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ARE YOU SURE YOU WANT TO WASTE POLICY CHANCES? WASTE GENERATION, LANDFILL DIVERSION AND ENVIRONMENTAL POLICY EFFECTIVENESS IN THE EU_{15}

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Are you SURE you want to waste policy chances?

Waste generation, landfill diversion and environmental policy effectiveness in the EU_{15}

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Abstract

We empirically test delinking of waste dynamics with regard to economic growth and the effectiveness of environmental and specific waste-related policies, by exploiting a newly constructed, integrated waste-economic-policy dataset based on official data for the EU15 for 1995-2007. We find that absolute delinking for waste generation is far from being achieved in the EU despite fairly stringent and longstanding policy commitment that goes back to the mid 1990s, but which however is biased towards waste management and waste disposal rather than waste prevention. Policy as well as country structural factors seem to impact instead on landfill diversion. Nevertheless, country heterogeneity matters: SURE based analyses show that EU average figures often hide high variance. Their results provide food for thought for a future most comprehensive EU waste policy strategy, which is now aimed mainly at landfill diversion, within a framework strongly oriented to allowing countries to decide about the implementation of EU directives.

JEL: *C23, Q38, Q56*

Keywords: *waste generation, landfill diversion, SUR, EU waste policy, environmental policy, delinking*

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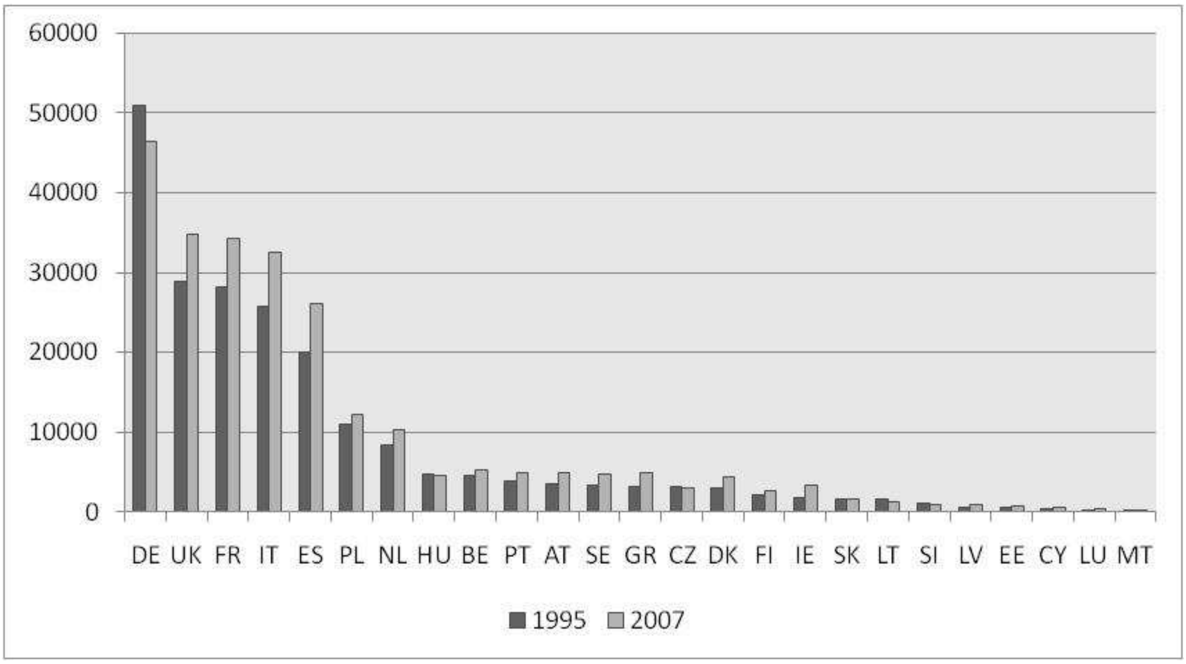
1. Introduction and relevant frameworks

Over the last 20 years, European environmental policies have become more oriented towards reducing the amount of municipal solid waste (MSW) landfilled and the promotion of other forms of waste disposal, such as recycling and incineration. In this context, decoupling or delinking, that is, improvements in environmental/resource indicators with respect to economic activity indicators, is increasingly used to evaluate progress in the use/conservation of natural and environmental resources. The Organisation for Economic Cooperation and Development is doing extensive work on decoupling indicators for reporting and policy evaluation purposes (OECD, [57]). Various decoupling or resource efficiency indicators are included in the European Environment Agency's (EEA) state-of-the-environment reports (EEA, [24], [25]), and a few European countries have begun to include indicators of delinking in official analyses of environmental performance (DEFRA/DTI, [18]). Furthermore, (EEA ETC/RWM, [26]) highlights the importance of market based instruments for achieving a higher degree of delinking for waste indicators. The European Union (EU) policy thematic strategies on resources and waste, include reference to absolute and relative delinking indicators (EEA, [22]; Jacobsen et al., [37]). The former is a negative relationship between economic growth and environmental impacts, associated with the descending side of an inverted U-shape, according to the environmental Kuznets curve (EKC) framework. The latter, the ascending side of the U-shape, is a positive, but decreasing in size, income-environment relationship. This represents a positive lower than unity elasticity in economic terms. There is no delinking observed on the ascending part of the EKC and, in addition, there is unity or higher than unity elasticity. The EKC literature has moved from basic conceptual intuitions and stylised/empirical facts, which traditionally fed EKC analysis, to the search for theoretical foundations. An extensive overview of the main theoretical issues (first developed by Andreoni and Levison, [3])[2] can be found in Brock and Taylor [8]. The field of economics of waste includes studies that date back before the 1980s (Richardson and Havlicek, [61]; Choe and Fraser, [13]; Beede and Bloom, [7]), and which increasingly emphasize policy aspects (Palmer et al., [58]; Walls and Palmer, [68]). Due to data availability, applied analysis has lagged behind theoretical analysis until recently (Johnstone and Labonne, [38]).

Increased delinking is the primary aim for waste, which, in terms of its environmental impacts and economic costs, is no less relevant than climate change and is also related to it given the greenhouse gas (GHG) emissions generated by various disposal options (Andersen et al., [1]). Andersen et al. [2] estimates waste trends for the EU-15 and the EU-10 new entrants, and finds that waste generation is linked to economic activities by non-constant trend ratios. This rather descriptive analysis of delinking in EU countries forecasts increased relative delinking; it does not confirm the EKC evidence. Projections for 2005-2020 for the UK, France and Italy, show growth in MSW of around 15-20 per cent, which, at least at first sight, may be compatible with relative delinking with respect to GDP (gross domestic product) and consumption growth. Figures 1-2 show the state of the art in the EU regarding waste generation and landfilling across countries.

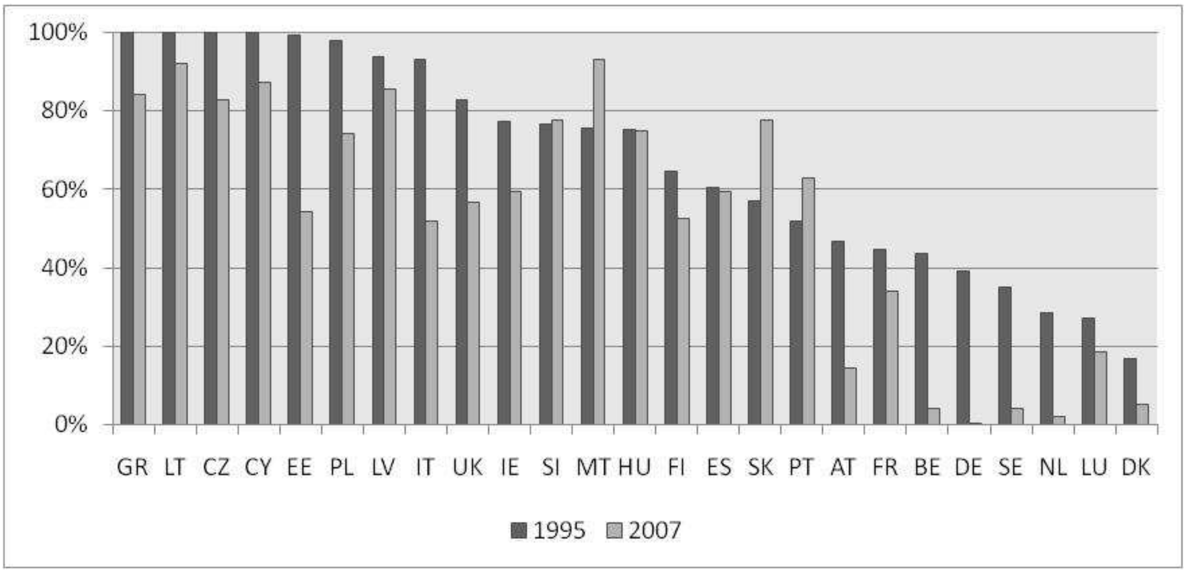
[2] Then other works followed in providing theoretical explanations for the EKC (among others Kelly, [41]; Chimeli and Braden, [11], [12]).

