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Catching-up in waste management. Evidence from the EU[*]

Giovanni Marin[†] Francesco Nicolli[‡] Roberto Zoboli[§]

Abstract

In this work we test for the presence of convergence in the main municipal solid waste-related indicators across EU countries over the years 1995-2009. We analyse in particular both sides of the waste sector: generation, considering waste collected per capita, and the main disposal choices, i.e. landfilling, recycling and incineration. We believe this is a relevant exercise, considering that in the last two decades the waste sector has experienced a profound transformation at European level. Landfill is losing its primary role as the main disposal technology, 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 the three different rival choices of waste disposal, as well as about waste generation, by assessing the presence of convergence and its main drivers.

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 between countries are decreasing over time. We believe in particular that several factors may have influenced this trend, like consumption per capita, the presence of environmental policy and the level of a country innovative activities measure by a coherent stock of patent applications in waste related sectors.

Keywords: Waste management, Beta-convergence, Sigma-convergence
JEL: Q53, Q58, O47

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1 Introduction

The European waste management system has experienced a profound reorganisation in the last two decades, driven by several economic, technological and institutional factors (Mazzanti and Zoboli, 2009). In particular, the composition of the waste management system has shifted radically, from a system highly based on landfilling to a system in which recycling and incineration sum up to more than the 60% of total waste treatment. This has represented a shift in the ‘waste management hierarchy’ (Waste Framework Directive, 2008/98/EC), in which 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 (see Mazzanti and Zoboli, 2009) highlights the important role of several driving forces in this phenomena. Firstly, income matters, as richer country diverted more waste to landfill and had the resource to incentivize the use of more advance waste disposal 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 alternative technologies. Finally, also technical change played a role, making more advance technologies (like recycling and incineration) 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 still 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 1995-2009. 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. Finally, exploiting the speed a convergence we did some basic projections of the year needed by laggards countries in order to get close to the frontier.

2 Data and methods

2.1 Data

We collect information on municipal solid waste (MSW henceforth) generation per capita and MSW by disposal choice (recycling, incineration and landfilling) for 22 EU countries[5] for the period 1995-2009 from Eurostat. Data on waste management are further extended with traditional controls such as wealth (GDP and 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 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).

For what concern the knowledge stock, 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

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[5] 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.

filled at the European Patent Office, sorted by priority year, and assigned to the applicants' country of residence. In additional to total patents, 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).

2.2 Empirical approach

The following equation[6] describes our econometric specification for the test of β-convergence[7]:

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

where $\Delta Waste_{i,t}$ is the annual change in the waste indicator, $\Delta Waste_{t}^{Front}$ is the annual change in the 'frontier' of the same waste indicator, that is common for all countries, $Dist\_Front_{i,t-1}$ 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.

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

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 close to the frontier between *t-1* and *t*, thus reducing the distance from the frontier. On the other hand, γ could be interpreted as an indicator about the possible 'diffusion' of improvements in waste performance from the frontier to follower countries.

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 all patents, 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

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[6] 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.

[7] 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.

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.

3 Results

3.1 Beta-convergence

Econometric results concerning our test of β-convergence for share of recycling, share of incineration, share of incineration and recycling and MSW generation are reported, respectively, in Table 1, Table 2, Table 3 and Table 4.

[Table 1, Table 2, Table 3 and Table 4 about here]

The specification in column 1 does not include any control besides the distance from the frontier and the growth at the frontier. For share of recycling, share of incineration and the sum of the two we observe a significant convergence pattern towards the frontier in the period 1995-2009. When considering waste generation per capita, however, no convergence is found. The interpretation of the convergence in waste per capita is less straightforward than the one for recycling and incineration. As regards waste generation per capita, the frontier represents the ‘worst’ outcome, that is countries with the highest amount of MSW generation per capita, generally corresponding to the countries with higher wealth. In this case, absence of β-convergence means that countries with lower MSW generation per capita did not increase MSW generation per capita more than countries with higher MSW generation per capita. In this first specification, growth at the frontier is not significant as regards the indicators of waste management options but it is positive and significant for MSW generation per capita.

