number of wealthy (Northern) Italian provinces. The analysis does not lead to a similar evidence for the regional dataset: just a relative delinking dynamic emerges. At the provincial level, a positive relationship between waste production and the share of separated waste collection emerges, which can be explained by the sharp difference in income and waste-policy performance between Northern and Southern Italy. Population density is never significant instead. Finally, the test on some policy proxies, i.e. the diffusion of the new waste tariff regime at the local-level and the ability of utilities to recover waste service cost, leads to the conclusion that they are not (yet) impacting waste production. The possible effect of two policy proxies are estimated: (1) the share of separately collected waste and (2) the shift from the tax waste collection to the tariff on waste management, which represent in Italy the (still evolving) move towards market-oriented management/policy approaches. The two variables do not affect the EKC evidence (province level). The only significant effect is positive: waste production is higher where the share of population experiencing the new tariff-based system is higher. Similar results emerge for the share of separate collection on total waste production,

[12] Panel data are a matrix of time series and cross section data. In essence, they merge time series for the observed units. In a nutshell, endogeneity (depending on the presence of Co-causation, Measurement error, Data unavailability on relevant variables) and Omission of relevant variables are the main sources of flaws in econometric analysis. A panel dataset framework is the sounder way to get rid of, or rather to minimise, such problems. Endogeneity associated to co-causation is still a problem, e.g. water demand studies, where an endogenous price factor is often present in panel analysis due to data unavailability. Nevertheless, panel datasets allow us to cope with unobserved heterogeneity. In other words, since estimation procedures are based on differences over time and/or cross section, all the elements we do not observe as researchers are cut off as long as time invariant elements (this may be a problem sometimes), "polishing" data from endogeneity sources. It is worth noting that main elements of the empirical models should be observed in any case, in order to correctly specify the model and avoid omission of irrelevant variables. With the omission of relevant variables we impose an incorrect restriction → bias on parameters. Instead, with the Inclusion of irrelevant variables there is an over fit of a model → reduced precision of estimates (relatively a minor problem). A Rule of thumb is the following: procedures from "general to particular" can be used in order to specify a model, when we do not start from a proper theoretical model (Hendry & Richard, 1983, Hendry, Pagan & Sargan, 1984). Economic theory, model conceptualization, and preliminary qualitative analysis are in any case needed to support the specification of a 'correct' empirical model. Finally, we note that Panel data may possess different features in each specific case study, depending on the "length" and "width" of the matrix: 'Long panels': exploit more the time series information whereas 'Large panel': cross country heterogeneity prevails on time series.

which is always significantly and positively related to waste production across different regressions. Richer provinces in Northern Italy tend to be more innovative in terms of new institutional/policy approaches (i.e. market-oriented management settings, introduction of market-based instruments, better enforcement of waste policies), but they produce more waste per capita. The analyses of material recycling in Karousakis (2006) gives support to this argument of positive correlation between income, waste production and waste management capacity. The ‘income effect’ still tends to prevail, and the endogenous dynamics linking waste and income is not (yet) influenced by the new (evolving) institutional/policy setting.

To lower the turning points and to avoid an increasing gap between geographical areas, innovative (market based) and more effective policy instruments should be implemented. In particular, the weight of waste policies should be rebalanced towards waste prevention targets and instruments, in line with the priorities stated by the EU and Member Countries. In fact, the indirect feedback effect of good post-production waste management policies/practices on reducing wastes production at source can be weak and slow. In general, the results confirm that more geographically-disaggregated data may offer more insights with respect to cross-country datasets, also from the policy perspective.

The literature on waste determinants and EKC for waste commented on above thus underlines the fact that waste indicators generally tend to increase with income or other economic drivers, like population, and, in general, an inverted U-shape curve is still not fitting data. A decreasing trend (negative elasticity) may be found in industrialised countries where waste management and policies are more developed. Nevertheless, the risk is that EKC trends (absolute delinking) is associated to few richer countries or areas, splitting countries into two or more pieces regarding waste indicator performances[13]. Evidence concerning other policy, structural and socio economic drivers, suggested below for Europe, is also in its infancy. The same applies if we focus on the quantitative analysis of the whole integrated system, from waste generation to recovery to landfilling.

The underpinnings of such (expected) evidence are many. Some authors have recently suggested that for stock pollution externalities the pollution income relationship difficultly turn into an EKC shaped curve, with pollution stocks monotonically rising with income (Lieb, 2004). Another structural motivation concerning the lack of evidence for 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, e.g. by exporting associated pollution or by relocating activities (Khanna and Plassmann, 2004)[14].

[13] Rothman (1998) argues that delinking is less likely to occur when we tackle “consumption-based” measures. Mazzanti and Zoboli 82005) find that the empirical model for waste production fits better with consumption with respect to GDP, though correlated.

[14] A worthwhile paper is by Fischer - Kowalski and Amann, 2001, which is strictly linked and refer to Matthews et al. (2000) presents descriptive quantitative evidence on material, waste and emission flows, from a perspective of material input-ouput accounting. Richer OECD countries are taken as examples. For material input, the intensity with respect to GDP shows relative but not absolute delinking, with material growing over 1975-1995 (the period considered) for all countries. As far as outflows (air emission and waste disposed into the environment) are concerned, evidence supports relative but not absolute delinking as well. Outflows are then broken down by the environmental media they enter. Looking at CO2, air emission and

4. A model for an empirical analysis of EU waste generation and management

4.1. Introductory notes

We here attempt to suggest how to set up an empirical model which (i) is consistent with the integrated waste framework depicted in first sections; (ii) is fed by current available data on waste at European level. The model is aimed at defining an original empirical structure for studying both waste production and waste management trends, including policy effectiveness, in a longitudinal (panel) perspective.

A note is worthwhile. It is clear that a 10-year EU-25 dataset is the minimum sufficient in statistical terms in order to carry out an EKC analysis concerning policy evaluation. A more robust analysis should exploit longer time series both for pure statistical reasons and for providing a sounder effectiveness analysis of a policy which has formally been introduced and ratified from 1999 on. Since policy effects are more visible on the medium and long run periods rather than in the sort term, at least a 10 year distance should be maintained between the implementation and the assessment of such a complex policy effort. Nevertheless, we first argue that, given it is the first time in Europe that we possess a sufficiently robust datasets in terms of quality and quantity of data, it is worth carrying out a quantitative exercise. The objective is certainly one of providing useful insights for policy making, but also one of learning by doing in sight of future assessments based on more data flows. Secondly, even if it is true that the 1999 EU Directive lies in the middle of the available time series, and there is some heterogeneity across countries with regard to the formal and/or substantial implementation of the policy (some that had anticipated the Directive, other that have transformed it into national legislation with delay, etc..), policy proxies can be set up in order to capture formal and less formal commitments. In other words, the Directive splits the database into two parts, and this is good for assessing whether a structural break occurred. Then, the heterogeneity concerning both formal ratification of the policy and the real commitment of different countries (which is partly independent on the 1999 implementation and formal commitment, and can characterise even years from 1995-1999) is possibly tested by setting up a vector of sound policy proxies indicators.

