Catching-up in waste management. Evidence from the EU

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Abstract

This work tests for the presence of convergence in the main municipal solid waste disposal choices across EU countries over the years 1995-2010. We believe this is a relevant exercise, considering that in the last two decades the waste sector has experienced a profound transformation at the European level. Landfilling is losing its primary role, and other activities, like recycling and incineration, are becoming increasingly important. In this context, β and σ tests of convergence can tell us more about the distribution of these different rival choices of waste disposal, by assessing on the one hand the presence of convergence and, on the other hand, the role played by environmental policy and green technological change in driving convergence.

Keywords: Waste management, Beta-convergence, Sigma-convergence, Green technological change, Waste policy.
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1 Introduction

Waste management and disposal, together with climate change mitigation, are among the main policy challenges in the European environmental Agenda. Since the introduction of the first Landfill Directive, back in 1999, landfill diversion and the promotion of alternative form of waste disposal have been seen as key policies to reach a good environmental status. In the first step of this process, the main focus was on the disposal side of the waste realm, as landfilling was seen as the option with the highest cost in term of both pollution and landscape degradation. Moreover, groundwater leakages and methane emission from landfills could cause serious health problems. For all these reasons, the European Union has issued various directives with the intention to promote the use of alternative disposal methodologies. The most important step in this transition has been the Waste Framework Directive (Directive 2008/98/EC) which depicted the policy and conceptual framework which should guide the European waste management evolution towards a "recycling society". A milestone of this first directive was the consolidation of the so-called waste hierarchy, i.e. a ranking of waste management choices, in which landfilling is consider as the worst possible option and prevention as the preferred one. A second step in this long path is the promulgation of the Circular Economy package in 2015, which poses the basis for a new definition of the European economic System[4]. In short, with the emphasis on the Circular Economy the European Parliament proposes a new conception of economy in which production is a circular flow, based on a solid combinations of re-using, repairing, refurbishing and recycling, with the final aim of turning waste into resources.

This new conceptualisation of the waste sector was reflected, in the last two decades, in a profound reorganisation of the entire waste management system, which was driven, according to Mazzanti and Zoboli (2009), by several economic, technological and institutional factors. In particular, this process placed a strong emphasis on landfill diversion, and to the promotion of alternative choices of waste disposal. The result of this process was a sudden increase of recycling and incineration activities, which in 2010 accounted on average for more than the 60% of total waste treatment. This has represented, in a sense, an application of the 'waste management hierarchy', in which

[4] See http://ec.europa.eu/environment/circular-economy/index_en.htm

the least preferred management option is disposal (i.e. landfilling), followed by recovery (including energy recovery such as incineration), recycling, re-use and waste prevention.

The literature (e.g. Mazzanti and Zoboli, 2009; Nicolli et al., 2012) highlights the important role of several driving forces in this phenomenon. Firstly, income matters, as richer country diverted more waste from landfill and had the resource to incentivize the use of more advance waste management options, like recycling. Secondly, social factors like population density played an important role, influencing the economic value of land and consequently the marginal cost of landfilling. Thirdly, a relevant role has been played by environmental policies, which altering the natural marginal cost of different disposal choices have been able to promote landfill diversion, incentivising the development and diffusion of alternative and more advanced technologies that became viable and less expensive in several countries.

Despite this positive result, less attention has been paid, up to now, in trying to understand how this process is developing, and it is not clear whether this reorganization of the waste management system is decreasing or widening the differences across European countries. We believe this is a relevant question, which allows to comprehend the geography of waste management and to have a more clear view of the overall performances of the EU. In particular, we will estimate, basing our analysis on traditional convergence studies, whether the amounts of waste generated, landfilled, recycled and incinerated are converging among the EU countries. The idea of convergence across countries was originally introduced by growth economists (see Barro and Sala-I-Martin, 2003, for a summary) who considered the concept of convergence as an implication of traditional neoclassical growth models. They usually considered two kinds of convergence: a first one known as β-convergence, occurs when poor countries have higher growth rates than richer ones, i.e. they are "catching up" with rich economies. On the other hand, the second concept of convergence, known as σ-convergence, is related to cross-sectional dispersion over the time period analysed. This second kind of analysis is basically conducted by performing a test of dispersion for every year of the sample period, checking if the dispersion is increasing or decreasing over time.

This work studies the process of convergence in the waste sector in EU, exploiting a rich data set which varies across 22 EU countries over the years 1995-2010. In doing so, we also control for several factors which might influence the convergence process, like the accumulated stock of knowledge, per capita GDP and environmental policies.

2 Conceptual Background

Building on the work of growth economists (see for reference the already mentioned work by Barro and Sala-i-Martin, 2003), several scholars in the field of environmental and natural resource economics has applied the consolidated framework of the convergence studies in order to assess how emission, especially air pollution, are spatially distributed over time and across space. The seminal contributions in this field by List (1999) and Strazicich and List (2003), found evidence of convergence in air pollutants (SOx and NOx) respectively for US States and OECD countries. Similarly, Aldy (2006) performed a series of convergence tests on the emission of CO2 in two different samples of respectively 23 OECD countries and 88 world countries over the years 1960-2000. He found a significant convergence in the OECD sample. Moving to the waste sector, Nicolli (2012) performed a set of different convergence tests on a series of waste indicators across Italian provinces, reinforcing the hypothesis that laggard provinces have been able to catch-up with more efficient ones.

Overall, this literature suggests as the convergence framework can be a suitable tool to analyse the development of recycling and incineration across European regions and through time. With convergence we mean here testing, on the one hand, if countries which are lagging behind are actually catching up more virtuous countries (in term of use of preferred waste management technologies, like recycling and incineration) and, on the other hand, testing if the disparities in waste performances are decreasing over time. The intuition behind this concept is that laggard countries in term of share of recycling and incineration, being more distant to the technological steady state, have an higher growth rate of technological adoption, and are consequently capable to catching up with more virtuous countries. This rational behind this hypothesis is complex and depend on a number of factors. Firstly, the marginal cost of recycling is increasing with respect to the share of recycling activities. This is largely due to separate collection costs, which became higher, the higher is the share of population covered by the system, and the higher the number of materials which are collected separately. Secondly, advanced collection systems may require the introduction of complex policy measure, like pay-as-you-throw schemes or deposit-and-refund systems, which increase the cost of moving from an average share of recycling to very high performances. Thirdly, the adoption and promotion of incineration activities is a complex matter, which includes not only high investment costs, but also an important policy debate. The effect of green lobbies with respect of incineration is, for instance, non-trivial. On the one hand, in fact, certain green groups may lobby in favour of incineration, if they consider it as a valid alternative to landfill. This is especially true in areas which experienced waste crisis. On the other hand, green activists may lobby against the construction of incineration if they have health or sanitary concerns. As a result, the marginal costs of incineration activities can be highly non-linear and partially unpredictable[5]. Moreover, laggard countries can benefit from knowledge and technology spillover from countries at the frontier, making these new technologies more convenient for second movers.

These mechanisms explain why we do expect the rate of expansion of recycling and incineration to decrease as they approach the steady state. As a consequence, the first research hypothesis reads as follow:

H 1: European countries are converging in terms of adoption of both recycling and incineration technologies.