Figure 1 - MSW generation in Europe. 1995-2007. (1000= 1Million tons)



Source: Eurostat

Figure 2 - MSW landfilled in Europe as share of total waste management. 1995-2007.



Source: Eurostat

EEA [22] shows that countries can be categorised under three waste management groupings, based on the strategies for diverting municipal waste away from landfill, and the relative shares of landfilling, materials recovery (mainly recycling and composting) and incineration. A first grouping comprises countries with high levels of both materials recovery and incineration, and relatively low levels of landfill, a second grouping includes countries with high materials recovery rates, medium incineration levels and medium dependence on landfill, while the third group of countries has low levels of both materials recovery and incineration, and relatively high dependence on landfill (EEA, [23]). Although costs and benefits should be evaluated specifically for each situation, the environmental impacts of landfilling and waste sites mostly in urban areas are massive (Pearce, [59]; Eshet et al., [28]; Ilhanfeldt and Taylor, [35]; Jenkins et al., [39]; Seok Lim and Missios, [63]; Lang, [43]). And although recycling is at the top of the EU's environmental waste hierarchy, it should not be taken by default as 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 Pearce [59] and Dijkgraaf and Vollebergh [19] among others. The focus has shifted over the last 3-4 years to the role of waste in production and consumption processes and how prevention of waste and better waste management can contribute to more sustainable outcomes.

In the long run, waste reduction at source, through the imposition of policy targets in terms of waste generated per capita, is probably the most effective and most efficient answer to the problem. Given the potentially high costs in the short run and resistance from member states, the first phase of policy implementation at EU level focuses on landfill diversion and increased shares of recycling/recovery, including incineration. For the purposes of our analysis, which focuses on the income-waste relationship in specific states as well as the average EU relationship, it is worth noting that members states, following the guidelines in the 2008 new waste framework directive[3], are expected to set up and propose to the EU Commission a waste policy strategy that

[3] Even the revised 2008 Waste Framework Directive, which was expected eventually 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

includes waste prevention, by 2013. This might even include waste generation per capita targets, currently in place only in Hungary and the region of Flanders in Belgium. Country based evidence is a necessary piece of the puzzle. It should be noted also that the EU Belgian presidency in 2009 launched an agenda based on the objectives of a 'EU recycling society' and a EU green economy. The attention on waste management and waste policy will increase.

In light of future scenarios, there is a real need to analyse empirically whether the policies implemented so far have been effective in changing the endogenous relationship between economic growth and waste trends. In other words, given that waste policies are motivated by the various negative externalities arising at different stages of the life cycle (at source, at disposal level), ex ante cost-benefit analysis would provide indications about the most effective option to pursue and the right level of tax to impose. Ex post effectiveness analysis would assess the short and long run effects of policies on the ultimate objective (IVM, [36]): to drive down the waste Kuznets curve (WKC). In the absence of effective policies, we can expect a somewhat linear positive relationship between waste generation and growth, with landfill diversion being affected only by market prices and the opportunity costs (of land).

Delinking trends in industrial materials and energy have been scrutinised in the advanced countries for several decades (for examples of early work on development and environment see Tilton [67] on metals/materials, and Martin [48] on energy for an extensive review). In the 1990s, research on delinking was extended to include air pollution and GHG emissions, including analyses of the relationship between pollution and economic growth, which are encompassed in the EKC.

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waste prevention targets. Art. 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 art. 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 6 years. It seems clear that absolute delinking for MSW generation is not present, and EU member countries have managed to postpone specific waste generation per capita targets.

In the waste realm, delinking analyses are still scarce. One of the earliest WKC studies is Cole et al. [16], which finds no evidence of an inverted U-shape in relation to municipal waste. Fischer-Kowalski and Amann [29] analysed the richer OECD countries, over the period 1975-1995, and found that absolute delinking holds for landfilled waste, but not waste generated. This suggests, as can be seen from the descriptive analyses, that the evidence for waste generation and waste disposal varies, depending on improved performance in waste recovery. A study by Johnstone and Labonne [38] uses a panel database on solid waste in the OECD countries to provide evidence on the economic and demographic determinants of rates of household solid waste generation, regressed over consumption expenditure, urbanisation and population density. Kaurosakis [40] deals with policy evaluation, and presents evidence on the determinants of waste generation and the driving forces behind the proportions of paper and glass that are recycled, and the proportion of waste that goes to land-fill. Recent studies by Mazzanti and Zoboli [51] analyse EU-15 and EU-25 panel data for all waste trends (from generation to landfill, including recycling and incineration) for 1995–2005, and find some weak evidence of delinking and signs of policy effectiveness; others focus on the international and policy relevant issue of trans-boundary shipments of waste (Baggs, [5]). From a regional studies and trade based perspective, spatial issues are attracting the attention of researchers (Ley et al., [44]; Mazzanti et al., [54]). Recent studies on waste and environmental policy are collected in Mazzanti and Montini (50).

This article provides empirical evidence on delinking trends for MSW generated and MSW landfilled, using both fixed effect models and seemingly unrelated regression equations (SURE). The importance of this analysis is huge: on the one hand it provides a deeper investigation into delinking trends in waste sector across European countries and on the other it provides ex-post evaluation of different policy related variables. In addition, it includes a novel application of SURE models to delinking analysis in the waste sector that takes account of slope heterogeneity. The main attractions of Zellner's [69] SURE is that it make it possible to exploit cross sectional correlation in the panel (if present), estimating single equations for each individual country. This enables us to correct for the presence of contemporaneous correlations across cross sectional units allowing the slope to change across different individuals. In addition to the important statistical implications of this estimator, the real value of SURE in this field is the possibility to account for slope heterogeneity, which enables a deeper understanding of the different behaviours of different countries, based on country level evidence of delinking. Our analysis is thus developed along three steps. In the first step we apply a traditional fixed effects model then, after testing for cross sectional correlation,[4] in the second step we apply SURE (if necessary) first constraining all slopes to be equal, and finally we allow slopes to change across individuals in the third step. Comparison of the results provides an in depth understanding of the delinking process, and especially of the differences in delinking trends across countries.

The literature includes examples of delinking studies that use SURE or a random-coefficients linear regression model (Swamy, [66]), in order to account for the presence of slope heterogeneity. One well known example is List and Gallet [45], who using a long dataset on NOx and SO_2 per capita emissions for US countries during the period 1929-1994, tested for the presence of an EKC, using a fixed effects model and then applying SURE. Allowing for slope heterogeneity, they find very different turning points with respect to the aggregate analysis, with on average higher turning points for NOx and lower for SO_2. Cole [14], using fixed effects and random coefficients estimators, study the relationship between income and three different pollutants: NOx for the years 1975,1980,1985 and 1990; SO_2 and CO_2 for 1984-2000, for a wide group of countries. Cole finds different results from the two estimation techniques used: he emphasises that allowing for slope heterogeneity in the panel may alter the results of the simple fixed effects model. Using random coefficients models he finds evidence of an EKC only for one pollutant (NOx), while fixed effects shows evidence of EKC for all the pollutants he studies.

[4] As mentioned before, SUR estimators correct for the presence of cross sectional correlation in the panel. For this reason after the fixed effects estimation we present some tests for cross sectional dependence, including the Breusch-pagan statistic for cross-sectional independence in the residuals of a fixed effect regression model (Greene, [31]), and a similar test proposed by Pesaran [60], more suitable for panels with small T and large N.

