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Breaking Environmental Kuznets Curves. Evaluating Energy and Policy Time Events Effects on CO_2 Trends for Advanced Countries

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Abstract

This paper documents the structural differences among advanced countries with regard to their long run carbon-income relationships. On the basis of a first application of intervention analysis to Environmental Kuznets curves, we show that time related effects, namely structural breaks, have been predominantly relevant in explaining the eventual occurrence of such bell shaped curves. We indeed find great heterogeneity of effects in comparing advanced countries long run performances. The different response in terms of environmental policy and innovation efforts of northern EU to exogenous policy events such as the 1992 climate change Rio convention, that gave earth to the Kyoto era, and to the second oil shock that preceded it in the 80's are among the underlying causes. Environmental policy can be or create the pre conditions to exert long run beneficial shocks to the energy-economic system. Evidence provides food for thought for the post Kyoto era policy making, just after the Rio+20 step.

JEL classification: C22, Q53

Keywords: Carbon Kuznets Curves, Rio convention, policy events, oil shocks, intervention analysis, structural breaks.

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1. Carbon Kuznets curves: exogenous time related events and policy perspectives

Stylized facts have been proposed on the relationship between pollution and economic development. This has become known as the Environmental Kuznets Curve (EKC) hypothesis and has attracted increasing research attention since the pioneering work of Grossman and Krueger (1995), Shafik (1994) and Holtz-Eakins and Selden (1992). A first insight on the main theoretical issues is developed by Andreoni and Levinson (2001); Copeland and Taylor (2004), Anderson and Cavendish (2001) and Brock and Taylor (2010, 2004) later followed. [3] can be found in Copeland and Taylor (2004), Anderson and Cavendish (2001) and Brock and Taylor (2010, 2004). The attention on the further development of EKC studies is still pulsant, as the survey by Carson (2010) shows. Modelling and policy issues are the hottest topics among others.

This paper focuses on the long run CO2 emissions-income relation, or Carbon Kuznets Curves (CKC), which offers the most robust time series data for applying advanced (long-run) panel data econometric techniques. Carbon is relevant also because (absolute) decoupling – that is, negative elasticity in the emissions-economic development relation - is not (yet) apparent for many major world economies (Musolesi et al., 2010). Some studies highlight evidence to support EKC shapes for CO2, but they vary by geographical area and estimation technique (Martinez-Zarzoso and Morancho, 2004; Cole, 2003; Galeotti et al., 2006). This evidence serves to counterbalance the rather pessimistic views of EKCs (see Harbaugh et al., 2002; Millimet, List and Stengos, 2003; Wagner, 2006; Sen and Melenberg, 2011, Luzzati and Orsini, 2009, who focus on energy EKC). Some researchers have extended their analyses to include developing vs. developed countries comparisons (Musolesi et al., 2010) or to investigation of specific developing countries (Nasir and Rehman, 2011; Orubu and Omotor, 2011).

In the case of the more advanced countries, evidence on CKC has grown although some of the results are not robust, and there is evidence of some heterogeneity problems. Also, the causes of decoupling need more investigation (Martinez-Zarzoso and Morancho, 2004). The lack of EKC evidence is confirmed by a compelling paper by Melenberg et al. (2009) on the OECD countries which concludes that a simplistic view of EKC is inappropriate and that time effects may be more relevant than income effects. Melenberg et al. (2009) disentangle income and (common) time related effects for the OECD countries in order to shed light on structural differences related to how different (groups) of countries have reacted to time related factors (policy, energy, technological shocks). Since this separation of income and time effects still leaves unexplored the content of the 'time related effect', [4] in the present paper we specifically investigate the role of potentially 'path breaking' or time related events. We use a time series framework, where we apply intervention analysis to shed light on the eventual role of path breaking events, and we scrutinize such issues as cointegration of the income-environment series, which is becoming an increasingly relevant issue in the EKC literature since the studies by Perman and Stern (2003) and Stern (2004).

We would emphasize the need for proper consideration of the role of exogenous events, such as policy and market shocks, for shaping CKC dynamics. Reactions to historical shocks, such as major policy events and oil price peaks, may differ between groups of countries and different regional areas. This 'historical' path of events and reactions is what determines current observed performance (emissions per GDP). Also, the existence of an EKC curve has often been tested

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[3] Other works followed (among others Pasche, 2002; Smulders and Bretscgher, 2000; Kelly, 2003; Chimeli and Braden, 2005, 2009; Egli and Steger, 2007; Kelly, 2003; Hartman and Kwon, 2005; Khanna and Plassmann, 2007). Kijima et al. (2010) provides a recent survey.

