Trade and convergence in CO_2 emissions: some preliminary evidence*

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PRELIMINARY DRAFT

Abstract

This paper makes the link between the literature on CO_2 per capita *emission* convergence and the literature on the impact of trade on *income* per capita convergence. It includes more countries than the recent papers on emission convergence and applies the methodology introduced by Ben David (2000) to take into account trade as a conditionning factor. Overall, it confirms that there is no sign of convergence at the world wide level but convergence between OECD countries. Trade appears to be a positive contributing factor, although it is difficult to disentangle its influence from the impact of income per capita similarity or geographic proximity.

JEL Classification numbers: F10, O40, Q53, Q56

Key Words: CO_2 emissions, income per capita, trade and convergence

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1 Introduction

Motivated by the concerns about global warming, there is an emerging literature on the convergence of CO_2 emissions at the world-wide level. Broadly speaking, the evidence gathered so far is one of conditional convergence of emissions per capita, i.e. limited to industrial countries, quite similarly to the early empirical results of the 80s regarding income per capita convergence. However, the evidence is still scant and debatable, and more research is needed to identify the conditions under which convergence in emissions may take place. This paper analyses the role of trade, a conditioning factor that has been mostly absent from the recent literature on emission convergence. This omission is all the more surprising that the evidence suggesting a positive link between trade on income convergence has been gathering strength recently (see below). Moreover, regarding the link between trade and emission convergence, one can think of arguments running in opposite directions. On the one hand, trade may foster technological transfer and harmonization of environmental standards, contributing to a shared reduction in emissions among trading partners. On the other hand, trade allows for specialisation so that if differences in environmental protection are prevalent, the pollution-haven effect may lead to trade being a source of divergence rather than convergence in emissions. These ambiguities certainly call for empirical analysis, and the evidence presented here is based on the largest possible set of countries and time span.

Studies on *emission* convergence have naturally been influenced by the empirical growth literature. The seminal paper by List (1999), which is the first one to address specifically the question of emission per capita convergence (in this case of NO_x and SO_2 emissions between US Environmental Protection Agency regions), relies both on cross-section indicators, such as the β-convergence measure introduced by Baumol (1986), and on time-series econometrics, estimating in this case the stochastic convergence test attributable to Carlino and Mills (1993, 1996). Later papers have adopted a similar approach, but refined the tests of stochastic convergence, with some of them also applying the dynamic distributional approach and the non parametric techniques introduced by Quah (1997). As in the economic convergence literature, the state of the art today is to provide evidence based on a variety of different indicators rather than to rely on a single technique. Regarding CO_2 emissions, most existing studies rely on the same data source (Marland et al, 2003) and cover a large time frame (forty years or more). The empirical evidence gathered so far is, broadly speaking, one of divergence at the world wide level but of convergence when the sample is limited to industrial countries (Aldy (2006a), Brock and Taylor (2003), Nguyen Van (2005), Stegman (2005) and Starzicich and List (2003)). However, the evidence regarding US states is more complex. List (1999) obtains convergence of NO_x and SO_2 emissions across US EPA regions over the 1929-1994 period, but Bulte et al (2007) find that convergence of CO_2 emissions between US States is weaker during the local control years (1929-1969), providing some support for the "race to the bottom" argument. For CO_2 emissions also Aldy (2006b) estimates that consumption-based emissions are converging while production-based emissions are diverging, suggesting that trade in emission-intensive goods (electricity in particular) might be part of the explanation. In sum, emission convergence does not seem to simply mimic income convergence, and an interesting avenue of research is the role of trade as a conditional factor.

The role of trade in *income* convergence has been adressed in a subset of papers from the more general literature on the link between trade and growth. As it is well known, this literature has been characterized by considerable disagreements in terms of both theoretical models and empirical work (see the survey of Rassekh (2004)). However, regarding more specifically the relationship between trade and income convergence, at the international level, it is fair to say that recent evidence is rather suggestive of a positive link (e.g. the surveys of Ben David (2000) or Giles and Mosk (2004)). This link has been adressed in two main ways. On the one hand, some studies try to relate income convergence with specific *trade liberalization* episodes, treating the latter as exogenous events. These "natural experiments" cases seem to support the view that trade reforms are associated with lower income differentials (Ben David (1993), Ben David and Bohara (1997)). However, the controversy between Slaughter (2001) and Ben David (2001) illustrates how this approach is sensitive to the choice of the pre and post-liberalization period. On the other hand, another group of studies analyze the link between income convergence and the *level* of trade. The basic insight here has been provided by Ben David (1996), who showed that grouping countries of the basis of trade produces a much higher incidence of income convergence than does a random grouping from the same pool of countries. This methodology has been further extended in a later paper (Ben David and Kimhi, 2004) to show that increases in trade correspond with increases in rates of convergence of the trading partners. More positive evidence is still provided by Giles and Stroomer (2006), who refine the analysis in several dimensions. Using non-linear techniques, they estimate convergence speeds in terms of half-lives and show subsequently with fuzzy regression methods that increased trade openness is associated with a faster rate of convergence.

This paper builds on the two types of literature reviewed above to assess the role of trade in emission convergence across countries. It adopts basically the empirical framework developed by Ben David (2000) and applies it to CO_2 per capita emissions, updating the econometric techniques used to test for stochastic convergence. The data base and convergence indicators are similar to those used in the emission convergence literature, as in Aldy (2006a), but now trade enters the picture and a particular care is given to complete data series in order to base empirical evidence on the largest possible set of countries. The next section describes briefly the data base and provides some preliminary descriptive statistics regarding emission convergence at the world level and within preferential trading areas. Section 3 presents the stochastic convergence methodology and discusses the obtained results. Overall, these results suggest that there is a positive link between trade and emission convergence at the international level, although the relationship only seems to matter once trade intensity goes beyond a certain threshold. Final comments and limitations are presented in the conclusion.

2 Preliminary descriptive analysis

After mentioning the principal data sources we present some descriptive statistics that help to characterize the dynamic pattern of cross-country per capita emissions (PCEs) in the long run. The first set of evidence is based on the concept of convergence curve (see Ben David (2000)), the second one on the dispersion of PCEs over time, the so-called "σ-convergence" in the growth literature. In each case, in order to identify broad patterns, the world measure is completed by sub-categories, grouping countries by income per capita level, geographical areas, or preferential trading areas.