He also finds a significant difference in slope coefficients among different countries, confirming his hypothesis that a single slope model may pose too strong a restriction on the data. Halkos [33], exploiting a dataset used also by Stern and Common [64], tests for the presence of EKC in SO_2 emissions during the period 1960-90, for 73 OECD and non-OECD countries.

A compelling recent study using SURE is by Martinez-Espineira and Lantz [49], who use the traditional EKC framework to study bird abundance in nine Canadian provinces, during the period 1968-2007, using a seemingly unrelated regressions approach. They find significant heterogeneity among provinces in relation to bird abundance: some of them see a turning point after 30,000 dollars, while in others the threshold is between 10,000 and 20,000 dollars. Also, in this case, slope heterogeneity is significant, confirming the hypothesis that within single states there may be considerable differences in environmental performances.

The original aim of our analysis is to bring together delinking analysis and policy assessment. Policy efforts are analysed in terms of their effectiveness in reducing waste generation, on the basis of the actions taken in response to the implementation of the policies relevant to the case considered here: namely the 1999 Landfill and Incineration Directives,[5] and more generally the commitment and effort of EU countries to implementing waste policies, including early 'policy actions' with regard to formal policy ratification, by some countries (e.g. Germany, Austria put in place a packaging waste management system).

The paper is structured as follows. Section 2 presents the data and the empirical model. We stress the uniqueness of a long panel and merged data at world level for waste, and the relevance of testing both official EUROSTAT environmental policy indicators and newly constructed –

[5] The Landfill Directive adopts two approaches: first it introduces stringent technical requirements for landfills; second, it diverts biodegradable municipal waste (BMW) from landfills by setting targets for the landfill of Biodegradable municipal Waste (BMW) in 2006, 2009 and 2016. The Incineration Directive (2000/76/EC on the incineration of waste) is an ancillary and complementary piece of EU waste policy strategy which includes the Waste Framework Directive, legislation that was revised at the end of 2008, but which still does not identify clear policy targets.

from EU waste official sources – indexes of policy stringency. Section 3 presents main results for the fixed effects and SURE models. Section 4 concludes, commenting on results with policy implications.

2. Data and empirical model

We exploit a dataset composed of the 15 European countries (EU15), for the period 1995-2007 to test delinking paths and the effectiveness of policy, controlling for socio economic and structural factors, in determining waste performances[6]. The two dependent variables are MSW collected, and solid waste landfilled, expressed in per capita ratios derived from EUROSTAT. Our main economic driver, as in other WKC studies, is data on final consumption expenditure by households, because this is considered to be better than GDP in this kind of study. Estimates (not shown) that exploit GDP present very similar results: this is a kind of sensitivity test. We include some other variables to control for socio-economic and policy aspects. First, population density since it is likely to impact on waste generation – with ambiguous sign given that urbanisation forces could drive up generation while economies of scale may after some point of waste quantity drive down collection of waste - and negatively on waste landfilled at micro and macroeconomic levels. In terms of construction of the policy indices, we exploit the country fact sheets available at EIONET[7] to compile an original index of policy stringency, which, interestingly, varies over time and across countries, and EUROSTAT data relative to the total amount of environmental taxation (not energy) per GDP in European countries. The index constructed (fig. 3) is a proxy for national policies for the time period examined. It captures all possible information on national implementation of waste related policies (MSW, packaging

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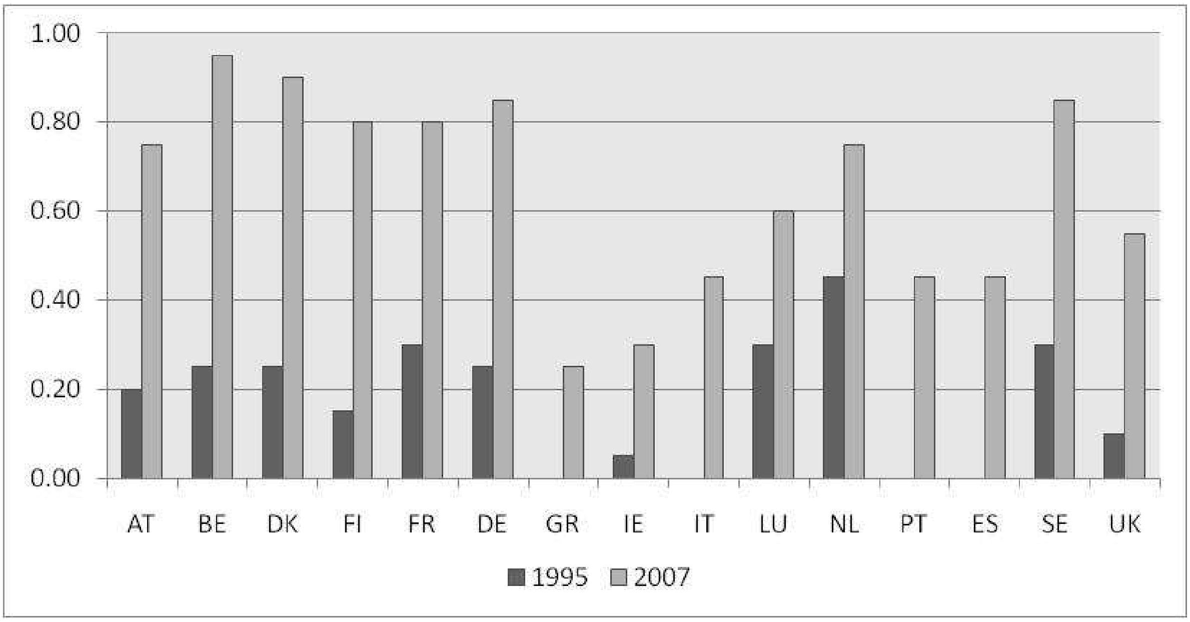
[6] We do not use EU27 data given the current lower availability and reliability of waste data for 'newcomers' eastern EU countries.

[7] EIONET is a partnership agency of the EEA and its member countries; it is fundamental to the collection and organisation of data for the EEA.

waste, end of life vehicles, landfill taxation etc.). We use the country studies available at EIONET as our information source. This index is extremely comprehensive with regard to landfill directive related variables,[8] and captures some of the waste prevention features of national policies.[9] It is consistent with a comprehensive environmental policy approach, which is not based on single economic instrument, discussed theoretically by Walls and Palmer [69].

Figure 3 – The policy index



Source: own calculation on EIONET data

We introduce total number of environmental management system (EMS) certifications, a factor that indirectly capture some effects of the packaging directive effects on firm behaviour

[8] Thus, in any given year, each country is associated with an index value, where 1 is the maximum potential value (assuming the presence of all the policies considered). We differentiate between the presence of a strategy (low value) and an effective regulatory policy (high value). The latter is assigned a bigger weight (0 for no policy, 1 for strategy only, 2 for a policy). Prominent examples of overall environmental policy performance indices, for several countries, based on a synthesis of diverse policy performances, can be found in Eliste and Fredrikkson [27] and Dasgupta et al. [17]. Cagatay and Mihci ([9]; [10]) provide an index of environmental sensitivity performance for 1990-1995, for acidification, climate change, water and even waste management.

[9] Altthough 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 amounts of MSW generated are not significant. Nevertheless, since our synthetic policy index also captures the variety of waste measures implemented by a country in addition to landfill diversion actions, some effects may emerge.

or, more generally, 'market innovativeness' in the waste management practices characterising a country. Environmental certification is often tested as a possible driver of environmental performance (Arimura et al., [4]; Barla, [6]). This is a more a market based factor linked to the techno-organisational innovation process eventually influencing environmental performances, and eventually responding to regulatory pressure. Future applied work should test also whether other market based factors such as market structure are relevant for explaining waste performances (Fleckinger and Glachant, [30]).

The data we use derive mainly from EUROSTAT structural indicators datasets, and are summarised in Table 1 which highlights the main research hypotheses.