Moreover, we expect this conditional convergence to lead to an overall reduction of disparities across waste management systems in EU, which can be translated in the second research hypothesis:

H 2: The adoption of recycling and incineration across European countries is converging also in absolute terms.

Moreover, during the last two decades a new but still limited body of literature has emerged, inside the wider debate on Environmental Kuznets Curve, with the specific

[5] For an Example of the political debate around incineration activities see D'Alisa et al. (2010).

aim to study and understand the evolution of waste disposal and waste generation through time. A common result of this first studies, was the absence of an inverted U-shape between GDP per capita and waste generation, but a certain degree of delinking between economic growth and landfill activity. The theoretical intuition behind these studies is that being environmental protection a normal good, wealthier households demand for greener disposal technologies, i.e. recycling and incineration. Cole et al. (1997), for instance, found a monotonically increasing relationship between income growth and waste generation in relation to municipal solid waste using a data set of 13 OECD countries over 15 years (1975–1990), while Fischer Kowalski and Amann (2001) found evidence of absolute delinking for landfilled waste by analysing OECD countries over the period 1975–1995. Similarly, Mazzanti and Zoboli (2009) and Nicolli et al. (2012) found a strong evidence of an EKC-like pattern in waste management choices across European countries, finding a robust correlation between income growth and the evolution of recycling and incineration technologies. Moreover, these last two contributions highlight as income is not the sole factor influencing waste disposal choices, but that also environmental policy, giving a price to the externality associated to landfill activities, played a fundamental role in incentivising recycling and incineration activities. Moving to our context, we hypothesize that environmental policies can have a reinforcing factor for laggard countries, allowing them to reduce the distance from the frontier. The introduction of a landfill tax, or a subsidy for recycling, is expected, in this view, to have a stronger effect for laggard countries given their lower than average marginal costs for recycling. As a consequence, our third research hypothesis reads as follow:

H 3: Environmental policy can increase the speed of convergence in the adoption of both recycling and incineration technologies.

Finally, a more recent strand of literature focused on the effect of technological change on the environment. Costantini et al. (2013), exploiting Italian input-output tables, show as innovation and environmental spillovers can drive regional and sector-specific environmental outcomes. Similarly, Gilli (2016) shows as the adoption of environmental friendly technologies, lowering abatement costs, are correlated to an overall reduction of CO2 emission for manufacturing sectors in OECD countries. Nevertheless, the recent review of the literature on eco-innovation by Barbieri et al. (2016) points out as there is no single and common mechanism through which innovation exerts its effect on environmental performance, as environmental realms are so different that similarity are hardly found. In the case of recycling, for instance, innovation generally came in the form of cost-reducing process technology, able to alter the relative prices of disposal options. The similar logic applies to incineration. Overall, the mechanism in play in the waste sector is that the introduction of cost-saving process innovations, making the "green" choice (i.e. recycling and incineration) close to competitive with the "brown" alternative (landfilling), have an overall positive impact on the environment.[6] As a consequence, it is reasonable to expect that a green knowledge stock based on patent data, representing overall country innovative activities in waste technologies, can have a positive effect on the speed of convergence in the adoption of both recycling and incineration. Our final hypothesis reads, consequently, as follows:

H 4: Green technological change can increase the speed of convergence for the adoption of both recycling and incineration.

3 Data and methods

3.1 Data

We collect information on recycling and incineration share of total municipal solid waste treatment for 22 EU countries[7] over the period 1995-2010 from Eurostat. Data on waste management are further extended with traditional controls such as wealth (consumption per capita, in euros at constant prices – base year 2000 – and expressed in Purchasing Power Parity) and population density (population per square meter), retrieved from Eurostat. Finally, we build an indicator of policy stringency. Such index is the result of a two-step process representing respectively: (1) the systemization and

[6] We refer here to the "European waste hierarchy" as reference for "green" and "brown" disposal choices.
[7] Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden and United Kingdom.

weighting of the different types of government directives to manage waste, and (2) their joint adoption per country per year. The first indicator (1) is based on the Countries' Fact Sheets on waste management available at Eionet, plus some additional information from the individual Government Departments of Environment web sites. On the basis of this information, we created a series of ordinal variables ranging from 0 to 2 and representing the policies adopted for the different fields of waste and their impact. Specifically, the variable takes the value of: (0) when the policy is not been adopted; (1) when the policy designed provided a scarce articulation of the waste management practice to apply (Low impact policy); (2) when the policy designed provided a very articulated standardisation of the waste management practice to apply (High impact policy). We determined the impact of the policy (1 or 2 values) according to a quantitative ranking based on the available policy information or the sampling distribution (preferably using the median as indicator of central tendency). For example, the simple adoption of an EU directive is coded as a Low impact policy. Conversely, effective regulation plans or policies setting a high threshold of waste management accomplishment are coded as High impact policies. In the case of the Landfill tax we used the level of the tax itself. Thus, countries associated with a tax level below the yearly median value were assigned with a weight equal to 1, and countries with a tax level bigger than the median value were associated with a weight equal to 2. After the creation of this new variable (1), we finalized the Policy Index by averaging all the policies adopted per country per year (hence, we averaged all the ordinal variables adopted per country per year).

Figures 1 to 3 depict the trend in the policy index for all the analysed countries against the European average (the dark line). Overall, all countries experienced a significant increase in the value of the indicator, which has been growing steadily in the entire analysed period. Nevertheless, it is possible to imagine a division of European countries in three groups, according to their performance. The first one is composed by countries associated with higher than average values in the indicator for the entire analysed period. This group includes all European leaders when it comes to waste management performances, like Austria, Germany and Denmark. A second group is composed by countries which more or less reflect the average European performances, like Czech Republic and Poland. Interestingly, for most of them, the incidence of waste policy was really low or nearly absent until year 2000, but after that date it experienced a significant increase. Finally, a last group of countries, like Malta, Greece and Portugal is characterised by a low presence of waste policies, and tend to score always below of the European average.

[Figures 1, 2 and 3 about here]

For what concerns the knowledge stocks for incineration and recycling, we refer here to the procedure developed by Popp (2002), and measure knowledge capital of country *i* at time *t* as follows:

$$K_{i,t} = \sum_{s=0}^{s=\infty} e^{-\beta_1(s)}\left(1 - e^{-\beta_2(s+1)}\right) \times p_{it} \qquad (1)$$

where β_1 is the rate of knowledge obsolescence, β_2 captures knowledge diffusion and *p* is the number of patents applied for by firm *i* in year *t*. According with previous work on patent data (Popp, 2002), we set the rate of knowledge obsolescence to 0.1 (β_1=0.1), and the rate of knowledge diffusion to 0.25 (β_2=0.25). We consider patent applications filled at the European Patent Office, sorted by priority year, and assigned to the applicants' country of residence. We select patents in the field of waste recycling and in the field of waste incineration based on the selection of IPC technology classes identified by the OECD (OECD ENV-TECH Indicator).

The overall trend in the knowledge stock over the analysed period is depict in Figure 4. As expected, the number of patent filed in recycling technologies is much higher than the ones in incineration technologies, and also the growth rate of the two stocks is different, being higher for recycling.

