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Municipal and Packaging Waste Kuznets Curves

Evidence on socio-economic and policy drivers from the EU 15

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Abstract

Waste generation and waste disposal are becoming increasingly prominent in the environmental arena, from a policy perspective and in the context of delinking analysis. In general, waste generation is still increasing proportionally with income, and economic and environmental costs associated to landfilling are also increasing.

This paper provides a comprehensive analysis of waste generation for municipal and packaging waste, based on panel data for the EU_{15}, to assess the effects of different drivers (economic, structural, policy). The evidence presents valuable policy implications since analyses the extent to which over the last decade delinking occurred for the two waste streams, and how EU waste policy eventually influenced the waste generation-income relationship. We show that for waste generation there is still no absolute delinking trend. Landfill and other waste policy levers do not seem to provide backward incentives for waste prevention, still not an explicit objective of EU environmental policy. As far as packaging waste is concerned, absolute delinking appears for some materials but not in the overall trend, showing the necessity of investigating performances on specific waste streams. Although absolute delinking is far from being generally achieved for waste generation in both cases, there are some first positive signs of an increasing relative delinking for waste generation. Nevertheless, the impact of waste policies, probably due to the strong focus on waste disposal and recovery objectives rather than waste reduction at source, is quite negligible and also endogenous regarding income dynamics. Thus, waste prevention must be the next core objective of waste regulation efforts in the future of the EU.

Jel: C23, Q38, Q56

Keywords: Waste Kuznets Curves, delinking, waste policies, policy effectiveness, panel data

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Delinking and waste policies in the EU

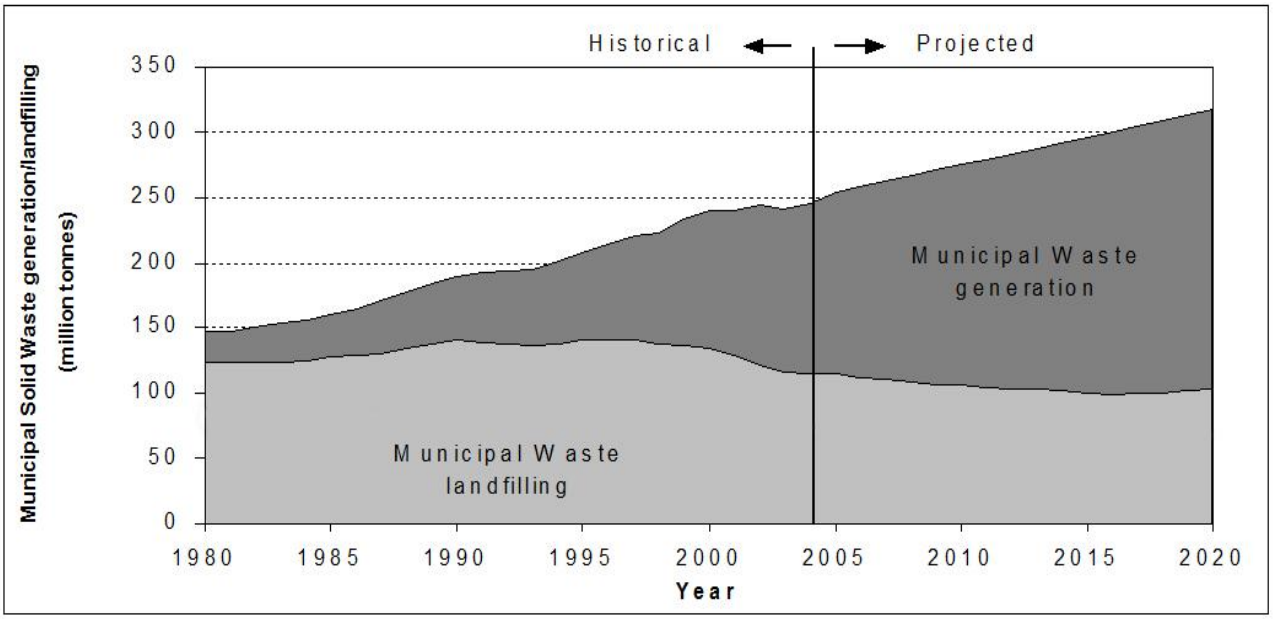
Indicators of 'decoupling/delinking' are used to measure improvements in environmental/resource efficiency with respect to economic activity. The European Union's (EU) 'thematic strategies' on resources and waste, include reference to 'absolute' and 'relative' delinking indicators (EC, 2003a,b; Jacobsen et al., 2004). The former are a negative relationship between economic growth and environmental impacts associated to the descending side of an inverted U shape according to the Environmental Kuznets Curves (EKC) framework. The achievement of delinking is of prime importance for waste, which plays as important a role in environmental impact and economic costs as climate change (Figure 1).

The EEA (2007) acknowledges that "It is increasingly important to provide answers to these questions because waste volumes in the EU are growing, driven by changing production and consumption patterns".

EEA (2007) shows that countries can be categorised under three waste management 'groupings', according to their strategies for diversion of municipal waste away from landfill, and the relative shares of landfilling, materials recovery (recycling and composting) and incineration. The first group comprises countries with high levels of materials recovery and incineration, and relatively low landfill levels. The second group includes countries with high materials recovery rates, medium incineration levels and medium level dependence on landfill. The third group includes those countries with low materials recovery and incineration levels and relatively high dependence on landfill

The environmental impacts of landfilling are massive (Pearce, 2004; El Fadel et al., 1997; Eshet et al., 2007). Landfilling should not become the default best economic practice in all situations; its costs and benefits are influenced by economic and technological factors. For examples of economic assessments of different waste disposal strategies, see, among others, Pearce (2004) and Vollebergh and Dijkgraaf (2004). It should be noted that reducing waste generation at source through the imposition of policy targets in terms of waste generated per capita, is probably the most effective and efficient way of handling the problem in the long run. Given its potential high cost in the short run, the first phase of policy implementation at EU level has focused on landfill diversion and increased levels of recycling/recovery, including incineration. Although waste prevention is at the top of the waste hierarchy in the EU, there are no directives so far that include actions oriented specifically towards waste prevention. Waste management (separated collection, recovery/recycling) and landfill diversion are the focus of existing waste policies, probably because of their presumed relatively lower implementation and compliance costs.