The specification that we test is a common EKC based (Cole et al., [15] Stern and Common, [65]; Maddison, [46]) reduced form (for waste related studies, see Dijkgraaf and Gradus, [20], [21]; Mazzanti and Zoboli, [51]). We do not include a third term in the income-environment polynomial due to its irrelevance in the waste framework (at best the presence of relative delinking is proved):

(1) Log (Waste per capita performance indicator[10]) $= \beta_{0i} + a_t + \beta_1 \text{Log}(C)_{it} + \beta_2 \text{Log}(C)^2_{it} + \beta_3 (Xi)_{it} + \beta_4 (Zi)_{it} + e_{it}$

where X includes socio-economic/structural factors (DENSPOP) and Z includes policy/market levers (POLIND, ENVTAX, and EMAS). The relation is estimated first with the fixed effects model then with the SURE technique, constraining all the slopes in a first phase and setting them free to change across individual estimations in the second step.[11] The analysis is conducted

[10] Either landfilled waste or waste generated in our paper. Incinerated waste is not included due to lower coverage even in the EU15.

[11] In this last step we voluntarily dropped 3 countries, in order to allow estimation of the SURE model with unconstrained slopes. This is because we have a relatively small T and without the exclusion of at least 3 countries it would not be possible to estimate this last regression. For this reason, in the first phase of the work, we dropped all observation relating to the 3 countries with the lowest amounts of waste generation, and the three countries with the lowest levels amount of waste landfilled in the second phase of the analysis.

first using MSW as the dependent variable and then MSW landfilled, in order to assess the trends in two of the main variables in waste management. Wherever possible, logarithmic values are used.

Table 1 - Descriptive statistics and summary of research hypotheses

	Variables	Acronyms	Units of measurement	Mean	Min	Max	Research Hypotheses
Dependent Variable	MSW generation	MSW-GENER	[Kg/capita]	545.26	302	804	
	MSW landfilled	MSW-LAND	[Kg/capita]	228.91	3	554.1	
Economic drivers	Consumption	CONS	[€ per inhabitant]	13,663	5,700	28,400	Linear or quadratic (inverted U) shape
Structural Variable	Population density	DENSPOP	[inhabitants/ Km^2]	157.06	16.8	484.2	MSW-GENER: either positive or negative effects can be expected depending on economies of scale vs opportunity cost of waste management MSW-LAND: negative correlation mostly expected due to economic and environmental external and opportunity costs of landfilling
Policy Variables	Waste-related policy	POLIND	0-1 index	0.45	0	0.95	Negative correlation[12]
	Environmental tax	ENVTAX	% National consumption	1.19	0.25	3.90	
Market variable	EMS innovation	EMS		0.014	0	0.183	

[12] Although positive correlation between policies and country environmental commitment can be and were found, dependent on endogeneity of policy action with respect to income level, the production of public environmental goods being a public good and luxury goods being helped by income conditions and by the health of public finances. Vicious or virtuous circles thus are possible paths in the environmental-income dynamics.

3. Econometric evidence

3.1 Waste generation drivers

In the fixed effects analysis (results in Table 2), the core specification shows a relative delinking associated with a quite low elasticity with respect to previous estimates, which remains in the range 0.31 to 0.38 across all the specifications tested.[13] This may be preliminary evidence that the EU 15 group is still far from absolute delinking, although progress is being made towards delinking.[14] In any case, this may be seen as a problematic result, considering that on the one side, waste prevention is at the top of EU waste hierarchy along with recycling, and on the other side and even more important, prevention at source is probably the most effective way of promoting waste management sustainability. Moving to the socio economic control, we see that population density is never statistically significant. Also not significant are the three policy variables tested: policy index, environmental taxation and EMAS certification as market/policy lever. Similarly, we expect the total amount of environmental taxes to be negatively correlated to the total amount of waste generated and positively to landfill diversion. We have the same expectations for EMAS certification. Nevertheless, this result is not unexpected, considering that waste policies do not put specific emphasis on waste prevention but are usually seen as an instrument to optimise waste management systems. Similarly, the amount of environmental taxes, which could be considered a proxy for commitment to environmental issues, does not alter the Kuznets delinking relation, which is in line with the lack of specific emphasis on waste prevention in these policy efforts.[15] Finally, EMAS certification was expected to have a positive correlation to waste prevention, being a proxy for product innovation and environmentally

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[13] The squared term is not presented because it is never statistically significant.

[14] Mazzanti et al., [52] found an elasticity of 0.772, using Eurostat Data from 1995 to 2005. The inclusion of years 2006 and 2007 reduces the income/waste elasticity, showing an improvement in environmental performances at the EU15 level.

[15] Moreover, a huge part of this variable is related to landfill tax in most countries. In Italy, e.g., 80% of such environmental taxation is linked to landfill tax revenues, as national statistical data show. In general, in the EU landfill tax comprises the major share of environmental taxes. One famous example is the UK landfill tax introduced in 1999 (Morris et al., [55]; Martin and Scott, [47]).

oriented production, but this variable is not significant. One reason may be the high variance of this factor in the EU, with Germany a clear outlier and other countries lagging behind with relatively new adoption dating only from the late 1990s – early 2000s for most. To deal with the endogeneity of policy commitment with regard to income levels we implement three different consistency tests, presented in Table A2 in the appendix. In the first two we used respectively the first and the second lag of POLIND as the policy proxy, in the third we instrument POLIND with its lag. Tests confirm the results obtained in the main analysis.

Table 2 - Waste Generation: Fixed effect model

	FEM	FEM	FEM	FEM
CONS	0.35***	0.38***	0.33***	0.31***
DENSPOP	0.18	0.17	0.26	0.28
POLIND	…	-0.02	…	…
EMS	…	…	0.17	…
ENVTAX	…	…	…	-0.04
Pesaran test[16]	0.0088	0.0090	0.4601	0.0024
F test	0.0000	0.0000	0.0000	0.0000

Note: In all the estimation we use the Huber/White/sandwich estimator of variance adjusted for correlations in the error terms over time within individuals (but not across individuals). This means that we consider that $Var(\varepsilon_{it}) = \sigma^2\varepsilon_{it}\ \forall\ i=1,.., N, t=1,…,T$, and that $Cov(\varepsilon_{it}, \varepsilon_{is}) \neq 0\ \forall\ t \neq s$. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively; F test shows overall significance for all regressions; R-squared presents reasonably high values for panel settings. EMAS data are available only for the period 1997-2007, and EMAS estimation does not include Germany because it is a strong outlier. Environmental tax data are not available for year 1995.

The results of the Pesaran (presented in Table 2) and Breusch-Pagan (presented in Table 3) tests show that the residual of the fixed effects model are affected by contemporaneous correlations across cross-sectional units, which can be exploited by techniques such as SURE models, which allow efficiency gains. Table 3 summarises the regression results from the first of the two SURE models for waste generation. This is a first possible model in which we constrain all the slopes to being equal; a kind of fixed effects with serial correction which is usually implemented in the econometric literature to cope with correlations remaining within a framework of homogeneous slope.

[16] Breusch pagan test results, not shown for reasons of space, are consistent with these results.

As we can see this 'correction' does not alter significantly the economic and statistical meaning of previous results.[17] Some new insights emerge however. If on the one hand, both specifications we test show significance of the squared term, demonstrating a Kuznets like path, this is nonetheless associated with a very high, and clearly 'out of range with respect to the observed values', turning point. In other words, there is still only relative delinking. The economic meaning is unchanged. The policy index is again not significant, while population density is. In this case, population density is linked to a negative and economically and statistically significant coefficient (Ziliak and McCloskey, [70]), suggesting that economies of scale related to agglomeration may have a positive effect with respect to waste prevention. We recall that there are no a priori expectations about this sign since opposite forces are at work; the corrected model changes (increases) the significance threshold as a result of higher efficiency.[18]

Table 3 - Waste generated. SURE Model, constrained slopes.

	Constrained slope SURE	Constrained slope SURE – all variables
CONS	0.95***	1.19***
$CONS^2$	-0.03***	-0.038***
DENSPOP	…	-0.29***
POLIND	…	-0.002
TP [CONS per capita, millions of €]	7.521	6.311
Breusch-Pagan test of independence (chi2)	0.000	0.000

Note:. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively.

[17] As already mentioned, SURE refers only to 12 of the 15 countries. The countries with the lowest levels of waste production, i.e. Luxembourg (330.473 Kg); Finland (2.675.416 Kg) and Ireland (3.389.645 Kg), were dropped from the data set to allow SURE given the constraints. See Table A1 in the appendix for a general overview.

