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HAVE AGRICULTURE GREEN HOUSE GAS EMISSIONS CONVERGED AMONG EUROPEAN UNION MEMBER STATES?

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Have Agriculture Green House Gas Emissions Converged among European Union Member States?

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Abstract: Panel unit root tests are used to identify convergence of Green House Gas (GHG) emissions among the agricultural sectors of the European Union 27 member states. Although a clear cut conclusion on the existence of convergence could not be established, it looks like there is some evidence of convergence for EU 27 during the entire 1973-2007 period. This same evidence exists for EU15 but only for the shorter 1996-2006 time period. If emissions are to converge, then it will be easier to make EU members to accept policy measures aimed at reducing the negative impact on environment.

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1. Introduction

The advent of the 21st century has witnessed an important discussion on climate change and the ways to deal with this global phenomenon. In this regard the Framework Convention on Climate Change and the 1997 Kyoto Conference established emissions targets and commitments for industrialized countries but not for the developing ones. This differential treatment may be rooted in the evidence on the existing high positive correlation between development and emissions level[1] , thus assigning an higher "social responsibility" to those who have both larger contributions to and larger resources to deal with the phenomenon.

This approach has, since then, been questioned by several non-governmental organizations and academics as well as policymakers. Alternatively a scheme of allocating emissions rights on a per capita basis has been proposed, following the intervention of Professor Saifuddin Soz, minister of environment and forests of India, during the Kyoto Conference: "Per capita basis is the most important criteria for deciding the rights to environmental space." (Soz 1997).

But if a common long term goal of allocating CO_2 emissions equally to all countries on a per capita basis is to be reached, then there must be emissions convergence among countries. As Aldy (2006) puts it: "The lack of emissions convergence may make developing countries less likely to agree to emissions abatement obligations. Efforts to increase the participation of developing countries through a per capita allocation rule may not garner the support of developed countries in the absence of emissions convergence."

List's (1999) paper may be considered the seminal work on investigating convergence or divergence in air pollutant emissions behaviour. It uses US Environment Protection Agency (EPA) data for the period 1929-1994, to evaluate the convergence of sulphur dioxides and nitrogen oxides emissions among the 10 EPA regions. He tests for both the cross-sectional convergence (using the Baumol ß-convergence technique) and the stochastic convergence by performing the Augmented Dickey-Fuller (ADF) unit root test. The results obtained provide some evidence that indicators of environmental quality have converged across US regions during that period.

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[1] Aldy (2006) found a correlation o 0.87 between the natural logarithm of per capita income and the natural logarithm of per capita emissions for a sample of 88 countries over the period of 1960-2000.

Four years later Strazicich and List (2003) recognize that the ADF test is not powerful enough to test for convergence and use the Im, Pesaran and Shin unit root test to conclude that there is stochastic convergence on per capita CO_2 per capita emissions among 21 OECD countries between 1960 and 1997.

Also claiming the inappropriateness of the ADF test, Aldy (2006) used the Dickey-Fuller Generalized Least Squares (DF-GLS) test to find evidence of convergence among a sample of 23 OECD countries during the 1960-2000 period. However when the sample is extended to 88 countries he finds no support for stochastic convergence and even finds evidence for some divergence in per capita CO_2 emissions.

Two more recent papers, both published in the same volume of *Environmental and Resource Economics*, come to quite opposite conclusions.

Westerlund and Basher (2008), using data spanning the period 1870-2002, conduct three unit root tests that allow for the presence of cross-section dependence amongst countries.[2] They conclude that at least for some of the 28, both developed and developing, countries included in the sample there is evidence of convergence in CO_2 emissions. Moreover this evidence can be extended to the entire panel.

Barassi et al. (2008), worked with a smaller sample (1950-2002) of 21 OECD countries and used the Hadri (2000) and Im, Pesaran and Shin (2003) panel unit root tests as well as the Harris, Leybourne and McCabe (2005) test which allows for cross-section dependence amongst countries. The results indicate that no panel convergence can be accepted and that individual convergence is present for only a very few countries.

Such different conclusions using relatively similar cross sections may have to be attributed, as Barassi et al. suggest when comparing there results with those of previous studies, to the sensitivity of results to the "econometric methodology employed and to a certain extent to the length of the time series."

The recent turnaround of the Common Agriculture Policy (CAP) of the European Union (EU) towards more rural development and environment policies at the expense of traditional market and price interventions prompted the idea of addressing the convergence issue at the agricultural sector level. Not that agriculture is among the larger contributors to air pollution (on the EU27 space, agriculture is responsible for only 10 to 12 % of total green house gas emissions in CO_2 equivalent, if the carbon sink

[2] The tests used are those proposed by Bai and Ng (2004), Philips and Sul (2003) and Moon and Perron (2004)

role performed is not accounted for) but because the spatial distribution of emissions could enlarge or reduce the foundations for the future CAP orientation.

The remainder of this paper is organized as follows. Section 2 describes the data used. Section 3 describes the methodology used and discusses the results. Section 4 provides some concluding remarks.

2. Data

The most used source of data in CO_2 emissions studies is the Carbon Dioxide Information Analysis Center database (http://cdiac.ornl.gov/trends/emis/em_cont.html) which contains, for all countries, the annual total and per capita CO_2 emissions up to 2005, sometimes starting as far back as 1751. For our purpose, however, this database is not appropriate insofar as it reports only emissions from fossil-fuel burning, cement manufacture and gas flaring, without further breakdown by economic activity.

Furthermore, as we are concerned with all green house gas (GHG) emissions and not only CO_2 we had then to use two different sources. The EUROSTAT - Environment and Energy database and an update to 2007 of the specific database used in Soares and Ronco (2005)[3]. The EUROSTAT data on GHG emissions by economic sector of activity, although available for each and every one of the 27 member states is rather limited as it covers only the 1990-2006 period. The second database is also a balanced one and covers the entire 1973-2007 period.

The choice of indicators was drastically limited by data availability. On the one hand it would be interesting to have an indicator relating the GHG emissions with the level of economic activity of the agricultural sector. This would be possible by computing either the level of GHG emissions per total agricultural value added or alternatively the GHG emissions per economic dimension of farms (total economic size unit of farms). Unfortunately no data series, for any of these two variables, long enough to allow for unit root testing are available for the present EU27 member states. Thus we were forced to take GHG emissions per hectare as a proxy for an indicator of emissions per economic activity of the sector. Even though, the EU27 series is still relatively small.