Adding controls (column 2 and 3) does not affect qualitatively the results on convergence, even though the magnitude (i.e. speed of convergence) increases substantially for incineration (and consequently for incineration and recycling). Adding controls, however, has an effect on the relationship between growth at the frontier and country-level growth for the share of incineration. The effect turns out to be negative: an increase in the share of incinerated MSW at the frontier negatively affects the share of incineration in laggard countries. A possible explanation is that countries with a large installed capacity of incineration facilities is expected to attract waste to be incinerated from countries with a small (or absent) installed capacity, due to the substantial fixed costs in building incineration plants. Our policy variable is positively related to the growth in the share of incinerated MSW (and, consequently, to the growth in the share of incinerated and recycled) but no effect is found for recycling alone and for MSW generation per capita. 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 technological variables.

Finally, we interact our indicator of distance from the frontier with our policy index (column 4) and with our technological variables (column 5) to investigated whether policy or technological capabilities played any role in accelerating (or decelerating) the convergence of laggard countries. Results show no differential effect for laggard countries for any of the waste indicators and any of the policy or technological variable.

3.2 Sigma-convergence

Figure 1 and Figure 2 show the degree of σ-convergence for, respectively, relative waste indicators (share of treated MSW by treatment option) and MSW generation and treatment per capita. Looking at the first figure, we observe a substantial σ-convergence (reduction in the variability across countries) for the share of MSW recycled and the share of MSW incinerated. As regards landfilling, however, the variability was quite stable, with an initial small reduction (from 1995 to 2005) and a small increase after 2005.

When looking at per capita variables (second figure), we observe a reduction in the variability for recycling and incineration, while the variability of total MSW generation per capita remained flat and the variability in MSW landfilled per capita rose steadily. This is due to the substantial decrease MSW landfilled in a group of Western European countries while no change in absolute level of MSW landfilled was observed for Eastern European and new member countries.

[Figure 1 and Figure 2 about here]

3.3 Convergence towards the frontier: some simulation

To conclude our empirical analysis, we try to provide some projections about the catching up of EU countries towards best practices (i.e. the frontier) in EU. For that purpose, we use 2009 as the starting year for the projection. We keep constant the level of the frontier at the level of 2009 and simulate the convergence pattern based on the distance from the frontier in 2009 and the β-convergence parameter as estimated in specification of column 3. The way the model is specified does not allow complete catching up (i.e. the distance cannot go to zero). For that reason, in Table 5 we estimate the years needed to reach a level 5 percent smaller than the frontier in 2009. Results for different cut-offs are available upon request.

[Table 5 about here]

Looking at recycling, we observe that three countries are already close to the frontier (distance smaller than 0.05): Germany, Greece and the Netherlands. Few other countries will converge in less than ten years (Belgium, Estonia and Sweden) while some countries will converge in more than 20 (Czech Republic, Hungary, Portugal) or 30 (Slovakia, 33) years. When looking at the share of incinerated MSW, some country (Estonia, Greece and Malta) shows no convergence because they were not incinerating waste in 2009. Convergence here is much slower, with some countries converging to frontier level in more than 50 years. This difference relative to recycling might reflect the choice of countries with small initial incineration rate to choose recycling as their most preferred option, moving up the waste management hierarchy. When combining incineration and recycling we find that convergence tends to be quite rapid, with all countries converging in 30 years or less to treatment options alternative to landfilling.

Finally, no statistically convergence was found in MSW generation per capita, limiting the relevance of these simulations.