[18] Some further estimates that constrain only CONS while leaving DENSPOP and POLIND unconstrained in scope, show that 4 countries are characterized by a positive coefficient (+) for density: France, Greece, Italy, Sweden; 8 have a negative coefficient (Austria, Belgium, Denmark, Germany, The Netherlands, Portugal, Spain, UK. For POLIND, Austria, Belgium, Denmark, Italy, The Netherlands, Portugal, Spain, UK show a positive sign while for France, Germany, Greece, and Sweden the sign is negative.

The last model we present for waste generation (Table 4) gives evidence of country heterogeneity in the income/waste relationship at the EU15 level. The analysis refers only to the main economic variable consumption.[19] The main advantage, from an interpretative point of view, is the possibility to compare the trends in different countries within the same framework of analysis, which highlights common elements and discrepancies. For instance, Table 4 shows that it is possible to split countries into three groupings: a first group includes Austria, Germany, Greece, Portugal and Spain, characterized by the presence of absolute delinking. This result is as expected for Austria and Germany, which are leaders in the waste sector and waste management and show performances above the EU average. Germany's national waste policy encourages implementation of EU waste directives[20]. The evidence for the three other countries, is more unexpected. From the graphical evidence plotted in the appendix figures, we believe that only Spain can be associated with real absolute delinking, while Greece and Portugal show respectively stabilization of waste generation, and an N shape which could derive partly from waste accounting 'data distortions' in some years, a fact which is plausible in the waste arena.[21] The turning point is always inside the range, and relative at quite high levels of income, except in the case of Germany, which is consistently associated with a very low turning point (1,633 €). Germany preceded and influenced EU policy by achieving higher performance through diffuse and stringent policy introduced in the early 1990s (EEA, [22]).

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[19] We attempted some estimates including DENSPOP and POLIND, which showed lower performance in terms of statistical fit of the model.

[20] Germany role and behavior depends on both a country real commitment on green strategies – waste and renewables among others - and eco-innovations, often fostered by regulatory interventions and public funding, and by idiosyncratic energy related country aspects. This green competitive advantage, though generating high national compliance costs, it is also a driver of the high tech / green contents of german export leading performances in the EU. An anecdote of Germany influence was the 1989 Toepfer law setting strict objectives on packaging waste recycling and recovery and producer responsability, which drove the 1994 Packaging EU Directive given the necessity of an homogenization of packaging laws to avoid trade distortions in the common market. On the energy side, the commitment of Germany on renewables energy, waste recycling and eco innovations depend on the scarcity of national sources. UK instead has placed lighter emphasis on recycling – mainly plastic - given the abundance of oil. This is an endowment based reasoning that explains the value of investigating country specific evidence in detail. All in all, Germany leadership is not undermined by this consideration: other countries such as Italy are not rich in energy sources but adopted far lighter green strategies.

[21] We refer the reader to Tables A2-3 in the Appendix, for graphical plots.

A second group for countries, characterized by the presence of relative delinking, includes the United Kingdom and The Netherlands. In this case there is a turning point, but it is out of the possible range of income.

The remaining countries, in the third group, show no evidence of delinking, but with differences among them. Coefficients are not highly significant for Belgium, Denmark[22] and France, but specific time series analysis conducted on these countries - not included here for reasons of space - shows an increasing and significant relationship.[23] Italy and Sweden show a U shaped relationship, characterized by a clear positive marginal effect. Overall, the tendency in this last group is for an increasing relationship between waste and income.

To summaries, SURE analyses are only able to identify differences across European countries that are hidden in the fixed effects estimation. In particular we see that, letting the slopes free to move across the different individual countries, we can categorise countries in three groups, based on the big differences among them. From a statistical point of view this result is also confirmed by the F test presented in the final line of Table 4, which confirms that letting the slopes move freely across countries provides more valuable information.[24]

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[22] Denmark performance may be influenced by the fact that construction and demolition waste were recently accounted as MSW. This shows how data commensurability is an issue in waste statistics. Within EU15 data commensurability is good, while data availability and commensurability are two points that for the time being does not allow a full integration of EU12 countries into the analysis.

[23] Analogously, an unconstrained SURE with only consumption as the main economic driver shows a statistically significant and positive relationship between income and waste generated. These results are not shown for reasons of space, but confirm the absence of delinking for Belgium, Denmark and Finland.

[24] The test follows an F statistic, and tests the hypothesis of slope homogeneity (under the null).

Tab 4 - Waste generated. SURE Model, unconstrained model

Countries	CONS	$CONS^2$	TP [€]	Delinking evidence
Austria	84.31***	-4.33***	16,646.52	Absolute
Belgium	-3.73	0.210	7,075.36	No delinking
Denmark	-11.26	0.62	8,051.13	No delinking
France	3.57	-0.17	33,767.68	No delinking
Germany	1.89***	-0.12***	1,633.113	Absolute
Greece	17.36***	-0.91***	13,548.99	Absolute
Italy	-8.73***	0.487***	7,842.28	No delinking
The Netherlands	9.28***	-0.47***	16,578.1	Relative
Portugal	8.89***	-0.48***	9,983.131	Absolute
Spain	24.03***	-1.29***	10,885.79	Absolute
Sweden	-17.5***	0.96***	8,700.899	No delinking
United Kingdom	5.09***	-0.25***	21,529.84	Relative

Breusch-Pagan test of independence (chi2) = 0.000 F test of slope homogeneity = 0.000

Note:. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively; SURE estimations refers only to 12 countries. Breusch-Pagan tests for cross-sectional independence in the residuals, while the F test is a test of slope homogeneity.

Some countries were able, during the period analysed, to reduce the amount of waste and to change the income environment relationship, promoting a process of delinking, driven by structural and policy factors. At the same time, some other countries show an increasing relationship, in which an increase in income is combining with an increasing trend in total amount of waste generated.[25] This evidence, which will be become more robust in future years from adding years to the already valuable EU waste time series, in our view should be very useful

[25] From a different but complementary perspective, we calculate the delinking indexes following the OECD [60] formula, which we present in the appendix (Fig A1). (SURE) econometric analysis is definitely a more robust way to assess delinking.

for the EU Commission and member states in transition for fixing a set of country diversified targets and policy tools on waste generation, under the umbrella of the waste framework directive and EU regulatory guideline.

3.2 Waste landfilled

The relationship was hypothesised to be bell-shaped, in accordance with the previsions of the more traditional WKC studies. In fact, on average, although some EU15 countries are still increasing their share of landfill[26] – due to policy failure and land-based idiosyncratic features, and heterogeneity is rather striking across Europe (figure 2), shares of landfilled waste have been constantly decreasing since the mid 1990s, when EUROSTAT data began to be collected. Therefore, we can expect to find a bell shape or even a strictly negative relationship in the turning points for most countries.

This expectation is confirmed by the following results, suggesting that from an EU average viewpoint, the period 1995-2007 is already on the descending side of the inverted U-shape relationship, as far as the relationship between landfill and economic growth is concerned. The estimation results presented in Table 5 confirm the presence of an absolute delinking, with a turning point corresponding to relatively low levels of income (turning point varies between 6,976€ and 12,637€ across specifications). Moving to the additional covariates, we see that population density is never significant. This result is counterintuitive; we would expect population density to be a proxy for the opportunity (economic) cost of land, and for this reason highly correlated to landfill diversion. Nevertheless, previous studies (Mazzanti et al., [52]) based on a shorter dataset find similar results for European countries, while they find a

[26] Ireland, Portugal, Spain, Italy, and surprisingly Denmark and the Netherlands, actually show a U shape, where the lowest peak around 2005 is followed by slight increase in landfilling (a recoupling in technical terms) over 2006-2007, which is sound to some extent, given that these were two years of robust economic growth. Recall that the social benefit cost ratio of landfilling relative to other options is highly idiosyncratic (Dijkgraaf and Vollebergh, [19]).

negative significant relationship between population density and waste landfilled in a wider EU25 analysis.

The inclusion of socio economic and policy drivers does not alter the results of the core specification, but adds some interesting elements. Regarding the policy proxy, both environmental taxation effect[27] and the waste policy index are statistically significant.[28] This means that the policy efforts implemented so far at national level, have promoted a stronger delinking between waste landfilled and domestic consumption.

