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WASTE PREVENTION, WASTE DISPOSAL AND LANDFILL POLICIES EFFECTIVENESS
A QUANTITATIVE ANALYSIS ON DELINKING AT EUROPEAN LEVEL

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Waste prevention, waste disposal and landfill policies effectiveness
A quantitative analysis on delinking at European level

(Very preliminary version not to be quoted)

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Abstract

Waste generation and waste disposal are mounting key issues in the environmental arena both from a policy perspective and from the point of view of the analyses of delinking. In fact, WKC studies and delinking analyses had rarely, if never, found a significant absolute delinking between waste generation growth and economic growth, with even rare signals of relative delinking. This paper presents many value added elements: it comprehensively analyse waste generation incineration and landfill trends in a panel scenario at EU 25 level, trying to assess both the effects of different drivers (economic, structural) and eventual heterogeneity regarding western and eastern EU countries. Evidence at such a panel level has never been presented. In addition, it presents evidence regarding the policy effectiveness, by testing the effects of waste management and especially landfill policy proxies on waste trends. This is absolutely relevant for an ex post evaluation of existing landfill and incineration directives implemented during the last decade and for providing food for thought to future policies on waste prevention. Ex-post policy effectiveness evaluation aims at answering the very basic question about if and how policies worked in pursuing their own objectives of environmental improvement or pressure abatement, how different have been the results from those expected ex-ante.

We claim that as far as waste is concerned, studies on cross country international sources often present data problems such as missing values, low data reliability for waste on some countries. Low commensurability of waste definitions is also a problem affecting quantitative studies. Furthermore, policy implications from international cross-country studies may be weak: 'average' elasticities stemming from international panel are difficult to interpret, since elasticities should be calculated at the most decentralised level possible, in order to be informative for policy makers. Thus, when dealing with waste in a WKC framework, recent works has underlined the value added which is associate with the exploitation of in-country panel data, rather than cross country analysis. WKC dynamics may surely differ country by country, and more heterogeneity can be found within countries. Italy then presents an interesting case study since northern and southern areas are very different with respect to waste generation and waste policies. Regional and National official datasets may provide a better and more reliable basis, offering in addition the possibility of exploiting geographically disaggregated datasets.

The current availability of data is sufficient to perform such a panel based investigation at the level of around 25 European countries for 10 years (1995-2004). Those datasets allow the integration in a full merged dataset covering socio-economic and environmental trends at a high disaggregated level. Policy evaluation is carried out exploiting the heterogeneity of waste management and policy implementation at local level.

Evidence shows that regarding waste generation no WKC trend is present, though elasticity to income drivers appears lower than in the past. Delinking signals appear strong for EU10, though this deserves further investigation. No landfill or other policy effects seem to provide backward incentives to waste prevention. Regarding landfill and incineration, the two trends are decreasing and increasing as expected, with a strong policy effects driving the trend. In addition, at all levels we find some other socio-economic factors impacting on waste trends. It is also worth noting that the effects of policies may in part be endogenous as related to economic indicators, a feature which is particularly relevant in the waste arena. Summing up, though delinking is far from being achieved completely especially for waste generation, some positive signals emerge, with a quite significant role played by the EU waste policies implemented in late nineties and early in this century.

Jel: C23, Q38, Q56

Keywords: WKC, delinking, waste generation, waste disposal, landfilling, landfill policies, evaluation methodology, incineration

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1. Introduction

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)[2] for materials and waste (waste Kuznets curve, WKC, hereafter) 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)[3].

There are few WKC analyses aimed at analysing the relationship between material flows/waste and economic drivers. As far as Europe is concerned, Mazzanti and Zoboli (2005) and Mazzanti (2007) find no WKC evidence exploiting municipal waste (MSW) and packaging waste panel datasets (Eurostat, 2003a); estimated elasticities of waste generation with respect to household expenditure are close to unity[4].

The literature still lacks single-country case studies using data at regional, provincial or municipal level. This is potentially a fruitful line of research. OECD and EU datasets (Eurostat, 2003), though improving in quality and coverage, may still be affected by differences in waste classifications across different countries. National official datasets may provide a better and more reliable basis, offering in addition the possibility of exploiting geographically disaggregated datasets for waste trends and waste policies. In this paper, we pursue this task of developing a very disaggregated, in-country analysis. We thus provide WKC evidence on MSW generation exploiting environmental-economic merged panel datasets at a decentralised level.

The empirical model we here proposed 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

[2] For recent surveys on the varied areas of application of the "WKC 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).

[3] See Jacobsen et al. (2004).

[4] Andersen et al (2006) econometrically estimate waste trends for EU15 and EU10 new entrants, finding that waste generation is linked to economic activities by non constant trend ratios, which is in line with WKC reasoning. A rather descriptive analysis of delinking of EU countries then shows forecast evidence in favour or relative delinking. In any case it is not confirming WKC evidence. For the period 2005-2020 projections for UK, France and Italy show a growth in MSW of around 15-20%.

respect to quality and quantity of data, the reasoning will also specifically revolve around a possible implementation of the model using current available data.

Moe 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 WKC, 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[5]. This confirms what asserted by List and Gallet (2002) 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.