2.1 Data sources

As in other studies in the field, data on CO_2 emissions come from the Carbon Dioxide Information Analysis Centre (CDIAC, see Marland et al, (2003)). They reflect anthropogenic emissions based on fossil fuel consumption, cement manufacturing and gas flaring, ignoring fuels supplied to ships and aircrafts. The selection criteria has been to include all countries reporting more than 1 million tons of carbon and with non missing observations during the 1960-2002 period. We put special emphasis in including low-income countries, aggregating series when changes of borders occurred during the sample period. The final sample includes 166 countries, i.e. 78 more countries than in the recent study of Aldy (2006a). [1] Data on population come from the US census bureau's webpage (http://www.census.gov/ipc/www/idbsprd.html), while import and export data where obtained from the COMTRADE data base.

2.2 Convergence curve

In case of absolute convergence, the unique factor driving the dynamics of PCEs would be the initial per capita emission level of each country. For each point of figure 1, those initial levels (relative to the world average) are reported on the horizontal axis, while the *effective* average annual growth rate of PCEs for the corresponding country over the sample period is reported on the vertical axis. What is depicted by the convergence curve is the benchmark, i.e. the *theoretical* annual growth rate needed for that country to reach, at the end of the period, exactly the world average level in emissions per capita (thus achieving perfect convergence worldwide).[2]

Figure 1: Growth and initial levels of CO_2 p.c. emissions, world sample

If absolute convergence were prevalent worldwide, most points of figure 1 would locate close to the convergence curve. The effective pattern is quite different from that, with a majority of initial low-emission countries

[1] See Table A1 in the Appendix for the list of countries, and Table A2 for the list of reconstructed countries.

[2] The mathematical expression of the convergence curve is $g_i = 100 * \left[\left(\frac{e_w^{02}}{e_i^{60}}\right)^{\frac{1}{42}} - 1\right]$, where e_i^{60} is the initial PCEs of country i, e_w^{02} is the world average PCEs at the end of the sample period and g_i is the required annual growth rate for country i to reach the world average level of PCEs at the end of the period.

locating beneath the curve (i.e. countries that start with low levels of emissions and remain so throughout the period) and a subset of initially large emission countries that locate above the curve. The overall picture is thus one of divergence rather than convergence at the world level. As this recalls the pattern obtained in the growth literature, it is tempting to repeat the exercise on subset of countries that are known to have converged in terms of income per capita. This is done for high income OECD countries (figure 2(a)) an the fifteen EU countries (figure 2(b)). In both cases, the pattern obtained is almost one of perfect convergence.

Figure 2: Growth and initial levels of CO_2 p.c. emissions, OECD and EU

Overall, the evidence gathered so far suggests that if there is some convergence in CO_2 per capita emissions, it is of the conditional type. Hence the need to control for income similarity, geographical proximity and trade relations as we pursue the analysis.

2.3 σ-convergence

Another common indicator of convergence is the evolution of the dispersion of PCEs across selected groups of countries. Figure 3 reports the standard deviation of PCEs over the sample period, both for the world sample and for different income groups (as defined by the World Bank). Whatever the group, there is no sign of convergence. What is striking is the low level of dispersion of PCEs for the low and middle income groups, while the standard deviation of high income countries is clearly above the world average. This explains why our figures for the world sample are larger than the corresponding ones in Aldy (2006a), as the latter includes less low income (and low-dispersion) countries. Also note that a considerable fraction of high-income dispersion is due to the influence of small group of highly polluting countries.[3] When this group of outliers is excluded from the sample, the dispersion of the high-income group is reduced by a rough 40%. The dispersion of the group remains larger than world average, and with no signs of convergence, a result that may seems surprising are figure 2(a) suggested convergence within OECD countries but one should

[3] These are usually small countries with a large petroleum production. They are underlined in table A1.

note that the high income group also includes a number of non-OCED countries.

Figure 3: Standard deviation of emissions p.c. according to income groups

As similar exercise is repeated in figure 4, which reports dispersion amongst geographical areas (outliers excluded). Note in general that the range of standard deviation is reduced with respect to the previous figure, suggesting that geography may matter in defining convergence clubs. However, apart from Europe & Central Asia, there is no sign of convergence, with a clear divergence pattern for two areas: Middle East & North Africa and East Asia & Pacific. Although on the rise, the dispersion of PCEs in South Asia is by far the lowest over all reggions.

Figure 4: Standard deviation of emissions p.c. according to geographical areas

Dispersion amongst preferential trade areas is adressed in figure 5. Consistently with the evidence reported in figure 2(b), there is a clear convergence pattern for the European Community founders (EEC6) and the free trade area including the these countries and those of the European Free Trade Area (EEC6-EFTA6). However, this convergence does not extend to the other two groups, the EFTA6 countries taken separately and the US-Canada free trade area.

Figure 5: Standard deviation of emissions p.c. according to preferential trade areas

In sum, the evidence based on dispersion results suggests again an absence of overall convergence of PCEs at the world-wide level, and limited convergence in certain groups of countries, in particular in Europe and for certain trade areas. We also repeated the analysis with alternative indicators (such as the inter-quartile range and the coefficient of variation), without affecting the basic results.

3 Time series analysis

In order to deepen the analysis, we borrow from the growth literature the methodology which is commonly used to estimate the rate of convergence in income per capita. We apply this technique to estimate the rate of convergence of PCEs within certain groups of countries. These groups are defined either on the basis of their initial emissions per capita levels or according to the intensity of their trade relationship.

3.1 Estimating the rate of convergence

The basic equation to estimate the rate of convergence of PCEs within a group of countries is the following:

$$(e_{it} - \overline{e}_t) = \phi(e_{i,t-1} - \overline{e}_{t-1}) + \varepsilon_{it} \tag{1}$$

where e_{it} is country i's log per capita emissions in year t, $\overline{e}_t$ is the group's average log per capita emissions in year t and ε_{it} is the usual iid term. If the *convergence coefficient*, ϕ, is lower than one, the gap decreases over time and the group experiences convergence, while the verdict is one of divergence if ϕ is larger than one.