The empirical model may be structured as a two stage procedure, which fits with both the conceptual framework and offers a more robust statistical framework, rarely attempted so far in this field. Conceptually, waste generation is the at source flow which is managed by being allocated to different disposal options: recycling, incineration, and landfilling, if we exclude illegal dumping of waste.

We may thus specify an empirical model which is divided into two levels of waste functions (reduced forms of the model): (i) one level dealing with waste generation, and eventually waste

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landfilled waste, they note that absolute delinking holds for waste landfilled (not produced!) and air emissions, but not for CO2.

composition (ii) and the second, consequently, dealing with the three waste management options. A two steps model is consistent with the fact that the drivers of waste generation/waste composition and the explanatory factors of the disposal options may differ (both between the two levels and across different options or waste objectives), and with the enchained consequential nature of waste dynamics.

On a statistical ground, we note that a panel structure of the dataset is necessary in order to deal with unobserved individual effects. A usual panel estimation is to specify a model which includes a dummy variable for each unit (say, a country)[15], with the possibility of inserting dummies also for time period effects[16]. This allows capturing fixed individual effects, which may be linked to factors like, say, technological features or capacity and other institutional country-related specific effects. Such effects are thus accounted for, while other unobserved heterogeneity is swept away. An intrinsic already noted "flaw"[17] of panel analysis is that it provides information on average coefficient for the sample considered. This may be a serious informative problem when analysing, for example, OECD dataset. Considering European countries, and the focus being European policies, an EU panel database is a sound compromise and a good way for getting policy relevant information. If the aim were the analysis of country-specific policy effect or delinking trends, time series or better, within-country panel should be preferred (Mazzanti, Montini and Zoboli, 2006).

4.2. First level: waste production

4.2.1 The model and the set of variables

The model is thus specified as follows (it represents the panel nature of data[18]).

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[15] Fixed effects model, that is a Least Square Dummy Variable model, which is an empirical speciation where heterogeneity is captured by placing a dummy on each unit (country). We might eventually want to estimate the relevance and sign of country-related dummies; though our database is wider than longer, with "only" 30 units in the data estimates of such coefficients are robust. In any case, our panel datasets capture relatively more cross-sectional heterogeneity than time-series dynamics.

[16] When a consistent time series in the panel is present, we may test and compare the base and the corrected auto correlation models. Following the procedure in Wooldridge (2002, p.176), which tests serial first order correlation by a t test on the coefficient of the lagged fitted residual term in a regression which sees as dependant variable the fitted residual in time T and the vector of explanatory factors. Lagged residuals are significant in both FEM and REM models, thus the correction model, which does not consider time T for estimation, is indicated. As noted by Wooldridge (2002, p.176), one interpretation of serial correlation in the errors of a panel data model is that the error in each time period contains a time constant omitted factor. Serial correlation may be verified by a test on the residuals (Wooldridge, 2002, p.176). If the null hypothesis of no correlation is not rejected, the model is definable as dynamically complete in the conditional mean. In any case, the loss of efficiency in presence of correlation, in models that involve relatively slowly changing variables, like consumption and output, is not so severe (Greene, 1997, p.589-590). In addition, we note that if the stationarity assumption holds, autocorrelation fades over time, but correlation have to be dealt with since it may cause more or less severe losses of efficiency. We recall that the corrected correlation model reduces the number of observations since it is based on T-1 periods, unlike the time period effect model.

[17] In fact, econometric panel studies usually provide information on mean-value coefficients since they usually rely on the assumption of different constant terms, but equal coefficients across units (fixed effects model).

[18] Time series analysis may be an alternative way of providing sound statistical evaluation of dynamic trends, focussing separately and specifically on single countries. The value added is that, opposite to panel models, which are usually structured as homogenous in slope coefficients (with heterogeneity captured by constant fixed effect terms), the relationships between variables (elasticities) are not average values for the sample, but average values for the period on which the country is analysed. Nevertheless, available annual data do not provide so far sufficient observations for waste indicators, contrary to, say, CO_2 data. An option would be to consider monthly data to lengthen the time series: as far as waste data are concerned, monthly data are both not available and maybe even not plausible as an option, differently from analysis on the drivers of, say, water demand or energy demand.

(1a) Waste generation $_{it}$= f(income driver$_{it}$, other explanatory factors$_{it}$, dummy variables$_{it}$)
(1b) Waste composition$_{it}$= f(income driver$_{it}$, other explanatory factors$_{it}$, dummy variables$_{it}$)

This level, composed of two quantitative indicators, provides direct information to the usual EKC hypothesis in terms of waste production which is in the end the ultimate objective of any social policy targeted on waste flows. In fact, many cited works have studied the determinants of MSW generation and (fewer studies) verified the delinking hypotheses on this ground. An EKC oriented structure of the model allows the estimation, from the parameters of the linear and squared /and eventually cubic) terms which concern economic drivers, of average turning points. Though we cannot assess specific turning points for each country, given the insufficient amount of data, the average turning point provides a hint on the GDP/Consumption level beyond which the relationship between , in this case, waste production and income turns negative. The same applies when we focus on landfill diversion indicators as dependant variables: the turning point is the observed peak after which landfill disposal eventually tends to decrease regarding its economic drivers (absolute delinking).

It would be also worth studying the constraints given by waste composition. The composition of waste flows can be relevant in constraining the possibility to pursue one route or another (i.e. they are not perfect substitutes for one another for all kind of waste). Nevertheless, if on the one hand the feasibility of empirical analyses at European level on waste production is good, capacity of data from many countries prevent a study on waste composition, for waste and MSW in specific terms. As far as (1a) is concerned, the income driver is the main explaining factor either in GDP or consumption terms. The estimate of the coefficient in a logarithmic specification allows the assessment of elasticities (a 0.5 elasticity means that a 1% increases in the economic driver causes, other things being equal, a 0.5% increase in waste, and so on). The empirical models are generally estimated in logarithmic forms to ease the assessment of elasticities, and in per capita terms. No golden rule nevertheless exists: for example, some studies aim at estimating the elasticity of WP with respect to population (Martinez-Zarzoso et al., 2006 for a study on CO_2 at EU25 level) in addition to that regarding income. Estimating the model in a non per capita basis allows it.