Figure 1: Projected generation and landfilling of municipal waste in the EU25



Source: EEA (2007), Figures from 1980-2004 are data from Eurostat. Figures from 2005-2020 are projections. BMW (Bio degradable Municipal waste)

This paper provides empirical evidence on delinking trends and Waste Kuznets Curves (WKC) for municipal solid waste (MSW). The primary aim is to provide preliminary robust empirical evidence for a vast regional area (the EU) on the economic and policy drivers of waste dynamics. Although waste policies have been in force for some time in the EU, and are a pillar of EU environmental policy, they have not been studied using qualitative methods. Empirical evidence on WKC dynamics for waste is scarce. Research on delinking for materials and waste is far less developed than research on air pollution and greenhouse gas emissions.

In addition, analyses using cross country, highly disaggregated panel data on waste are also very scarce, with most studies involving single countries at the regional, provincial or municipal levels. In spite of the significant environmental, policy and economic relevance of waste issues[2], there is very little empirical evidence on delinking even for major waste streams, such as municipal waste, packaging and other waste.

The original point in our analysis is to bring together delinking analysis and policy assessment. Policy efforts are analysed in their effectiveness in reducing waste generation, on the basis of the actions taken in response to implementation of the relevant policies for the case considered here: namely the 1999 Landfill and incineration Directives[3], the 1994 and revised packaging waste directives, and more generally the commitment and effort put on implementing waste policies by EU countries, including earlier 'policy actions' taken by some countries with regard to formal policy ratification (e.g. Germany, Austria put in place a packaging waste management system before the directive was agreed in 1994)[4].

[2] EEA (2005): 'The sixth Environment Action Programme (6EAP) highlights the need to undertake '*ex post* evaluation of the effectiveness of existing measures in meeting their environmental objectives'. The EEA Strategy, as adopted in 2003, sets out the main priorities of the Agency for the period 2004-2008. It identifies ex-post policy effectiveness analysis as one of the agency's priorities for the future'.

[3] "The Landfill Directive pursues two approaches: firstly to introduce stringent technical requirements for landfills; and secondly, to divert biodegradable municipal waste (BMW) from landfills by setting targets for the landfill of BMW in 2006, 2009 and 2016. The Incineration Directive (Directive 2000/76/EC on the incineration of waste) is an ancillary and complementary piece of the EU waste policy strategy which also includes the Waste Framework Directive, legislation that was revised at the end of 2008 (EC, 2008), but which still does not identify clear policy targets.

[4] We exploit national differences in time and stringency of policy adoptions. Policy heterogeneity is relevant in environmental policies whose implementation is rather decentralised. As example the EEA study (EEA, 2005) on packaging waste (directive) for some countries state: 'National approaches towards creating a packaging waste management

If the 1999 landfill directives and earlier or later (in the ratification stage) actions taken by countries is the cornerstone for the analysis on MSW delinking and policy analyses, the history of packaging waste, in terms of policy action, goes further back to the early 90's[5]. The Packaging Waste Directive is one of the few environmental Directives to contain directly measurable, quantitative targets, and it has now been in place for more than a decade[6]. As commented on by the EEA (2005): 'The packaging directive aims to harmonise national measures concerning the management of packaging and packaging waste. This is in order to prevent any impact thereof on the environment of all Member States as well as of third countries or to reduce such impact, thus providing a high level of environmental protection, and to ensure the functioning of the internal market, avoiding obstacles to trade and distortion and restriction of competition within the Community. The directive lays down measures aimed, as a first priority, at preventing the production of packaging waste and, as additional fundamental principles, at reusing packaging, at recycling and other forms of recovering packaging waste, hence reducing the final disposal of such waste'.

The need for jointly analysing socio economic determinants of delinking and policy evaluations emerge in the final considerations of the EEA (2005) cited study which focused mainly on 1994-2001: 'the concept of relative decoupling is used to measure increased efficiency: if the growth rate of packaging generated is lower than the growth rate of the GDP, relative decoupling is achieved. From this perspective, all countries except Italy have achieved a relative decoupling. Ireland has achieved relative decoupling, because although it has seen a huge 36% increase in packaging generated, growth in GDP in the same period has been even bigger (41%). Changes in private consumption expenditure, size of households, and population are often used as other parameters to explain the generation of municipal waste, packaging and packaging waste. Nothing conclusive can be said in this respect although more detailed analysis is necessary to estimate the relationships. Austria and the UK have managed to have high increases in private consumption expenditure without this affecting the amount of packaging'.

Table 1. New targets in the packaging directive

Material	Recycling target	Recovery target
Glass	60 %	
Paper and board	60 %	
Metals	50 %	
Plastic	22.5 %	
Wood	15 %	
Total packaging	min 55 %, max 80 %	min 60 %

Note: Targets are by weight, and to be achieved no later than 31 December 2008. Source: EEA (2005)

system differ. Four out of five countries have chosen a producer responsibility scheme. Some countries include all packaging waste in the system, while other countries focus primarily on commercial waste. In general, packaging waste management systems include a number of measures and are primarily aimed at increasing recovery and recycling, while efforts on prevention of packaging waste are clearly less embedded in the systems'.

[5] We unluckily cannot analyse policy effectiveness by testing a break in the series since we observe 1995-2005: a period covered by the first phase of the Directive. 2003 is too recent for assessing the effective the revised Directive. For MSW instead the 1999 break associated to the landfill Directive is tested.