[Figure 4 about here]

Finally, Figure 5 compares the different levels of national patent stocks for both recycling and incineration technologies. The most striking evidence highlighted by this graph, is once again the wide heterogeneity across European countries (see Nicolli et al., 2012). Interestingly, this ranking is slightly different with respect to the policy index one, and countries like Italy and United Kingdom are in a much higher position.

[Figure 5 about here]

3.2 Empirical approach

The following equation[8] describes our econometric specification for the test of β-convergence:[9]

$$\Delta Waste_{i,t} = \alpha + \beta Dist\_Front_{i,t-1} + X'_{i,t-1}\delta + \tau_t + \varepsilon_{i,t} \qquad (2)$$

where $\Delta Waste_{i,t}$ is the annual change in the waste indicator, $Dist\_Front_{i,t-1}$ is the distance (always positive, or zero for the frontier country in year *t*) between the level of the waste indicator at the frontier and the level of the same indicator in country i, $X'_{i,t-1}$ is a set of controls, τ_t is the year-specific dummies to control for country-invariant time-specific shocks (e.g. EU-level policies) and $\varepsilon_{i,t}$ is the residual. Table 1 at the end of this section presents some basic descriptive statistics for the variables employed in the analysis.

Further discussion is needed on the procedure we adopt to build the 'frontier'. For each year, we identify the country in which the specific indicator was the highest and identify this value as the frontier. It should be noted that this concept of frontier differs from the one generally employed in methodological frameworks such as the stochastic frontier approach or data envelopment analysis (e.g. Zofio and Prieto, 2001). We do not try to

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[8] We employ an approach that is quite common in studies investigating convergence patterns. We refer, for example, to Nicoletti and Scarpetta (2003) that investigate convergence patterns in multi-factor productivity across OECD countries.

[9] This specification is equivalent to a more standard approach to testing β-convergence:

$$\Delta Waste_{i,t} = \alpha + (1-\beta) Waste_{i,t-1} + X'_{i,t-1}\delta + \tau_t + \varepsilon_{i,t}$$

We employ the specification reported in equation 1 instead of the classical specification as in equation 2 because the richer specification in equation 1 is more suitable to test for possible interactions between the distance from the frontier and other factors that are likely to accelerate the convergence process. Baseline results for the specification based on the more standard approach are available upon request.

estimate the potential theoretical technical frontier but we just aim at observing the best performer in each year.

Figures 6 and 7 plot the country on the frontier for each year. For recycling (Figure 6), the frontier is steadily increasing through time, ranging from about the 45% in 1995 to the 62 per cent in 2010. The country at the frontier is always Austria, with the exception of Germany in years 2007 and 2010. The frontier for incineration has, on the contrary, a less stable path, even though the country at the frontier is always Denmark, whose share has been ranging between 52% to 62%.

[Figures 6 and 7 about here]

Our main parameter of interest is β. A positive value implies that countries more distant from the frontier in the past (*t-1*) grew on average faster than countries closes to the frontier between *t-1* and *t*, thus reducing the distance from the frontier.

Our set of baseline controls includes the logarithm of population density, the logarithm of real consumption per capita (in PPP), the policy indicator and patent stocks for patents related to incineration technologies and patents related to recycling technologies, all measured in *t-1*. Finally, we also interact our indicator of policy and our indicators of waste management technologies with the distance from the frontier to understand whether convergence is different for countries with greater technological capabilities or countries characterized by different levels of policy stringency.

As regards the measure of σ-convergence, we compute for each year the coefficient of variation (ratio between standard deviation and mean) of our indicators of waste management for all countries. We prefer the coefficient of variation to the simple standard deviation because it does not depend on the average level of the indicator.

Figure 8 and 9 present a preliminary evidence of the presence of converge across European countries. In this simple exercises we plotted the share of recycling (resp. incineration) in the first year in the horizontal line, versus the change in recycling (resp. incineration) experienced by all countries over the period 1995-2010. As a consequence, every dot in the graphs below represent a combination of initial value versus growth rate of recycling and incineration activities. Similarly, the dashed line, represent the fitted value of a simple regression between these values. In line with the prediction of hypothesis 1 presented above, there is a negative relationship between the rate of adoption of these technologies and the starting year, which suggests that countries are converging in term of adoption of recycling and incineration technologies.

[Figures 8 and 9 and Table 1 about here]

4 Results

4.1 Beta-convergence

Econometric results concerning our test of β-convergence for share of recycling and share of incineration are reported, respectively, in Table 2 and 3.

[Tables 2 and 3 about here]

The specification in column 1 does not include any control besides the distance from the frontier. For both the share of recycling and the share of incineration the coefficient have the expected positive sign, meaning that laggard countries have higher growth rates than countries closer to the technological frontier, but this coefficient is never statistically significant. Overall, in the period 1995-2010 we do not observe any evidence of unconditional convergence, suggesting that countries, without considering other structural factors, do not converge towards the frontier. Interestingly, including country fixed effect in column 2, the coefficient of the distance to the frontier term becomes significant and associated with the expected negative coefficient. As in growth studies, also in this case, if recycling and incineration growth rates are characterized by conditional instead of unconditional convergence, countries will converge towards different steady states in the long run (Rodrik, 2013). Similarly, this lack of support for unconditional convergence opens interesting empirical questions on identifying the conditioning factors which makes convergence feasible.[10] Overall, this first evidence provides only partial support for hypothesis 1.

In this vein, adding the full set of controls in column 3 does not affect qualitatively the results obtained in column 2, even though the magnitude (i.e. speed of convergence) of the distance to the frontier effect decreases significantly with respect to the fixed effect model. Moving to the other covariates, the patent stock has the expected positive effect on the growth of both recycling and incineration, while our policy variable always shows the expected positive coefficient, but is never statistically significant. It should be noted, however, that most EU-level policies were introduced in all countries at the same time, their effect being partialled out by time dummies. To conclude, no effect is found for population density and consumption per capita.

Moving to the third research hypothesis, column 4 of Table 2 shows as the policy index has a positive and significant effect on the speed of convergence. This result suggests that environmental policy has been able to reduce the differences across countries in terms of adoption of recycling technologies, reducing the overall differences between countries closer to the frontier and laggard countries. The same does not hold for incineration, where the interaction term is not statistically significant. This discrepancies between the two case studies is probably due by the different nature of policy support across EU countries, which have been mostly devoted to landfill reduction in a first phase (thanks to bans from landfilling for dangerous/biodegradable waste and in some cases landfill taxes) and to the support of recycling activities and complex separate collection scheme in a second phase.

A similar result is found for the interaction term between the patent stock and the distance from the frontier. Also in this case, the effect is positive only in the case of recycling technologies. This evidence confirms the hypothesis that the introduction of cost-saving process innovation has been able to reduce disparities across European waste management systems, supporting the use of recycling activities. Overall, our analysis supports hypotheses three and four only for the share of recycling.

Finally, Figures 10 and 11 depict the trend of year-specific convergence coefficients using column 3 as a benchmark specification. The plot describes the estimated beta

[10] See again Rodrik (2013) for an analogy on economic growth studies.

coefficients obtained by running year-by-year regressions. The two figures show very different trends. In the case of recycling, in fact, the size of convergence coefficients is increasing through time, suggesting that despite the average result (represented in the figure by means of a dashed line) there is a tendency in increasing the speed of convergence. In the case of incineration, on the contrary, the trend is fairly stable, even though there are some anomalous values. Overall, this last result supports the hypothesis that the speed of convergence, at least in the case of recycling, is expected to increase through time.