[3] The database was constructed by multiplying the EMEP/CORINAIR emissions coefficients in CO_2 equivalent by the respective areas and livestock numbers. Further details can be found in the Working Paper

A final note on data used is needed. It is well known that forestry is a carbon sink, not a source of emissions. We extended the analysis to what can be called the "Net GHG Emissions" e.g. (CO_2 emitted minus CO_2 sunk) and found that the results obtained were quite similar.

Our investigation was then carried using the following indicators and data

	Indicator	**Sample Period**	**Source**
EU27	GHG / Utilised Area	1990 -2006	EUROSTAT
EU15	GHG /Utilised Area	1973 -2007	Soares and Ronco

To have a feeling of the convergence of these indicators we started by a graphical inspection of the data by means of what can be called the non stochastic convergence.

3. Convergence analysis

3.1. Non stochastic convergence

To test for non stochastic convergence we used two different approaches. The so called σ-convergence and the demeaned convergence.

Sigma convergence, in the Barro and Sala-i-Martin, sense [4], is assessed by computing the annual standard deviation of the natural logarithm of the emissions indicator. If this dispersion measure declines over time there is an indication that the indicator is converging among the involved countries or regions.

Figure 1 depicts the results obtained for the EU member states, and seems to indicate that up to 1995 there is no sign of convergence. On the contrary the slightly declining trend from then on apparently denounces the possibility of convergence. If one takes into account the carbon sink role of the agricultural sector as a whole and compute the standard deviation of the natural logarithm of net GHG emissions the picture is that presented in Figure 2. There again no signs of convergence can be detected for the 1990 – 1995 period, but the possibility of convergence cannot be excluded from then on.

[4] Barro, J.R.and X. Sala-i-Martin (1992), "Convergence" *Journal of Political Economy* **100**(2), 223-251

Figure 1. Sigma Convergence of GHG Emissions (in Mg of CO_2 equivalent / ha), EU27

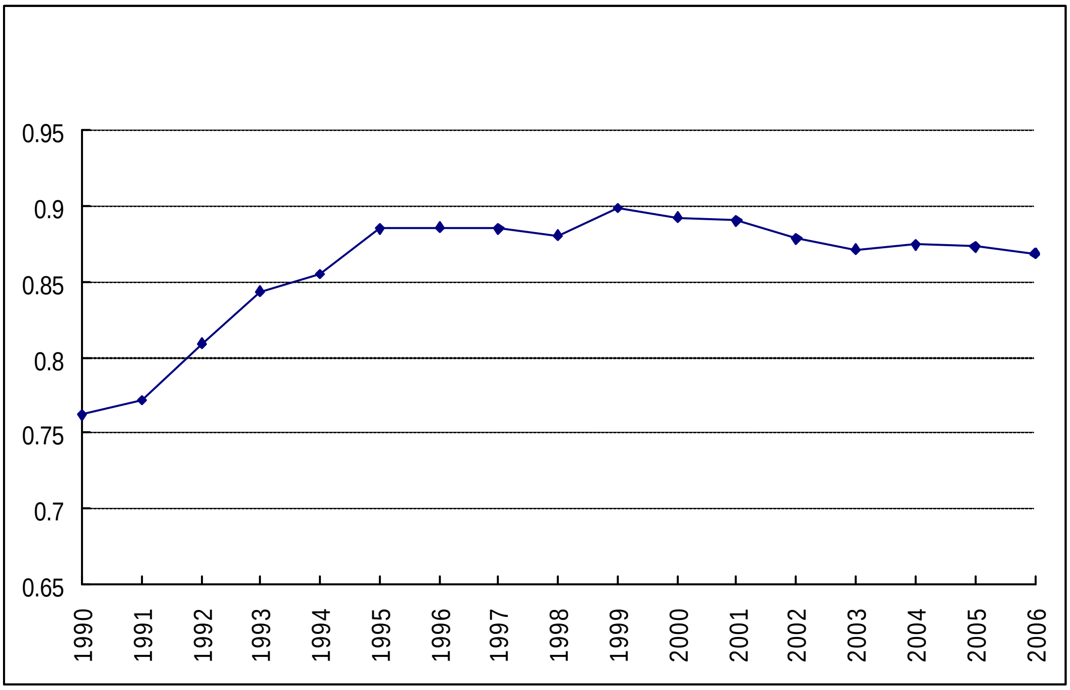


Figure 2. Sigma Convergence of Net GHG Emissions (in Mg of CO_2 equivalent / ha), EU27