To implement unit root tests we define the emission gap as $z_{it} \equiv e_{it} - \overline{e}_t$ and rewrite equation (1) in its equivalent form:

$$\Delta z_{it} = \rho z_{i,t-1} + \varepsilon_{it} \tag{2}$$

where $\Delta z_{it} \equiv z_{it} - z_{i,t-1}$ and $\rho = \phi - 1$. Equation (2) is the standard form generally to apply tests of the Dickey-Fuller type. Ben David (2000) computed the ADF test by adding p difference terms $(\sum_{p=1}^{P} \beta_p \Delta z_{i,t-p})$ as regressors in equation (2). We make use here of two more powerful tests that have been recently introduced. The first one is the Levin, Lin and Chu (2001) common unit root test (LLC-test below), which assumes that $\phi_i = \phi$ but allows the lag order for the difference terms to vary across cross-sections $(\sum_{p=1}^{P} \beta_{ip} \Delta z_{i,t-p})$. The second one is the individual Fisher-PP test, proposed by Choi (2001) and Maddala and Wu (1999), which allows ϕ to vary across cross-sections.

3.2 Results

Applying the above methodology at the world wide level leads to results reported in the first line of table 1. Not surprisingly, it turns out that PCEs are diverging within countries of the world sample, and significantly so according to the LLC-test. The remaining part of the table reports result obtained when the sample is split into two, three or up to eight groups of identical size obtained when countries are ranked by increasing level of initial PCEs. The resulting pattern regarding the estimated convergence coefficient *vis-a-vis* the emission range is one of inverted U, i.e. smaller than one at both extremes and larger then one in between. The estimated parameters are systematically and significantly different from one at the upper end of the distribution, suggesting that there is significant convergence within the highest emission group but divergence within all previous groups along the emission ladder.

Table 1: Convergence rates: countries grouped by initial emission levels

In order to link this pattern with trade we repeat the above calculations for thirteen different preferential trade areas. Overall the evidence is for convergence, and significantly so for the four previously analyzed trading zones (figure 5) plus the Andean Community of Nations (ACN) and the Economic and Monetary Community of Central Africa (CEMAC). The only two cases of significant divergence may simply arise from the presence of outliers in the sample, i.e. Brunei in the case of the ASEAN Free Trade Area (AFTA) and Trinidad and Tobago in the case of the Caribbean Community (CARICOM)

Table 2: Convergence rates: among preferential trade areas

Part of the differences between preferential trading areas may be due to differences in timing (when the reduction in trade barriers only covers part of the 1960-2002 period) or in depth of integration. Thus the analysis is completed by estimating the rate of convergence within *revealed* preferential trading partners. To achieve this we identify, for each country in the sample, the major trading partners defined as those that correspond, on average, to more than 4% of the source country's imports or exports. For each country, the convergence coefficient is estimated among the corresponding import or export group. Results are ranked by increasing value of the estimated parameter and reported in table 3 (import-based groups) and table 4 (export-based groups)

Table 3: Convergence rates: import-based groups

The evidence is rather mixed, with a majority of trading groups exhibiting neither significant divergence nor convergence. Regarding import-based groups, the number of converging countries is double the number of diverging countries, but this difference vanishing when one turns to export-based groups. The composition of the significantly diverging group differs according to trade orientation (import or export-based groups), while a group of six high-income countries (Austria, Singapore, Canada, Australia, New Zealand and the USA) systematically appears as significantly converging. Another common characteristics of both tables is that the average size of the converging group (3.7 countries) is smaller than in the diverging group (around 5.6 countries). Althoug further analysis is clearly needed, this may suggest that for trade to be associated with convergence, the import and export pattern of the country must be very much concentrated.

Table 4: Convergence rates: export-based groups

4 Conclusions

Although there is now a rich empirical literature regarding both convergence of CO_2 per capita emissions on the one hand, and the impact of trade on income per capita on the other hand, the link between trade and convergence of per capita emissions had still to be adressed. As a first step in this direction this paper, while confirming the absence of convergence in per capita emissions at the world-wide level, provides some evidence in support of a positive link between trade and emission convergence. This may be of critical importance regarding the political economy of environmental treaties. If trade intensity can indeed be associated with emission per capita convergence, and if the globalization trend is to persist, then an allocation scheme of emission permits based on population may be perceived as progressively less unfavourable by those countries that have the largest per capita emissions today.

This certainly calls for further analysis in the field, given also that the present paper left unsolved a number of empirical caveats. It is in particular puzzling that the evidence based on preferential trade areas seems more assertive of a positive link than when estimated convergence is based on the major trading partners of each country. More generally, what we need are refinements that would help to assess the relative importance of trade, geography and income per capita similarity as different factors conditionning the convergence of CO_2 per capita emissions.

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Figure 1: Growth and initial levels of CO_2 p.c. emissions, world sample

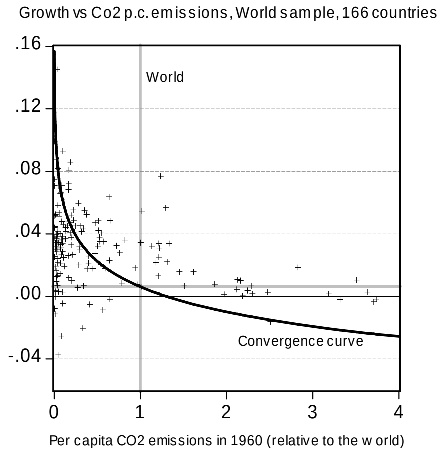
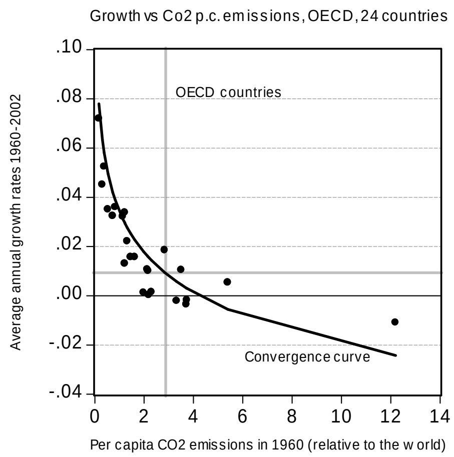