[Figures 10 and 11 about here]

4.2 Sigma-convergence

Figure 12 shows the degree of sigma convergence for, respectively, recycling and incineration. More specifically, we plotted here the coefficient of variation (i.e. the ratio of standard deviation to the mean) of both recycling and incineration ratio through time. According to the theory, a decreasing trend in this measure suggests the presence of absolute convergence, while an increasing trend supports the other alternative. Looking at the first figure, we observe a substantial σ-convergence (reduction in the variability across countries) for both variables, even though there are some relevant differences. Incineration was, in fact, more disperse in 1995, and has been decreasing at a lower rate with respect to recycling. Despite that, the analysis provides a strong support for our hypothesis two, which in other term means that the overall disparities across countries have been decreasing in the analysed period.

[Figure 12 about here]

5. Conclusions

The European waste management system has experience a deep transformation in the last twenty years, which has been driven, according to previous studies, by a host of factors ranging from policy drivers to land values and overall income levels. In this context, the present study seeks to understand if and how recycling and incineration shares have been converging towards the frontier, or if this process has been widening the differences across European countries.

Interestingly, the analysis shows as countries are not converging unconditionally for what concerns recycling or incineration, which in other terms means that without considering other factors, economies tend to diverge in their degree of adoption and use of green waste disposal technologies. Different results are found, on the contrary, once we condition the relationship for fixed effects. This means that there are several factors which might influence and promote the process of convergence, the most important being green technological change and environmental policies.

Overall, the empirical analysis confirms that, in the case of recycling, both environmental policy and technological change exert a positive effect on the speed of convergence, reducing inter-country disparities. A much weaker evidence has been found, on the contrary, for incineration, where the process of convergence is slower and the impact of technological change is less pronounced. This result is probably due to the characteristics of incineration activities which on the one hand impose long term and expensive investments to countries, and on the other hand are potentially subject to the opposition of national green groups, which may lobby in favour of recycling and against incineration.

The overall picture, as shown in the absolute convergence analysis, is however clear, and supports the idea that the European waste management system is converging towards a common path characterised by a progressive reduction of landfill activities in favour of recycling and, to a lesser extent, incineration.

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Table 1. Descriptive statistics

	Obs.	Mean	St. Dev.	Min	Max	Source
Change in share of recycling	346	0.258	0.182	0	0.646	Eurostat
Change in share of Incineration	346	0.175	0.175	0	0.614	Eurostat
Distance from frontier (Recycling)	346	0.341	0.177	0	0.613	Eurostat
Distance from frontier (Incineration)	346	0.506	0.313	0	0.961	Eurostat
Policy index	330	0.088	0.055	0	0.22	EIONET
Stock 'recycling' patents	352	37.039	79.371	0	407.994	OECD - REGPAT
Stock 'incineration' patents	352	13.647	27.204	0	134.602	OECD - REGPAT
Pop density (log)	352	4.788	0.932	2.59	7.183	Eurostat
Consumption per capita (log)	352	9.475	1.201	8.748	10.373	Eurostat

Table 2. Econometric results. Dependent variable: Change in share of recycling.

	(1)	(2)	(3)	(4)	(5)
Distance from frontier (t-1)	0.00617	0.183***	0.0236**	-0.0290	0.0180*
	(0.00654)	(0.0411)	(0.0102)	(0.0181)	(0.0104)
Policy index (t-1)			0.0627	-0.115	0.0538
			(0.0552)	(0.0728)	(0.0549)
Stock 'recycling' patents (t-1)			0.0000305*	0.0000357*	0.00000344
			(0.0000176)	(0.0000192)	(0.0000141)
Log pop density (t-1)			-0.00180	-0.00142	-0.00194
			(0.00315)	(0.00336)	(0.00306)
Log consumption per capita (t-1)			0.00150	0.000832	0.000969
			(0.00113)	(0.000876)	(0.000914)
Distance from frontier (t-1) x				0.514***	
Policy index (t-1)				(0.137)	
Distance from frontier (t-1) x					0.000351**
Stock 'recycling' patents (t-1)					(0.000154)
F	2.677	5.510	31.41	13.27	18.95
r2	0.0638	0.164	0.0800	0.104	0.0901
N	324	324	324	324	324

OLS estimates (except FE estimates in column 2). Standard errors clustered by country in parenthesis. Year dummies included. * p<0.1, ** p<0.05, *** p<0.01.

Table 3. Econometric results. Dependent variable: Change in share of incineration.

	(1)	(2)	(3)	(4)	(5)
Distance from frontier (t-1)	0.00939	0.182***	0.0349***	0.0401**	0.0307**
	(0.00902)	(0.0539)	(0.0111)	(0.0176)	(0.0126)
Policy index (t-1)			0.133**	0.152**	0.128**
			(0.0496)	(0.0643)	(0.0493)
Stock 'incineration' patents (t-1)			0.0000692*	0.0000705*	-0.0000635
			(0.0000339)	(0.0000345)	(0.000108)
Log pop density (t-1)			0.000486	0.000428	0.000370
			(0.00157)	(0.00161)	(0.00156)
Log consumption per capita (t-1)			0.000887	0.000954	0.000762
			(0.000549)	(0.000601)	(0.000548)
Distance from frontier (t-1) x				-0.0461	
Policy index (t-1)				(0.127)	
Distance from frontier (t-1) x					0.000411
Stock 'incineration' patents (t-1)					(0.000327)
F	1.944	7.601	79.37	370.0	71.25
R sq	0.0334	0.134	0.0776	0.0779	0.0795
N	324	324	324	324	324

OLS estimates (except FE estimates in column 2). Standard errors clustered by country in parenthesis. Year dummies included. * p<0.1, ** p<0.05, *** p<0.01.

Figure 1. Trend of the Policy Index for selected countries and European average. (First group).