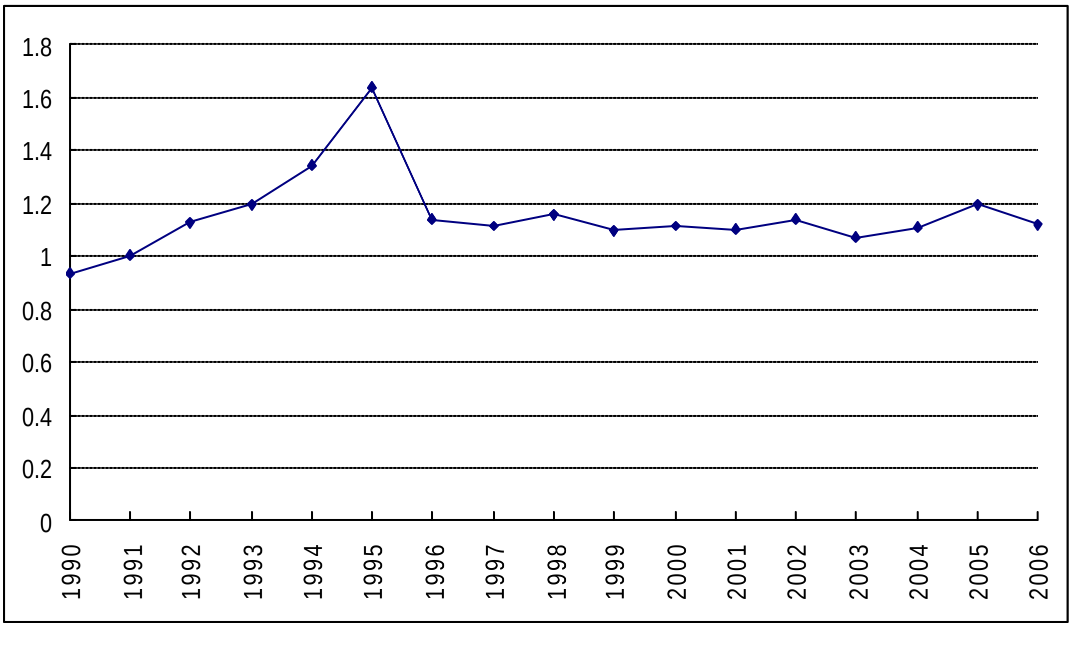
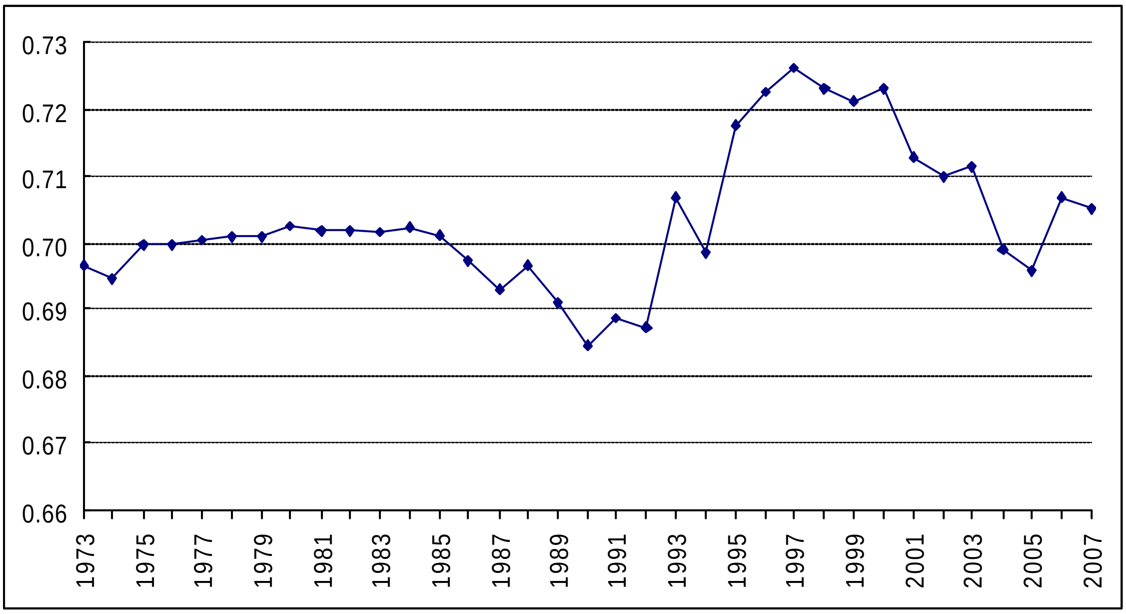


Figure 3. Sigma Convergence of GHG Emissions (in Mg of CO_2 equivalent / ha), EU15



As to the EU15 member states Figure 3 is not very enlightening on the presence or absence of convergence.

In what concerns demeaned convergence[5] Figure 4 does not allow us to conclude either on the existence of convergence or divergence among the EU27 member states. In any case it can be seen that Belgium, Denmark, France, Germany, Ireland, Luxembourg, Malta, Netherlands and United Kingdom show emission levels above the EU27 average.

The difficulty in identifying convergence or divergence when dealing with net GHG emissions is also present in Figure 5. But in this case three of the nine countries that have GHG emissions above average (France, Germany and Malta) no longer have above the average net GHG emissions. One possible explanation for this difference is that the forest sub-sector, at least in France and Germany, is relatively more important than in the other countries, thus augmenting the carbon sink capacity of the agricultural sector as a whole.

[5] The demeaning consists in computing the natural logarithm of the emissions relative to their cross-sectional mean.

Figure 4 . Cross-sectional demeaned GHG Emissions (in Mg of CO_2 equivalent/ha), EU27, 1990-2006