Figure 2: Growth and initial levels of CO_2 p.c. emissions, OECD and EU



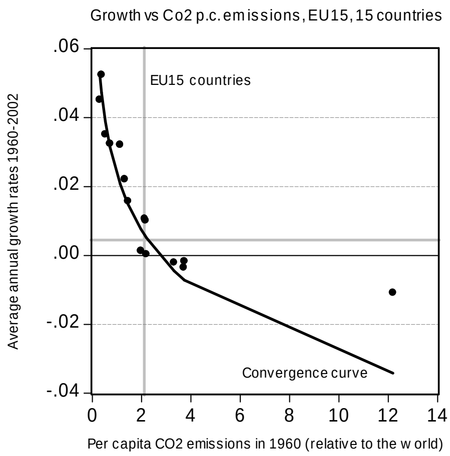


Figure 3: Standard deviation of emissions p.c. according to income groups

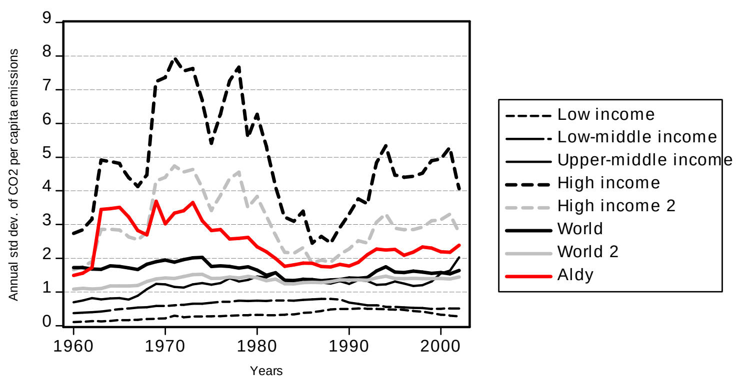
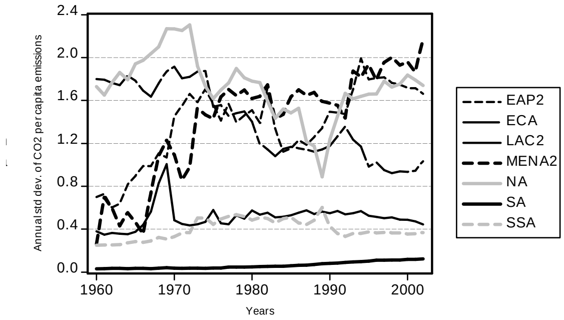


Figure 4: Standard deviation of emissions p.c. according to geographical areas



EAP2: East Asia and Pacific, without outliers
ECA: Europe and Central Asia
LAC2: Latin America, without outliers
MENA2: Middle East and North Africa, without outliers
NA: North America
SA: South America
SSA: Sub-Saharan Africa

Figure 5: Standard deviation of emissions p.c. according to preferential trade areas

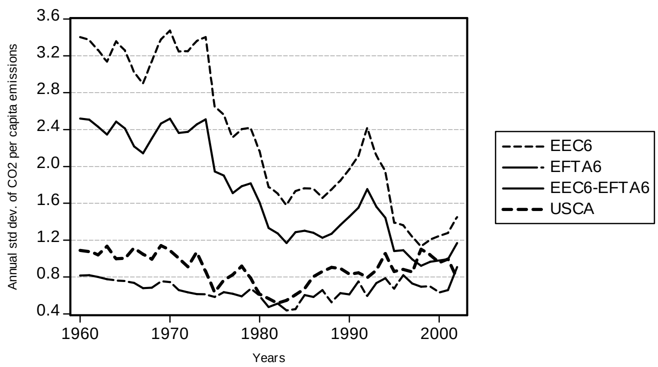


Table 1: Convergence rates: countries grouped by initial emission level

Country range		Common unit root LLC test				Individual unit root PP-Fisher test	
First	Last	coeff	t-stat	Obs	Half / double life	Chi-square	Obs
1	166	1.003***	4.09	6768	262	258.259	7138
1	83	0.999	-0.92	3364	-592	215.76***	3569
84	166	1.032***	27.04	3394	22	66.91	3569
1	56	0.997*	-1.56	2288	-262	178.96***	2408
57	111	1.019***	6.61	2206	36	81.96	2365
112	166	1.035***	23.99	2226	20	53.85	2365
1	42	0.997	-1.23	1717	-234	109.41**	1806
43	83	1.014***	3.92	1640	51	62.66	1763
84	125	1.029***	9.74	1702	24	34.58	1806
126	166	1.025***	10.61	1672	28	43.97	1763
1	34	0.996*	-1.37	1391	-177	75.35	1462
35	67	1.011***	2.95	1324	63	53.78	1419
68	100	1.020***	4.56	1318	35	58.36	1419
101	133	1.040***	11.22	1335	18	39.19	1419
134	166	0.997***	-0.58	1354	-248	71.08	1419
1	28	0.997	-1.10	1151	-203	61.40	1204
29	56	1.009**	2.23	1144	75	41.53	1204
57	83	1.018***	3.46	1071	39	41.69	1161
84	111	1.023***	6.34	1131	31	35.86	1204
112	139	1.040***	12.50	1123	17	37.88	1204
140	166	0.979***	-2.98	1126	-32	75.25**	1161
1	24	0.999	-0.44	983	-471	46.65	1032
25	48	1.006**	1.03	974	118	45.95	1032
49	72	1.022***	4.79	958	32	23.43	1032
73	95	1.018***	3.34	931	38	47.55	989
96	119	1.024***	4.28	960	29	30.67	1032
120	143	1.043***	8.65	968	17	22.46	1032
144	166	0.977***	-2.97	963	-30	58.13	989
1	21	0.999	-0.17	857	-949	40.43	903
22	42	1.003	0.47	862	218	54.60*	903
43	63	1.007	1.37	855	94	37.95	903
64	83	1.023***	4.04	786	30	33.67	860
84	104	1.028***	6.51	857	25	18.56	903
105	125	1.036***	6.61	863	19	30.67	903
126	146	1.029***	6.32	845	24	33.43	903
147	166	0.980**	-1.84	805	-35	49.76	860

*,**,*** indicate significance at the 10%,5% and 1% level respectively.