[4] Barassi et al. (2011), state that: "this can be appealing in the case of emissions because country specific (or international) changes in environmental regulations, or historical events (such as world war I and II), although infrequent, may still cause shifts in the deterministics of a country's per capita CO2 series".

for an OECD reference sample, in cross country international frameworks. Results may generally depend on the balance between high income countries showing an inverted U shaped dynamics, and low income OECD countries that continue to show a positive elasticity (Akbostanci et al., 2009). We move beyond that framework and analyze how 'homogeneous' world areas within advanced economies have reacted to time related shocks; including major policy events. At 20 years since then, we especially focus on Rio1992 as structural break.

It should be noted that Kuznets rejected the notion of uniform patterns of development across time and national contexts (Sirquin, 2010). The application of Intervention models in a time series parametric framework - which is the core methdological novelty of the present paper - clearly shows that time related effects or structural breaks, are more relevant than income effects for explaining the occurrence of a Kuznets curve. These different reactions to shocks appear to be extremely significant for understanding the current situation. The different responses (in the form of environmental policies and innovation efforts) of the northern EU countries to exogenous policy events, such as the oil shocks and the Rio 1992 climate change convention that later gave birth the Kyoto protocol (see Huang et al., 2008 for an EKC study focused on Kyoto issues), are among the potential causes of the observed long run structural differences that continue to influence current policy debates and bargaining. In relation to contemporary climate policy, in addition to the occurrence of oil shocks, there is evidence that 'policy' events (e.g. higher carbon taxes, stricter emissions trading system caps) could effectively 'shock' EKC and produce breaks in the income-carbon trends, or a stronger decoupling of emissions from economic growth. In the year of Rio+20 conventions and in a period where the post Kyoto setting is being shaped, it is relevant to understand the extent to which past trends had been influenced by various historical 'events'. If it is the case, attention should be posed to the introduction of credible and substantive policies to tackle CO2 growth (+45% globally since Rio 1992). 2012 witnesses the end of the wobbling 'Kyoto period' and a somewhat inconclusive Rio+20 conventions. Notwithstanding a negative judgment might emerge 20 years since Rio 1992, it is worth noting that some advanced countries have succeeded in curbing emissions while keeping competitiveness. It is extremely relevant to investigate what forces were behind those successes. If some leaders exist, it might be fruitful to learn.

The paper is structured as follows. Section 2 discusses specification issues and explains the econometric methodology, focusing primarily on how events are modeled in a time series setting. Section 3 presents the data and the aggregation of countries. Section 4 comments on the main results of the intervention analysis which focuses on market and policy events. Section 5 concludes with a summary of results and some policy implications.

2. Time series decomposition with known and unknown events

2.1. Evaluating the effect of 'exogenous events' in the CKC framework using intervention analysis

The 'intervention analysis' developed by Box and Tiao (1975) is the (time series) methodology applied here. It decomposes the time series into a stochastic processes, and interventions, such as public policies, which could modify the normal evolution of the time series. Closely related to this work is work that focuses on assessing environmental policies to reduce pollution (Sharma and Khare, 1999; Lee and List, 2004), and the studies by Fomby and Hayes (1990) who examine the impact of redistributive policies in the US, and Lloyd et al. (1998), Murray et al. (1993) and Thompson and Noordewier (1992) who evaluate respectively anti-cartel policies, anti-drinking campaigns and incentive programs in relation to automobile sales.

In the present study we slightly modify the standard intervention analysis and adapt it to the context of a CKC by replacing the ARIMA specification in the stochastic part of the model (usual in intervention analysis) by a polynomial function of per capita income which accounts for CKC structural dynamics.

The intervention we are most interested in is the 1992 UN Framework Convention at Rio. In our view, the Rio convention has been more important than the Kyoto protocol for determining potential breaks in ’country behavior’ in relation to climate change. It is common knowledge that some countries reacted promptly (becoming early movers), for example, by implementing ecological tax reforms aimed at achieving double dividends (Andersen, 2011; Andersen and Ekins, 2009; Andersen et al., 2007), while others (US) continued for two decades to try to postpone these strict and formal abatement targets at the global level. The post Rio framework towards Kyoto has been characterized by leaders and laggards, which makes the 1992-1997 period (pre Kyoto but formally within Kyoto given that targets were related to 1990 figures) extremely significant. The Rio+20 will be held in 2012. Thus, an assessment of the path breaking effects of the years before is timely and important for informing future scenarios.