Policy variables can be included even at this level of analysis, though we may expect that, this is valid in particular for landfill like policies, the effect is not significant. Waste prevention specific policies seem to not exist to date. If some countries had introduced it recently, there is not enough space for assessing the causal effect. We observe that with respect to policy variables, the most interesting but tricky part of the model set up, case studies on single countries may be highly complementary to the present quantitative analysis, insofar as they collect qualitative and quantitative information on policy implementation and use of specific environmental economic and non economic instruments. This is the area where EUROSTAT datasets are of little help and other directions of data collection should be sought.

We refer to tab.1 for other structural and socio economic variables we deem relevant at this level. Among others, structural economic development variables like agricultural/manufacturing/services

shares, land use and finally population density (which captures some urbanisation-related and geographical features of the country as well), could be significant in explaining WP.
The inclusion of socio economic variables in the model is needed in order to mitigate as far as possible the omission of relevant variables, which leads to more serious flaws with respect to the inclusion of irrelevant ones. Among the other problems, this may effectively overestimate the role played as drivers by economic (GDP) and policy related variables. It is true that the researcher cannot include all the latent not observed socio economic trends affecting the objective variables. Nevertheless, some of the socio economic variables (see tab.1) may capture more than one structural/institutional element characterising a country. A clear and full assessment of such variables may explain the different development at the time of the recent landfill policy introduction. Landfill policies interact with the existing structural elements; in the long run an EU landfill policy could close gaps between countries in terms of waste performances. In the current short run situations, socio economic indicators and their interaction with recent or in many cases very recent landfill polices are of high importance.
Summing up the part devoted to explanatory variables, we identified the following classes of independent variables (an example is given in brackets):

- Economic drivers (GDP, consumption);
- Socio-economic and structural country indicators, acting as "control" variables" for both economic drivers and the below policy related variables (populations density, economic structural of the economy, mainly including sectoral and technological factors). Structural indicators, as well as policy variables, may be important drivers of EKC shapes; their omission could overestimate the "pure" GDP economic effect[19]. A specific attention is to be devoted to structural indicators concerning:
    - structural change of the economy, along the development path[20].

[19] Actually, a "pure" GDP effect does not exist. The majority of EKC literature has largely exploited empirical forms with almost only economic drivers, since availability of other factors is scarce when dealing with cross country international datasets. GDP captures demand side and supply side omitted variables that should be accounted for as soon as sufficient data emerge. The pure role of economic drivers (e.g. changing preferences, income effects) may as a consequence narrow down.

[20] Auci and Becchetti (2006) present recent evidence on CO_2, building on 197 countries from the WDI dataset, over 1960-2001. The paper provides slightly new evidence since it specifies as dependant variable CO_2 per unit of GDP instead of CO_2 in per capita terms. Data include emission from aggregate fossil fuels consumed by domestic systems. This allows the assessment of supply side effects, like scale and technology factors, which may represent the main explanation behind the EKC. The hypothesis is that GDP may capture by correlation the underlying effect of economy restructuring, which is, in the end, the ultimate factor driving the elasticity from positive to negative. See also Managi (2006) who present evidence for ECK concerning US data on pesticides for 48 states over 1970-1997, including abatement efforts and a proxy of environmental productivity as drivers in addition to real GDP. When included, such variables reduce the EKC income driven dynamic, showing the relevancy of pollution abatement, as proxy of policy factors, and environmental productivity, as main drivers of reduced environmental impact. On the same line, Liaskas et al. (2000) present evidence on a delinking between GDP and CO2 emissions in the EU, which is strictly linked, according to their decomposition of industrial emissions, to a delinking between industrial ouput and energy use which translates into the EKC income environment inverted U shape relationship. While a secondary relevant effect is attributed to the changing fuel mix, primarily from oil to a natural gas and also renewable energies, there is no evidence of significant effects of economy restructuring on the delinking at EU level.
Horbach (2002) focuses on an empirical analysis of structural change between economic branches as one major determinant of EKC. Time series evidence for Germany shows that the decline in environmental intensive branches (those having pollution abatement investments higher than 5% of total investments from 1993 and 1997) can be explained by the increase in energy prices and by the economic restructuring of a country.

- innovation intensity of a country. Tab.1 shows the ouput and input innovations variables which are available for an EU panel application: patent applications for million inhabitants and the R&D oriented ones: gross domestic expenditures on R&D, and the relative shares of R&D financed by industry, government (and abroad) [21]. Innovation intensity could be exploited as country effect, mostly in specifications for waste prevention and recycling/recovery. Another potential variable is the "stock of man made capital" (Gross fixed capital formation) and the productivity per employee, two dynamic which captures technological investments and development of the economy (whose data present good availability for all EU25 countries).

- Policy variables
  - Policies factors inspired by European Directives (Landfill and Incineration), with implementation mainly at national level, with exceptions (landfill tax)
  - Structural waste management indicators, capturing the state of the waste management before such policies were implemented (shares of waste landfilled, landfill sites per capita)
  - Decentralised Waste management policy drivers (waste tariff, cost recovery of waste services)
  - Other environmental and waste related effects, but not directly linked to MSW and landfill/incineration policies (packaging waste status of policy implementation, electricity prices)
- Interaction variables (capturing "complementarity or substitution" effects)

Two notes are needed. First, the above list is generally valid for both level of analysis. It is true that (tab.1) the hypothesised sign on the relationship may change from waste production (prevention) to different waste management routes to some extent. This depends from the complex web of relationships, in terms of enchained consequential effects between the various key factors. As we will see, economic drivers and socio-economic and structural country indicators are used in both levels.

Secondly, for policy variables the reasoning is a bit different. Ideally and conceptually, we should not use overlapping bundles of policy variables in the two systems for assessing direct effects. Nevertheless, since (i) policy targeted at waste prevention are not present if not very rarely and recently, and (ii) indirect effects are also relevant, the policy indicators listed here may be included even in level 1 (WP), in order to assess eventual indirect effects acting by market driven feedback effects. Their specific and proper level is nevertheless that of waste management options.

[21] These latter input variables should be preferred to an index of patents applications (to European patent office), available in EUROSTAT per million inhabitants. In fact, we argue that R&D, an innovative input, measures the country intensity and commitment to innovation. Patents, though often used as main ouput innovation indicator, are a mean, alternative to others, of protecting property rights. At the ouput side, indictor of process and product innovation adoptions could also be used (Mazzanti and Zoboli, 2006a; Mazzanti, Montini and Zoboli, 2006c). The imperfect measuring of innovation by patents is commented by Gu - Tang (2004), who stress that some firms protect property rights by trade secrets and copyrights instead of patenting.