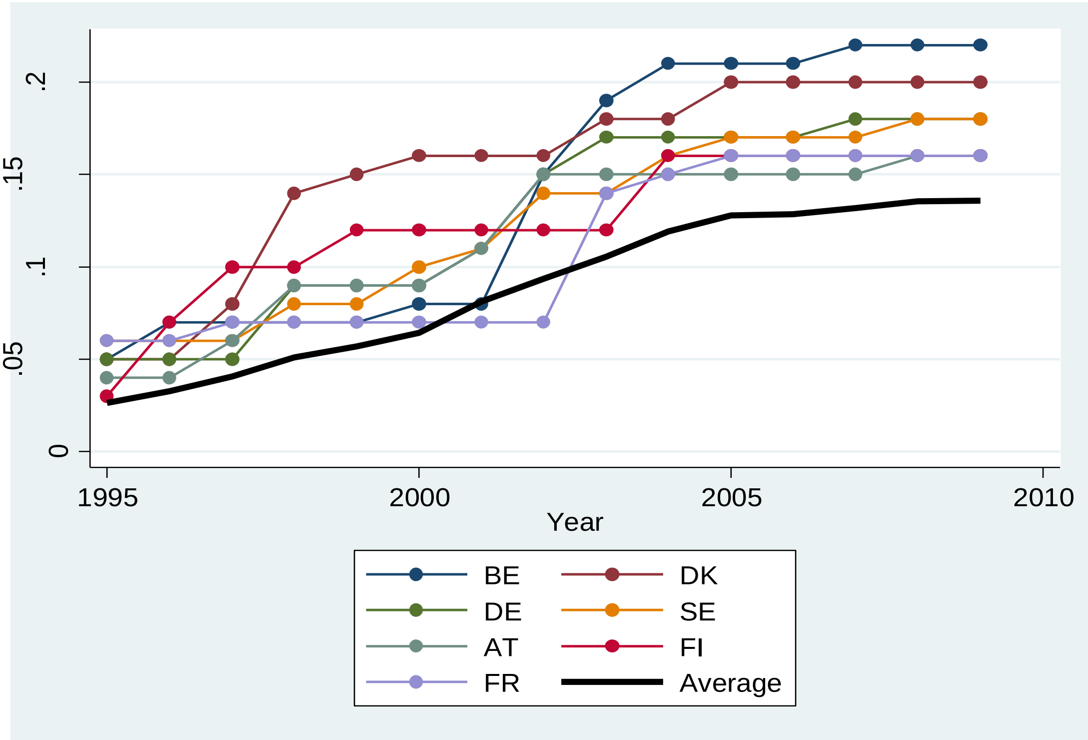

Figure 2. Trend of the Policy Index for selected countries and European average. (Second group).

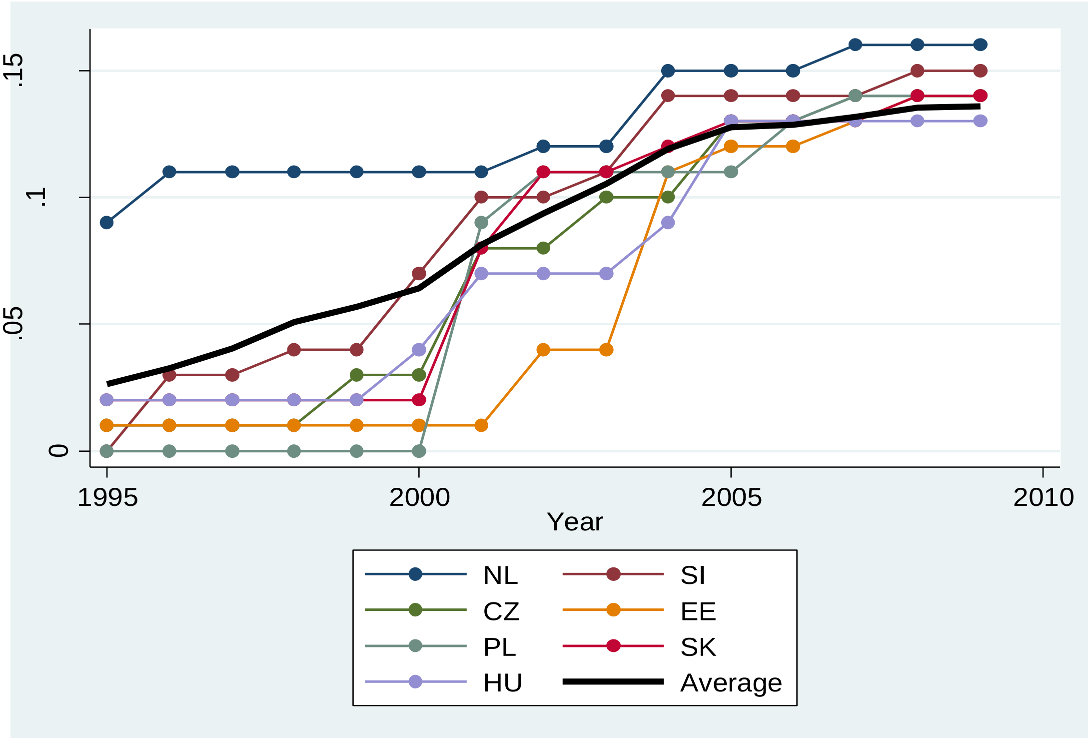

Figure 3. Trend of the Policy Index for selected countries and European average. (Third group).