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Table 1 – Convergence in recycling share of total MSW treated

Dep: Sh_recycl(t) - Sh_recycl(t-1)	(1)	(2)	(3)	(4)	(5)
Sh_recycl_frontier(t) - Sh_recycl_frontier (t-1)	0.313	0.346	0.250	0.242	0.294
	(0.258)	(0.294)	(0.280)	(0.270)	(0.332)
Dist_front_Sh_recycl (t-1)	0.151***	0.156***	0.160***	0.189***	0.133***
	(0.0469)	(0.0508)	(0.0505)	(0.0639)	(0.0331)
Policy index (t-1)		0.000280	-0.000386	0.000387	-0.0000994
		(0.000514)	(0.000637)	(0.000829)	(0.000776)
log(Pop_dens) (t-1)		-0.00342	-0.00417*	-0.00427*	-0.00382*
		(0.00212)	(0.00232)	(0.00217)	(0.00212)
log(Cons_pc_PPP) (t-1)		-0.000214	-0.000969	-0.00119*	-0.000912
		(0.000996)	(0.000703)	(0.000686)	(0.000836)
log(Total_pat_stock) (t-1)			-0.00142	-0.00113	-0.00212
			(0.00246)	(0.00251)	(0.00285)
log(Inciner_pat_stock) (t-1)			0.000338	-0.000896	-0.00949
			(0.00554)	(0.00489)	(0.0188)
log(Recycl_pat_stock) (t-1)			0.00443	0.00483	0.00813
			(0.00646)	(0.00610)	(0.0127)
Dist_front_Sh_recycl (t-1) x Policy index (t-1)				-0.00668	
				(0.00498)	
Dist_front_Sh_recycl (t-1) x log(Inciner_pat_stock) (t-1)					0.0740
					(0.105)
Dist_front_Sh_recycl (t-1) x log(Recycl_pat_stock) (t-1)					-0.0119
					(0.0514)
F	68.09	98.22	133.6	.	.
R sq	0.172	0.179	0.186	0.190	0.200
N	308	308	308	308	308

Pooled OLS estimates with year dummies. Standard errors clustered by countries in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 2 – Convergence in incineration share of total MSW treated

Dep: Sh_incin(t) - Sh_incin(t-1)	(1)	(2)	(3)	(4)	(5)
Sh_incin_frontier(t) - Sh_incin_frontier (t-1)	0.366	-0.474	-0.678**	-0.707**	-0.721**
	(0.226)	(0.286)	(0.282)	(0.283)	(0.274)
Dist_front_Sh_incin (t-1)	0.0429**	0.0765***	0.108***	0.100***	0.0945***
	(0.0196)	(0.0197)	(0.0302)	(0.0345)	(0.0325)
Policy index (t-1)		0.00166***	0.00178***	0.00164***	0.00198***
		(0.000492)	(0.000442)	(0.000470)	(0.000485)
log(Pop_dens) (t-1)		-0.00103	-0.00201	-0.00174	-0.000805
		(0.00213)	(0.00202)	(0.00190)	(0.00224)
log(Cons_pc_PPP) (t-1)		0.00260**	0.00318**	0.00305*	0.00298**
		(0.00101)	(0.00137)	(0.00147)	(0.00143)
log(Total_pat_stock) (t-1)			0.00378	0.00381	0.00355
			(0.00293)	(0.00290)	(0.00277)
log(Inciner_pat_stock) (t-1)			-0.00643	-0.00610	-0.00101
			(0.00621)	(0.00626)	(0.00936)
log(Recycl_pat_stock) (t-1)			0.00178	0.00149	-0.00455
			(0.00717)	(0.00707)	(0.00852)
Dist_front_Sh_incin (t-1) x Policy index (t-1)				0.00135	
				(0.00259)	
Dist_front_Sh_incin (t-1) x log(Inciner_pat_stock) (t-1)					-0.0278
					(0.129)
Dist_front_Sh_incin (t-1) x log(Recycl_pat_stock) (t-1)					0.0403
					(0.0877)
F	3.252	20.67	89.53	.	.
R sq	0.0688	0.0977	0.112	0.113	0.119
N	308	308	308	308	308

Pooled OLS estimates with year dummies. Standard errors clustered by countries in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 3 – Convergence in recycling + incineration share of total MSW treated