4.2.2 Economic drivers, structural features and policy dynamics. The relevance of endogeneity issues

Some methodological notes are needed here for their core importance in the model setting, in its empirical investigation and in the final interpretation of results. The focus is the relevance of endogeneity issues for empirical analysis and policy effectiveness assessment.

Much of the endogeneity problem relies on relationships between variables and on the way a model is structured. All explanatory variables in empirical models should be exogenous. Each effect or impact on the dependant variable is in fact determined "other things being equal": assessing the relationship between changes in the dependant and one independent variable, all the others being fixed. Problems for estimation and results interpretations arise when some independent variables are affected by endogeneity. Endogeneity cam come from many causes (Wooldridge, 2002, chapters 4,5): data unavailability, which does not allow the inclusion of core control variables; measurement error, simultaneity (causality relationship between explanatory variables). An equation can present more than one source of endogeneity given available data. One simple way to mitigate the problem is to carefully start from the analysis of all available independent variables.

It is relevant to remember that the correlation matrix concerning explanatory variables is to be carefully studied in a preliminary phase. This is useful in order to (a) preliminary investigate the links in a simple way (b) mitigate the presence of high correlation between independent variables, which should be addressed by: deleting those variables which present significant high correlations overall, testing and eventually taking into account of endogeneity attached to some variables[22], including them separately in the following multivariate analysis[23] those variables which are both deemed crucial, but are highly correlated to each other[24]. Another method should be that of using instrumental variables: that is variables that are highly correlated with the one in question but not correlated with the other explanatory elements. In practice, the results are very burdensome and often not feasible. Another way is to define another model equation for the supposed endogenous variable, associated with a vector of possible explanatory variables. The empirical model may then be extended in terms of equations number, if some variables are drawn out and set themselves as potential factors to be explained. A typical example in the literature is the endogeneity of techno-organisational innovation and other high performance practices when exploited as drivers of

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[22] See Wooldridge (2002, pp. 90-92) for a comprehensive discussion on "two-stage least squares" and for a clear presentation of regression based form (omitted variable approaches) of the Hausman endogeneity test (p.118).

[23] We remind that pairs of variables (dependant/independent) which are significantly correlated (say, higher than 0,20 value) could arise as non significantly linked in the multivariate analysis, given that the inclusion of other explanatory factors allows a more robust assessment of each specific link between the dependant and the vector of independent (in other words, each link is assessed by controlling for the other N-1 variables, that is taking as fixed the effect of other factors. The policy effect is assessed given the role played by other socio economic drivers, taken as fixed parameters when estimating the specific waste-policy link). Summing up, controlling for other factors mitigates the risk of incorrectly interpreting spurious correlations (statistically significant correlations between variables, driven by latent not observed or not included effects) as effective meaningful links. Economic theory should also inform the model in order to avoid the risk of coming across spurious correlations even in a multivariate analysis.

[24] In a nutshell, a rule of thumb for evaluating the extent to which correlations are too high is the following: observed correlations higher than 0,40 should lead to the separate inclusion of those variables. Correlations between 0,20 and 0,40 could lead to the inclusion of both variables as independent ones in the model, though a safer threshold is probably 0,30.

country or firm/industry performance. If endogeneity is deemed relevant, a two equations system should be used, with a performance equation and an innovation equation. Innovation is certainly to be included as a driver of performance, but other elements, including past performances, may drive innovative processes. Instead of features like, say, size and sector, or country morphological features, some elements are not exogenous to the depicted framework. Empirical endogeneity also depends on the time span under observation. The more years are considered, other things being equal, the higher the possibility of endogeneity being an issue. Some potential endogenous variable may be consistently assumed exogenous in an observed short time period, if their dynamic is slow evolving.

Some examples linked to our analysis are also worth doing. Economic drivers may be highly correlated with other socio economic variables. Policy variables may present correlated dynamics by country or by groups of homogenous countries. An interesting point arises in Mazzanti, Montini and Zoboli (2006a) concerning the impact on WP of variables like share of separated collection, cost recovery, share of population/municipalities adopting a tariff instead of a tax. First, all are quite positively correlated to each other. Thus, they are tested separately, then, they present quite significant correlation with income. This is part of the evidence data tells us: waste management and policy proxies are not significant, or even positively associated to WP.

The positive and significant sign of the variable 'share of separated collection' is anecdotal and may be interpreted as following: the separately-collected share of total waste produced is sharply higher in Northern and richer areas of Italy. Waste management is easier where public institutions are more committed to waste collection and recovery/recycling, where European and national policies are better and more fully implemented, and when funding possibilities are higher, also as a consequence of the introduction of the waste management tariff. Thus, the higher the waste generation, as is the case in Northern provinces, the higher the separate waste collection, and both are driven by and correlated to provincial economic welfare indexes (value added, GNP, household expenditure). It might be expected that a better performing and more effective collection/management system (i.e. a high share of separate collection) can be also a factor possibly contributing to reduce the still positive correlation between waste production and economic drivers. However, this 'waste prevention effect' of the collection systems is far from being sure and it is not emerging in practice. Therefore, the establishment of policy targets at the source, i.e. waste production, would be needed.

For the assessment of policy effectiveness even at European level, it is worth having in mind the possible "endogeneity" of policy implementation: wealthier western countries are (still) associated with positive elasticities of waste with respect to income drivers. Policies or management schemes performances may also be positively correlated with waste production: it is WP, via income, for example, that "drives" higher shares of separate collection and new (market oriented) tariff schemes. Being the environment and waste management for society and single agents a luxury good, higher incomes spur better performances. In the short run we nevertheless may observe that scale effects still outbalance, say, relative delinking or better practices, leading to an increase of

WP. Longer time series (than 10 years) will be necessary to reassess such dynamics at the light of a medium long run development of conflicting scale and pro-environment effects.

This could be valid both for WP, as commented here, and even for the analysis at the disposal level we deal with below.

The ouput arising from this level 1 is worth in itself for the elements noted above, but it also has an instrumental value for the next level, since WP (and composition) is the inflow to recycling, recovery and landfills. We maybe expect, for example, that a landfill policy is more effective in a country or period of slow-growing WP, though the sign of the relationship is probably not so clear cut.