[6] EEA (2005): 'The Commission proposed a new directive in 1992, but the first discussions started already in 1988. Since 1990, the Commission worked out seven pre-draft versions all containing three major elements. A maximum output of packaging waste per capita of 150 kg per year to be achieved in ten years; A mandatory minimum recovery rate of 60 % and a recycling rate of 40 % to be achieved within five years, rising to 90 % and 60 % in ten years; A binding hierarchy of disposal options (prevention, reuse, recycling, etc.)'. On 15 July 1992, the Commission presented a proposal for a new directive on packaging and packaging waste. The proposal upheld the ambitious targets for recovery and recycling of packaging waste, but the per capita limit of the volume of packaging material and the binding waste hierarchy of the pre-draft had been eliminated, mainly because it was not acceptable for the producers of packaging. On 20 December 1994, the Council of Ministers accepted the revised proposal, which became Directive 94/62/EC. The directive was adopted under article 100A (harmonisation directive). The first recycling and recovery targets of the directive were to be met by 2001 and were revised in 2004 (table 1) setting a more stringent second policy step, which always encompass differences across materials. The new material targets are largely based on a cost-benefit analysis carried out in 2003 for the European Commission

We further note, looking at current and future policy actions to which this paper may provide relevant evidence, that even the revised 2008 Waste Framework Directive, which was at some time expected to include some per capita targets for MSW generation, although it explicitly reassesses the objective of delinking and the necessity for using economic policy instruments to tackle waste externalities according to relative social costs, does not ultimately fix waste prevention targets. Article 9 on waste prevention sets future actions only in terms of stating that by the end of 2014, waste prevention and decoupling objectives for 2020 will be presented, and article 29 indicates that countries should prepare waste prevention programmes by 2013 (the EEA is required to report annually on this evolution from 2008 to 2013), with delinking performance to be evaluated every six years. It would seem clear that absolute delinking is not present for MSW generation and EU member countries have managed to postpone specific waste generation per capita targets.

The paper is structured as follows. Section 2 presents some research hypotheses that descend from the recent literature on WKC and waste policies. Section 3 defines the data and the empirical model, offering comments on main evidence. Section 4 concludes.

2. Waste Kuznets Curves: Empirical framework and research hypotheses

The report that gave birth to the Environmental Kuznets Curve literature (World Bank, 1992) presented some evidence based on cross country regression analysis of data from the 1980s; no WKC were found. A more recent report (DEFRA; 2003) highlights the positive elasticity of waste generation to income as a primary concern for policy: waste generation seems still to be characterised by a strict positive relationship with economic drivers.

One of the earliest WKC studies was by Cole et al. (1997), who found no evidence of an inverted U-shape for municipal waste. They found no turning point (TP) in their study, which exploited data on MSW, for the period 1975-90, for 13 OECD countries. Similarly, Seppala et al. (2001), in a study of five industrialised countries including Japan, the US and Germany, over a similar time period (1970-1994), also found no evidence of delinking regarding 'direct material flows'. However, there is some emerging evidence of delinking, although for quite specific (waste) indicators. Berrens et al. (1998) and Wang et al. (1998), focusing on stocks of hazardous waste in the US and exploiting a county-based cross sectional dataset also find evidence in favour of a negative elasticity.

A 2004 study by Johnstone and Labonne using panel data on solid waste in the OECD countries, provides evidence of economic and demographic determinants of rates of household solid waste generation, regressed over consumption expenditure, urbanisation and population density. This study finds positive elasticities, in the range 0.15 to 0.69, while Mazzanti and Zoboli (2005), in a study of a group of European countries, find evidence of neither absolute nor relative delinking. Using European panel data Mazzanti and Zoboli found no WKC evidence for either municipal waste or packaging waste respectively for 1995-2000 and 1997-2000. Estimated elasticities of waste generation with respect to household consumption were close to unity.

Few WKC studies incorporate waste policy analyses. Kaurosakis (2009) deals with policy evaluation, and presents evidence on the determinants of waste generation and the driving forces behind the proportions of paper/glass recycled, and the proportion of waste going to landfill. The data are for a panel of 30 OECD countries and the results show that MSW increases monotonically with income, and that urbanisation exerts an even stronger effect on waste generation, while the time-invariant policy index is not significant.

Other studies have investigated policy actions, but at the level of single countries, exploiting rich regional data, which however allows moderate generalisation of results. Mazzanti et al. (2008) find some WKC evidence and signs that waste management instruments do have an effect on reducing waste generation in Italy, where trends are affected by economic, policy and structural geographical differences.[7] There are also some studies on specific evaluations of the Landfill Directive - the main driver of regulatory actions in the EU, and the UK landfill tax - introduced in 1996 and one of the few

[7] See the collection of WKC policy oriented works in Mazzanti and Montini (2009).

cases of a real environmental tax based on evaluation of the marginal external costs. These studies, which were based on rather sparse data, present interesting but only qualitative assessments. They include, among others, a work by Martin and Scott (2003), which stresses that tax aimed at reducing landfilling of waste in favour of recovery, recycling, re-use and waste minimisation has failed to significantly change the behaviour of domestic waste producers.

The brief survey thus shows there is plenty of room and need of further research along the envisaged directions (par.1). Our first objective in this paper is to provide new empirical evidence on WKC and waste policy effectiveness in the EU, distinguishing between socio-economic and policy factors that drive (municipal and packaging) waste trends. What is required is WKC analyses combined with studies of policy effectiveness and an extensive evaluation of waste drivers. The general value added of delinking analysis is not (only) to show whether economic drivers produce decoupling effects, but more especially, to assess whether and to what extent, there are additional factors that influence this core relationship, and increase the explanatory power of the model proposed. Our work on the EU allows some generalisation since it focuses on a large regional area that is relatively homogenous and has common waste policy references in the form of EU Directives. The WKC model is appropriate for assessing the effects of socio-economic and structural factors in the BAU scenario, and the role of policy levers in explaining the eventual delinking between environmental pressure and growth, without which we can expect a lower or even no delinking. A secondary objective is to identify differences between the municipal and packaging income-environment-policy relationships, in order to provide food for though to eventually reform future EU policies.