2. A short survey of recent studies and methodological issues of delinking and EKC

The EKC framework extends the basic decoupling reasoning, modelling a multivariate analysis of the environment-income relationship. 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

[5] In fact, it has to be reminded 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 set of countries are often difficult to interpret. We remark the need of placing 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 exist ways for quantitatively addressing this heterogeneity. The superiority of the rather complex heterogeneous panel data models is also questioned (Baltagi et al. (2002) 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 re 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.

[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 WKC 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.

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. 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).

We refer to Ekins (1997), Dinda (2004, 2005), Stern at al. (1996), Stern (2003, 2004), Managi (2005), Mazzanti, Montini and Zoboli (2006, 2007) 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 WKC studies, waste is the lowest level in the ranking, less investigated even than issue like deforestation, biodiversity.

Thus, there are still few WKC 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) presents 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 ins some recent studies, waste generation seems still to be characterised by a strict relationship between economic drivers and the environmental pressure. Both the literature on the determinants of waste production and the WKC 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 provide average figures/estimates.

Then, Cole et al. (1997) find no evidence for an inverted U-shape WKC curves 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 WKC 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[7]. 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 works is nevertheless emerging for waste, though always limited by data availability. A macroeconomic based study is by Johnstone and Labonne (2004) who use 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[8].

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 land-filled. A panel database from 30 OECD countries over 1980-2000 (four period data, thus observations are 120) is exploited. Although not explicitly dealing with WKC, it shows that MSW increases monotonically with income, with an elasticity around 0.42-0.45. Urbanisation exerts even a stronger effect on waste generation, while population density is not significant, as the policy index[9]. 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 thus extensions re 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

[7] 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 WKC relationship: thus internal migration (as well as trade flows) may be a latent contributing factor to the observed WKC, adding new insights on the ancillary factors correlated to the environment-income dynamic along the development path

[8] 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.

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

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.

3. Waste indicators and delinking analysis: recent empirical evidence

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).

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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, 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 WKC 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 WKC hypothesis. Given (i) the relative homogeneity across those countries in terms of structural characteristics, and (ii) the panel framing which helps

[10] 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).

[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).

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 WKC; 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 one exploiting panel data at regional, provincial or municipal level, for assessing WKC evidence at national level. Heterogeneity may exist in WKC shapes across countries, as noted in the literature, and the heterogeneity associated to disaggregated data help producing better estimates for WKC 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 (WKC) 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 delinking between waste production and economic drivers is taking place. The empirical analysis of different specifications show mixed evidence in favour of a WKC relationship. Evidence supporting a WKC 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 bring 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 WKC 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, 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 WKC for waste above commented thus underlines 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 WKC trends (absolute delinking) are associated to few richer countries or areas, splitting countries into two or more pieces regarding waste indicator performances. Evidence concerning other policy, structural and socio economic drivers, below suggested for Europe, and is also in its infancy. The same applies if we focus on the quantitative analysis of the whole integrated system, form 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 a WKC 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)[12].

[12] 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 support relative but not absolute delinking as well. Outflows are then broken down by the environmental media they enter.

4. Empirical Analyses

4.1 The Data set

The Data set includes data on Waste Collected, Waste Landfilled and Incinerated (and recycled, as residual element) of all European Countries from 1995 to 2005, from Eurostat sources. We used either Household Expenditure or GDP per capita as main economic driver, following the hypothesis that consumption could be a better independent variable for Waste collection and disposal (Rothman 1998, Jacobsen 2004, Mazzanti e Zoboli 2005). Some other variables are included into the standard WKC specification as control for intra-country heterogeneity. These control variables are divided into two main groups: Structural Variable and policy indexes (tab.1).

The first group controls for the socio economics factors that could change between such different countries, like Population density, urban population degree, households size, share of manufacturing in the economy and others[13] (the full list of socio-economics structural variables, and a descriptive statistic is reported in the Appendix[14]).

The second group controls for the presence of environmental policies in the analysed countries. The importance of introducing policy proxies is underlined in other studies (Markandya and Golub, 2004; Kaurosakis, 2006). Their role is also more relevant in our case, because many European policies were emanated in the last years, and their inclusion in a WKC framework could be a sort of ex-post effectiveness evaluation. For that reason we included in our analysis two different kinds of policies proxies. The first one is related to the commons European Landfilled directives and Incinerations directive and their implementations in the member states. These proxies are built as a dummy variable with value 1 if the country has transposed the directive into national law. The other group of policies indexes is more countries specific. The first one is a dummy that takes value 1 if the country received an infraction in a specific year. The second one is a decentralised waste management index that reflects the level of Waste policies decentralisations between countries, and the last one is the Environmental policy index. That index is a proxy of the national policies level over the time period examined here. It capture all possible information regarding national implementation of waste related policies as MSW, BSW, Pack, ELV, WEE, etc… independently on the Directive dynamic. We used the country studies available on EIONET that shows the presence in a given year of a policy and its starting years of implementation. Thus, in any given year each country is associated with an index value. The index may either be presented in its original form: number of policy present, or as an index ranging from 0 to 1, assigning 1 to the maximum potential value (all considered policies present). It is worth noting that in case of a national policy action, we have differentiated between the presence of only a "strategy" (low value) and that of an effective regulatory policy (high value). The latter has been assigned a stronger weight (0 for no policy, 1 only strategy, 2 policy)[15].

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

[13] In line with Torras and Boyce (Torras and Boyce, 1998), we have also included in the analysis an income distribution related variable.