Our main aim is to verify whether this exogenous time related event has had an effect on the long run carbon-income relationship. It is likely that other events have influenced the time series evolution of emissions; we account for such unknown events and rely on a outlier detection procedure (de Jong and Penzer, 1998).

In relation to the model, we suppose that the evolution over time of per capita CO2 emissions (in log) can be expressed as:

$$y_t = S_t + g\left(\delta, \omega, \psi, t\right) \qquad (1)$$

where S_t is the stochastic component of the model and, in our benchmark specification, is assumed to represent a standard (cubic at first) long-rung CKC, say:

$$S_t = f\left(\mathbf{x}_t, \theta\right) = \theta_0 + \theta_1 x_t + \theta_2 x_t^2 + \theta_3 x_t^3 + \varepsilon_t \qquad (2)$$

where x_t is per capita GDP (in log) and ε_t is a white noise term. The function, $g\left(\delta, \omega, \psi, t\right)$ allows for some deterministic effects of time t, the effects of some exogenous variables, ψ, measured through the vectors of parameters δ and ω; it can be rewritten as the sum of a finite number of interventions:

$$g(\delta, \omega, \psi, t) = \sum_{j=1}^{k} \Upsilon_j \qquad (3)$$

2.2. Searching for breaks

The 1992 UN Framework Convention (and the resulting 1997 Kyoto protocol) can be supposed to have provoked a ‘gradual start, permanent duration’ effect on the long run carbon income trend. This can be modeled combining a step function with an exponential (or first order) transfer function allowing for (eventually) a non-linear effect of the intervention:

$$\psi_t^s = step\_1993_t = \begin{cases} 1, \text{ if } t \geq 1993(4) \\ 0, \text{otherwise} \end{cases}, \qquad (4)$$

$$\Upsilon_1 = [\omega\mathbf{B}/\left(1 - \delta\mathbf{B}\right)]\psi_t^s$$

where $\mathbf{B}$ is the backward shift operator such that $\mathbf{B}^i y_t = y_{t-i}$ .The magnitude of the impact that

occurred after the event is given by ω, and δ is the rate of decay of the variation. When $\delta < 1$ the series will reach a new steady state and the steady state gain is $\omega/(1-\delta)$. When $\delta = 1$, a step change in the input produces instead a ramp function in the output of magnitude ω. Finally, $\delta > 1$ will produce an exponential pattern decay. Depending on the value of δ, the intervention will produce a *permanent* or *transitory* effect (see Box and Tiao, 1975, p. 71-72).
A *linear and permanent* effect can be modelled directly (in a more parsimonious way) using a 'ramp' function:

$$\psi_t^r = ramp\_1993_t = \begin{cases} t-1992, \text{ if } t \geq 1993(6) \\ 0, \text{ otherwise} \end{cases}, \qquad (5)$$

$$\Upsilon_1 = \lambda \psi_t^r$$

where λ measures the magnitude of the change in the trend of the series.
The initial specifications to be estimated can be written as:

$$y_t = \theta_0 + \theta_1 x_t + \theta_2 x_t^2 + \theta_3 x_t^3 + [\omega \mathbf{B}/\left(1-\delta \mathbf{B}\right)]\psi_t^s + \varepsilon_t 5\_A \qquad (8)$$

$$y_t = \theta_0 + \theta_1 x_t + \theta_2 x_t^2 + \theta_3 x_t^3 + \lambda \psi_t^r + \varepsilon_t 5\_B \qquad (9)$$

In that follows the Maximum Likelihood estimation results are provided for both specifications. There is, of course, a trade-off between the greater flexibility of the step function (with exponential transfer function) and the greater parsimony of the ramp function. Thus, standard criteria (Akaike information criteria, AIC, Schwartze-Bayes criteria, SBC) may be used in order to choose the most preferred.
Finally, unknown events, namely ${}_{j=2}^{k}\ \Upsilon_j$, are detected and are added to specification (5) above by using the OUTLIER statement of the ARIMA procedure (we exploit software SAS 9.2) which is based on Jong and Penzer (1998). Typical unkknown events we look for are oil shocks and other energy related events. They are unknown since we do not know in advance the exact time in which the structural break may have happened.