Tab 5- Landfilled Waste: Fixed effects model

	FEM	**FEM**	**FEM**	**FEM**
CONS	32.65**	23.80**	16.06**	31.33**
CONS^2	-1.82**	-1.26**	-0.92**	-1.77**
DENSPOP	5.23	3.11	1.66	6.71
POLIND	…	-1.64***	…	…
EMS	…	…	5.92	…
ENVTAX	…	…	…	-0.74**
TP [€]	7,86187	12,637.76	…	6,976.3
Pesaran test	0.0353	0.0141	0.0255	0.0447
F test	0.0000	0.0000	0.0000	0.0000

Note: In all the estimation we use. the Huber/White/sandwich estimator of variance and adjusted for correlations in the error terms over time within individuals (but not across individuals). This means that we consider that $Var(\varepsilon_{it}) = \sigma^2\varepsilon_{it}$ $\forall$ i=1,.., N, t=1,…,T, and that $Cov(\varepsilon_{it}, \varepsilon_{is}) \neq 0$ $\forall$ $t \neq s$. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively; F test shows overall significance for all regressions; R-squared presents reasonably high values for panel settings. EMAS data are available only for the period 1997-2007, and the EMAS estimation does not include Germany because it is a strong outlier. Environmental tax data are not available for year 1995.

This is an important result because it underlines the potentially high level of effectiveness of – decentralised - European policy, in terms of diverting waste from landfill. Policies help in the effort to *tunnel through* the business-as-usual, endogenous delinking trend that is driven by economic drivers. Only EMAS do not have a significant coefficient, which is evidence that a high number rate of certificated firms and technologies is still not associated with better performances of waste management and disposal.

[27] Recall that environmental taxation net of energy is mostly landfill taxation, around 80% of that for example in Italy.

[28] Since we suspected the presence endogeneity of policy commitment with regard to income levels, we implemented three different consistency tests, presented in the Appendix in Table A3. The first two respectively use the first and the second lags of POLIND as the policy proxy, the third includes POLIND instrumented with its lag. The tests confirmed the results obtained in the main analysis.

Even for landfilling the results of the Pesaran and Breusch-Pagan tests confirm the presence of contemporaneous correlations across cross-sectional units. Table 6 summarises the results for the constrained SURE.[29] The core specification confirms our previous result of absolute delinking, but with an even lower turning point (1,659.39€). In terms of averages, this mean that 1995-2007 is already along the descending side of the inverted U-shape relationship.

Table 6 – SUR: landfilled waste

	Constrained SUR	Constrained SUR – all covariates
CONS	1.49***	4.27***
CONS²	-0.10***	-0.19***
DENSPOP	…	-3.68***
POLIND	…	-0.82***
TP [€]	1,659.39	47,328.06
Breusch-Pagan test of independence (chi2)	0.000	0.000

Note:. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively; SURE estimations refers only to 12 countries.

New and more interesting elements emerge from the other specifications, again showing the presence of a delinking trend, but this time associated with a high and out of range turning point (47,328€, while the income range is 5,700-28,400€). This specification also sheds new light on the variable population density, which now is highly significant from both an economic and statistical point of view (the size of the parameter is larger than in the waste generation case, higher than 3) and negatively related to landfilled waste. Both the opportunity costs linked to the higher value of land in densely populated and urban areas (value of land, of commercial activities a crowded out by landfill sites, and other public investments), and the higher externality costs in more densely populated areas, ceteris paribus, seem to be driving down the use of landfill as a disposal option.

[29] As before, SURE refers only to 12 of the 15 countries. The countries with the lowest levels of waste to landfill, i.e. Luxembourg (61.904 Kg); Sweden (191.378 Kg) and Belgium (222.275 Kg), are dropped.

Moreover, the policy index is again significant and associated with a negative coefficient of relevant size. This new insight, combined with the high significance of the policy related variable, probably explain the progression from the previous strong absolute delinking to the relative delinking found in this last specification. To summarise, the use of a constrained SURE model in this analysis would suggest that the baseline income waste relationship does not on its own explain landfill diversion. Other forces, such as population density, impact on waste performance. This does not infringe the core evidence we found to support the general effectiveness of environmental and waste policy efforts in driving down disposal by landfill.

Finally, Table 7 presents the results of the fully unconstrained SURE model. The regression results generally confirm the previous evidence of a bell-shaped income-landfill diversion relationship, with the exceptions of Spain, the Netherlands and Denmark – three cases of relatively worse performance envisaged above. All the other countries analysed show an absolute delinking in the waste income relationship over the considered period.

In Denmark and the Netherlands, although in both countries there is geographical space for landfilling, the U shape seems to be capturing some statistical irregularities (see figures A2-3) within a still clear absolute delinking over the entire period.[30] Spain is the only case that does not show a clear 'marginal effect', that is more in line with the evidence of relative delinking. In other words, the size of the two estimated coefficients leads to a calculated weight of CONS and $CONS^2$ biased towards the former. This is the only case where the turning point is within the estimated range.

The country specific evidence from the SURE model shows its potential for interpreting ex post dynamics and informing future policy. The threat of a recoupling is looming even for countries with relatively good performance.

[30] The TP for Denmark and The Netherlands is slightly outside the range of values. Delinking is thus absolute.

Table 7 - Unconstrained SUR - landfilled waste

	CONS	CONS²	TP [€]	Delinking
Austria	3.71***	-0.33***	269.7	Absolute
Denmark	-120.6***	6.05***	21,160	Absolute
Finland	43.74***	-2.32***	12,296.32	Absolute
France	84.01***	-4.45***	12,358.26	Absolute
Germany	12.97***	-1.3***	142.27	Absolute
Greece	17.38***	-0.92***	12,210.49	Absolute
Ireland	15.59***	-0.82***	12,204.52	Absolute
Italy	22.7***	-1.25***	8,642.7	Absolute
The Netherlands	-144.14**	7.28**	19,837.1	Absolute
Portugal	40.9***	-2.27***	8,052.68	Absolute
Spain	-10.14***	0.54***	10,209.04	Relative
United Kingdom	48.21***	-2.54***	12,930.44	Absolute

Breusch-Pagan test of independence (chi2) = 0.000,
F test of slope homogeneity = 0.000

Note:. (…) means not included; significance at 10%, 5% and 1% denoted by *, ** and ***, respectively; SURE estimations refers only to 12 countries. Breusch-Pagan tests for cross-sectional independence in the residuals, while the F test is a test of slope homogeneity.

3.3 Simulating policy effects

Along similar lines as in Cole et al. [15], we explore as a final investigation the effect of what could have occurred to the delinking process if structural and policy variables were in 1995 at their 2007 level. Using a two stage procedure, it is possible to asses the degree to which 1995 waste generation and waste landfilled quantities would have changed, if the three main variables were at their 2007 level, holding the other variables constant. We calculated the predicted values of our core relationships using 1995 data, and in the second step, we replaced 1995 data relative to the three variables of interest (policy index, population density and environmental taxation over consumption) with their 2007 values. In this way, it is possible to measure the effect of 2007 regulation and population density on 1995 waste indicators.

Table 8 indicates that the effect of the policy indicator is positive and associated to a negative sign in both cases, but with a higher coefficient in the case of landfilled waste. This is an expected result, considering that previous models underlined that policy index is strongly related to waste landfilled but is not able to promote landfill prevention. In other terms, we can read this result as the effect of 2007 regulation on 1995 waste performances, coming to the conclusion that a stronger regulation would have had a significant effect in reducing the amount of waste landfilled. A different and probably unexpected result, is given by the environmental tax, that shows a positive result for both MSW generated and Landfilled. Even though these results may seems counterintuitive, given the strong link found up to date between regulation and waste performances, we have to note here that the level of environmental taxation with respect to income has a decreasing path over the time period analysed, i.e. the share of environmental taxation on income is lower in 2007 than in 1995. This is a well known fact in the EU policy arena: environmental and energy taxes have shown stable or decreasing paths on average, with many countries witnessing reductions in real terms. In other terms, the results in the previous table stress the importance of environmental regulation, showing that 2007 taxation (slightly lower than 1995 level) has a positive effect on 1995 level of both waste generated and waste landfilled. Analogously, the results for population density show a positive relationship in the case of waste generation and a negative one in the case of waste to landfill, in line with previous result. Summarizing, we have seen here that policy levers has definitely been on of the main responsible of the process of landfill diversion, and that a stringent regulation starting from 1995 would have reduced the amount of waste landfilled quite consistently.