In order to verify the delinking relationships between waste indicators and the economic, socio-economic/structural[8] and policy drivers, we refer to the established EKC framework.

The main methodological problem for applied analysis in this delinking-related framework is how to specify the WKC functional relationship. Some authors estimate second order polynomial, others estimate third or even fourth order polynomials, comparing different specifications for relative robustness. N shapes are not relevant here given that the evidence for waste shows that even bell shapes are rare.

We test our hypotheses by specifying the proper reduced form usual in the EKC field (Cole et al., 1997):

$$(1)\quad \log(WI^{9}) = \beta_{0i} + \beta_{t} + \beta_{1}\mathrm{Log}(C^{10})_{it} + \beta_{2}\mathrm{Log}(C)^{2}_{it} + \beta_{3}(Xi) + \beta_{4}(Zi) + e_{it}$$

where the first two terms are intercept parameters, which vary across countries and years. X refers to all other structural and socio-economic drivers that are added to the baseline specification in order to correct for the omission of relevant variables. Z is a vector of policy related variables (see Tables 2-3 for a description of the variables with a summary on main hypotheses tested).[11] In order to mitigate collinearity flaws, when highly correlated to each other, the variables included in the vectors X and Z are tested separately. The error term has the usual properties in panel settings, although obviously differing between fixed effects (FE) and Random Effects Model (REM) settings.

The set of research hypotheses regarding the drivers of waste generation can be summarised below, also referring to table 2 for a further synthesis. Though most expected relationships are similar for

[8] We define these factors as structural since, with respect to waste trends, they are a set of exogenous potential drivers that are influenced by the historical, institutional and cultural development of the country and also are relevant for waste management and disposal based on idiosyncratic geographical aspects (e.g. population density).

[9] Waste Indicators: MSW and packaging waste generation (classified in 4 material types) per capita.

[10] We took household expenditure (consumption) per capita as the main economic driver, based on the hypothesis that consumption is a better independent variable for waste collection and disposal (Rothman, 1998, Jacobsen et al., 2004).

[11] The model is based on a framework derived from the EKC literature. All variables are specified in logarithmic form using per capita values, to provide elasticity values and to smooth the data. Except where it is not feasible, logarithmic transformations are used for all covariates.

MSW and packaging waste, we note when possible differences in the sign of the link could be expected at conceptual level.

Regarding economic drivers, a WKC oriented structure of the model allows the estimation of an eventual TP for waste generation. The TP hints at the GDP/consumption level beyond which the relationship (in this case, between waste production and income) turns negative. Existing econometric and descriptive empirical evidence shows that only a relative delinking is observed. We aim to provide new evidence based on official EU data.

We also test various hypotheses on the possible effects exerted by socio-economic and structural variables, which represent a diverse set of factors.

Population density (or urban population)[12] is likely to have a positive impact on waste generation. In more densely populated areas, only economies of scale spurred by urbanisation could invert the trend and reduce generation. Household features may matter at this level. In fact, we expect that the larger the size of the household, the less waste will be generated per capita. Nevertheless, even a positive link could be plausible in the case of collection schemes, and waste management at the domestic level (composting) is poorly developed on average. Thus, more single person households should increase waste generation.

We use the average age in a country as a further control variable. From a socio-economic point of view, there may be opposite forces at play: if, on the one hand, older people produce less waste than younger residents, it is also true that older people may be less accustomed or committed to collection and recycling of waste. On the other hand, the opportunity cost of time is lower for older people, and waste collection/recycling efforts require time. The sign of the relationship, then, is unpredictable. Interaction with data on education level would be interesting, but this would be the subject for micro-based studies, which would probably test these other factors more robustly (e.g. Hage, 2008 on Sweden).

A final structural driver we test, eventually associated to policy actions in the eco innovation realm, is the number of ISO registered firms a country show (EUROSTAT data, turned into per capita level). We may expect that the larger the share of ISO firms the lower waste generation is. This hypothesis is especially tailored for packaging waste, which depends largely on the eco-management of commercial activities (producer responsibility is a pillar of the implementation) and then on their eco-innovation management.[13]

We also include in our analysis various types of specific policy proxies that regard potential effects on MSW, packaging, or either of them: this is a key point in our conceptual and applied reasoning. The first is related to the European Landfill and Incineration Directives and their implementation in member states. These proxies are built as dummy variables that take the value 1 in a given year between 1995-2005 if a country has transposed these Directives into its national law. We expect implementation to be positively correlated with delinking performance for MSW, though policy endogeneity with respect to income is an issue to consider and may lead to a positive correlation between policy stringency and waste performances, mediated by income[14].

The second group of policy indexes is more country specific. We first exploit a 'decentralised waste management index' that reflects the degree of waste policy decentralisation across countries.[15]

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[12] Given their high correlation, these two variables can be used alternatively in the econometric exercises.

[13] National approaches towards creating a packaging waste management system differ. More than 50% of countries have chosen a producer responsibility scheme. Some countries include all packaging waste in the system, while other countries focus primarily on commercial waste.

[14] Policy Endogeneity remains an issue worth considering for interpreting results, especially in the waste arena. Mazzanti, Montini and Zoboli (2008) find MSW policy tools to be endogenous with regard to waste generation, given a correlation with income levels. Recent studies have in fact started to analyse the drivers of environmental regulations, this defined endogenous factors (Cole et al., 2006; Alpay et al., 2006). Efforts aimed at setting up environmental policy indexes for climate change, waste and other realms show that developed countries are more stringent in pursuing environmental regulations. Consistently with the EKC reasoning, policies may result endogenous along economic development, especially correlated with income factors at both supply and demand levels (Cagatay and Mihci, 2006).