Summing up, the first step analyses the extent to which waste generation is associated with its main economic driver, say valued added/GDP/consumption, and other explanatory factors (population density, other socio economic drivers, structural economic elements, policy factors, etc..). The aim of the investigation is both to recover the elasticity of waste generation with respect to the income related driver and to assess the eventual presence of an EKC shape for the relationship between waste and income (Johnstone and Labonne, 2002; Karousakis, 2006; Mazzanti and Zoboli, 2005). In addition, the significance and eventually, where plausible, the elasticity of waste production with respect to other drivers may be estimated. This first step is the most common in the literature dealing with waste determinants and EKC dynamics of waste and materials. Then waste production is to be allocated among different options.

Our aim is to set a model where this level is integrated with the three main disposal options. A recent contribution which attempts this goal using OECD data is Karousakis (2006)[25].

4.3. Second level: waste management

The three main disposal routes, as well as separate collection at source, are modelled as consequence below. They are characterised by, among the other things (refer to tab.1 for a full sketch of independent variables): (a) a different development at the time of landfill policy introduction; (b) capacity constraints in the short-term; (c) a different cost to users; (d) a set of specific policies and programmes. It is highly worth noting that the three management routes are linked by some post-treatment flows (e.g. waste form incineration, waste from recycling industries, etc.), but in general they can be assumed as alternative separate routes. If this hypothesis should not be deemed valid, the model would have to be modified to account for interrelationships at level 2. The second level of the empirical model is then:

(2a) landfill per capita[26] $_{it}$ *= f (waste generation [predicted values]* $_{it}$, *policy variables* $_{it}$, *socio economic controls variables* $_{it}$ *)*

[25] The present proposed empirical model goes beyond the estimates provided by Karousakis since it aims at integrating the levels, not treating them separately. It will be clear below what we propose to create a chained integration between level 1 and 2. Then, we also fill the model with more reliable recent EU data, associated with a longer and even wider dataset.

(2b) incineration per capita$_{it}$= f (waste generation [predicted values]$_{it}$, policy variables$_{it}$, socio economic controls variables$_{it}$)

(2c) recycling per capita$_{it}$= f (waste generation [predicted values]$_{it}$, policy variables$_{it}$, socio economic controls variables$_{it}$)

The specifications could be assessed with the dependant variable either quantified in tonnes (per capita) or specified as a share (e.g. share of national waste flow incinerated). Since both types of information are easily available, it is worth trying both directions. The ouput provide different information. For example, regarding the effect of a continuous variable like consumption, in one case we get an elasticity signalling the amount of waste incinerated generated by an increase in consumption, in the other case we get the effect on the relative share. The signs of the relationships may differ in some case: the elasticity in terms of tonnes being, say, positive and significant, while negative and significant in terms of shares (the other two options should be associated with even greater increases and elasticities, other things being equal, in this example).
In adding disposal options into the picture[27], we may define at least three (alternative) methods for estimating the empirical model[28]:

1. A first way is including the economic driver as an explanatory factor for disposal options, as for WP. Other policy variables, specific to one disposal option only, or common to all options, are then tested, as well as structural variables, common to all regressions. Correlations between socio economic elements and policy proxies are to be verified, giving priority, other things being equal, to proxies which mitigate the problems of correlation. See table 2 as main reference for the potential variables to be used in specifications 2a,2b,2c.
2. A second way is including waste production as an explanatory factor for disposal options. This is the easiest way to deal with the consequential nature of the systemic relationship between production and management of waste. Directly "controlling" for waste production (main scale driver) is also aimed at dealing with the entangled, though not necessarily correlated in statistical terms, dynamics of the 3 management options, which derive from their dependence on WP and scale economic effects being main drivers[29]. The rest of the reasoning is the same as above. Elasticities of dependant variables 2a,2b,2c with respect to

[26] The same reasoning on specifications in per capita or nominal terms applies here. The estimation of population elasticity is interesting at the light of EU newcomer's income and also population trends that differ form the almost similar population growth rates of western areas.
[27] Most contributions just focused on the first step, we are aware of rare attempts to bring together the two levels, given the usual and well known difficulty of setting up reliable and quantitatively sufficient datasets.
[28] At a mere statistical level, it could be plausible to estimate all three specifications and compare them both in terms of economic significance of parameters and relationships and in terms of statistical performance.
[29] Lag values of WP/GDP/C could also be tested as drivers to account for further dynamic effects. The sole panel structure does not capture eventual lag effects of variables.

income and waste production, both relevant in economic policy terms, are assessable. Income and WP should not be used jointly as explanatory variables.

3. Another way to empirically deal with the systemic nature of the issue is to get the predicted values[30] from equation (1), and using such predicted values for WP (or W composition) into specifications (2a,2b,2c). For an example of such a methodology see, in the context of ex post evaluation of environmental policy, Millock and Nauges (2006), and also Mazzanti and Zoboli (2006) in the realm of environmental innovation. This method is used either to deal with endogeneity problem in cross section dataset or to properly specify a multi stage empirical model when necessary from a conceptual point of view[31]. It includes in the estimation the exogeneity of MSW generation, if it is deemed to be a problem.

The use of predicted values may be valuable in order to capture the consequential nature of the two levels. Nevertheless, a comparative estimate may be carried out considering the two steps as statistically separated, though conceptually integrated. In other words, we include as main driver in the first level the economic factor of relevancy as well as other potential drivers, while the second level does not witnesses economic drivers, but waste related, policy and other socio economic and structural factors, including technological elements.

Summing up, once the production of waste empirical reduced form is estimated, we include its predicted values or the real value in following specifications, or the income determinants in alternative. We suggest running both 2a,2b,2c regressions in tonnes of waste landfilled, incinerated and recycled (per capita terms[32]), or specifying as dependant variable a share percentage index, ranging between 0 and 100, representing the share characterising each country. Considering illegal dumping, the three percentages only approximately sum up to 100[33].

Finally, another option would be the specification of the dependant variables 2a,2b,2c in "relative terms", by couples of disposal options. In other words, according to our aims, we may want to specify, for example, landfilling and incineration "shares" as a ratio index, that captures the extent to which, for the possible three combinations landfilling-incineration, landfilling-recycling and incineration-recycling, waste is diverting from one to the other and by what effects[34]. By using this

[30] Since predicted values, as residuals, are estimated from the regression in level 1, they "contain" the information on the included drivers of WP. WP predicted values are thus specific to the estimated regression. There is some space of arbitrarily choice in selecting the set of explanatory variables when estimating them. No rule of thumb may exist; case by case analysis is needed. In any case the first stage regression (level 1), producing the fitted values, must contain both all drives for x and *all* exogenous structural variables then included in the second stage regression, along with x and its predicted values or eventually first stage residuals. Otherwise, inconsistent estimators of relevant coefficients may arise. See also Wooldridge (1999, pp.506-7) and Kennedy (2003, pp.197-8). This method is a bit more cumbersome. Summing up, the same structural variables should be present in all regressions.