Table 2: Convergence rates: among preferential trade areas

Group	Period	Common unit root LLC test						Individual unit root PP-Fisher test	
		# countries	coeff	t-stat	Obs	Half / double life	P(coeff)	Chi-square	Obs
ACN	1960-2002	5	0.978***	-2.40	208	-32	6%	15.83	215
AFTA	1960-2002	9	1.049***	3.92	333	14		4.95	387
CACM	1960-2002	5	0.975	-1.00	202	-27	5%	18.19*	215
CARICOM	1960-2002	12	1.027***	3.36	502	26		14.40	515
COMESA	1960-2002	12	0.993*	-1.34	493	-94		34.50*	517
EEC6	1960-2002	6	0.979***	-3.49	252	-33	1%	28.67***	258
EFTA6	1960-2002	6	0.955***	-3.79	243	-15	1%	37.62***	258
EEC&EFTA6	1960-2002	12	0.976***	-4.50	489	-28	1%	56.15***	516
EU15	1960-2002	15	0.976***	-5.71	618	-28	1%	76.39***	645
MERCOSUR	1960-2002	4	0.999	-0.21	165	-577	45%	5.70	172
NAFTA	1960-2002	3	1.001	0.32	125	475		9.04	129
CEMAC	1960-2002	6	0.959**	-1.89	244	-17		23.77**	258

Table 3: Convergence rates: import-based groups

		Common unit root LLC test				Individual unit root PP-Fisher test	
Group	# partners	coeff	t-stat	Obs	Half / double life	Chi-square	Obs
POL	4 (7)	0.958***	-4.24	166	-16	24.23***	172
IRN	5 (6)	0.970***	-3.69	203	-22	32.36***	215
BGR	4	0.967***	-2.58	165	-21	14.96*	172
ROM	3 (4)	0.960***	-2.51	122	-17	10.77*	129
HUN	3 (6)	0.945***	-2.47	124	-12	13.13**	129
AUT	4	0.967**	-2.09	155	-21	13.87*	172
SGP	4	0.994**	-1.84	206	-112	19.05**	215
CAN	2	0.993**	-1.76	126	-96	14.33**	129
AUS	4	0.994*	-1.53	163	-111	9.11	172
TTO	4	0.994*	-1.48	205	-113	14.57	215
CYP	7	0.996*	-1.44	283	-171	15.48	301
NZL	7	0.995*	-1.38	205	-135	9.87	215
USA	5	0.996	-1.18	195	-159	15.39	215
THA	5	0.996	-1.16	208	-189	19.96**	215
FIN	6 (7)	0.995	-1.16	193	-146	15.18	215
MEX	3	0.996	-1.13	125	-173	13.87**	129
VEN	4	0.997	-1.03	168	-205	8.45	172
GRC	8	0.997	-0.91	320	-254	21.96	344
PHL	4	0.998	-0.88	207	-278	22.37**	215
PNG	4	0.997	-0.85	204	-268	16.18*	215
KWT	6	0.997	-0.81	242	-264	12.67	258
SAU	6	0.997	-0.77	241	-275	18.58*	258
JAM	6	0.998	-0.72	288	-283	15.32	301
IDN	6	0.998	-0.69	249	-328	26.85***	258
DOM	3 (4)	0.998	-0.55	164	-415	7.87	172
GAB	4	0.998	-0.55	166	-348	7.96	172
NOR	7	0.998	-0.51	270	-343	11.94	301
ARE	5	0.998	-0.51	208	-355	18.71**	215
ZAF	5	0.998	-0.45	201	-436	11.84	215
GBR	6 (7)	0.999	-0.43	235	-495	11.29	258
TUR	7 (8)	0.999	-0.40	279	-630	17.95	301
DZA	6	0.999	-0.35	245	-686	11.06	258
HND	4	0.999	-0.35	164	-666	7.73	172
JOR	8	0.999	-0.31	321	-787	21.95	344
ESP	6	0.999	-0.29	245	-770	11.79	258
ISL	9	0.999	-0.28	307	-666	12.21	344
PRT	7	1.000	-0.17	281	-1474	7.17	301
MAC	5	0.999	-0.17	241	-1307	12.14	258
SYR	5 (6)	1.000	-0.08	207	-3013	9.43	215
IND	4 (8)	1.000	-0.08	161	-3013	15.77**	172
MUS	7	1.000	-0.03	287	-8154	15.75	301
FRA	6 (8)	1.000	0.09	239	2568	5.69	258
MAR	7	1.000	0.11	246	2476	11.28	258
ECU	6	1.000	0.12	200	2311	22.57**	215
PRY	7	1.000	0.12	283	2476	27.17**	301
HKG	5	1.000	0.13	201	1576	10.60	215
CHN	6	1.000	0.15	236	1415	10.18	258
CHL	5	1.000	0.16	202	1733	20.26**	215
BRA	6	1.001	0.20	245	1284	35.24***	258
KEN	7	1.001	0.21	282	1083	23.78**	301
ARG	6	1.001	0.23	246	1101	21.31**	258
ISR	6 (8)	1.001	0.25	249	925	7.43	258
CRI	6	1.001	0.32	249	937	16.44	258
CMR	5	1.001	0.33	208	779	9.22	215
GTM	5 (6)	1.001	0.33	208	806	7.74	215
EGY	5 (7)	1.001	0.38	207	619	6.25	215
BOL	6	1.001	0.42	242	762	21.23**	258
PER	7	1.001	0.47	202	608	21.39**	215
LBN	5	1.002	0.50	207	459	4.15	215
KOR	4	1.002	0.51	203	403	5.12	215
LKA	10	1.002	0.58	203	459	16.78*	215
SLV	6 (7)	1.001	0.62	289	542	17.23	301
TUN	4	1.002	0.71	164	350	3.07	172
IRL	5 (6)	1.003	0.76	164	223	5.00	172
ITA	5 (6)	1.003	0.80	202	253	3.74	215
URY	6	1.002	0.80	244	375	6.40*	258
CHE	6	1.003	0.93	242	239	4.17	258
SWE	8	1.005*	1.34	313	129	22.90	344
ETH	8	1.003*	1.42	326	227	19.55	344
JPN	5	1.005**	1.73	249	150	2.87	258
NLD	4 (6)	1.008**	1.88	160	87	1.28	172
DNK	7	1.008**	2.10	275	82	6.10	301
NPL	6	1.016***	4.00	244	43	7.53	258