[14] All this variables are expressed in per capita values. The population data used for this kind of calculation refers to Eurostat.

[15] In the MSW Landfilled analysis the policy index is only related to policies and instruments with the specific aim to divert waste from landfill (Ban from landfill, landfill tax, national landfill policies)

4.2 The model and the set of variables

The model is thus specified as follows (it represents the panel nature of data[16]). All variables are specified in logarithmic form using per capita values of alla waste and economic variables, to easily provide elasticity values and to smooth data. Unless unfeasible, logarithmic transformations are used for all covariates. Ancillary tests are anyhow carried out on non logarithmic forms. There is scope for further research in estimating delinking trends on waste absolute levels (not per capita), as suggested by some experts in the filed. The reason is that for sustainability and policy compliance, absolute and not per capita levels matter.

Nevertheless, we think that for waste, differently than from other environmental fields (emissions), sticking to per capita indicators is economically and ecologically relevant. For example all analyses carried out by APAT are in per capita terms.

The reduced form for waste generation[17] is then:

(1) Waste generation $_{it}$ *= f(income driver*$_{it}$*, other explanatory factors*$_{it}$*, policy variables*$_{it}$*)*

This level provides direct information to the usual WKC 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 WKC 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 countries, given the insufficient amount of data, the average turning point provides an 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 tend 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 the 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 for many countries prevent a study on waste composition, for waste and MSW in specific terms.

[16] 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, CO2 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.

[17] Actually, as stressed and commented by Andersen et al (2006), waste generation data are measured by waste collection, the observable factor. This is worth knowing for result interpretations since data may present, according to this, unusual trends in specific years or countries, for idiosyncratic features.

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 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.

We refer to tab.1 for other structural and socio economic variables we deem relevant at this level. Among the 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 arise 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, see table 1 for the proxies we effectively used for estimation purposes and a summary of related research hypotheses):

- 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 WKC shapes; their omission could overestimate the "pure" GDP economic effect[18]. A specific attention is to be devoted to structural indicators concerning:
  - Structural change of the economy, along the development path[19].

[18] Actually, a "pure" GDP effect does not exist. The majority of WKC 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.

[19] 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 that 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

- 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) [20]. 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 at national level
  - Decentralised Waste management

Two notes are needed. First, the above list is generally valid for all 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 use not 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 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. Table 1 presents a synthetic sketch of hypothetical links between waste trends and defined independent variables.

WKC. 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 WKC 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 WKC 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.

[20] 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.

4.3 Second level: waste management and disposal

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[21]): (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 focusing on the disposal stage of the "waste filiere":

(2a) landfill per capita[22]$_{it}$= f (waste generation [predicted values]$_{it}$, policy variables$_{it}$, socio economic controls variables$_{it}$)

(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$_{it}$)[23]

[21] We exploited EUROSTAT sources as far as possible. Some structural indicators were not used for massive lack of information. In order to include as many variables as possible, nevertheless, when missing values were acceptably low in number, we opted either for filling gaps observed for one (max 2 years) with contiguous values or interpolating the series. Some variables, given lack of time variant data, were set up as constant, with only cross country heterogeneity.

[22] 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.

[23] The analysis on recycling is an extension which will be soon added, after some problems with these data reliability are worked out.

Tab.1 Descriptive statistics and a summary of Research hypotheses (EU 25 (1995-2005))

	MIN	MAX	AVERAGE	acronym	
DEPENDENT VARIABLES					
MSW Collected/generated (kg per capita)	239,00	753,00	484,70	MSW-GEN	
MSW Landfilled (kg per capita)	9,00	659,40	283,95	MSW-LAND	
MSW Incinerated (kg per capita)	0,00	396,60	73,47	MSW-INC	
MSW recycled (kg per capita)				MSW-REC	
INDEPENDENT VARIABLES					
1. ECONOMIC DRIVERS					**HYPOTHESISED CORRELATION[24]**
GDP at 1995 constant prices (Euro per inhabitant - at 1995 prices and exchange rates)	1400,00	54100,00	15401,45	GDP	+, eventual EKC shapes to be tested
Final Consumption Expenditure of Households (Euro per inhabitant - at 1995 prices and exchange rates)	900,00	21000,00	8103,27	C	+, eventual EKC shapes to be tested
2. STRUCTURAL SOCIO-ECONOMIC VARIABLES					
Household expenditure for food and non-alcohol beverages, clothing and footwear, furnishing, household equipment and routine maintenance at current prices (% of total household consumption expenditure)	18,10	48,90	28,76	COMPC	+ (GEN, LAND)
Population Density	16,70	1276,00	174,80	DENS	+ (GEN, REC?) - (LAND, INC?) Highly correlated
Urban Population (% OF TOTAL)	50,60	97,20	71,36	URBPOP	
Household Size	1,90	3,40	2,62	SIZE	- (GEN) + (REC?)
Single households	10,12	38,30	25,04	SINGLE	+ (GEN)
Index of Oldness (population 60 and over to population 20 to 59 years)	27,00	45,50	35,56	OLDNESS	- (GEN, REC?)
Inequality of Income Distribution. The ratio of total income received by the 20 % of the population with the highest income (top quintile) to that received by the 20 % of the population with the lowest income (lowest quintile).	2,90	8,20	4,55	INEQ	(- GEN, + REC)? Highly correlatd with GDP/C
Value added at factor cost, Share of Manufacturing	9,10	36,30	18,54	PERCVAMAN	?
Gross Fixed Capital Formation (Euro per inhabitant)	205,80	12697,10	3632,80	K	Highly correlatd with GDP/C
Gross Domestic Expenditure on R&D (% of GDP)	0,19	4,25	1,37	RD	+ (INC) ? (REC) - (LAND) Highly correlatd with GDP/C
Land Use (share of agricultural land)	21,00	38361,00	18899,07	LANDUSE	+ LAND - INC ? GEN
3. POLICY VARIABLES					
Decentralised Waste Management Policy Drivers (dummy)	0	1	0,24	DECPOLIND	? (LAND, INC) - (GEN)
Incineration Directive (dummy: years/country in which Directive is ratified)	0	1	0,24	INCDIRECT	? GEN (if any, -) + INC ? REC - LAND
Landfill Directive (dummy: years/country in which Directive is ratified)	0	1	0,27	LANDDIR	? GEN (if any, -) + INC, REC - LAND
Infractions (dummy: presence of infractions, information from country factsheets and other documents)	0	1	0,05	INFRACT	
Waste Policy Index (range 0 - 1)	0,00	0,95	0,34	POLIND01	
Landfill specific Policy Index (range 0 - 1)	0,00			LANDPOLIND	