[31] See Woolridge (2002, pp. 90-93) for a comprehensive discussion on "two-stage estimations". He notes that the first stage regression producing the fitted values must contain all instruments for x and all exogenous variables then included in the second stage regression. Otherwise, inconsistent estimators of relevant coefficients may arise. In this case, the economics driver would act as an instrument; some of the other covariates should be common to the first and second level following the above reasoning.

[32] Otherwise, if we aim at assessing whether population growth affects landfilling, we can estimate them in a non per capita term, including population as driver.

[33] All in all, the estimation of different specifications, if on the one hand it is aimed at verifying partially different hypothesis, on the other hand it is also possibly intended as a test for result robustness. This depends on the defined objectives and hypothesis of the empirical research.

[34] Given shares are in percentage terms, the ratio index assumes values from, theoretically, $+\infty$ (very high/very low) to 0 (very low/very high). Excluding the possibility of observing real 0 values, the variable is

approach, we should merge the vectors of explanatory referring to the two considered variables. It may be a useful alternative to deal with the systemic nature of the waste framework at the level of disposal options.

To conclude on this final point, and referring back to what discussed in par. 4 of the complementary paper by Mazzanti and Zoboli, the diversion indicator “landfilled waste / waste production” is a relative term indicator compatible with the present reasoning. Instead of including waste production or correlate divers as explanatory variables, we may exploit such specific indicator for landfill even for the full quantitative analysis. The pro is that we appreciate a dynamic where two structural elements such as landfilling and waste production are integrated (the economic driver can be used being WP here part of the dependant variable), the con is that relative or absolute delinking, with respect to WP, cannot be ascertained. A decrease in the indicator (drivers that negatively correlated with this indicator) implies that the ratio is decreasing, not necessarily that landfilling per se is diminishing.

We observe that the possibilities listed above are a more comprehensive and maybe correct way to deal with the nature of the waste system, instead of estimating separately all four models, and only including income for disposal options (as in Karousakis, 2006).

Concerning independent variables, general issues were addressed above. We refer the reader to tab.1. We here note the higher relevancy and need, with respect to the EP level, of policy related variables, both of national and decentralised nature. There is not one direction for setting such variables; official data availability is limited and reliance on national case studies is necessary. We note that it is worth testing, besides the single effects of specific policy proxies, the role of interaction of variables. They may be capturing “complementarity or substitution” effects characterising policy factors[35]. As examples, recalling some parts of the conceptual analysis, the effect of landfill related instruments and of waste management tax and tariffs could be mitigated or undermined by the interaction of such economic stimulus with country-specific structural elements much as the development of separate collection and recycling markets. Counterintuitive results could emerge from testing such interactions: the lower the net cost of collection (i.e. net of revenues from recycled materials and energy), and then the lower the prevention effect of ‘full cost’ tariffs and charges, and of landfill taxes. Other interactions should be set by following the same line of reasoning.

thus well treatable in statistical terms, being continuous; it assumes the value 1 when shares of disposal options are equal to each other (i.e.30%).

[35] For a recent paper dealing with complementarities between policies see Mohnen and Roller (2005); for an analysis of complementarities from a methodological perspective and some applications to environmental innovation see Mazzanti, Montini and Zoboli (2006c).

5. Final remarks

To sum up, the two levels of analysis presented above are aimed at assessing: (i) the EKC hypothesis as regarding waste production, with respect to GDP, consumption. Elasticities of waste production with reference to GDP, consumption and population are calculated; (ii) the eventual *indirect effects* of landfill/incineration policies and single instruments at waste management level on waste production; (iii) the *direct effect*s of landfill and incineration Directive, with ancillary factors, on the dynamics of waste management; (iv) the effect of waste economic instruments and decentralised waste management features on waste disposal allocation; (v) the consequential effect of economic drivers and waste production on separate and relative dynamics of recycling, incineration and landfilling; (vi) the role played by structural socio economic and institutional variables at both level of analyses.

The presented framework for panel analysis on EU 25 countries has many added values: it considers a dataset which, differently from other studies, is more homogenous across countries and therefore useful for policy making. As far as food for policy making is concerned, a panel data analysis focussing on a homogenous set of countries is associated with fewer flaws and is more policy informative, if compared to international cross section/panel analysis. We may argue that an EU data framework balances between the (statistical and economic) need of having a sufficient heterogeneity in observed data, but not so high across units to make any interpretation of outcomes rather difficult if not meaningless[36].

In fact, recent analyses, though sound and robust, are undermined in scope since they rely on OECD datasets, which are, as the authors themselves point out, not always reliable and full of missing values for the time span 1980-2000. We refer mainly to Beede and Bloom (1995), Johnstone and Labonne (2000) and Karousakis (2006). The latter two exploit basically the same OECD dataset 1980-2000. Karousakis includes some policy variables into the investigation, but exploits in the end only 120 observations (four five year periods per 30 countries). Johnstone and Labonne seem to exploit a full dataset, though they point out (p.531, 534): “while efforts are made in order to ensure that countries use consistent definitions of MSW, there are differences between waste classifications used by different countries, and as such care must be taken when interpret ting the descriptive data [..] The most important point to bear in mind is the large number of missing observations for the household waste data”. We note that past evidence on waste generation may be partially affected by the quality of data for the eighties. Then, EKC dynamics difficultly characterised the relationship over this time span. Attention was mainly devoted to income and population elasticities.

[36] Then, the relative homogeneity, which characterises the European framework, in addition to the European framing of most waste policies, add informative value to 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).

Thus, the value added of this research hypothesis is strictly linked to the current availability of updated reliable data for a homogenous area like Europe, where country heterogeneity helps the statistical investigation, but where a European analysis is of some relevance for polices, differently from OECD based sides. Data which are sufficiently long in time and geographically wide for investigating the full set of objectives: (1) elasticities of waste generation with respect to economic drivers; (2) EKC hypothesis; (3) policy effects on delinking; (4) explanatory factors of all disposal options.

In addition, the frame entangles the empirical model of waste generation determinants and disposal options by exploiting a two stage procedure, which is usually applied for tackling endogeneity; it has a sufficient amount of information both on the time series side (10 years) and on the cross section side (30 countries). We may thus exploit both the time and cross section information. Unobserved effects are dealt with and specific country effects controlled for. Autocorrelation is necessarily tested given the time series nature of data. The temporal structure of the panel model allows a proper investigation of causal effects between variables, which are not assessable in cross section analysis or in short panel (2-3 years).

Table 2 presents the independent variables which we may include in the model, suggesting a potential allocation with respect to the 4-5 (including or excluding waste composition) regressions of the entire two levels.