Table 4: Convergence rates: export-based groups

Group	# partners	Common unit root LLC test: coeff	t-stat	Obs	Half / double life	Individual unit root PP-Fisher test: Chi-square	Obs
AUT	4	0.951***	-5.67	161	-14	126.43***	172
CYP	4 (6)	0.955***	-4.432	156	-15	37.83***	172
POL	3 (6)	0.953***	-4.387	123	-14	29.19***	129
HUN	3 (6)	0.945***	-2.474	124	-12	13.13**	129
TWN	3	0.994**	-2.038	162	-112	10.26	172
PAK	7	0.994**	-1.818	235	-107	20.23	258
CAN	2	0.993**	-1.756	126	-96	14.33**	129
AUS	4	0.995**	-1.679	208	-131	11.05	215
USA	4	0.994*	-1.503	163	-111	14.15*	172
NZL	4	0.995*	-1.377	205	-135	9.87	215
MYS	4	0.995*	-1.376	199	-153	13.66	215
SGP	5	0.996*	-1.374	242	-192	16.07	258
THA	6	0.997	-1.166	278	-226	16.52	301
MAC	6	0.996	-1.158	240	-191	27.89***	258
TTO	1	0.966	-1.046	84	-20	3.93	86
SYR	3 (4)	0.989	-1.044	160	-64	9.72	172
TUN	3 (4)	0.992	-1.003	119	-90	10.03	129
ISR	7 (9)	0.997	-0.951	274	-225	14.33	301
KWT	1	0.975	-0.877	84	-27	3.63	86
IDN	4	0.998	-0.769	209	-296	26.76***	215
ZAF	5 (6)	0.998	-0.713	203	-287	10.20	215
BGR	5 (8)	0.995	-0.71	204	-133	8.11	215
SAU	4 (5)	0.998	-0.627	204	-341	14.91	215
ROM	4	0.995	-0.596	167	-149	7.64	172
HKG	5	0.998	-0.487	201	-444	22.61**	215
GRC	5	0.999	-0.473	203	-471	7.26	215
ISL	7(8)	0.999	-0.435	280	-498	12.46	301
LKA	4 (5)	0.999	-0.412	162	-568	8.70	172
BRA	6	0.999	-0.351	243	-745	20.90*	258
MAR	6 (7)	0.999	-0.329	251	-641	19.69*	258
ARE	1	0.989	-0.307	83	-63	3.86	86
NPL	4	0.999	-0.294	165	-962	12.12	172
CMR	5	0.999	-0.216	209	-513	12.29	215
ESP	7	1.000	-0.169	281	-1474	7.17	301
PRT	7	1.000	-0.169	281	-1474	7.17	301
PHL	4	1.000	-0.116	160	-2038	11.20	172
JOR	4 (5)	0.999	-0.079	195	-866	3.04	215
IND	4 (5)	1.000	-0.075	161	-3013	15.77**	172
CHL	7	1.000	-0.06	288	-4951	28.85**	301
FRA	6 (7)	1.000	0.085	239	2568	5.69	258
KOR	5	1.000	0.139	195	1475	9.09	215
JPN	6	1.000	0.147	236	1415	10.18	258
GBR	6 (7)	1.001	0.251	242	846	7.88	258
CHN	3	1.001	0.292	160	708	7.26	172
ARG	6 (7)	1.001	0.315	245	937	11.78	258
ETH	6	1.001	0.334	247	856	20.25*	258
EGY	5 (6)	1.001	0.343	242	730	8.62	258
JAM	5	1.001	0.377	242	472	9.25	258
TUR	6 (7)	1.001	0.44	202	588	4.91	215
DZA	6	1.001	0.448	241	550	5.32	258
PRY	6 (7)	1.001	0.63	243	485	6.84	258
CHE	6	1.002	0.713	248	330	4.52	258
ITA	5	1.002	0.723	207	302	3.69	215
DOM	2	1.002	0.742	106	280	0.94	129
NLD	5 (7)	1.003	0.796	202	253	3.74	215
DNK	7	1.003	0.87	279	228	7.71	301
GER	7 (8)	1.003	0.9	283	265	5.01	301
PNG	5	1.004	0.911	197	171	33.28***	215
IRL	5 (6)	1.004	0.966	200	186	5.74	215
MEX	1	1.004	0.988	84	158	0.99	86
GAB	3	1.004	0.993	163	157	6.56	172
LBN	7	1.003	1.013	289	216	15.08	301
ECU	3	1.003	1.208	158	228	1.57	172
VEN	2 (3)	1.008	1.235	126	89	3.76	129
URY	4 (5)	1.003	1.238	164	233	1.93	172
SLV	6 (7)	1.003*	1.294	250	267	8.16	258
MUS	4	1.004*	1.304	166	164	1.18	172
SWE	8	1.005*	1.341	313	129	22.90	344
KEN	7 (8)	1.003*	1.385	243	225	7.11	258
BOL	4 (5)	1.003*	1.459	207	201	1.68	215
PER	4	1.005**	1.745	161	135	1.81	172
COL	4	1.006**	1.911	159	114	2.31	172
NOR	7 (8)	1.008**	2.098	275	82	6.10	301
PAN	3 (4)	1.007***	2.398	126	104	0.75	129
FIN	5 (7)	1.012***	2.575	158	60	0.46	172
GTM	4 (5)	1.006***	2.667	168	113	1.15	172
CRI	3 (4)	1.008***	2.899	126	91	0.73	129