Table 8 – Simulation effects

	MSW GENER	MSW LAND
POLIND	-0.0161	-1.006
ENVTAX	0.0210	0.0905
DENSPOP	0.0432	-0.2599

Results are statistically significant and are calculated using fixed effect predicted values.

4. Conclusions

This paper provides new evidence on the socio economic and policy drivers of two main waste variables, waste generation and landfill diversion, by exploiting a fairly long and highly original, country-based, panel dataset for the EU15. The environment is relevant given the increasing strictness of waste policies in the EU, promoted by Germany's leadership since the mid 1990s. We focus on the period 1995-2007 since there is good availability of data. The lens we use is mainly ex post effectiveness of policy action, but we also look at the future in relation to the current transition in the implementation of waste prevention policy targets in addition to the already adopted disposal based (landfill diversion) and management based (recycling and recovery) targets.

Given the strong decentralization of environmental policy in the EU, use of the SURE model is coherent with the need to investigate both average EU performance and national trends in waste-income performance and the effectiveness of waste and environmental policies more generally.

The evidence shows that although waste generation-income macroeconomic elasticity has decreased compared to several years ago, neither environmental taxes nor specific waste policy efforts have produced substantial 'absolute delinking'. As expected and in line with currently available forecasting figures, waste generation is increasing. Given that member states must propose new waste strategies by 2013, including specific waste prevention targets, we need to take urgent action on how to shape efficient and effective policies targeted at reducing waste generated per GDP and per capita, in order to complement established but evidently not sufficient waste management and disposal targets.

It should be noted that SURE, as expected, increases efficiency while not affecting substantially the economic meaning of the results, and also that population density seems to drive down waste generation. This should be taken into account in considering the relationship between endogenous changes such as increasing urbanization and waste generation. Although it enhances the statistical significance of density, the more efficient estimation provided by SURE does not change the result that environmental and waste policy actions are ineffective. Even more market based actions, such as diffusion of EMS in a country, possibly related to its waste and material reduction strategy, seem to be ineffective. However, the EU situation is highly dynamic, and shows increased adoption of environmental policies in recent years, but still with Germany as an absolute outlier and most of the rest of Europe lagging far behind.

In terms of the possibility of identifying 'groupings' of countries through the unconstrained SURE procedures, we find that EU15 waste generation–income relationship encompasses three main groups: the first is Austria, Germany, Greece, Portugal and Spain, characterized by the presence of absolute delinking. This result is as expected based on the fact that Austria and Germany are leaders in the waste sector and in waste management and show performances above the EU average. The presence in this group of the three other countries is surprising. We believe that only Spain can be associated to a real absolute delinking, while Greece and Portugal show stabilization in waste generation, and an N shape respectively. The second group of countries, which is characterized by the presence of a relative delinking, is composed of the United Kingdom and The Netherlands.

The remaining countries show no evidence of delinking, but with differences among them. Italy and Sweden show a U shaped relationship, characterized by a clear positive marginal effect. Overall, the tendency in this last group is towards an increasing relationship between waste and income.

The picture is different for landfilled waste. For most countries, a turning point was achieved in the Mid 1990s. We find that environmental tax – mainly based on landfill taxation – and pure waste based national strategies captured by the policy index affect landfill diversion with an economic and statistical high significance. The EU strategy based mainly on disposal targets, which was implemented by the Landfill Directive in 1999, and some anticipatory action by more virtuous countries (Nordic countries, Germany) is being effective. However, it is not having an effect on the core issue of preventing waste from being produced.

Population density, as expected, is a significant structural factor driving down landfilled waste, for reasons associated with to the often very high economic opportunity costs of landfill sites and the higher environmental social costs in densely populated areas. The economic significance of estimated coefficients is comparatively higher with regard its effect on waste generation, than on landfilling, in the end.

A bell shaped income-landfill diversion relationship emerges for all countries, except Spain, the Netherlands, and Denmark. If for Denmark and the Netherlands, though both countries may possess land space for landfilling, the U shape seems capturing more statistical irregularities within a still clear absolute delinking over the entire period, Spain is the only case showing a not clear 'marginal effect', more in line with an evidence of relative delinking. Nevertheless, we highlight that our results suggest as real the possibility of recoupling which may be relevant also for countries with relatively good environmental performance over the past. For instance, the evidence we capture for Denmark and The Netherlands may drive the attention on a potential future real recoupling.

Future research could extend waste economics by focusing on unexplored issues such as transboundary shipments of waste, which would overlap the trade and environmental policy fields, the spatial dimensions of waste flows across countries and within regions, new assessments and policy indicators, the influence of socio-demographic trends in forecasting scenarios, the role of the waste market structure in explaining waste related performance, and differences between advanced countries such as the EU15, and EU transition economies that are only entering the sphere of marked based environmental policy.

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Appendix

A1 - Waste generated and waste landfilled (kg)

Countries	*Waste generated*	Countries	*Waste Landfilled*
Luxembourg	330.473,78	**Luxembourg**	61.904,31
Finland	2.675.416,19	**Sweden**	191.378,40
Ireland	3.389.645,44	**Belgium**	222.275,21
Denmark	4.363.114,28	**Denmark**	223.330,44
Sweden	4.720.667,13	**Holland**	229.011,89
Austria	4.954.457,03	**Germany**	246.944,72
Portugal	5.002.772,84	**Austria**	713.707,38
Greece	5.004.939,52	**Finlend**	1.408.946,99
Belgium	5.207.590,73	**Ireland**	2.013.949,64
Holland	10.305.534,96	**Protugal**	3.147.931,22
Spain	26.151.083,03	**Greece**	4.211.745,98
Italy	32.522.207,85	**France**	11.727.545,90
France	34.295.147,74	**Spain**	15.566.120,85
United Kingdom	34.787.152,97	**Italy**	16.911.548,08
Germany	46.425.606,98	**United Kingdom**	19.704.611,12

Table A2 – fixed effects estimates with policy lags and IV: waste generation

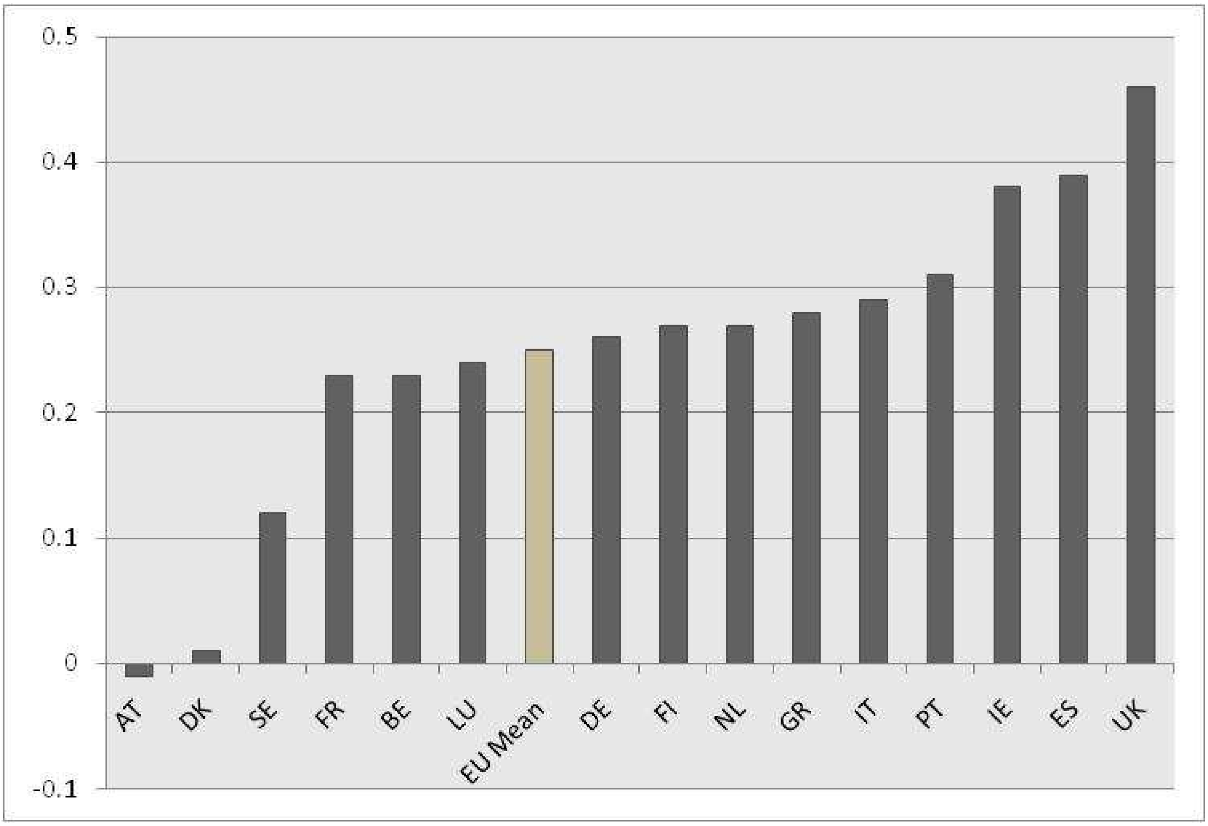
	Lagged estimation		IV estimation
CONS	0,38***	0,35***	0,39***
DENSPOP	0,05	0,04	0,05
POLIND (lag1)	-0,04	…	…
POLIND (lag2)	…	-0,04	…
POLIND	…	…	-0,05