[24] When not specified the hypothesised correlation is related to all levels of waste generation and disposal. (?) means that the hypothesis is ambiguos either because opposite forces ma influence the link or because economci theory and other scientific fields do not provide clear insights.

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

We here briefly comment on endogeneity linked to economic and waste dynamics that may be of relevance for the estimation and the interpretation of results.

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 waste generation, as is the case in Northern provinces, the higher 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 of 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 to positive elasticities of waste with respect to income drivers. Policies or management schemes performances may also arise positive 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 above commented, but it also has an instrumental value for 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 to 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 WKC shape for the relationship between waste and income (Johnstone and Labonne, 2002; Karousakis, 2006; Mazzanti and Zoboli, 2005).

5. Empirical Results

We here present results regarding the estimation of generated, Landfilled and incinerated MSW. The levels of analyses are three according to the set of variables used (baseline WKC model, with structural factors, with structural factors and policy variables) and three, whenever possible, on a geographical EU division (EU25, EU10, EU15). Recycling will be added as extension as soon as data are checked in terms of reliability for all EU25 countries. Given the large number of cases under investigation (three specifications and three geographical level, and in addition GDP and consumption related models) we report in tables only EU25 analyses for Consumption and GDP. Other analyses are available upon request.

The main methodological problem for the applied analysis in this delinking-related framework is how to specify the WKC functional relationship. There is no consensus on this point. Some authors adopt second order polynomial, others have estimated third and even forth order polynomials, comparing different specifications for relative robustness. It is worth noting that neither the quadratic nor cubic function can be considered a full realistic representation of the income-environment relationship. The cubic implies that environmental degradation will tend to plus or minus infinity as income increases, the quadratic implies that environmental degradation could eventually tend to zero. The issue is thus unresolved. Third or forth level polynomial could also lead to N rather than U shaped curves, opening new problematic issues in understanding the income-environment phenomenon for policymaking. This N shape is justified by a non-linear effect by the scale of economic activity on the environment, which is difficulty to prove. We here test the hypothesis by specifying a proper reduced form usual in the WKC field (Stern, 2004):

$$(4) \qquad \log(\text{waste indicator}) = \beta_{0i} + \alpha_t + \beta_1 \text{Log}(\text{Economic driver})_{it} + \beta_2 \text{Log}(\text{economic driver})^2_{it} + \beta_4(Xi) + e_{it}$$

where the first two terms are intercept parameters, which vary across provinces, and years[25]. X refer to all other structural, socio economic and policy drivers that are added to the baseline specific both in order to correct for omission of relevant variables, finding a corrected effect of economci drivers, and to jointly test additional hypothesis stemming from economic, environmental and waste-related environments.

Results are presented starting with MSW generated in the paragraphs below. For all the results, significance at 90%, 95% and 99% is denoted by *, ** or *** respectively. All the regressions are estimated both by Fixed and random effects, and the best method is chosen following the Hausman test. For reason of space only the more efficient result is reported in the tables, with the relative p-value of its Hausman test.

[25] Cubic specifications are not empirically relevant for waste given TP has rarely or never been observed.

We note that the first analysis (MSW generated) generally favour FE models, while the other two generally prefer RE. Nevertheless, the results of these two different techniques are substantially quite similar. We always try to estimate the relationship also in first differences to take into account of possible serial correlation of the data, but the results are also very similar to the fixed effect estimation. Statistical significance and elasticity are not affected if not at marginal level. For that reason we never reported in the tables differences estimation's results. We also try to introduce in the fixed effect analysis temporal dummies, but they were never significant or presented not meaningful specifications. All regressions present consumption as main economic driver, but in general results is very similar between the two drivers. Furthermore all the analysis is express in a log-log specification[26]. All the analysis are divided in three steps: i) first of all we try to estimate a traditional WKC specification, with only the main economic driver, ii) then we introduce the structural drivers as control variables, iii) and then we test the significance of the different policy index. To control for the heterogeneity across countries, all this steps are tested in the main data set with all the European countries and in the two sub-samples, (EU15), and new incoming countries (EU10)[27]. Main comments are for EU25 analysis, the most robust and relevant in statistical (and policy) terms. Additional comments are provided for EU15-10 analyses, mainly when significant differences are noted.