Appendix Table A1: List of countries

n°	Country	WB code	WB geo c	WB income c	Weight
1	Afghanistan	AFG	SA	LI	1
2	Albania	ALB	ECA	LMI	1
3	**Algeria**	DZA	MENA	LMI	1
4	American Samoa	ASM	EAP	UMI	1
5	**Angola**	AGO	SSA	LI	1
6	Antigua & Barbuda	ATG	LAC	HInOECD	1
7	**Argentina**	ARG	LAC	UMI	1
8	**Australia**	AUS	EAP	HIOECD	1
9	**Austria**	AUT	ECA	HIOECD	1
10	Bahamas	BHS	LAC	HInOECD	1
11	**Bahrain**	BHR	MENA	HInOECD	1
12	Barbados	BRB	LAC	HInOECD	1
13	**Belgium**	BEL	ECA	HIOECD	1
14	Belize	BLZ	LAC	UMI	1
15	Benin	BEN	SSA	LI	1
16	Bermuda	BMU	NA	HInOECD	1
17	**Bolivia**	BOL	LAC	LMI	1
18	**Brazil**	BRA	LAC	LMI	1
19	Brunei	BRN	EAP	HInOECD	1
20	**Bulgaria**	BGR	ECA	LMI	1
21	Burkina Faso	BFA	SSA	LI	1
22	Cambodia	KHM	EAP	LI	1
23	**Canada**	CAN	NA	HIOECD	1
24	Cape Verde	CPV	SSA	LMI	1
25	Cayman Islands	CYM	LAC	HInOECD	1
26	Central African R.	CAF	SSA	LI	1
27	Chad	TCD	SSA	LI	1
28	**Chile**	CHL	LAC	UMI	1
29	**China**	CHN	EAP	LMI	1
30	**Colombia**	COL	LAC	LMI	1
31	Comoros	COM	SSA	LI	1
32	Congo (Rep.)	COG	SSA	LI	1
33	**Costa Rica**	CRI	LAC	UMI	1
34	**Côte d'Ivoire**	CIV	SSA	LI	1
35	**Cuba**	CUB	LAC	LMI	1
36	**Cyprus**	CYP	ECA	HInOECD	1
37	**Czechoslovakia**		ECA	UMI	2
38	Korea (D.R.)	PRK	EAP	LI	1
39	**Denmark**	DNK	ECA	HIOECD	1
40	Djibouti	DJI	MENA	LMI	1
41	Dominica	DMA	LAC	UMI	1
42	**Dominican R.**	DOM	LAC	LMI	1
43	Bangladesh & Pakistan		SA	LI	2
44	**Ecuador**	ECU	LAC	LMI	1
45	**Egypt**	EGY	MENA	LMI	1
46	**El Salvador**	SLV	LAC	LMI	1
47	Equatorial Guinea	GNQ	SSA	LI	1
48	**Ethiopia**	ETH	SSA	LI	1
49	Faeroe Islands	FRO	ECA	HInOECD	1
50	Fiji	FJI	EAP	LMI	1
51	**Finland**	FIN	ECA	HIOECD	1
52	**France & Monaco**	FRA	ECA	HIOECD	1
53	French Guiana				0
54	French Polynesia	PYF	EAP	HInOECD	1
55	Gabon	GAB	SSA	UMI	1
56	Gambia	GMB	SSA	LI	1
57	**Germany**	DEU	ECA	HIOECD	1
58	**Ghana**	GHA	SSA	LI	1
59	Gibraltar				0
60	**Greece**	GRC	ECA	HIOECD	1
61	Greenland	GRL	ECA	HInOECD	1
62	Grenada	GRD	LAC	UMI	1
63	Guadeloupe				0
64	Guam	GUM	EAP	HInOECD	1
65	**Guatemala**	GTM	LAC	LMI	1
66	Guinea	GIN	SSA	LI	1
67	Guinea Bissau	GNB	SSA	LI	1
68	Guyana	GUY	LAC	LMI	1
69	Haiti	HTI	LAC	LI	1
70	**Honduras**	HND	LAC	LMI	1
71	**Hong Kong**	HKG	EAP	HInOECD	1
72	**Hungary**	HUN	ECA	UMI	1
73	Iceland	ISL	ECA	HIOECD	1
74	**India**	IND	SA	LI	1
75	**Indonesia**	IDN	EAP	LI	1
76	**Iraq**	IRQ	MENA	LMI	1
77	**Ireland**	IRL	ECA	HIOECD	1
78	**Iran**	IRN	MENA	LMI	1
79	**Israel**	ISR	MENA	HInOECD	1
80	**Italy & San Marino**	ITA	ECA	HIOECD	1
81	**Jamaica**	JAM	LAC	LMI	1
82	**Japan**	JPN	EAP	HIOECD	1
83	**Jordan**	JOR	MENA	LMI	1
84	**Kenya**	KEN	SSA	LI	1
85	**Kuwait**	KWT	MENA	HInOECD	1
86	Laos	LAO	EAP	LI	1
87	**Lebanon**	LBN	MENA	UMI	1
88	Liberia	LBR	SSA	LI	1
89	Libya	LBY	MENA	UMI	1
90	**Luxembourg**	LUX	ECA	HIOECD	1
91	Macau	MAC	EAP	HInOECD	1
92	Madagascar	MDG	SSA	LI	1
93	Malaysia	MYS	EAP	UMI	1
94	Mali	MLI	SSA	LI	1
95	Malta	MLT	MENA	HInOECD	1
96	Martinique				0
97	Mauritania	MRT	SSA	LI	1
98	Mauritius	MUS	SSA	UMI	1
99	**Mexico**	MEX	LAC	UMI	1
100	**Mongolia**	MNG	EAP	LI	1
101	**Morocco**	MAR	MENA	LMI	1
102	Mozambique	MOZ	SSA	LI	1
103	**Myanmar**	MMR	EAP	LI	1
104	Nepal	NPL	SA	LI	1
105	Netherland Antilles & Aruba		LAC	HInOECD	2
106	**Netherlands**	NLD	ECA	HIOECD	1
107	New Caledonia	NCL	EAP	HInOECD	1
108	**New Zealand**	NZL	EAP	HIOECD	1
109	**Nicaragua**	NIC	LAC	LI	1
110	Niger	NER	SSA	LI	1
111	**Nigeria**	NGA	SSA	LI	1
112	**Norway**	NOR	ECA	HIOECD	1
113	Palau	PLW	EAP	UMI	1
114	**Panama**	PAN	LAC	UMI	1
115	Papua New Guinea	PNG	EAP	LI	1
116	Paraguay	PRY	LAC	LMI	1
117	**Peru**	PER	LAC	LMI	1
118	**Philippines**	PHL	EAP	LMI	1
119	**Poland**	POL	ECA	UMI	1
120	**Portugal**	PRT	ECA	HIOECD	1
121	**Puerto Rico**	PRI	LAC	HInOECD	1
122	**Qatar**	QAT	MENA	HInOECD	1
123	**Cameroon**	CMR	SSA	LI	1
124	**Korea (R.)**	KOR	EAP	HIOECD	1
125	Reunion				0
126	Rhodesia-Nyasaland (MLW & ZAM & ZMB)		SSA	LI	3
127	**Romania**	ROM	ECA	LMI	1
128	Rwanda-Urundi (Rwanda & Burundi)		SSA	LI	2
129	St. Lucia	LCA	LAC	UMI	1
130	Samoa	WSM	EAP	LMI	1
131	Sao Tome & Principe	STP	SSA	LI	1
132	**Saudi Arabia**	SAU	MENA	UMI	1
133	Senegal	SEN	SSA	LI	1
134	Sierra Leone	SLE	SSA	LI	1
135	**Singapore**	SGP	EAP	HInOECD	1
136	Solomon Islands	SLB	EAP	LI	1
137	**South Africa**	ZAF	SSA	LMI	1
138	**Spain**	ESP	ECA	HIOECD	1
139	**Sri Lanka**	LKA	SA	LMI	1
140	St. Pierre & Miquelon				0
141	St. Vincent & The Grenadines	VCT	LAC	LMI	1
142	**Sudan**	SDN	SSA	LI	1
143	Suriname	SUR	LAC	LMI	1
144	**Sweden**	SWE	ECA	HIOECD	1
145	**Switzerland**	CHE	ECA	HIOECD	1
146	**Syria**	SYR	MENA	LMI	1
147	**Taiwan**				0
148	**Thailand**	THA	EAP	LMI	1
149	Togo	TGO	SSA	LI	1
150	Tonga	TON	EAP	LMI	1
151	**Trinidad & Tobago**	TTO	LAC	UMI	1
152	**Tunisia**	TUN	MENA	LMI	1
153	**Turkey**	TUR	ECA	LMI	1
154	Virgin Islands (US)	VIR	LAC	HInOECD	1
155	Uganda	UGA	SSA	LI	1
156	**United Arab Emirates**	ARE	MENA	HInOECD	1
157	**United Kingdom**	GBR	ECA	HIOECD	1
158	Tanzania	TZA	SSA	LI	1
159	**USA**	USA	NA	HIOECD	1
160	**Uruguay**	URY	LAC	UMI	1
161	**USSR**	USSR	ECA	LMI	15
162	**Venezuela**	VEN	LAC	UMI	1
163	Vietnam	VNM	EAP	LI	1
164	Yemen	YEM	MENA	LI	1
165	**Former Yugoslavia**		ECA	UMI	5
166	Zaire	ZAR	SSA	LI	1