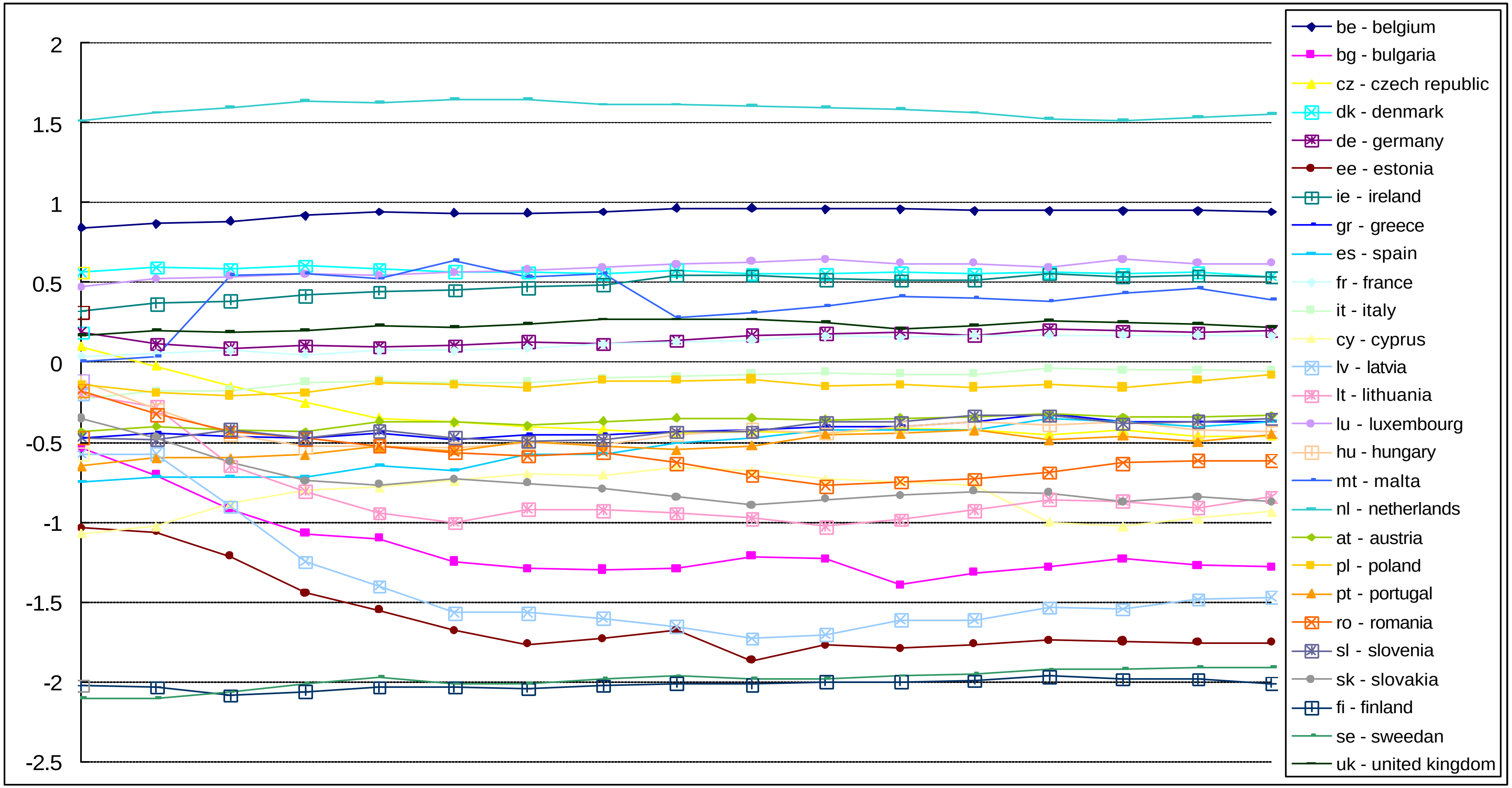


Figure 5 . Cross-sectional demeaned Net GHG Emissions (in Mg of CO_2 equivalent/ha), EU27, 1990-2006

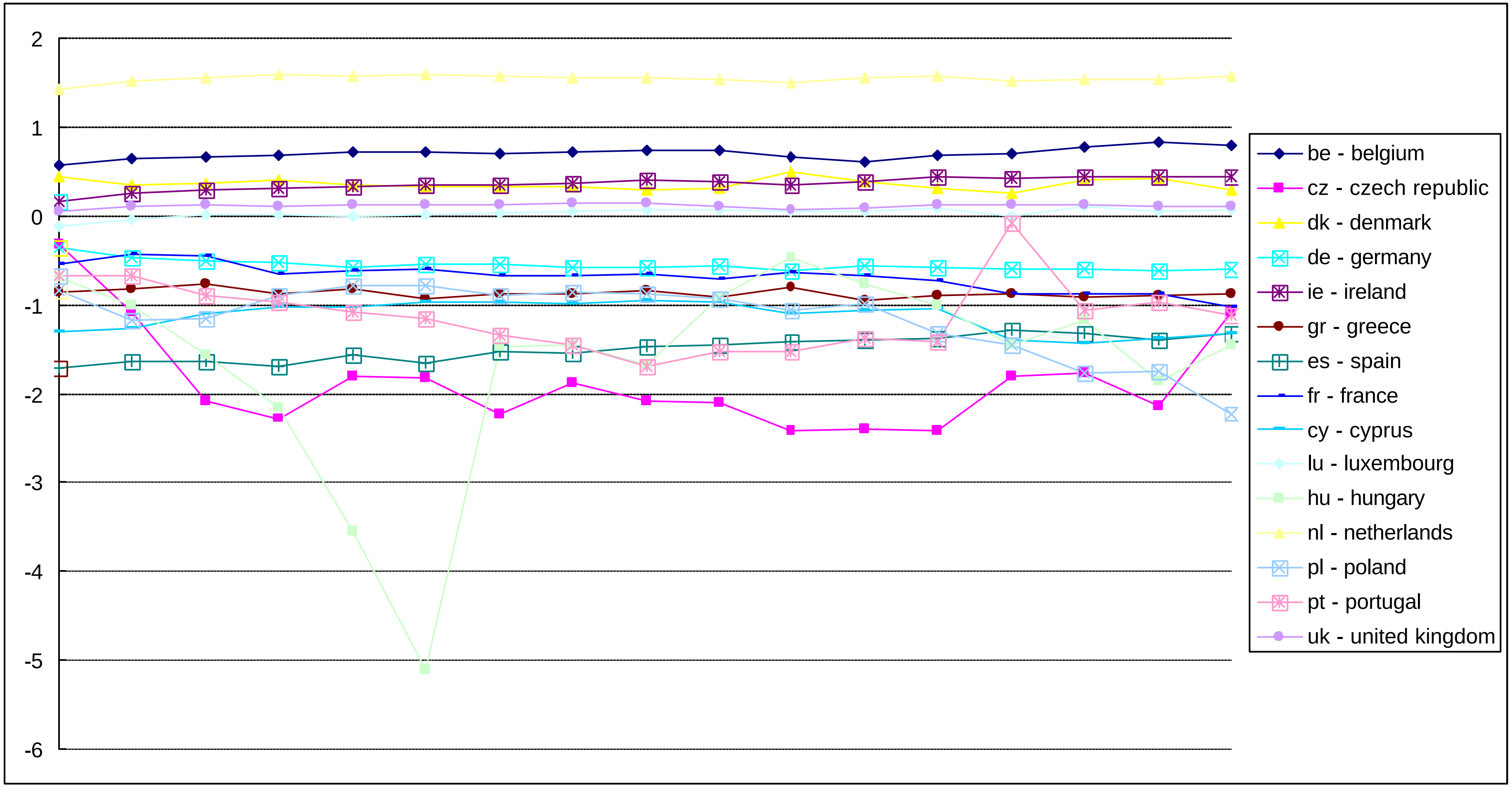
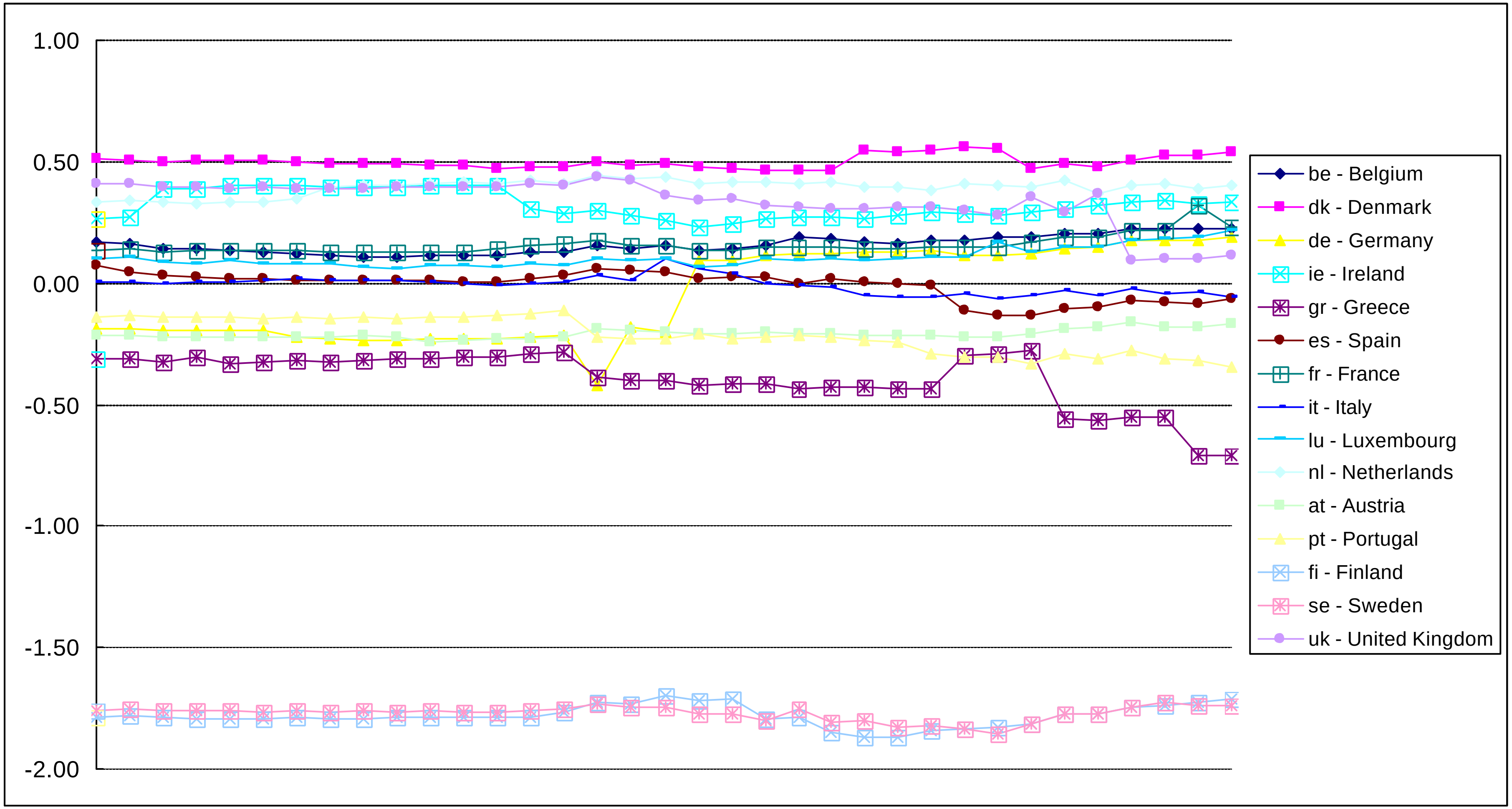