5.1 Municipal Solid Waste generation

5.1.1 Baseline WKC

For MSW generation (actually collection) the analyses (tab.2) do not show overall WKC evidence[28]. Only the linear term shows a significant and positive coefficient for consumption (GDP specifications do not show different outcomes in all MSW generated evidence), with an elasticity of 0.2***[29]. The analysis in the EU15 is similar to the case of EU25, but it shows a higher elasticity (0.79***)[30]. Those elasticities are quite lower with regard previous analyses on Europe (Mazzanti and Zoboli, 2005), and seem to imply a delinking process more active in EU10 countries. Then, the analysis on the EU10 group, that is less statistical robust than others, does not show an WKC evidence for consumption[31], but only for GDP. In general, we thus observe a "relative

[26] We have also runt regression on non-transformed data. The results are in general similar but statistically less robust. They are not presented, but quoted in the test if the difference between the log and non long specification appears relevant to us.

[27] For reasons of space we never include the results of these two sub-categories in tables, but we reported it in the test if the differences between the groups and the completed dataset appear relevant to us.

[28] Running the regression in the quadratic form results that the linear term has a negative coefficient and the quadratic term a positive one. This is due to the data's nature, and captures the effect of same low-income countries (like Lithuania, Czech Republic, Slovakia, Poland and Slovenia) that registered a reduction in the total MSW collected in the studied period. This little anomaly generated a downward sloped relationship between MSW collected and consumption (or GDP) in the first phase, relative to low level of income. In fact the hypothetical (and inverted) turning point of this kind of relationship is at very low level of consumption (1533 euro).

[29] The analysis on the non transformed variable shows an WKC evidence, but with an out of sample turning point (75639 euro), due to the different way in which this kind of specification take into account for non-linearity.

[30] Using as main driver log GDP we can find a WKC evidence, but with a high level turning point (48000 euro). Only Luxembourg has an income higher than that value, and only for some years. In fact running the regression without that country we found an increasing monotonic relationship between MSW collected and Log GDP, with only the linear term positive and statistically significant.

[31] It shows an evidence of WKC using Log GDP as main driver, but with a very low turning point (2799 euro), which poses some economic interpretation problems. This result is interesting but it deserves future checks, given the limited number of observations and the wobbling reliability of data in some EU countries. If it is not influenced by data quality, it may be interpreted by the (observed even in other contexts) delinking occurring in some eastern countries (Hungary

delinking" evidence in the relation, even if the elasticity varies. This is a first interesting result we find, partially confirms expectations but with some positive signals. Let us see whether other factors may influence the WKC.

Tab. 2- MSW generation regression results (EU25)

Dependent variable	Log WASTE Collected / POP	Log WASTE Collected / POP	Log WASTE Collected / POP	Log WASTE Collected / POP	Log WASTE Collected / POP
Model	REM	FEM	REM	REM	REM
Constant	4.094701***	4.263049***	4.397559***	4.285783***	4.367955***
Log C	.2352809***	.2014938***	.2278843***	.241025***	.2293811***
Log C^2					
Log landuse		1.22379***	.3636298*	.3599412**	.3658253**
Log PercVAman		-2.23853***	-2.100101***	-2.08987***	-.0199995***
Landdir			-.0139928		
Incdirect				-.0264635**	
polind01					-.018781
Turning Point	/	/	/	/	/
N	275	264	264	264	264
Hausman test	.7160	.0377	0.1239	0.1775	0.1180

5.1.2 Municipal Solid Waste: Structural socio economic drivers

The introduction of socio-economics controls does not alter previous results. Also in this case the analysis shows an evidence of relative delinking with elasticity equal to 0.2*** in the complete sample, and elasticity equal to 0.72*** in the sub-sample EU15. Again the analysis in the sub-group EU10 is less robust. The most significant and robust control variables are the share of agriculture in the land use and the share of manufacturing[32] in the total economic activities. Population Density or alternatively urban population (they are correlated) also impacts positively o waste generation. The land use has always a positive coefficient – the bigger share of land dedicated to agriculture has a country, the more waste that country produces – while the share of manufacturing has always the opposite sign. This is coherent with our expectation and takes in to account the different level of industrialization of the countries in the analysis. We supposed in fact that a more industrialized country could have a bigger awareness of environmental topics than a less developed one. The income distribution variable is statistically significant in some specifications (lower inequality, more waste generation) but given its high correlation with income driver (0.4) its role is statistically flawed, and probably less relevant whatsoever in an EU based analysis with respect to worldwide studies on developing countries. Finally, household size is positively correlated with waste generation. All other factors presented in tab.1 are tested but never significant, including the composition of consumption, an hypothesis stemming from some reports on waste tends in the EU[33]. This is probably due to a low heterogeneity in the relatively short run period. Summing

among the others) which may drive the general empirical picture. Even the EU25 quadratic analysis shows a U shape curve affected by the delinking occurring in low income eastern countries.

[32] Greece has no available data, for that reason the observations numbers in that analysis is equal to 264.