CDIAC World sample (CDIAC geographical areas)	166
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Appendix Table A2: Reconstructed countries:

- Czechoslovakia (Czech Republic & Slovakia):

  CDIAC CO2 emissions 1950-2002 = Czechoslovakia (1950-1991) + Slovakia (1992-2002) + Czech Republic (1992-2002)
  US Census population = Slovakia (1950-2002) + Czech Republic (1950-2002)

- Bangladesh & Pakistan:

  CDIAC CO2 emissions 1950-2002 = East & West Pakistan (1950-1971) + Pakistan (1972-2002) + Bangladesh (1972-2002)
  *US Census populatio*n = Pakistan (1950-2002) + Bangladesh (1950-2002)

- Germany:

  CDIAC CO2 emissions (1950-2002) = Federal Republic of Germany (1950-1990) + German Democratic Republic (1950-1990) + Germany (1991-2002)
  US Census population = Germany (1950-2002)

- Malaysia:

  CDIAC CO2 emissions (1957-2002) = Peninsular Malaysia (1957-1969) + Sabah (1957-1969) + Sarawak (1957-1968 and 1969 corrected) + Malaysia (1970-2002)
  US Census population = Malaysia (1950-2002)

- Netherland Antilles & Aruba:

  CDIAC CO2 emissions (1950-2002) = Netherland Antilles & Aruba (1950-1985) + Netherland Antilles (1986-2002) + Aruba (1986-2002)
  US Census population = Aruba (1950-2002) + Netherland Antilles (1950-2002)

- Rhodesia-Nyasaland (Zimbabwe & Zambia & Malawi):

  CDIAC CO2 emissions (1950-2002) = Rhodesia-Nyasaland (1950-1963) Zimbabwe (1964-2002) + Zambia (1964-2002) + Malawi (1964-2002)
  US Census population = Zimbabwe (1950-2002) + Zambia (1950-2002) + Malawi (1950-2002)

- Rwanda-Urundi (Rwanda & Burundi):

  CDIAC CO2 emissions (1950-2002) = Rwanda-Urundi (1950-1961) + Rwanda (1962-2002) + Burundi (1962-2002)
  US Census population = Rwanda (1950-2002) + Burundi (1950-2002)

- Tanzania (Tanganyika & Zanzibar):

  CDIAC CO2 emissions (1950-2002) = Tanganyika (1950-1969) + Zanzibar (1950-1969) + Tanzania (1970-2002)
  US Census population = Tanzania (1950-2002)

- USSR:

  CDIAC CO2 emissions (1950-2002) = USSR (1950-1991) + Armenia (1992-2002) + Azerbaijan (1992-2002) + Belarus (1992-2002) + Estonia (1992-2002) + Georgia (1992-2002) + Kazakhstan (1992-2002) + Kirghizstan (1992-2002) + Latvia (1992-2002) + Lithuania (1992-2002) + Moldavia (1992-2002) + Russia (1992-2002) + Tajikistan (1992-2002) + Turkmenistan (1992-2002) + Ukraine (1992-2002) + Uzbekistan (1992-2002)
  US Census population = Armenia (1950-2002) + Azerbaijan (1950-2002) + Belarus (1950-2002) + Estonia (1950-2002) + Georgia (1950-2002) + Kazakhstan (1950-2002) + Kirghizstan (1950-2002) + Latvia (1950-2002) + Lithuania (1950-2002) + Moldavia (1950-2002) + Russia (1950-2002) + Tajikistan (1950-2002) + Turkmenistan (1950-2002) + Ukraine (1950-2002) + Uzbekistan (1950-2002)

- Vietnam:

  CDIAC CO2 emissions (1955-2002) = Republic of South Vietnam (1955-1969) + Democratic Republic of Vietnam (1955-1969) + Vietnam (1970-2002)
  US Census population = Vietnam (1950-2002)

- Yemen:

  CDIAC CO2 emissions (1955-2002) = Democratic Yemen (1955-1990) + Former Yemen (1955-1990) + Yemen (1991-2002)
  US Census population = Yemen (1950-2002)

- Yugoslavia:

  CDIAC CO2 emissions (1950-2002) = Yugoslavia (1950-1991) + Bosnia-Herzegovina (1992-2002) + Croatia (1992-2002) + Macedonia (1992-2002) + Serbia & Montenegro (1992-2002) + Slovenia (1992-2002)
  US Census population = Bosnia-Herzegovina (1950-2002) + Croatia (1950-2002) + Macedonia (1950-2002) + Serbia & Montenegro (1950-2002) + Slovenia (1950-2002)