Tab.1. A list of potential independent variables for the specified empirical model (some hypotheses are discussed in the notes, also recalling what argued in the text)

Dependant variables (25*10=250 panel; 25 countries; 1995-2004[37])			Waste generation at source	Waste management		
			Waste production (Waste composition)	recycling	Energy recovery	landfilling
Independent variables	Availability: years and countries	comment	Cells below show the expected signs of links[38]: the sign refers to the associated β coefficient in a specific regression			
Economic drivers						
GDP; GDP/population (GDP squared)	25*10=250 panel[39]; 25 countries; 1995-2004	Consumption is tested as alternative and potentially better economic driver	+ / EKC hp[40]	+ / ? (as well as WP when included in alternative)[41]		
Consumption; Consumption/population (C squared)						
Economic structural features (Share of manufacturing, services, etc..)	Value added at factor cost , even in share terms, may be used as proxy: 1995-2004 quite good availability for EU25, with some gaps		?[42]	?		
Domestic material consumption	1990-2001; EU15 only	Check availability for other newcomers	+	+		
Socio-economic and structural drivers						
Population	25*10=250 panel; 25 countries; 1995-2004	to be included separately in the non per capita specification, if there is interest in the elasticity of waste to population growth	+ (elasticities may be lower or higher than one)	+ (elasticities may be lower or higher than one)		
Population density[43] (surface/pop)		Testing scale effects	?	?		

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[37] Some missing values, which could be dealt with by discussed methods.

[38] Where (?) is present it means that both signs should be expected or that positive and negative force balance each other. The following notes attempt to discuss some of the underlying hypotheses in those cases. Regarding WP, the inclusion of waste management may be not plausible, though possibly tested. Socio-Economic theory and past empirical evidence cannot inform the tested hypothesis. For Waste generation at source only hypothesis related to waste production are presented. Concerning waste composition, which we have included as being part of the conceptual model, no relationship is commented since the analysis is unfeasible at the current time.

[39] The aim is to construct a panel with 25 countries and 10 years for as many variables as possible. Missing values, if not many and if randomised across countries and over years, may be replaced as suggested in order to minimise data losses and increase the explanatory power of the model.

[40] For these two economic drivers the EKC hypothesis may be tested regarding waste prevention and eventually waste management options. Squared terms are included: the EKC assumption is valid if the first term is positive and the second squared term negative, both being significant. This would confirm absolute delinking on average. Without squared terms, the coefficient tells us whether no delinking, relative delinking or absolute delinking is occurring (positive higher than one, positive lower than one, negative).

[41] An increase of GDP/C/WP increases the flow of waste and the amount of managed materials. Overall, the sign is positive though the effect on the allocation and diversion from landfills depend on structural and policy variables.

[42] It may be assumed that an increasing services share reduces the amount of waste produced by the economy, though the effective delinking associated with services has to be still robustly proved both for air emissions and material flows. See Kander (2005), who is sceptical about the idea that the transition to a service economy will bring about dematerialization of production (attributable in case to higher productivities in manufacturing sectors, some own which may achieve good environmental performances, and to the low (productivity) growth of services) and Mazzanti, Montini and Zoboli (2006b), who provide mixed evidence concerning Italian air emissions sectoral drivers over 1990-2000. On the one hand, “real” services production may indeed stay constant or even decline (the productivity/price/ costs dynamics of the service sector possibly not favouring services as hypothesised by the Baumol’s disease), on the other hand technological improvements may always be stronger in manufacturing, bringing about better environmental performances. Structural changes related to energy sources play also a major role in explaining EKC dynamics and dematerialization.

[43] Population by itself captures a specific country/regional dynamics; population density should capture some heterogeneity across countries.

Household size	2003 available for all countries; Time series with missing values; 1997-2001 for EU15	(population) or potential efficiency deriving from high density/large size; it is possibly linked to other structural country effects				
land use	2000 available but Missing values	It may be a structural relevant factor affecting historical disposal choices	?[44]	?	?	
Household urbanisation degree	1999 Many missing values	As above, but it captures some different elements in between land use and density	?	?		
Inequality of income distribution	1995-2000; many countries but Some gaps	Never tested in the waste framework apart from US studies on waste, income levels and migrations. A more equal distribution may increase average willingness to pay for waste prevention and recycling, through diverse market and non market mechanisms	?, +	+	?	?
Innovation structural drivers						
Gross domestic expenditures on R&D (GERD)	Good availability over time and across countries 1995-2004, some missing in eastern EU	They control for country heterogeneity in innovation intensity: relevant as drivers for waste prevention and incineration activities. Data on specific environmental R&D not available	-, ?[45]	+		-
Shares of GERD financed by industry and government						
Patent applications for million inhabitants	Good availability over time and across countries	Available at 1995 prices and exchange rates, Purchasing power standard, total and per inhabitant				
Gross (fixed) capital formation (eventually by investment products)						
Labour productivity per person employed, per hour worked		Indicator, EU25=100				
Policy related drivers[46]						
National Policies						
Synthetic Policy index	0-1 continuous variable	If available from EEA or OECD. See Karousakis (2006) for an EEA index (data for one year). It captures a general country commitment to environmental policy. High	-	+	?	-

[44] The shear of Built up areas may be positively related to WP and recycling and negatively related given scarcity of land (opportunity costs of soil exploitation), to energy recovery and landfills. The same reasoning revolving around scale and marginal disincentives nevertheless applies.

[45] Depending on complementarity links between environmental (material/waste oriented) and non environmental innovation, whose assessment is rather complex (see Mazzanti and Zoboli, 2006c; Mazzanti, Montini and Zoboli, 2006c).