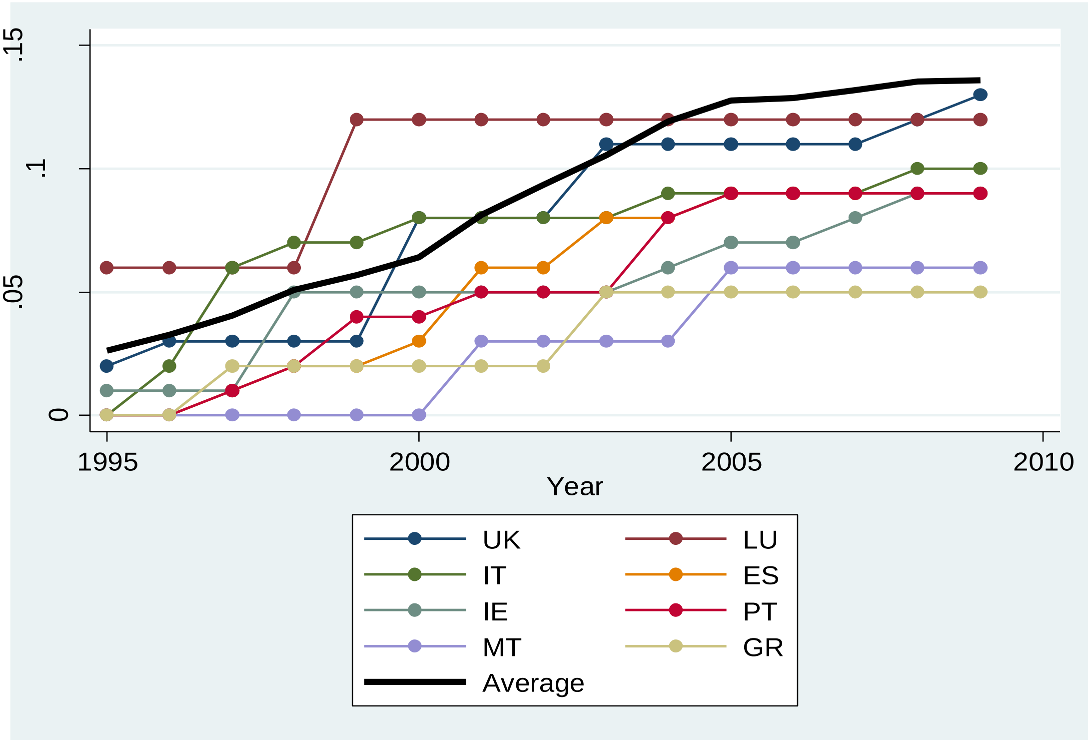

Figure 4. Trend of the patent stocks

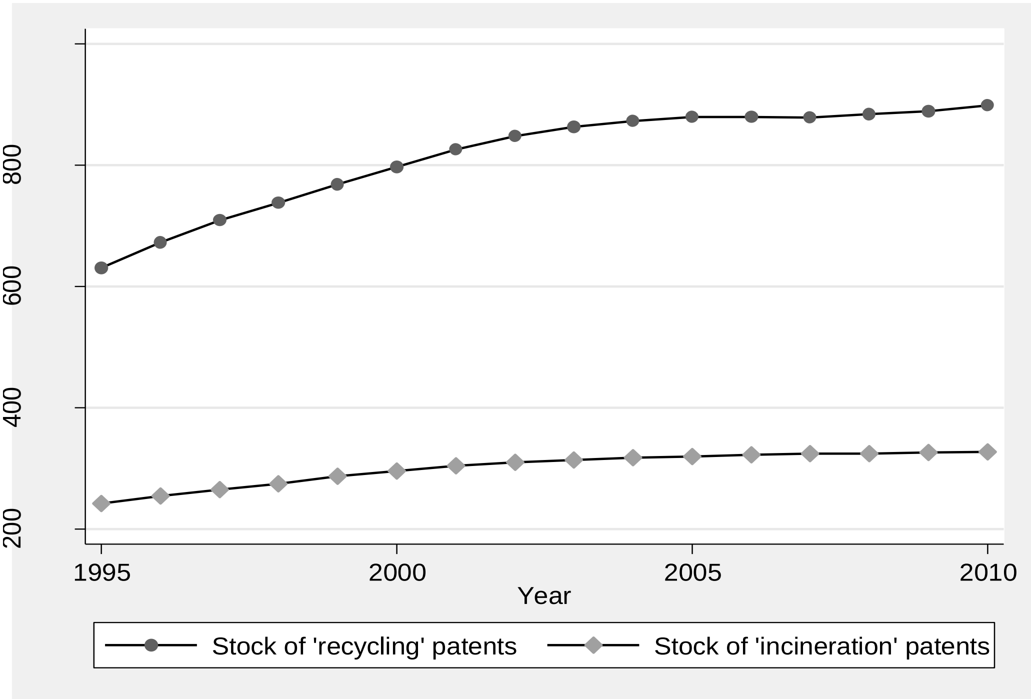

Figure 5. Patent stocks level in year 2010 for all the analysed European countries

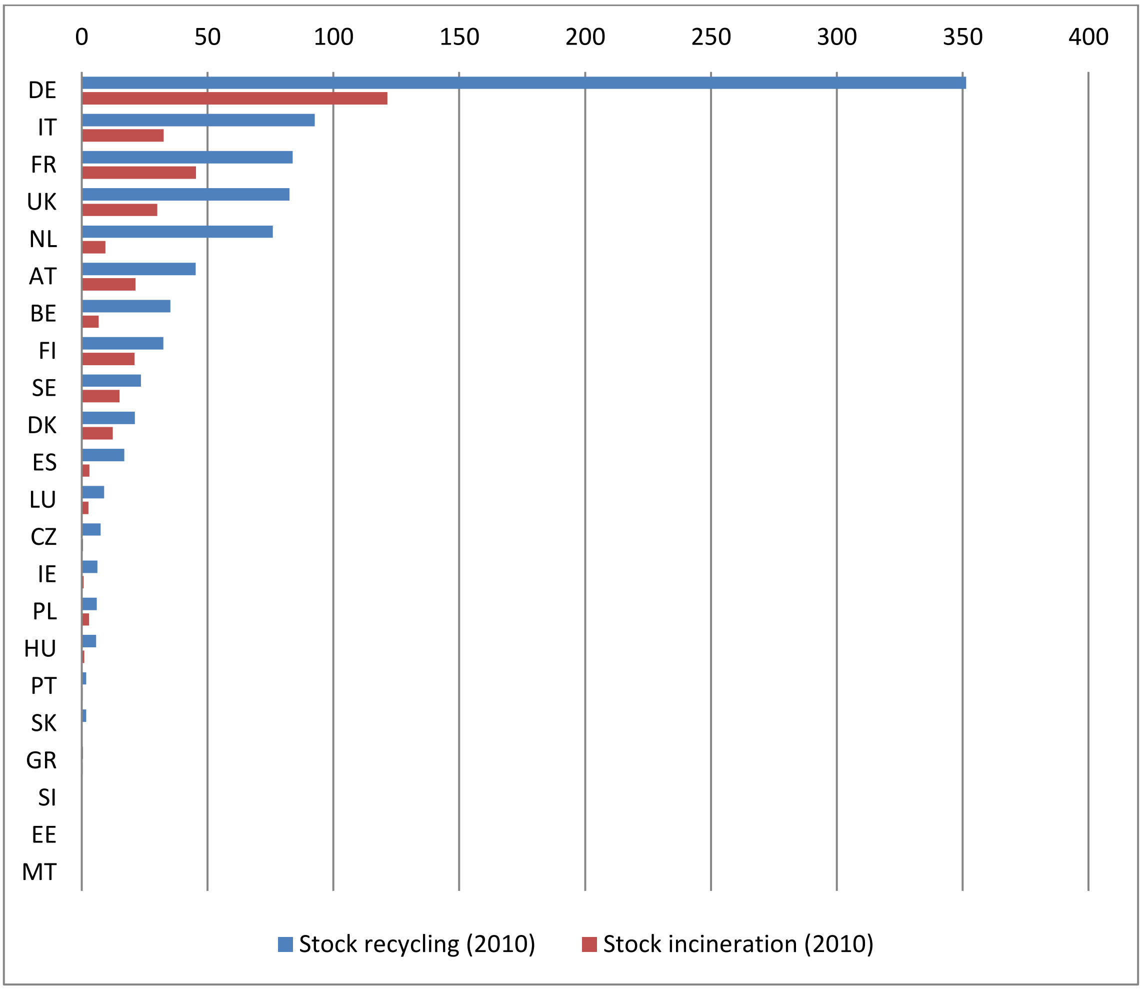

Figure 6. Recycling share, Frontier.

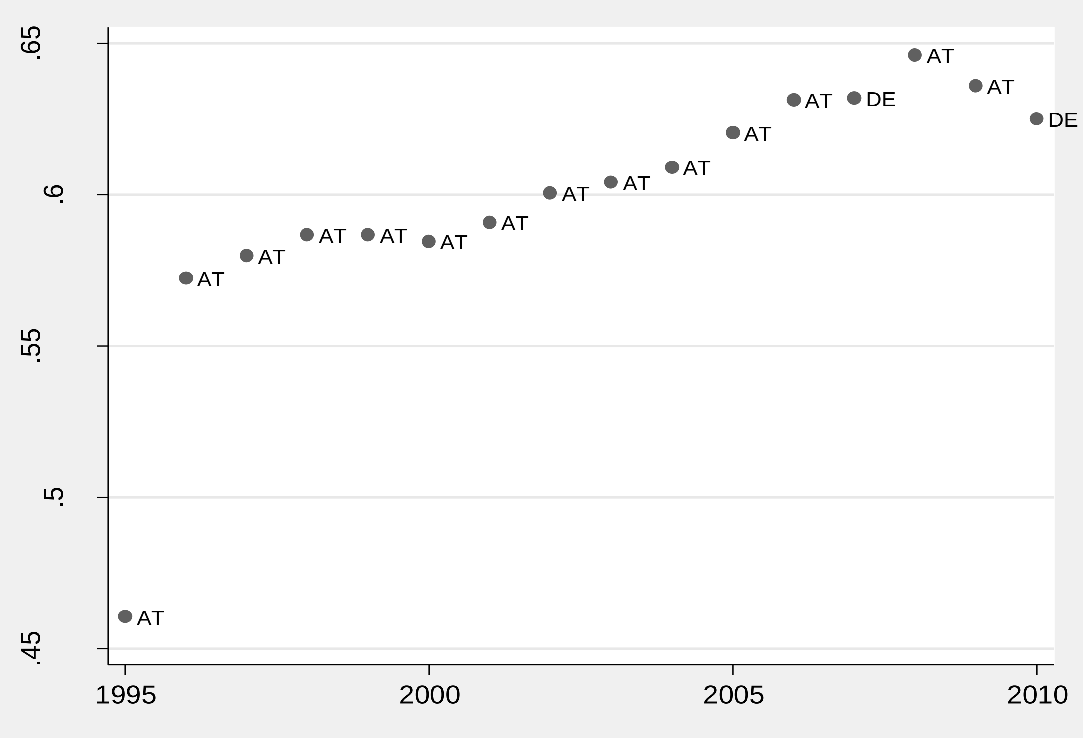

Figure 7. Incineration share, Frontier.