[33] We note that in the EU15 case something changes. Manufacturing share and density are not significant, while it emerges a negative sign on single households (expected) and a positive sign for oldness, which are quite counterintuitive to some extent. Agricultural land share turns to a negative value. EU10 analyses present density and age with positive signs, but as said statistical reliability is lower.

up, socio-economic structural factors add some useful hints and food for thought for waste management. They do not impact on the core relationship between waste and consumption/GDP which acquires robustness from such additional investigations.

5.1.3 Municipal Solid Waste: Policy effects

The evidence shown in the table above confirmed, adding new and updated insights, what suggested by recent studies (Mazzanti, Zoboli, 2005). Such studies implicitly assessed that waste policies implemented in late 1990s have not stimulated waste preventions, even by anticipatory strategies by involved agents. We here test exploit policy proxies adding newly created variables to the set of explanatory factors.

In our case, neither landfill directive nor the environmental policy index are statistically significant[34]. Only the incineration directive dummy is significant, and negatively related to waste generation This means that the efforts done until now are unable to encourage a stronger delinking between Waste collection and domestic consumption. The analysis in the smaller samples gives the same results, underlining that tendency. The other policies indexes are never significant, though we note that in some EU15 GDP specifications landfill directive dummies arise with a negative sign, and policy index with a positive sign that signals the commented endogeneity (it is in fact correlated with income, differently from policy dummies). All in all, policy levers appear to have a very marginal impact, if any, on waste generation, it is coherent with the lack of waste prevention oriented policies and with the difficult, if possible at all, backward effects, potentially exerted by landfill policies on waste generation.

5.2 Landfilled Waste

5.2.1 Baseline WKC

The analysis relative to waste Landfilled reported in the table 2 below shows evidence in support of a WKC. This is expected given the scenario of recent years. What is instead not clearly understandable from qualitative analysis or descriptive statistics is the relative effects of different drivers.

What seems a little bit strange in that analysis is that the turning point is at very low level of consumption (1720€). That might represent in our opinion the second part of the typical inverted U relationship: the process of diverting waste from Landfilled started before 1995, and so our data registers only the downward sloped part of the relationship and the turning point (see fitted graph in appendix)[35]. In the sub sample EU15 the relationship is quite similar, but the turning point is coherently a bit higher (7779€). In the EU 10 sample instead the quadratic term lost his significance and the linear term remains significant but shows a negative coefficient for consumption (-.2788139***)[36]. The overall EU25 picture is then affected substantially by a striking heterogeneity between EU15 and EU10. The latter group shows a sharp decline of landfill waste with respect to

[34] The analyses for the untransformed variables give the same results for what concern the directives. What differ in that case is that the environmental policy index is significant (at a 5% level) and negatively correlated to GDP or household consumption.

[35] These results are confirmed also using Log GDP as main driver, but they differ using non transformed variable. In that case the quadratic term lost his significance and the linear term remains significant but shows a negative coefficient (-.0055317*** for GDP and -.0123402*** for consumption)

[36] The results in the sub-samples are the same in all the specification, both log and non log, and either using household consumption or GDP as main economic driver.

consumption. This phenomenon has already been discussed above. It may be flawed by data quality (if landfill is a weak link under this respect in EU10 counties[37]), or driven by an effective good performance of countries, that are experiencing a period of economci growth started in late nineties associated with the implementation of environmental policies (needed to joining the EU) proposed by richer countries. One may claim that from a development point of view EU10 countries have more chances to be more efficient, compared at the same level of income, since their growth is embedded in a scenario characterised by a rich set of environmental policies that cannot be avoided, being a prerequisite among others for entry in the EU, by new incoming countries.

Tab.2 – MSW landfilled EU25

Dependent variable	Log WASTE Landfilled / POP	Log WASTE Landfilled / POP	Log WASTE Landfilled / POP	Log WASTE Landfilled / POP	Log WASTE Landfilled / POP
Model	REM	FEM	REM	REM	REM
Constant	-9.67483*	-9.32966***	-10.74397	-5.874086	-9.821522**
Log C	4.239412***	4.52268***	4.156763***	3.004908***	4.4184***
Log C^2	-.2845168***	-.313874***	-.260092***	-.187152***	-.2963276***
Log Oldness		-1.56985**	-.3263082	-.7721762	-1.751776**
Landdir			-.317485***		
Landpolind				-.126946***	
Decpolind					.4994323*
Turning Point	1720	1345	2954	3065	1728
N	275	275	275	275	275
Hausman	0.2739	0.0355	0.3375	0.0726	

5.2.2 Landfilled Waste: Structural socio economic drivers

The introduction of some control variables does not alter previous results, and shows again a trend of absolute delinking for what concern waste disposal in Europe. The only significant variable in that case is the oldness indicator, which shows that countries with a higher percentage of people over 60 deliver less waste to landfill. This is a typical control variable for taking in to account different social structures in the analyzed countries. Other factors we find significant are density and urbanisation degree (EU25/EU15, respectively positive and negative signs).[38]

The analysis in the sub samples is very interesting in that case. It confirms what shown in the simple WKC regression (a higher turning point for EU15 and a decreasing relationship for EU10[39]) but underline the important role ruled by RD. In fact in the EU10 sample the national expenditure on R&D is an important variable, robust and negatively correlated with Landfilled waste (-32.9325***), a result that we will find for incineration below, obviously with an opposite sign on the link. Besides, the introduction of other controls does

[37] Analyses country by country would tell more on this aspect.