Table A3- fixed effects estimates with policy lags and IV: landfilled waste

	Lagged estimation		IV estimation
CONS	20.13***	15.39	21.95***
$CONS^2$	-1.07***	-0.81	-1.15***
DENSPOP	3.53	3.88	3.35
POLIND (lag1)	-1.70***	…	…
POLIND (lag2)	…	-1.83***	…
POLIND	…	…	-2.10***
TP	12,167.72	13,359.73	13,953.40

Figure A1 – Delinking indexes for waste generation and landfilling – OECD (2002)

Waste generation



Landfilling

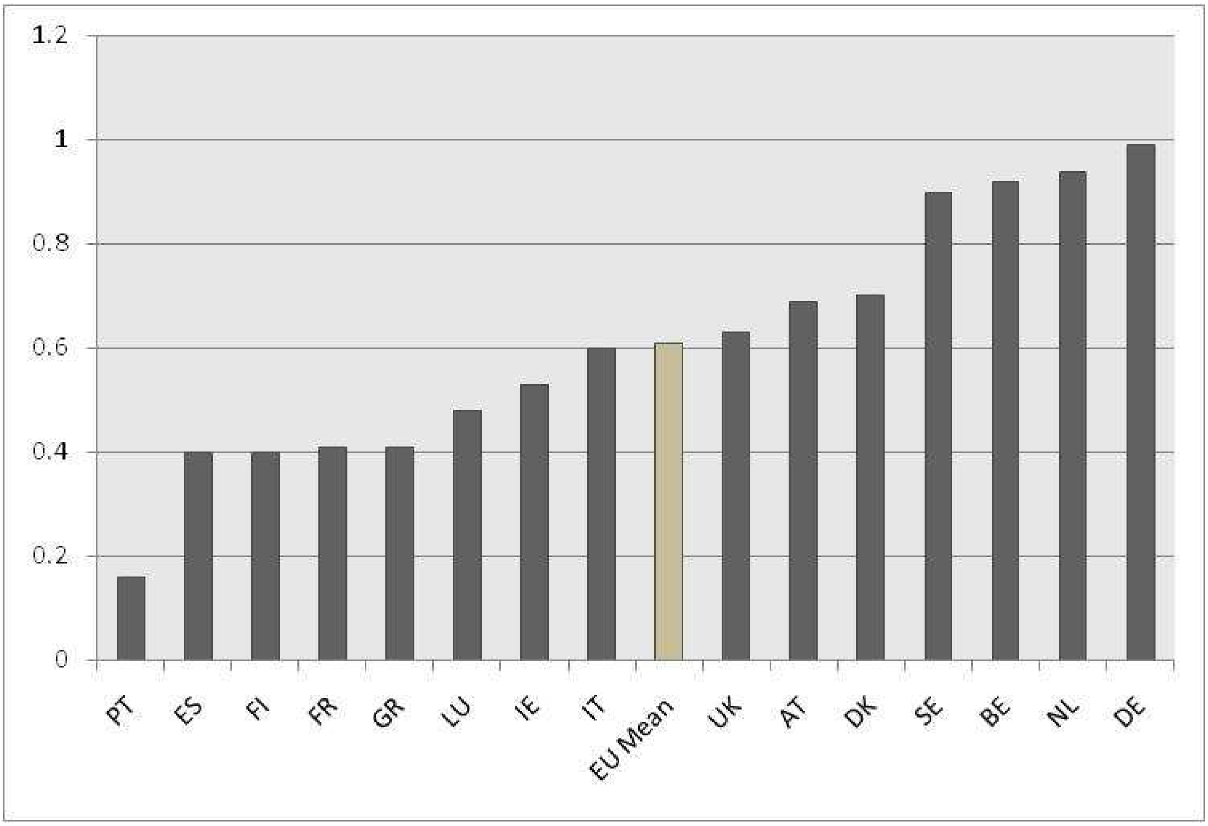


Figure A2- Waste generation vs consumption per capita

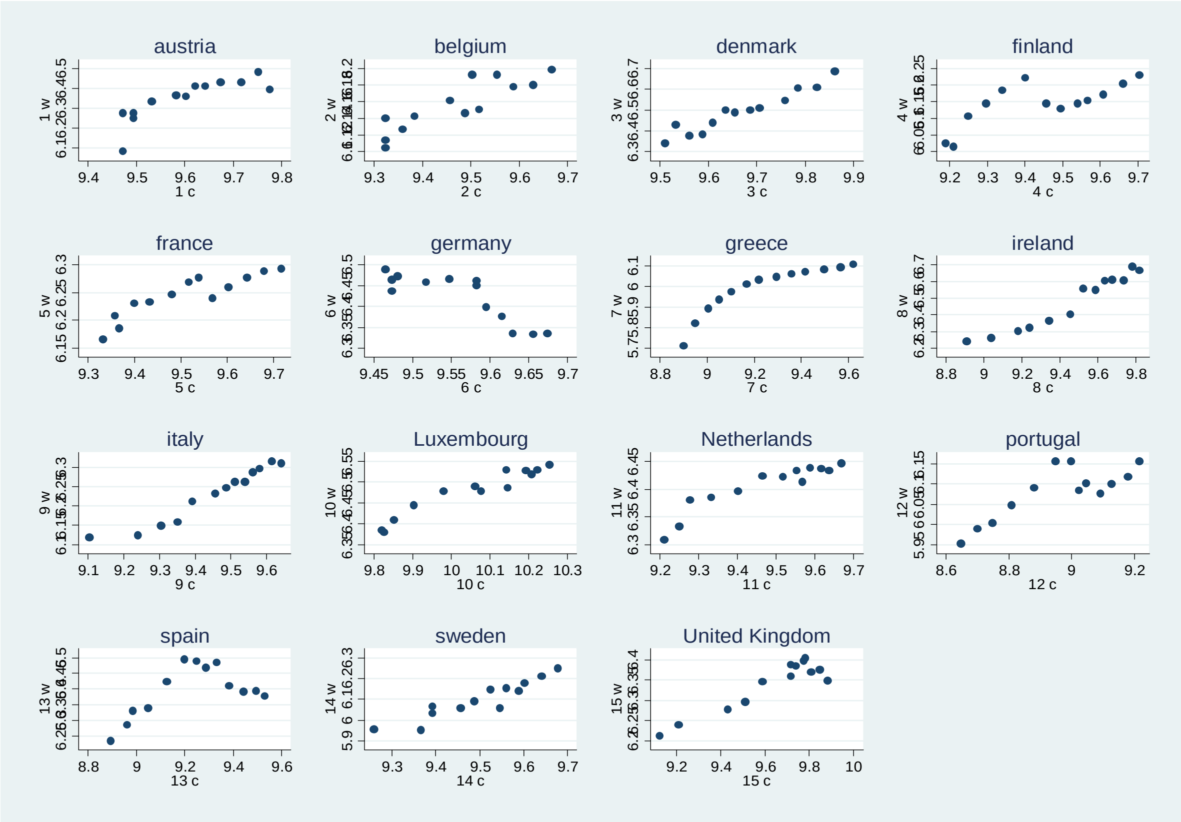


Figure A3- Waste landfilled vs consumption per capita