[46] Since policy targeted at waste prevention are not present if not very rarely and recently, the here listed policy indicators may be included even in level 1 (WP), in order to assess eventual indirect effects acting by market driven feedback effects. Their specific and proper level is nevertheless that of waste management options.

		heterogeneity may be revealed.				
Landfill tax presence at national level (dummy) / landfill (national) tax value	To be valued; the dummy variable is quite easily defined observing national case studies	The dummy[47] is a rough variable; the value is a good variable but most countries witness a regional implementation.		+	+	-
Number of years of effective implementation of the landfill Directive (temporal effect)	Available for all countries; to be set up	The continuous variable captures the possible time dependant effects of the policy; complementary to the dummy above (interaction also potential variable)	- if deemed significant in this level[48]	+	+	-
Share of national territory/population covered by the landfill tax	Difficultly available (derivable from national case studies?)	It would capture, mainly in decentralised environments, the effective state of landfill policies in a country		+	+	-
Incineration tax presence at national level (dummy)	To be valued; the dummy variable is quite easily defined observing national case studies	The dummy is a rough variable; the value is a good variable but most countries witness a regional implementation. No national tax landfill exists.		+	?	?[49]
Year of effective implementation of the incineration Directive	Available for all countries; to be set up	The variable captures the possible time dependant effects of the policy	- if significant	+	+	?[50]
Structural waste management indicators						
N. of landfill sites (per capita, per ton of waste generated)	Discrete availability[51], even for east Europe (but missing values, and some countries do not report data)		?[52]	? (general issue: the existing capital stock probably favours specific choices, though at the margin private and social costs rise when full capacity is reached, disincentiving that management option). In the short run the sign can be + and – in the long run (considering the effect of landfill infrastructures / shares on landfilling dynamics and so on.)		
N. of incineration sites (per capita, per ton of waste generated)						
Landfill share in total disposal	Available 1995 and 2003 (check) The 2003 value or the percentage change can be alternatively tested					
incineration share in total disposal						
Recycling share in total disposal						
Decentralised waste	Available,	Dummy or three	- (?)[53]	+	?	-

[47] Two specifications are possible: either a dummy assuming value 1 if implementation has already occurred (or by a certain date), or (maybe better, exploiting the panel data structure) a dummy assuming 1 for countries/years witnessing implementation, 0 otherwise.

[48] For landfill and incineration policy having a role in the decoupling process, it is required that it has a feedback on consumers or other waste producers, due for example to price effects or other factors. It is a matter of price elasticity of waste production, and it depends on many factors (income, age of consumers and so on) but cannot be considered very high. Furthermore, consumers can also react by increasing illegal waste dumping, especially in pay-as-you-throw systems (promoted by the Waste strategy). All in all, it is not a sure channel of waste prevention affects from landfill policy.

[49] The transposition of incineration directive, by imposing higher technical and environmental standard to new/retrofitted plants can increase costs (short term) and then it can be non favourable to diversion from landfill

[50] The transposition of incineration directive, by imposing higher technical and environmental standard to new/retrofitted plants can increase costs (short term) and then it can be non favourable to diversion from landfill

[51] Discrete panel data availability concerning landfill/incineration sites (which has to be normalised by population or surface), bad availability for interesting variables like "remaining capacity if landfills" and landfill sites total area".

[52] Without specific waste prevention policies, the historical capital/infrastructural stock (dense in sunk costs) associated to management options may even generate positive impact on waste generation.

management (dummy)	constant structural variable over the period	levels categorical (yes, no; Partially Decentralised)				
MSW fraction separately collected	1997-2003 available for many countries with missing values in Eastern EU	A variable, at least representative of one year or of average figures, is feasible: More information derivable from national case studies?	?	+[54]	+	-
Decentralised Waste management policy drivers						
Waste management related prices (tariff, charges, taxes) • Presence (dummy) • Share of regions/provinces/municipalities covered by the instrument • Share of population covered by the instrument	Limited availability (derivable from national case studies?)	Rough availability from the list of economic instruments in place (decentralised socio economic indicators, ETC dataset)		+	+,?	?
Presence of waste tariff or waste tax (are correlated to waste generation/waste externality or to other variables (income, household size)?)	(Derivable from national case studies?)	Dummy variable capturing the presence of real economic instruments in waste management: Pigovian instruments vs cost recovery instruments	- (?)[55]	+	+	-
Cost recovery of waste services by tariff or taxes		It captures the "private" nature of waste services.				
Other environmental and waste related effects (but not directly linked to MSW and landfill/incineration policies)						
Packaging policy in place (packaging waste status)	Available, constant structural variable over the period	Dummy or qualitative categorical variable	?, -[56]	+	?	-
WEEE policy in place		Dummy or qualitative categorical variable				
RDF production capacity		Dummy or qualitative categorical variable				
Compost production capacity (compost share)		Dummy or qualitative categorical variable				
Price ratio of Virgin/secondary market materials	Potential availability	Continuous variable depending on availability; dummy or categorical otherwise	-	+	+	-
Energy intensity of the economy	Very good availability by country and years	Gross inland consumption of energy divided by GDP	?	?	+	?
Electricity prices	Good availability, apart from	€/kwh, industrial and consumer use	?	?	+[57]	?

[53] We may assume that a decentralised waste management operates more efficiently with respect to at source and landfilling objectives. No clear cut hypothesis can nevertheless be defined.

[54] Autonomous development/policy of separate collection pushes in the direction of developments in the material recycling/recovery route and partly RDF-based incineration. The effect on WP is less clear, endogenous dynamics may occur as described in the work.

[55] The more separate collection and recycling markets are well-developed, the lower the net cost of collection (i.e. net of revenues from recycled materials and energy), and then the lower the prevention effect of 'full cost' tariffs and charges.

[56] In the long run higher production costs (heterogeneous by material) may incentive lower product weight and less use of (certain) material. Product Innovation and material substitution could over compensate scale effects due to consumption growth.

[57] High energy prices (electricity) can favour the expansion of capacity and the redirection of waste flows to incineration.

	some eastern EU countries					
Interaction variables (capturing "complementarity or substitution" effects)						
Landfill policy proxy (above) interacted (times) with proxies of development of recycling and recovery sectors/industries and incineration sectors (recycling share in total disposal)	Availability depending on what said above	Interaction variable may be used to verify specific hypothesis of complementarity or substitutions between diverse elements of the system, as suggested in the framework description	? (Very high share of incineration/landfilling on total waste management can be a limitation for further expansion, but the lock-in effect for the dominant technology can favour a further expansion. The expected sign is thus ambiguos, positive if it prevails the lock in effects, negative otherwise)	+	?	-
Interaction of waste full cost pricing instruments with proxies of development of recycling and recovery sectors/industries and incineration sectors (recycling share in total disposal)				+	?	-

The table should be read as a consequence of table 1, where factors influencing the effectiveness where listed, commented. Table 2 attempts to make a concrete step towards the implementation and estimation of the empirical model, listing variables and commenting on their availability and typology. The data source is EUROSTAT for all variables, except policy related variables. We observe that with respect to policy variables, the most interesting but tricky part of the model set up, case studies on single countries may be highly complementary to the present quantitative analysis, insofar they collect qualitative and quantitative information on policy implementation and use of specific environmental economic and non economic instruments. This is the area where EUROSTAT datasets are of little help and other directions of data collection should be sought for.

§such variables are available only for some years over 1995-2004: in those cases we may fill missing values by own calculated forecasts or we may use an average value for all years (this prevents some panel estimations since we lose temporal heterogeneity).

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