[38] Those signs become both positive in EU10. Apart usual data caveats in sub samples, this may imply for urbanisation degree a different influence or level of opportunity costs linked to the urbanisation. Urbanisation is in EU10 countries still in its infancy and strong OC in terms of eland and land prices do not emerge, prevailing scale effects with negative impacts on the environment through landfilling.

[39] WKC evidence is instead present with GDP. It does not alter our comments.

not alter the turning point in the EU15 analysis, but increase the elasticity of the relation in the EU 10. The coefficient indeed, with the introduction of other covariates became bigger than one (-.1515886**)[40].

5.2.3 Landfilled Waste: Policy effects

In the case of Landfilled waste the effect of policies indexes on the relationship is very different from the case of MSW collected. The analysis shows that both the policy levers tested (the policy index, the landfill directive dummy, and the incineration directive dummy, the latter two are highly correlated in any case following a joint implementation by country and over time[41]) are highly significant and negatively correlated to consumption[42]. These results, strikingly new in the literature, are also confirmed in both sub-samples. The main relationship remains the same in terms of kind of specification and level of significance, and the turning point becomes a little bit higher. This is really an important result because it underlines the high level reached by policies in diverting waste from Landfills. Indeed, even if policies were not being able to prevent waste generation, they had the capacity to recombine the composition of waste disposal encouraging incineration (and recycling[43]), as we can see in the further paragraphs. On the opposite the other environmental policy proxies analyzed, the decentralised waste management index (taking three values, low/medium/high), is significant at 1% and has a positive coefficient. This seems to suggest that the more waste management is decentralised within country the more landfill prevention is difficult. Interpretations are quite open and not easy at first sight; we underline that this variable is time invariant in the dataset. Its statistical power is lower capturing only cross country (lower if compared to other proxies) heterogeneity.

We stress again that from a statistical viewpoint policy dummies appear not be touched by endogeneity issues, being uncorrelated with income variables, while the policy index, probably because of the non discrete structure, is. Endogeneity remains an issue worth considering for interpreting results.

5.3 Incinerated Waste

5.3.1 Baseline WKC

The analysis relative to waste incinerated shown in the table below is based on a smaller sample then the previous one. In this case in fact we have dropped from the main data set all the observations relative to countries who register many missing data in the analysed period[44]. The result is a sub sample composed by the EU15 countries less Ireland and Greece[45]. Missing data for such countries are real absence of data, given incineration is a relatively new disposal option adopted largely by EU15 countries. Statistically speaking, contrary to what we see regarding recycling, "0" values are real ones, not statistical approximations of low figures. In the first regression we can observe the joint significance of both linear and quadratic term. This in due to the

[40] Following Torrace and Boyce (1998) hypothesis we tested also in that case an income distribution variable, but it does not result statistically significant. It is in any case highly correlated with income.
[41] We recall that the dummy varies both through time and across countries, being 1 after Directive ratification in a country.
[42] All other specifications (log, non log, and with GDP as main driver) confirms these results
[43] Descriptive findings need to be validated b econometric analyses hat will extend the present paper.
[44] In the case of waste incinerated we consider that the missing data represent countries that have not any incineration plant. In fact the EU10 countries generally register many missing data, and the presence of some waste incinerated only in recent years.
[45] The result is an unbalanced panel, because also other countries, like Portugal and Finland register some missing data in the years between 1995 and 1998.

presence of an outlier, Luxembourg, which registers a very high income and a relative low level of waste incinerated. It is the only country with a consumption level in line with the turning point. With the exclusion of this country from the dataset indeed, the quadratic term loses its significance and the relation became linear and with an elasticity greater than one (1.67***), as shown in the last column of the table 3 below. The role of this country as a problematic outlier in statistical terms appears again. In conclusion, from that first step we can evince that in the analysed period the trend for the European country is towards incineration between the different waste disposal options.

5.3.2 Incinerated Waste: Structural socio economic drivers

Among the other covariates tested in the analysis the more significant are oldness and RD[46]. The first one is significant and positively correlated with waste incinerated only in the non transformed specification, while RD[47], and is always significant. Furthermore RD has a positive coefficient; this mean that countries with a bigger expense in R&D have a bigger share of waste incinerate. This is an expected result that underlines the importance of R&D in this field characterised by innovative technologies in rapid change and big economies of scale. The inclusion of these control variables does not alter in a significant way the previous turning point, and also in this case the only country with a consumption level higher than the turning point is Luxembourg. In the analysis without Luxemburg indeed, as in the previous case, only the linear term is significant, and the RD coefficient is significant and positively correlated with waste incinerated (30.24889***). The inclusion of the other covariant in this case generates a decrease in the consumption elasticity (1.171387***) that remains significant and bigger than one. The turning point in this case is smaller than before but also in this case the only country with a consumption value bigger than the TP is Luxembourg. Furthermore, the analysis without Luxembourg confirms previous results, and only the linear term is significant and positive. The inclusion of RD in the regression, that is positive and highly significant (30.24889***) reduce the elasticity of the relationship (1.17***)[48].