Figure 6. Cross-sectional demeaned GHG Emissions (in Mg of CO_2 equivalent/ha), EU15, 1973-2007



Regarding the extended data sample for EU 15, besides the same difficulty in identifying a common behaviour, Figure 6 reveals that Belgium, Denmark, France, Ireland, Luxembourg, Netherlands and the United Kingdom keep their position of above the average level of emissions. For Germany the same happens after the reunification. It is curious to note that from the six founding fathers of the European Union (then European Economic Community) only Italy shows GHG emissions below the average. In addition the data seems to indicate a positive correlation between emissions and the crop and livestock intensity levels, which is not surprising.

The inconclusiveness of these non stochastic convergence analysis calls for a more powerful tool, namely the unit root testing of the data both on the individual country time series as well as on the common panel data.

3.2. Stochastic convergence

From the brief methodological review made in the introductory section it is apparent that the adoption of different unit root tests as well as the sample length may lead to contradictory results. With this in mind we decided to perform two types of panel unit root tests: with common and with individual unit root processes.[6]

The general model used to apply the tests is quite standard and can be described as

(1) $$y_{it} = a_i + t_i t + r_i y_{it-1} + e_{it}$$

where y_{it} is the natural logarithm of the emissions indicator in country *i* relative to the average cross-sectional value in year *t*, a_i and t_i are an intercept and a trend parameter, t is the time trend variable and the e_{it} are the error terms.

The existence of a unit root $(r_i = 1)$ implies that y_{it} is a non stationary series for which any new shock e_{it} will cause a permanent change thus suggesting divergence in the emissions indicator. The acceptance of the alternative means convergence.

3.2.1. Tests with common unit root process

In the Levin, Lin, and Chu (LLC) and the Breitung tests we considered the following specification

[6] Tests were performed using the EViews 6 pack for panel data estimation

(2) $$\Delta y_{it} = a_i + t_i t + f y_{it-1} + \sum_{j=1}^{p_i} b_{it} \Delta y_{it-j} + e_{it}$$

where a common $f = r - 1$ is assumed and the lag order for the difference terms, p_i is allowed to vary across cross-sections.[7]

The null and alternative hypothesis can then be written as

H_o: $f = 0$ and H_1: $f < 0$

Under the null hypothesis, there is a unit root while under the alternative there is no unit root.