[15] This discrete index variable captures the extent to which a country is decentralised in (waste) policies, and more generally is structured as a federal state. Actually, 4 countries are associated to the value 1: Italy, Germany, Austria, Spain (main federal states), 2 have the value 0.5 (UK and Belgium), all others have the value 0.

Decentralisation may positively affect waste generation, via prevention and better waste management performance, because of higher flexibility and specificity in policy implementation, which may account for local idiosyncratic cost and benefit elements related to policy (Pearce, 2004).[16] Although decentralisation may improve policy implementation in the EU, including policies for waste prevention, it may have some drawbacks in terms of exploitation of local rents by public and private agents. In principle, rents are neither good nor bad in the environmental realm.

We also include an environmental policy index, of general 'waste policy commitment'.[17] this may be a valid proxy for national policies over the time period examined. It captures all possible information regarding national implementation of waste related policies (MSW, biodegradable solid waste, packaging waste, end of life vehicles, other)[18]. We used the country studies available on EIONET as our information source. The index is both very comprehensive with regard to Landfill Directive related variables, and also may capture some of the waste prevention features of national policies. It should be noted that, besides the decentralised policy index, all other proxies vary across countries and over time, rare fact in the literature.

Finally, we exploit EUROSTAT information on the share of environmental tax revenue on GDP. This is another general proxy of environmental policy. We may expect that the effect, if any, is of negative sign, though the endogeneity issue remains open. Thus, the estimated sign that regards waste performances and policy links is to a grater extent unpredictable: potentially negative (stricter policy reduces waste generation) if the policy is mainly exogenous, potentially positive if some endogeneity has occurred during the implementation phase (richer countries have anticipated polices or show stricter polices).

Introducing policy proxies is crucial in the waste arena and could constitute the main contribution of our work. Their role is very relevant because many European policies have been enacted quite recently, and their inclusion in a WKC framework could produce a sort of ex-post effectiveness evaluation. Both structural indicators and policy variables could be important drivers of WKC shapes; their omission could overestimate the 'pure' economic effect.

3. Data and empirical evidence

In order to test the hypotheses, we exploit information on waste generation for MSW and packaging in a group of European countries respectively for 1995-2005 (in the MSW case) and 1997-05 (in the packaging waste case) (Eurostat sources). The standard WKC specification includes two groups of variables - socio-economic/structural variables and policy indexes - to control for inter-country heterogeneity. The first group controls for the socio-economics factors that might differ between countries, such as population density, urban population degree, household size, share of manufacturing in the economy based on data mainly from EUROSTAT structural indicators datasets. Variables for policy indexes are constructed based on the country fact sheets available at EIONET,[19] and public information on the ratification of the EU Landfill and Incineration Directives. We refer again to table 2.

Next paragraphs report a comparative analysis of the trend of various waste indicators, related to MSW and packaging waste generation.

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[16] Fredriksson (2000) studies the pros and cons of decentralisation vs centralised management options regarding the siting of waste facilities. Decentralised systems are theoretically preferable initially, although drawbacks may emerge.

[17] Though specific waste prevention targets actions do not exist, (landfill related) policy variables can be included even at this level of analysis. We can hypothesise that the backward effects of landfill policies and waste management actions on the MSW generated are not significant. Nevertheless, since our synthetic policy index also captures the variety of national measures implemented on waste in addition to landfill diversion, some effects may emerge.

[18] Thus, in any given year, each country is associated with an index value, which assigns 1 to the maximum potential value (among all the considered policies). We differentiate between the presence of only strategy (low value), and an effective regulatory policy (high value). The latter is assigned a stronger weight (0 for no policy, 1 only strategy, 2 policy). Prominent examples of overall environmental policy performance index setups for many countries based on a synthesis of diverse policy performances can be found in Eliste and Fredrikkson (1998). Cagatay and Michi (2006, 2003) provide an index of environmental sensitivity performance for 1990-1995, for acidification, climate change, water and even waste management.

[19] EIONET is the information network of the EEA and its member countries, and collects and disseminates data and information on the European environment.

3.1. MSW generation drivers

For what concern MSW generation, the analysis shows in the core specification (model 1) a relative delinking associated with a quite high elasticity of consumption, which is a problematic evidence insofar waste prevention at source is probably the most effective way of tackling waste sustainability and externalities, while the EU does not witness clear waste generation targets at the horizon, still focusing (often) strong policy pressures much more on waste management levels of the waste chain. Furthermore, the square consumption term is not significant in all the specifications tested, as reported in the table 4 below, denying the presence of an absolute delinking.

Moving to the other explanatory forces we may note that is possible to identify a significant and positive effect for size and oldness, i. e. household size and elderly index correlate positively with waste generation. Both effects may be somewhat counterintuitive, especially the former. One might in fact expect that waste generation per capita is higher where single households are more relevant, though the evidence we find suggests that socio-economic phenomenon can provide partially unexpected and counterintuitive outcomes, possibly dependant on regional features. It is worth noting both that SIZE is not relevant if we looked at EU25[20] and that socio-economic drivers are probably better investigated at microeconomic level where their variability is higher (Hage et al., 2009). The OLDNESS effect, though one may have expected that young people may face higher opportunity costs for waste management (Hage et al., 2009) is possibly explained by a stronger pro-environment commitment and education levels of young generations in the EU15.

The effect of population density shows a significant and positive coefficient. This result may suggest that more urbanized areas failed to promote active strategies able to exploit scale advantages in waste management by urbanization. This evidence signals possible inefficiency at a large scale on average.