We finally note that for both incineration and landfilling of waste we run some regressions using as alternative covariate to GDP/C the MSW generated or the predicted values of MSW generated, estimated from a first stage regression of MSW on economci drivers only[49]. This is a way to empirically chain the steps of waste filiere from generation to collection and disposal, where landfill and incineration are competing. As expected, MSW generated in both cases is highly significant with elasticities, measuring percentage changes, around unity or even higher.

Table 3- Incineration (EU15)

Dependent	Log WASTE	Log WASTE	Log WASTE	Log WASTE	Log WASTE

[46] Also the urbanisation degree emerges with a positive sign. This is worth noting, though the variable is more problematic given the correlation with GDP, since the sign is reversed with respect to landfill analyse in EU15. Opportunity costs and land scarcity seems to affect differently incineration and landfill, favouring the former and discouraging the latter. Other latent factors not captured here may explain this outcome.

[47] GERD is tested either with or without consumption and GDP, given their very high correlation. Its significance does not change, and then on substance results are independent on this choice.

[48] The analysis in the other specification gives the same results.

[49] See Woolridge (2002, pp. 90-93) for a comprehensive discussion on "two-stage least squares".

variable	Incinerated / POP	Incinerated / POP	Incinerated / POP	Incinerated / POP	Incinerated / POP
Model	REM	REM	REM	FEM	REM (exclud. Luxem)
Constant	-100.9929***	-96.47706***	-98.60375***	-112.8572***	-11.0653***
Log C	21.22301***	20.56153***	20.95569***	24.5401***	1.676026***
Log C^2	-1.060871**	-1.051592***	-1.059773***	-1.281698***	
Log RD		43.57101***			
Incdirect			.0695726***		
Polind01				.3802696***	
Decpolind					
Turning Point	21084	17612	19670	14375	
N	137	137	137	137	126
Hausman	0.2534	0.2221	0.4619	0.0058	0.9901

5.3.3 Incinerated Waste: Policy effects

The introduction of the environmental policy index and the incineration directive dummy in the regression gives very important results. As in the case of waste Landfilled both indicator are statistically significant at 1%, but in that case they are positively correlated with the amount of waste incinerated. This is an important result because it confirms what we have supposed above about European policies. In fact also in this case we can see how European policies (incineration directive) and country-specific policy (the environmental policy index) has reached the aim of diverting waste from landfill stimulating incineration. This is a common trend among all the countries analyzed, and is confirm by this last step. On the other side the last policy indicator, the decentralised policy index is consistent and has a negative coefficient, in line with what we have seen in the landfill analysis. Policy Indexes are highly correlated with RD, for this reason in this step we have omitted this last variable. A result is worth noting regarding this point. If inserted together, notwithstanding the correlation, R&D effects prevail, lowering policy importance. The interpretation might be that, overall, it has been the innovative dynamics to spur incineration (and landfill diversion), more than policy levers.

6. Conclusions

The paper aims are to establish a sound framework to analyse delinking for diverse waste related trends within a WKC conceptual environment that hosts the relevant policy evaluation stage. Thus, we present new evidence on waste generation and waste disposal delinking by exploiting a rich EU based datasets, that allows various analyse son the relative role played in driving the waste process by main economci drivers, structural socio-economic and, least but not important, policy factors. The core WKC hypothesis is tested and verified in it robustness by adding potential explanatory variables, and jointly used to carry out ex post policy evaluation. On the basis of the available panel datasets, we are able to provide first robust evidence on a very recent period of time, characterised by an increasing role of waste policies introduced at the beginning of this period. The scenario is then really favouring this type of investigation from statistical and policy viewpoints. We are not aware of any other study on the waste sector that can rely on such statistically robust and policy-relevant pillars.

Evidence shows that regarding waste generation no WKC trend is present, though elasticity to income drivers appears lower than in the past, pointing to the presence of current relative delinking. Delinking signals appear strong for EU10, though this deserves further investigation for a more robust validation. No landfill or other

policy effects seem to provide backward incentives to waste prevention. Regarding landfill and incineration, the two trends are decreasing and increasing as expected, with a significant policy effects driving the trend: both policy dummies and the policy index we set up are negatively correlated to landfill waste across specifications. In addition, at all levels we find additional socio-economic factors impacting on waste trends, confirming that EKC analyses cannot rely on a simple environment-income relationship. It is also worth noting that the effects of policies may in part be endogenous as related to economic indicators, a feature which is particularly relevant in the waste arena. Summing up, though delinking is far from being achieved completely especially for waste generation, some positive signals emerge, with a quite significant role played by the EU waste policies implemented in late nineties and early in this century in diverting waste away from landfill and towards incineration and recycling, though the role played by other socio economic and technological factors (R&D) must not be under considered. Policies interact with other socio-economic and economci factors over an endogenous scenario where vicious or virtuous circles drive the waste performance of countries and regions.

Further research is needed to incrementally investigate the role of policies in affecting waste-income elasticity, even by setting up more complex policy indicators to analyse more in depth sub regional delinking in specific areas or groups of countries, to complement such quantitative analysis with quantitative and qualitative research studies at national level. High value relies in within country studies and in analyses that focus on incoming countries for which empirical evidence is more fragile but crucial to inform policy makers. The key role of EU and national agencies for providing good and reliable data as food for econometric analysis and policy evaluation is emphasised by the present work.

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