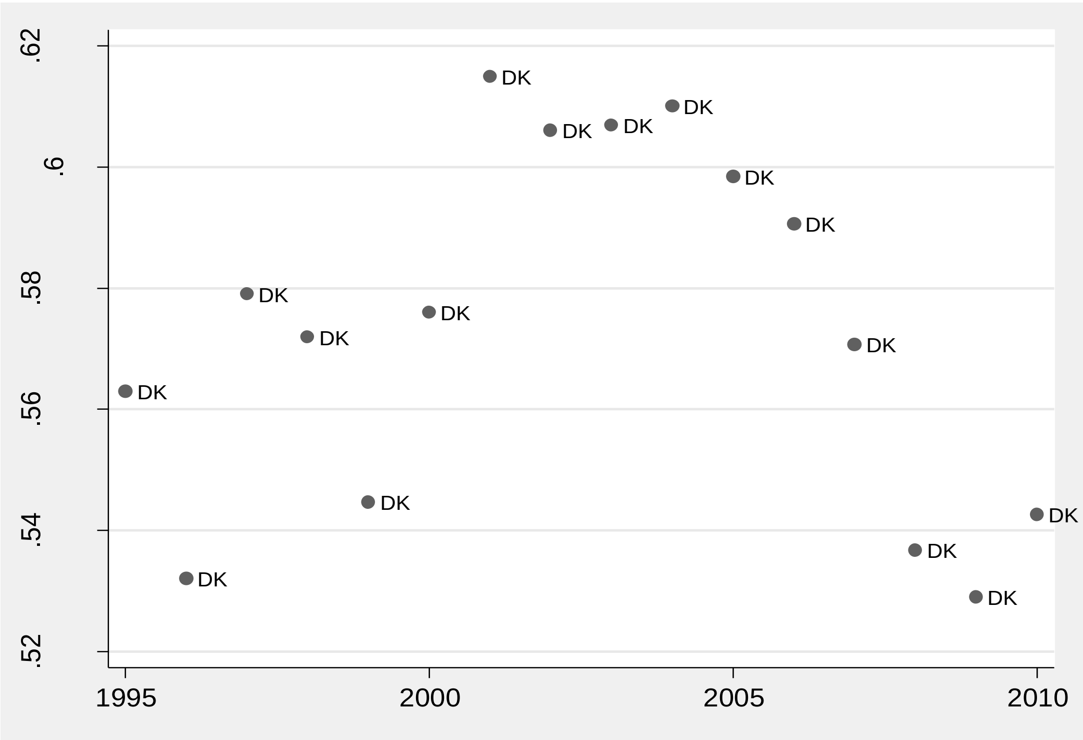

Figure 8. Change in the share of recycling vs share of recycling in 1995.

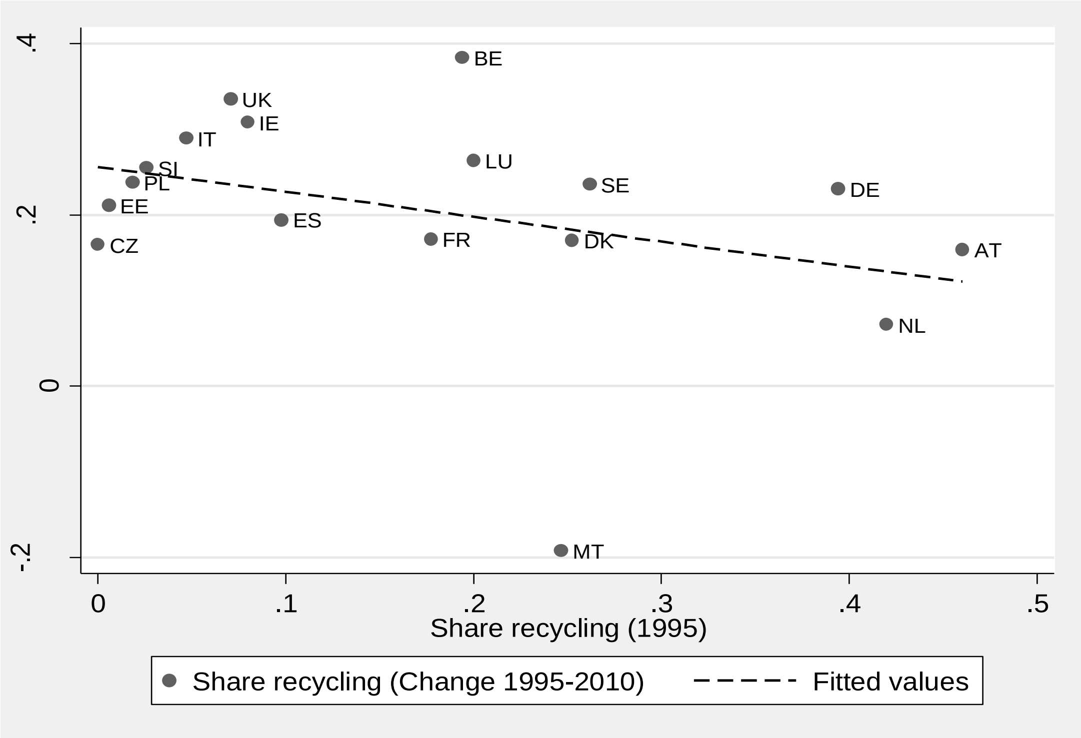

Figure 9. Change in the share of incineration vs share of incineration in 1995.