Finally, as we can see in the last specifications (columns 3, 4 and 5), the inclusion of policy related variables do not alter previous results and significances in terms of elasticities. Waste Policies, as expected and discussed, have not influenced the BAU path of Kuznets/delinking relationships, coherently with the lack of specific emphasis on waste prevention of such policy efforts. As a matter of fact, environmental policies are never significant in the specification tested underlining their ineffectiveness in promoting waste prevention. This result was highly expected, considering that all waste related policies in the European Union are usually aimed at optimize the waste management system, and were not directly thought as an instrument to reduce the amount of waste collected.

Table 4 - Waste Generation (MSW) drivers

Model	1	2	3	4	5
C	0.799***	0.793***	0.781***	0.728***	0.803***
DENS	…	0.314**	0.034	0.343**	0.320**
SIZE	…	0.293**	0.373***	0.310***	0.293***
OLDNESS	…	0.369**	0.380***	0.307**	0.381***
DECPOLIND	…	…	-0.031	…	…
POLIND	…	…	…	0.002	…
LANDDIR	…	…	…	…	-0.003
TP	/	/	/	/	/
N	165	165	165	165	165
Estimation	FEM	FEM	REM	FEM	FEM

[20] Though evidence is contingent. Household size and the elderly index correlate positively with waste generation in western countries. Eastern countries (for which evidence is not shown here) instead present a more expected negative sign that may derive from the stronger correlation between elderly ratio and rural areas, where waste generation is intrinsically lower.

(…) means not included; F tests and R^2 (not shown) present robust values. FEM is always preferred by Hausman tests; REM is used in presence of time invariant variables.

3.2 Packaging waste: delinking and drivers

The second level of study is based on data relative to packaging waste (tables 5-6). The analysis has been sub divided in two different levels, the first one involving the total amount of packaging waste generate and the second one relative to the behavior of the three major waste sector in the packaging arena, i.e. Plastic, Paper and glass (see fig.1). The structure of the analysis is the same as before, and besides the basic specification a set of socio economic driver has been tested as long as some policy related variables.

For what concern total packaging waste generated there is again no evidence of absolute delinking: the squared term is never statistically significant and the elasticity of the relationship is close to one, even higher than for MSW. The inclusion of relevant socio economic driver does not alter the result obtained in the basic specification. Population density has a low level of significance while oldness tends to be positively related, as seen before, to the total amount of waste produced. Moreover all the policy-related variables are not significant, underlining how also in these case the policies actuated at national and communitarian level have not been able to reduce the amount of pack waste generated. The only variable that shows a negative, but weak, link with waste generation is the share of environmental/energy taxes on GDP (column 5), but given its low statistical significance and its generality as a proxy of environmental policy commitment we cannot consider this element as a strong determinant of waste prevention. Most results are similar to MSW previous cases, showing that waste generation trends, at least at source, are quite interrelated and needful of attention given the general lack of delinking and policy impacts on BAU dynamics.

Finally, the other 'policy based' / country idiosyncratic factor, the share of ISO certified firms (weighted by country GDP), does not impact though the sign is negative. The role of ISO14000 firms in determining a lower amount of waste generated through product innovation and environmentally oriented production processes may nevertheless be expected to play a greater role regarding packaging waste.

Table 6 - Packaging Waste: drivers

Model	1	2	3	4	5	6
C	1.111***	0.953***	0.944***	1.008***	0.863***	0.978***
DENS	…	1.161*	0.112	1.177*	0.109	1.135*
OLDNESS	…	0.586***	0.536***	0.648***	0.641***	0.614***
DECPOLIND	…	…	0.023	…	…	…
POLIND	…	…	…	-0.038	…	…
TAX	…	…	…	…	-0.054*	…
ISO	…	…	…	…	…	-0.0009
TP	/	/	/	/	/	/
N	135	135	135	135	135	135
Estimation	FEM	FEM	REM	FEM	REM	FEM

(…) means not included; F tests and R^2 (not shown) present robust values. FEM is always preferred by Hausman tests; REM is used in presence of time invariant variables.

3.2.1 Packaging waste: evidence for specific materials

Taking in consideration the single categories of packaging waste (table 7) we can add some elements to the previous discussion. As we can see in the following table in fact, the three main components of packaging waste show very different trends. Thus, the claim of 'packaging waste' private associations and lobbies that packaging waste has experienced a (relative) delinking can be valid on an overall basis. We nevertheless have found here little support even for this statement. The claim that absolute

delinking has been already achieved may be valid for some materials. Thus the picture is quite differentiated and a diversified analysis is worthwhile.

Basically, paper and glass are experiencing a decoupling trend, while the plastic trend is strongly increasing. For what concerns plastic, the relationship is non linear, and population density and oldness are, again, significant covariates.[21] Furthermore, the environmental tax commitment is not able to incentive prevention, given its very low significance. The evidence is plausible given the increasing role that diverse - and associated to different degrees of recyclability and recoverability – plastic materials play in production processes. Renewable alternatives (e.g. corn made product) are still in their infancy. Given that plastic poses a great challenge in terms of recyclability and recoverability, with some exceptions, the evidence is quite gloomy for environmental performances in the EU. Price mechanisms and technological support to alternatives are ways to tackle the issue (Mazzanti and Zoboli, 2006). In this preliminary macroeconomic evidence, we note that all policy and management levers (POLIND, TAX, and ISO) do not affect the waste trend (columns 2-4).

On the other side, paper and board shows a strong evidence of delinking with a turning point[22] inside the range of observed values, the first evidence of this kind we find and quite rare as far as waste issues are concerned on a general basis. In this case the delinking trend is affected by policy factors as far as POLIND is concerned, with the 'wrong' sign. Nevertheless, we have discussed the potential endogeneity of especially waste policies in the EU (also commented on in notes 14 and 19): on average richer countries implement policies earlier and / or with stronger stringency. At least in the short run they may still show higher waste per capita[23]. Non specific waste factors such as TAX and ISO are irrelevant. From a statistical viewpoint, it is here worth noting, as known, how the inclusion of irrelevant covariates may affect the estimation of other coefficients (column 7 as example).