The third test used was the Hadri test which is an extension to panel data of the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test for individual series. The Hadri test is based on the residuals from the OLS regression of y_{it} on a constant, or on a constant and a trend. In this test the null hypothesis is the absence of a unit root while under the alternative there is a unit root.

The results obtained for the EU27 and EU15 are reported in Tables 1 and 2

Table 1. GHG / ha: Common unit root process test results, EU27 (1990 - 2006)

Method	Statistic	Prob.	Total balanced observations
Levin, Lin & Chu t-stat	-8.30327	0.0000	424
Breitung t-stat	3.10219	0.9990	397
Hadri			
Hadri Z-stat	9.5063	0.0000	459
HAC Z-stat	11.8797	0.0000	459

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 2 (for LLC and Breitung tests)

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

For EU27, the LLC test results showing in Table 1 indicate rejection of the null hypothesis at the 5% level thus indicating the existence of convergence at the panel level, while for the Breitung test the results indicate the opposite (the existence of a unit root means divergence). As to the Hadri results they indicate non stationarity (rejection of the no unit root at the 1% level) thus meaning divergence.

[7] Lags are introduced to correct for serial correlation

Table 2. GHG / ha: Common unit root process test results, EU15 (1973 - 2007)

Method	Statistic	Prob.	Total balanced observations
Levin, Lin & Chu t-stat	0.10289	0.5410	499
Breitung t-stat	3.69654	0.9999	484
Hadri			
Hadri Z-stat	4.1035	0.0000	525
HAC Z-stat	4.9399	0.0000	525

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 4 (for LLC and Breitung tests)

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

The picture looks more consistent for EU15 where all results point towards the existence of a unit root and consequently indicating divergence.

Although not unexpected, these results deserve some qualification. First, Hlouskova and Wagner (2006) refer that the Hadri test "may yield results that directly contradict those obtained using alternative test statistics" because, when the sample time period T is small and when there is no unit root, it experiences significant size distortion in the presence of auto correlation. In particular the, Hadri test appears to over-reject the null of stationarity.

Second, the length of the time period and the time period itself are also influential. Just looking at Figures 1, 2 and 3 (without carrying any test for structural breaks) the year of 1995 looks like a turning point for the behaviour of GHG emissions, both in EU27 and EU15. Thus, in the case of EU15 we decided to perform the panel unit root tests separately for the sub-periods 1973-1995 and 1996-2007. For EU27 we performed tests for the 1996-2006 sub-period only.[8]

The results can be seen in Tables 3 and 4 from which it is apparent that for 1996-2007 the LLC test indicates that convergence may be expected. The other tests, however, show results identical to those in Tables 1 and 2.

Taking into account that the Hadri test over rejects the null stationary, the only argument that precludes the strong conclusion that there is GHG emissions convergence among EU27 member states from 1990 onwards and among EU15 member states from 1996 onwards are the results of the Breitung test. Let us then settle for a weaker

[8] In the case of EU27 the sub-period 1990-1995 would be too small for any estimation.

conclusion: there is evidence that, from the nineties on, GHG emissions by the agricultural sectors of EU countries tend to converge.

Table3. GHG / ha: Common unit root process test results, EU27 (1996 - 2006)

Method	Statistic	Prob.
Levin, Lin & Chu t-stat	-6.68885	0.0000
Breitung t-stat	-0.10807	0.4570
Hadri		
Hadri Z-stat	16.7272	0.0000
HAC Z-stat	174.0290	0.0000

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 1
(for LLC and Breitung tests)

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

Table 4. GHG / ha: Common unit root process test results, EU15

Method	1973-1995		1996-2007	
	Statistic	Prob.	Statistic	Prob.
Levin, Lin & Chu t-stat	-1.7613	0.0391	-6.2528	0.0000
Breitung t-stat	1.4692	0.9291	2.7166	0.9967
Hadri				
Hadri Z-stat	6.0579	0.0000	8.3463	0.0000
HAC Z-stat	4.6509	0.0000	115.2770	0.0000

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 4
(for LLC and Breitung tests)

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

It will be interesting to see if the tests with individual unit root process do back this same conclusion.

3.2.2. Tests with individual unit root process

Three tests were used: the Im, Pesaran, and Shin (IPS), the Fisher Augmented Dickey-Fuller (ADF) and the Fisher Phillips-Perron (PP) test. For all three we considered a specification similar to (2)

(3) $$\Delta y_{it} = a_i + t_i t + f_i y_{it-1} + \sum_{j=1}^{p_i} b_{it} \Delta y_{it-j} + e_{it}$$

where each cross section may have a different r_i coefficient, with $f_i = r_i - 1$

The null and alternative hypothesis can then be written as

$$H_o: f_i = 0 \quad \text{and} \quad H_1: \begin{cases} f_i = 0 & \text{for } i = 1,2,\ldots N_1 \\ f_i < 0 & \text{for } i = N_1+1, N_1+2,\ldots N \end{cases}$$

While under the null hypothesis there is a unit root, now under the alternative at least one of the N cross sections may not have a unit root.

The results obtained for the EU27 and EU15 are reported in Tables 5 to 8.

Table 5. GHG / ha: Individual unit root process test results, EU27 (1990 - 2006)

Method	Statistic	Prob.	Total balanced observations
Im, Pesaran and Shin W-stat	-1.85023	0.0321	424
ADF - Fisher Chi-square	79.4466	0.0137	424
PP - Fisher Chi-square	164.485	0.0000	432

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 2

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

All results in Table 5 lead to the rejection of the null at the 5% level thus reinforcing the conclusion that there may be convergence for EU27. But for the more recent period (1996 – 2006) Table 6 shows exactly the opposite.

For EU15, figures in Table 7 do confirm the divergence already detected in Table 2.

But again, if one subdivides the entire sample period in the two separate sub-periods, the hypothesis of convergence for 1996-2007 seems plausible, as shown by the figures in Table 8.