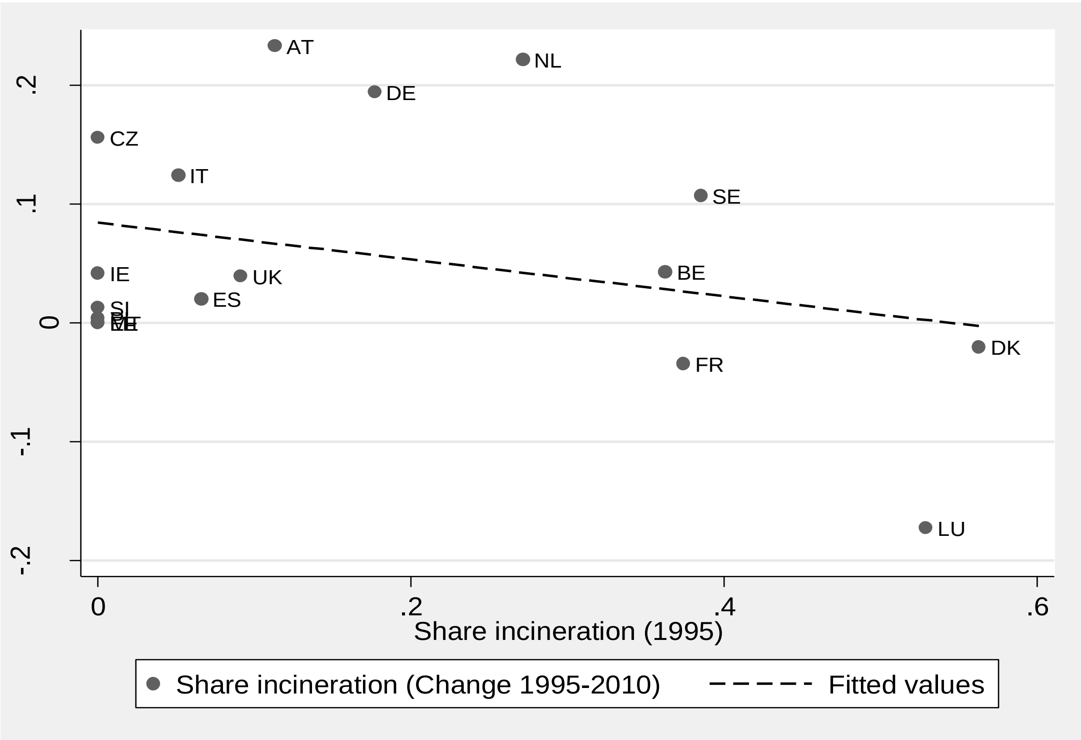

Figure 10. Year specific convergence coefficients for recycling

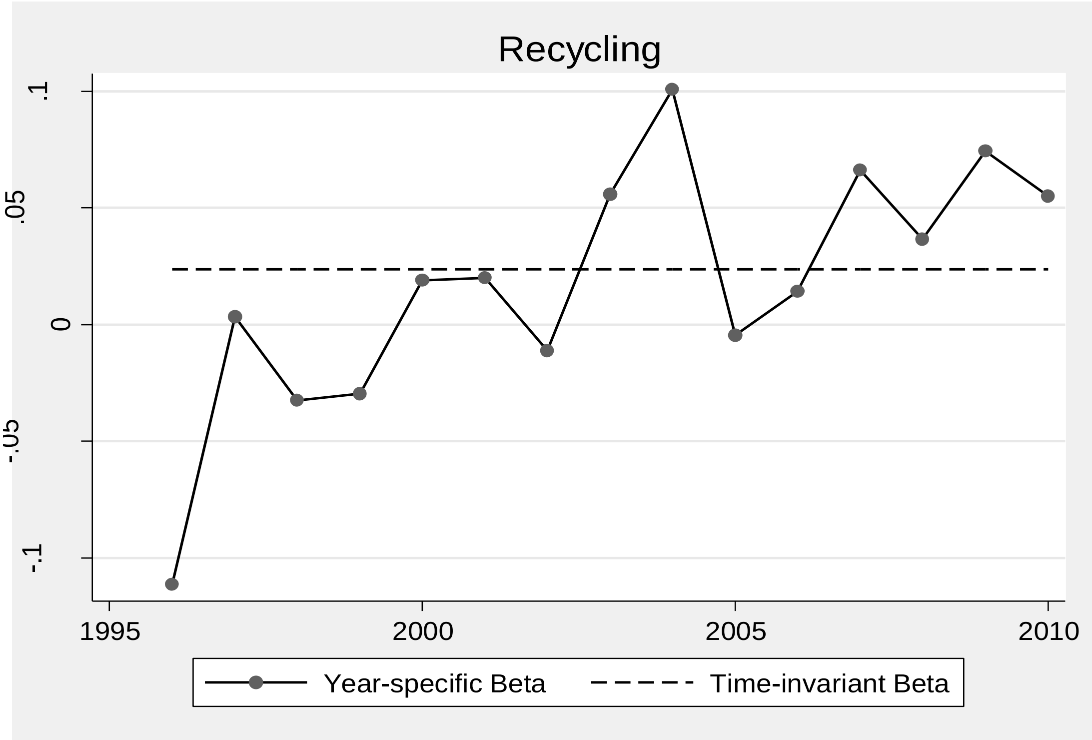

Figure 11. Year specific convergence coefficients for incineration

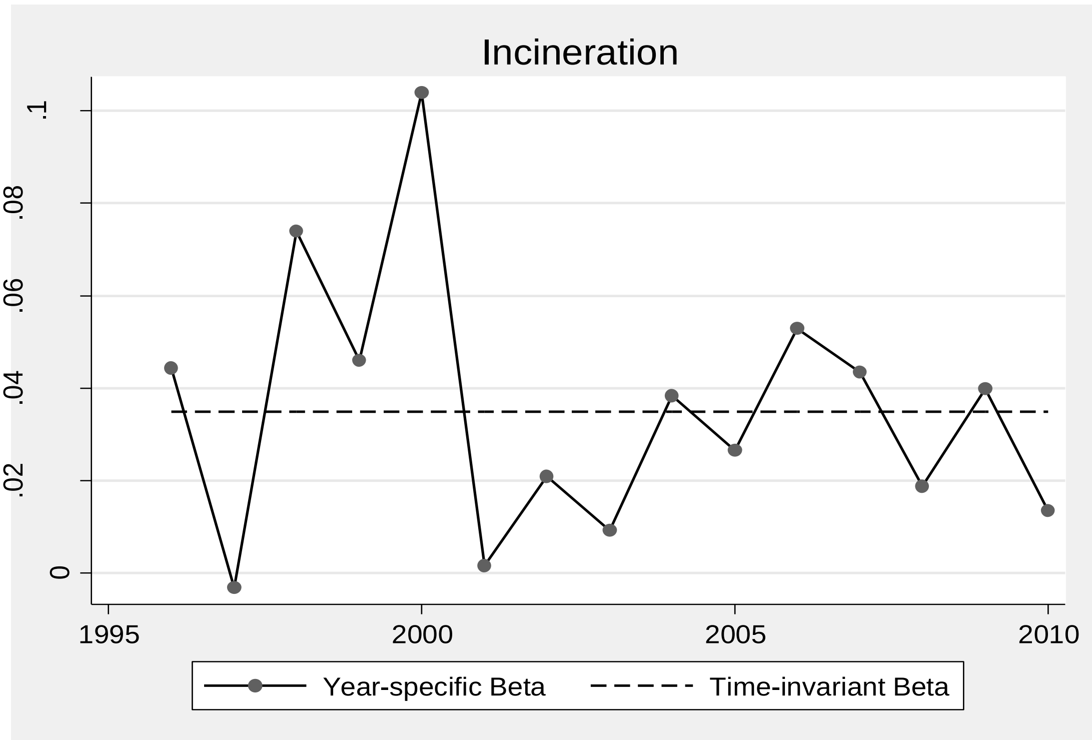

Figure 12. Sigma convergence