Glass, on the contrary, presents evidence of relative delinking, associated with a low elasticity, and a negative value of the oldness variable. What is even more interesting in this case is the high significance of the 'environmental tax variable', that seems to hint to some correlations between environmental policy (tax) intensity of a country and the waste prevention aim, ceteris paribus. As far as glass is concerned, the environmental policy commitment of a country seems to matter, and gives explanation of the (weak) effect we found above for total packaging, that depended on latent heterogeneous dynamics. Along the same reasoning, estimates in table 6 show the relevance, provided data availability on specific waste streams, of analyzing dynamics and drivers for diverse waste categories, within MSW (in the future, such as BMW on which the landfill directive is implemented) and packaging waste.

A closer look at the 'glass picture' highlights that in this and only case in this paper, case policy & management levers play a role. Negative and significant coefficients emerge for TAX and POLIND. Their economic significance is also not negligible and comparable, though the two variables are linked to different 'scale' (POLIND is an index, TAX a share) and this matters if we reason around marginal effects of defined changes.

Summing up, results are quite fitting with anecdotal evidence in the waste sector and present expected outcomes. Plastics shows no delinking at all, with even an increasing trend with respect to income, with in addition an irrelevant role of all policy & management levers. Paper presents robust TP, with a limited role played by policy & management levers. Finally, Glass is associated to a relative delinking showing moderately low elasticities, with a significant role played by policy & management levers in determining a reshaping of the EKC.

[21] Both these elements are positively correlated to the amount of waste produced, and they may be interpreted as in the MSW case.

[22] We note that for both plastic and paper TP are quite in sensitive to the used specification, demonstrating robustness.

[23] The correlation between C and POLIND is 0.69, between C and TAX 0.14. Two stage regressions tackling endogeneity may be example of refined and further analyses for POLIND (Mazzanti and Montini, 2009).

Table 7 - Packaging Waste: subcategories

	Plastic				Paper and card board				Glass			
Model	1	2	3	4	5	6	7	8	9	10	11	
C	-9.711**	-9.59**	-10.286**	-9.452**	7.712***	8.127***	9.776***	7.24***	0.480***	0.715***	0.281**	0.487***
C^2	0.536**	0.527**	0.568**	0.522**	-0.402***	-0.429***	-0.507***	-0.378***	…	…	…	…
DENS	3.638***	3.517***	3.550***	3.701***	…	…	…	…	…	…	…	…
OLDNESS	0.682**	0.589	0.661*	0.706**	0.570***	0.275	0.351**	0.527***	-0.958***	-0.700***	-0.690***	-0.949
POLIND	…	0.051	…	…	…	0.099**	…	…	…	-0.157**		…
TAX	…	…	0.0005	…	…	…	0.046	…	…	…	-0.104***	…
ISO	…	…	…	-0.0005	…	…	…	0.001	…	…	…	-0.0002
TP (€ per capita)	8593	8943	8557	8549	14647	12991	15383	14425	/	/	/	/
N	135	135	135	135	135	135	135	135	135	135	135	135
Estimation	FEM	FEM	REM		FEM	FEM	REM		FEM	FEM	REM	FEM

(…) means not included as not significant; F tests and R^2 (not shown) present robust values. FEM or REM is chosen accordingly to the Hausman's Test results.

4. Conclusions

Our study aimed to establish a sound framework to analyse delinking for diverse waste related trends, within a delinking oriented conceptual framework that encompasses the policy evaluation stage. The paper provides new evidence on waste generation, exploiting a rich, updated EU-based dataset that allows various analyses on the relative roles of: economic drivers and structural socio-economic and policy drivers in the waste system.

Concluding we can see as at an aggregate level both MSW and packaging waste are not decoupling from consumption, and the policy levers are still far from influencing this trend, if not in specific cases (glass). Disaggregating the packaging analysis in its main sub-categories is possible to have more insights on the sector, and we see as Glass and paper have achieved a decoupling, the plastic waste is strongly increasing with consumption. MSW shows income-elasticities that are lower in the past, moving towards relative delinking paths. This is not sufficient to achieve future EU targets. In addition MSW is as expected not affected by the current package of waste policies, focused on management & disposal, and finally urbanization / population density levers, increasingly important in the future as a socio economic phenomenon, are now – as shown by other works – positively affecting landfill diversion but not – as presented here – waste generation. Pressures on incineration and recycling thus will increase if waste prevention does not become a core objective of EU policy. This is relevant since on the one hand incineration though potentially lowering its emissions, is exposed to NIMBY issues, and both options are associated to increasing marginal costs after economies of scale are exploited.

Overall, our evidence supports the claim that in order to pursue a more sustainable dynamic of waste generation and disposal, the weight of policy actions should be rebalanced towards the former: although waste prevention at source is at the top of the EU waste hierarchy, policy efforts so far have been biased towards disposal and recycling. In addition, only a few areas (e.g. Hungary, and the region of Flanders) have implemented physical per capita targets (e.g. tonnes per capita) and delinking benchmarks (e.g. waste volumes are confined to a particular share of GDP per year). Waste prevention targets and benchmarking are ways of shaping future waste policies.

Policies may have contributed to creating and sustaining markets and rents associated with waste management and disposal options, such as recycling, incineration and landfill. There is a risk that EU/national waste policies and the dynamics of the waste system will become locked into this pattern with a lower weight assigned to waste prevention, which may receive priority in principle, but is never effectively targeted or implemented by policy. The higher present costs of a prevention strategy may work to lower the target costs, at all stages of the waste chain in the future.

Further research should focus on heterogeneous panel models to investigate the potential different relationships and performances of (the main) EU countries, and on new or updated policy indicators to further test policy effectiveness.