Dep: Sh_rec_incin(t) - Sh_ rec_incin(t-1)	(1)	(2)	(3)	(4)	(5)
Sh_rec_incin_front (t) - Sh_rec_incin_front (t-1)	-4.300	-10.76*	-11.57*	-10.39*	-11.61
	(3.964)	(5.840)	(6.129)	(6.002)	(6.959)
Dist_front_Sh_rec_incin (t-1)	0.0756**	0.123***	0.172***	0.183**	0.165***
	(0.0272)	(0.0411)	(0.0596)	(0.0648)	(0.0443)
Policy index (t-1)		0.00278**	0.00242**	0.00282**	0.00243*
		(0.00104)	(0.00106)	(0.00118)	(0.00125)
log(Pop_dens) (t-1)		-0.00365	-0.00640**	-0.00716**	-0.00578**
		(0.00337)	(0.00283)	(0.00301)	(0.00247)
log(Cons_pc_PPP) (t-1)		0.00338*	0.00334	0.00338	0.00329*
		(0.00191)	(0.00202)	(0.00202)	(0.00176)
log(Total_pat_stock) (t-1)			0.00519	0.00485	0.00509*
			(0.00322)	(0.00317)	(0.00265)
log(Inciner_pat_stock) (t-1)			-0.0109	-0.0120	-0.00547
			(0.00867)	(0.00862)	(0.0224)
log(Recycl_pat_stock) (t-1)			0.00775	0.00871	0.00284
			(0.00755)	(0.00760)	(0.0177)
Dist_front_Sh_rec_incin (t-1) x Policy index (t-1)				-0.00352	
				(0.00308)	
Dist_front_Sh_rec_incin (t-1) x log(Inciner_pat_stock) (t-1)					-0.0231
					(0.0948)
Dist_front_Sh_rec_incin (t-1) x log(Recycl_pat_stock) (t-1)					0.0220
					(0.0611)
F	7.488	13.83	21.15	.	.
R sq	0.102	0.144	0.188	0.191	0.189
N	308	308	308	308	308

Pooled OLS estimates with year dummies. Standard errors clustered by countries in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 4 – Convergence in per capita MSW generation

Dep: log(MSW gen pc) (t) - log(MSW gen pc) (t-1)	(1)	(2)	(3)	(4)	(5)
log(MSW gen pc_front) (t) - log(MSW gen pc_front) (t-1)	0.629***	0.667***	0.701***	0.714***	0.706***
	(0.149)	(0.180)	(0.166)	(0.176)	(0.175)
Dist_front log(MSW gen pc_front) (t-1)	0.0116	0.0150*	0.0167	-0.0227	0.00523
	(0.00691)	(0.00806)	(0.00999)	(0.0326)	(0.0175)
Policy index (t-1)		0.000339	0.000687	-0.000978	0.000652
		(0.000672)	(0.000760)	(0.00137)	(0.000854)
log(Pop_dens) (t-1)		0.00315	0.00476	0.00552*	0.00579*
		(0.00335)	(0.00339)	(0.00291)	(0.00313)
log(Cons_pc_PPP) (t-1)		-0.000219	0.000195	-0.000545	-0.000290
		(0.00127)	(0.00122)	(0.00119)	(0.00107)
log(Total_pat_stock) (t-1)			0.00255	0.00318	0.00197
			(0.00351)	(0.00364)	(0.00368)
log(Inciner_pat_stock) (t-1)			0.00878*	0.0122**	0.00749
			(0.00506)	(0.00532)	(0.00772)
log(Recycl_pat_stock) (t-1)			-0.0119*	-0.0154*	-0.0130
			(0.00645)	(0.00770)	(0.00817)
Dist_front log(MSW gen pc_front) (t-1) x Policy index (t-1)				0.00484	
				(0.00333)	
Dist_front log(MSW gen pc_front) (t-1) x log(Inciner_pat_stock) (t-1)					0.00595
					(0.0137)
Dist_front log(MSW gen pc_front) (t-1) x log(Recycl_pat_stock) (t-1)					0.00742
					(0.0126)
F	13.60	29.64	46.96	.	.
R sq	0.141	0.144	0.151	0.165	0.156
N	308	308	308	308	308

Pooled OLS estimates with year dummies. Standard errors clustered by countries in parenthesis. * p<0.1, ** p<0.05, *** p<0.01.