Table 6. GHG / ha: Individual unit root process test results, EU27 (1996-2006)

Method	Statistic	Prob.
Im, Pesaran and Shin W-stat	1.7060	0.9560
ADF - Fisher Chi-square	38.9546	0.9387
PP - Fisher Chi-square	178.5020	0.0000

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 1

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

Table 7. Individual unit root process test results, EU15 (1973 - 2007)

Method	Statistic	Prob.	Total balanced observations
Im, Pesaran and Shin W-stat	2.35477	0.9907	499
ADF - Fisher Chi-square	16.7959	0.9749	499
PP - Fisher Chi-square	37.6391	0.1592	510

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified Aikaike Information Criterion: 0 to 2

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

Table 8. Individual unit root process test results, EU15

Method	1973-1995		1996-2007	
	Statistic	Prob.	Statistic	Prob.
Im, Pesaran and Shin W-stat	1.5864	0.9437	-1.3516	0.0883
ADF - Fisher Chi-square	18.6430	0.9472	48.8054	0.0165
PP - Fisher Chi-square	25.4173	0.7045	115.9950	0.0000

Tests specifications:

Exogenous variables: Individual effects, individual linear trends

Automatic selection of lags based on Modified A ikaike Information Criterion: 0 to 2

Newey-West bandwidth selection using Quadratic Spectral kernel

Source: Computed

As seen before, the alternative hypothesis for the IPS, ADF and PP tests under individual unit root process is "no unit root for some cross sections". Looking at the individual results for the IPS and ADF tests for EU27 in Table A1 in the Appendix, it is apparent that there is no unit root for the Czech Republic, Germany, Lithuania, Netherlands and Slovakia. In the PP test there are even more cross sections without unit root: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Lithuania, Hungary, Netherlands, Austria, Portugal, Slovakia and Sweden. But when we reduce the sample to 1996-2006 the results for IPS and ADF are reversed, with less cross sections without unit root, as it shows in Table A2.

Individual unit root process results for EU15, showing in Tables A3 and A4, confirm the absence of convergence either for the entire sample or the 1973 -1995 sub-period, whereas Table A5 confirms the convergence for 1996-2007.

What implications can this conclusion have on future CAP orientation?

It is worth noting that the possible convergence of GHG emissions was detected for the period following the 1992 McSharry reform, the first to include environmental concerns and policy measures. From then on, this orientation has been stressed again and again in the successive CAP update reforms, namely the 2000 Agenda and the 2008 agreement on the Health check debate started in 2007.

If the GHG emissions are to converge then this policy can be more easily accepted by all member states including the Eastern Europe new members. In other words the policy measures aiming at a better environment quality are economically justified on the grounds of the internalisation of the negative externalities generated in the agricultural sector. And this will certainly help society, policy makers and politicians to agree upon paying for the internalisation of the positive externalities agriculture produces.

4. Concluding remarks

Although a clear cut conclusion on the existence of convergence of GHG emissions among EU27 member states could not be established it looks like there is some evidence of convergence for the 1973-2007 period. This same evidence exists for EU15 but only for the 1996-2006 time period. Having obtained different results with different methodological tools was not unexpected, according to previous studies on time series convergence. It is also necessary to emphasize the decisive influence of the sample dimension in the results.

The informed reader may have noticed that the existence of structural breaks and its influence was not addressed, except for the distinction between two sub periods for the EU15 sample and the consideration of a sub-period from 1996 to 2006 for the EU27 data. It would not have made much sense to deal with breaks with such a small data sample.

In any case if the CAP is moving towards more rural development and environmental policies an accurate knowledge of GHG emissions behaviour is certainly required. In that sense studies like the present one, with longer and more detailed data samples, will certainly help.

APPENDIX

Table A-1 . GHG / ha: Individual unit root process test results, EU27

	Im, Pesaran and Shin Test		Augmented Dickey FullerTest		Phillips - Perron Test	
	IPS W-Statistic	Prob.	ADF-Fisher Chi-square	Prob.	PP- Fisher Chi-square	Prob.
	-1.85023	0.0321	79.4466	0.0137	164.4850	0.0000
	Individual series results		Individual series results		Individual series results	
	Prob.		Prob.		Prob.	
BE	0.6148	*	0.6148	*	0.0482	**
BG	0.2109	*	0.2109	*	0.0001	***
CZ	0.0388	**	0.0388	**	0.0018	***
DK	0.4405	*	0.4405	*	0.0083	***
DE	0.0012	***	0.0012	***	0.0010	***
EE	0.8423	*	0.8423	*	0.8717	*
IE	0.7160	*	0.7160	*	0.6774	*
GR	0.2648	*	0.2648	*	0.2684	*
ES	0.9338	*	0.9338	*	0.5882	*
FR	0.9265	*	0.9265	*	0.8793	*
IT	0.3212	*	0.3212	*	0.1035	*
CY	0.6201	*	0.6201	*	0.5361	*
LV	0.8686	*	0.8686	*	0.1580	*
LT	0.0008	***	0.0008	***	0.0001	***
LU	0.8817	*	0.8817	*	0.4087	*
HU	0.5153	*	0.5153	*	0.0032	***
MT	0.2162	*	0.2162	*	0.1998	*
NL	0.0265	**	0.0265	**	0.0062	***
AT	0.9460	*	0.9460	*	0.0886	**
PL	0.3184	*	0.3184	*	0.2562	*
PT	0.1922	*	0.1922	*	0.0813	**
RO	0.6359	*	0.6359	*	0.6308	*
SL	0.2907	*	0.2907	*	0.2710	*
SK	0.0801	**	0.0801	**	0.0001	***
FI	0.1801	*	0.1801	*	0.2142	*
SE	0.4126	*	0.4126	*	0.0694	**
UK	0.6935	*	0.6935	*	0.8732	*

*, **, *** indicate rejection of the null at 10 , 5 and 1 % respectively

Source: Computed

Table A-2 . GHG /ha: Individual unit root process test results, EU27 (1996 - 2006)