Table 2. Descriptive statistics and a summary of Research hypotheses

	MIN	MAX	Mean	acronym	
DEPENDENT VARIABLES					Descriptive stats are calculated for EU$_{15}$ over 1995-2
MSW Collected/generated (kg per	239.00	753.00	484.70	MSW-GEN	
Packaging waste generation (kg per 15	66154.6	225158.6	158594.5	PACK-GEN	
INDEPENDENT VARIABLES					
1. ECONOMIC DRIVERS					HYPOTHESISED CORRELATION[24]
Final Consumption Expenditure of Households (Euro per inhabitant - at 1995 prices and exchange rates)	900.00	21000.00	8103.27	C	+ G (eventual inverted U) - P
2. STRUCTURAL AND SOCIO-ECONOMIC VARIABLES					
Population Density	16.70	1276.00	174.80	DENS	
Urban Population (% of total)[25]	50.60	97.20	71.36	URBPOP	? G ? P
Household Size	1.9	3.4	2.62	SIZE	- G
Single households (%)	10.12	38.30	25.04	SINGLE	+ G
Age index or 'elderly ratio' (population 60 and over to population 20 to 59 years)	0.3	0.5	0.358	OLDNESS	? G
Value added at factor cost, Share of Manufacturing	9.10	36.30	18.54	VAMAN	- G - P
Number of ISO14000 certified firms on GDP (rescaled)	0	101.603	8.313	ISO	- G - P
3. POLICY VARIABLES					
Decentralised Waste Management Policy Drivers (dummy)	0	1	0.24	DECPOLIND	? G,P
Landfill Directive (dummy: years/country	0	1	0.27	LANDIR	- G
Waste strategy Policy Index (range 0 - 1)	0.00	0.95	0.34	POLIND	- P
Share of environmental and energy taxes on	1.95	5.83	2.96	TAX	- P

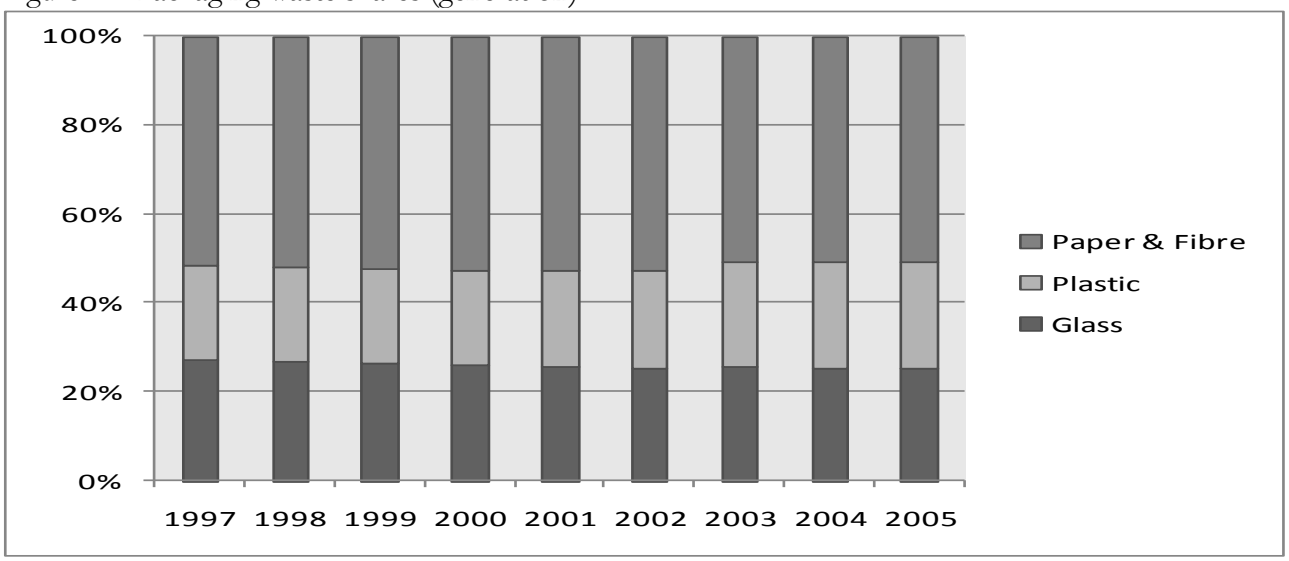
[24] The sign on the hypothesised correlation is shown, as well as the level at which this is most relevant (G for generation,, P for packaging). The element (?) means that the hypothesis is ambiguous either because opposing forces may be influencing the link or because economic theory and other scientific fields do not provide clear insights.

[25] Given high correlation, population density and urban population are used alternatively in estimations.

Table 3 – descriptive statistics by countries (consumption and waste generation per capita)

Countries	C (€ per capita)	MSW-GEN kg per capita	PACK-GEN kg per capita
Austria	12700 - 14500	438 - 630	131306.5 - 146209.8
Belgium	11400 - 13000	456 - 464	133340.6 - 158860.8
Denmark	13400 - 15600	567 - 737	158251.7 - 181655.6
Finland	9700 - 13200	414 - 468	81503.41 - 131539.5
France	11200 - 13500	476 - 543	190481.2 - 212580.6
Germany	13300 - 14500	533 - 601	167205.6 - 188011.3
Greece	6100 - 8200	302 - 438	66154.15 - 95734.38
Ireland	7300 - 11300	514 - 740	164759.8 - 225158.6
Italy	8800 - 9900	454 - 542	167530.3 - 207113.1
Luxembourg	16300 - 21000	592 - 705	180956.8 - 217213.1
Netherlands	10100 - 12300	549 - 624	161298.6 - 209601.8
Portugal	5500 - 6900	385 - 446	101390.3 - 142281.2
Spain	6900 - 9000	510 - 597	147010.8 - 181198.5
Sweden	10500 - 13000	386 - 482	104403.8 - 167796.3
United Kingdom	9200 - 12500	499 - 584	156161.5 - 175427.3

Figure 1 – Packaging waste shares (generation)



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