Table 5 – Years from 2009 to achieve convergence (distance<0.05) to the frontier in 2009

	Recycling (beta=0.156***)	Incineration (beta=0.077***)	Rec + incin (beta=0.123***)	MSW gen (beta=0.015)
Austria	10	15	12	12
Belgium	9	6	10	20
Czech Republic	23	43	20	29
Denmark	12	0	10	0
Estonia	2	-	27	28
Finland	18	38	18	20
France	20	22	17	17
Germany	0	0	0	12
Greece	0	-	26	22
Hungary	21	47	20	23
Ireland	11	60	20	0
Italy	19	40	19	17
Luxembourg	16	21	15	0
Malta	16	-	30	4
Netherlands	0	0	0	9
Poland	14	86	24	29
Portugal	23	33	19	18
Slovakia	33	36	23	28
Slovenia	11	75	22	18
Spain	19	46	20	16
Sweden	3	0	4	20
United Kingdom	16	45	18	17

Figure 1 – Sigma-convergence in treatment management options (in shares of total MSW treated)

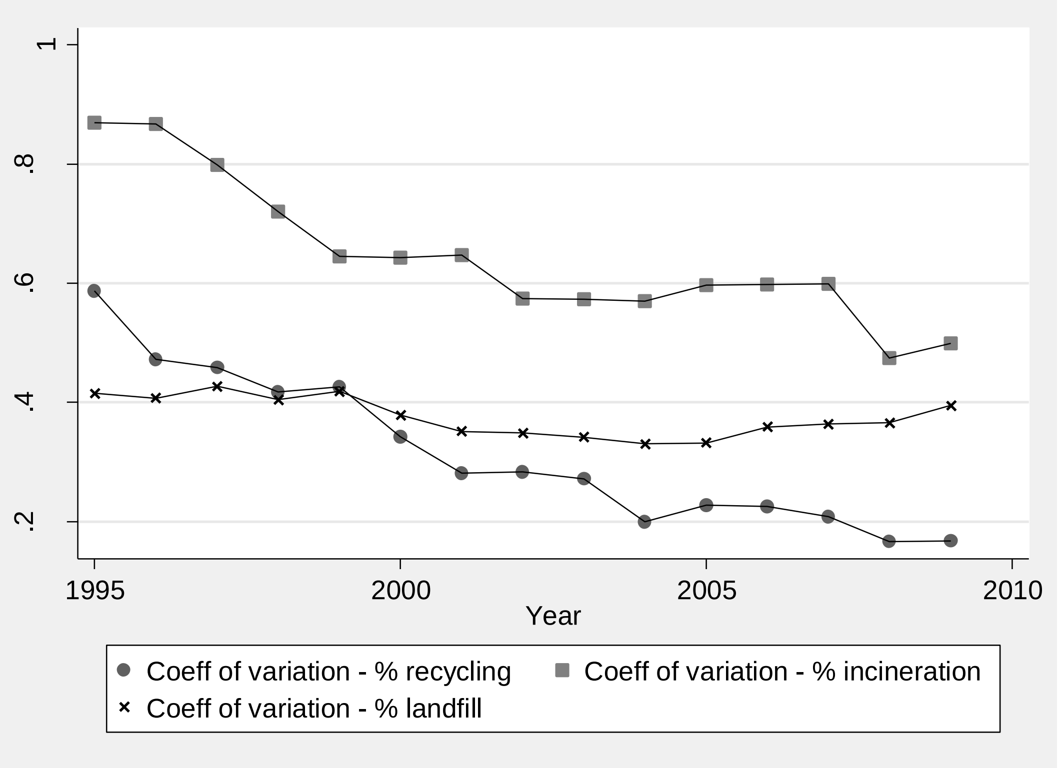

Figure 2 – Sigma-convergence in treatment management options (log of MSW per capita)