	Im, Pesaran and Shin Test			Augmented Dickey FullertonTest			Phillips - Perron Test		
	IPS W-Statistic	Prob.		ADF-Fisher Chi-square	Prob.		PP- Fisher Chi-square	Prob.	
	1.7060	0.9560		38.9546	0.9387				
	Individual series results			Individual series results			Individual series results		
	Prob.			Prob.			Prob.		
BE	0.7329	*		0.7329	*		0.1366	*	
BG	0.2433	*		0.2433	*		0.0001	***	
CZ	0.1764	*		0.1764	*		0.0603	**	
DK	0.0146	**		0.0146	**		0.0001	***	
DE	0.5439	*		0.5439	*		0.7493	*	
EE	0.0698	**		0.0698	**		0.0005	***	
IE	0.5522	*		0.5522	*		0.0206	**	
GR	0.5892	*		0.5892	*		0.8346	*	
ES	0.9481	*		0.9481	*		0.5012	*	
FR	0.9935	*		0.9935	*		0.9968	*	
IT	0.8035	*		0.8035	*		0.9923	*	
CY	0.5102	*		0.5102	*		0.0004	***	
LV	0.8229	*		0.8229	*		0.4585	*	
LT	0.6928	*		0.6928	*		0.8872	*	
LU	0.7928	*		0.7928	*		0.0106	**	
HU	0.9846	*		0.9846	*		0.9334	*	
MT	0.4489	*		0.4489	*		0.0005	***	
NL	0.8619	*		0.8619	*		1.0000	*	
AT	0.4081	*		0.4081	*		0.3467	*	
PL	0.8143	*		0.8143	*		0.9660	*	
PT	0.3954	*		0.3954	*		0.0045	*	
RO	0.928	*		0.9280	*		0.9957	*	
SL	0.6922	*		0.6922	*		0.6197	*	
SK	0.5539	*		0.5539	*		0.0001	***	
FI	0.9124	*		0.9124	*		0.9336	*	
SE	0.4914	*		0.4914	*		0.0034	***	
UK	0.4391	*		0.4391	*		0.0001	***	

*, **, *** indicate rejection of the null at 10 , 5 and 1 % respectively

Source: Computed

Table A-3 . GHG / ha: Individual unit root process test results, EU15 (1973-2007)

	Im, Pesaran and Shin Test		Augmented Dickey FullerTest		Phillips - Perron Test	
	IPS W-Statistic	Prob.	ADF-Fisher Chi-square	Prob.	PP- Fisher Chi-square	Prob.
	2.35477	0.9907	16.7959	0.9749	37.6391	0.1592
	Individual series results		Individual series results		Individual series results	
	Prob.		Prob.		Prob.	
BE	0.1864	*	0.1864	*	0.0006	***
DK	0.2747	*	0.2747	*	0.1888	*
DE	0.6284	*	0.6284	*	0.3233	*
IE	0.4746	*	0.4746	*	0.3729	*
GR	0.6888	*	0.6888	*	0.6848	*
ES	0.7100	*	0.7100	*	0.6325	*
FR	0.9981	*	0.9981	*	0.3217	*
IT	0.6449	*	0.6449	*	0.4040	*
LU	0.9939	*	0.9939	*	0.9550	*
NL	0.8655	*	0.8655	*	0.6171	*
AT	0.4587	*	0.4587	*	0.4161	*
PT	0.1690	*	0.1690	*	0.2200	*
FI	0.8987	*	0.8987	*	0.6979	*
SE	0.9385	*	0.9385	*	0.7296	*
UK	0.8333	*	0.8333	*	0.3179	*

*, **, *** indicate rejection of the null at 10 , 5 and 1 % respectively

Source: Computed

Table A-4 . GHG / ha: Individual unit root process test results, EU15 (1973-1995)

	Im, Pesaran and Shin Test		Augmented Dickey FullerTest		Phillips - Perron Test	
	IPS W-Statistic	Prob.	ADF-Fisher Chi-square	Prob.	PP- Fisher Chi-square	Prob.
	1.58644	0.9437	18.6430	0.9472	25.4173	0.7045
	Individual series results		Individual series results		Individual series results	
	Prob.		Prob.		Prob.	
BE	0.7694	*	0.7694	*	0.7240	*
DK	0.6005	*	0.6005	*	0.2541	*
DE	0.9132	*	0.9132	*	0.7009	*
IE	0.1830	*	0.1830	*	0.1499	*
GR	0.6701	*	0.6701	*	0.6684	*
ES	0.1728	*	0.1728	*	0.1740	*
FR	0.5678	*	0.5678	*	0.4804	*
IT	0.4223	*	0.4223	*	0.3673	*
LU	0.2796	*	0.2796	*	0.3698	*
NL	0.9232	*	0.9232	*	0.8576	*
AT	0.4501	*	0.4501	*	0.4428	*
PT	0.4369	*	0.4369	*	0.5094	*
FI	0.9744	*	0.9744	*	0.9877	*
SE	0.9186	*	0.9186	*	0.1229	*
UK	0.9191	*	0.9191	*	0.8776	*

*, **, *** indicate rejection of the null at 10 , 5 and 1 % respectively

Source: Computed

Table A-5 . GHG / ha: Individual unit root process test results, EU15 (1996-2007)

	Im, Pesaran and Shin Test		Augmented Dickey FullerTest		Phillips - Perron Test	
	IPS W-Statistic	Prob.	ADF-Fisher Chi-square	Prob.	PP- Fisher Chi-square	Prob.
	-1.35161	0.0883	48.8054	0.0165	115.995	0.0000
	Individual series results		Individual series results		Individual series results	
	Prob.		Prob.		Prob.	
BE	0.0376	**	0.0376	**	0.0001	***
DK	0.2433	*	0.2433	*	0.2193	*
DE	0.7998	*	0.7998	*	0.9311	*
IE	0.5124	*	0.5124	*	0.1595	*
GR	0.6713	*	0.6713	*	0.7516	*
ES	0.8917	*	0.8917	*	0.9980	*
FR	0.9988	*	0.9988	*	0.0805	*
IT	0.0538	**	0.0538	**	0.0106	**
LU	0.0190	**	0.0190	**	0.0001	***
NL	0.0040	***	0.0040	***	0.0001	***
AT	0.4007	*	0.4007	*	0.0003	***
PT	0.7741	*	0.7741	*	0.4626	*
FI	0.0190	**	0.0190	**	0.0001	***
SE	0.6106	*	0.6106	*	0.6102	*
UK	0.7605	*	0.7605	*	0.3865	*

*, **, *** indicate rejection of the null at 10 , 5 and 1 % respectively
Source:Computed

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