2.3. Cointegration issues

The issues of non stationary variables and co integration are relevant both in the intervention model framework and in the standard CKC analyses because they affect the way the statistical analysis has to be conducted. In the intervention model framework, the identification of the order of integration determines whether the statistical analysis should be conducted on the level or on the differenced series, whereas in the EKC estimation indicates whether co-integration has to be tested, in order to asses that there exists a non-spurious CO2-income relation.
Such issues were however quite neglected in the first wave of EKC studies, mainly due to the presence of cross sectional data and a bias towards the turning point assessment. To date, there has been an increasing interest for such issues within the economics of EKC (Stern, 2004; Perman and Stern, 2003). Recent studies found quite often that both CO2 and GDP have unit roots, even if the results seem to be quite sensitive to the nature of the data (panel or time series), the choice of the tests, the lag order of ADF type tests, accounting for breaks and nonlinearities, etc (see, among others, Barassi et al., 2011; Panopolou and Pantelidis, 2009, Song et al., 2008).

3. The Data

To accomplish the main goal of the paper we categorise countries according to their structural (policy) orientation on climate change issues. We believe that environmental policy, eco-innovation and energy (intensity and fuel mix) are key pillars. Differently from most papers in the literature that either do not differentiate by country or region (e.g. OECD based analysis, which possess limited policy content) or compare developing and advanced countries (one reason is that CKC are hardly expected for developing countries, see Musolesi et al., 2010), three macro 'economic-policy' areas are analysed and compared in the paper.

Very recently Ordas-Criado and Grether (2011) group countries by income and geographical features in a carbon dioxide convergence analysis, taking EU15 as a group among others. We aim at focusing on the analysis of differences and similarity among advanced countries, in order to show which are really 'leaders' among advanced countries and which instead lag behind as far as structural carbon emission abatament is concerned. This turns out to be a reasonable classifcation ex post, at least to represent a (within groups) common CO2-income nexus without incurring in serious missspecification flaws. Environmental policy, eco-innovation and energy issuesare key pillars which are behind our categorisation[5]. Groups are:

(a) The 'Umbrella group'

group (a loose coalition of non EU developed countries formed after Kyoto that has sustained a mild approach to climate policy). We refer to Barrett (2005) for a detailed analysis of the various coalitions that are related to international environmental agreements. We here follow Barrett in defining the Umbrella group.

We remark that even today the Climate change policy commitment of North America and Oceania is drastically different from that of the EU. Norway is rather outside the European climate policy and represents a conclamate outlier.: Australia, Canada, Japan, New Zealand, Norway, U.S.A.

(b) The 'EU North': Belgium, Denmark, Finland, France, Germany, Netherlands, Sweden, U.K.

(c) The 'EU south'[6]: Austria, Greece, Ireland, Italy, Portugal, Spain.

Before and after Kyoto and Rio Convention, the northern EU countries behave quite differently with respect to climate change policies. Scandinavian countries were the only to implement quite full ecological tax reform in the early 90's partly as a consequence of the 1992 Delors white book. The UK and Germany than followed. Ecological tax reforms (Andersen and Ekins, 2009;) are instead still absent both from most if not all (a) and (c) groups for various reasons. The dynamic has not changed since the past periods, with striking examples such a Denmark, a country that collects in environmental taxes 20 times the amount of Italy (4 billions Euros), that has a much larger GDP. A recent OECD paper (Johnstone at al., 2010) shows that (over 2001-2007) stringency is higher in Germany, Denmark, Sweden, with most of (b) having a value higher than 6 (1-7 index), Canada, Japan and US in the middle of the table and Greece, Spain and Italy showing index lower than 5 in an area where some less developed countries stay.

Secondly, recent studies (among others, Johnstone, Hascic and Popp, 2010, Popp, 2002) have presented various evidence on the relation between environmental regulations and green innovations. It is interesting, in examining the trend of EPO patent applications in renewable,

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[5] The ex ante categorisation is complementary to ex post classifications of EKC transitions (Martuani and Martinez-Zarzoso, 2011). We nevertheless move from a classification in three areas to a country specific analysis of time and income related effects, which is the heart of the paper message.

[6] Ireland is included here given that its macroeconomic indicators and performance was (and is) more cohrent with countries such as Spain and Portugal among others.

that the German leadership begins in the late 80's (a period when Germany started to strengthen its environmental policy commitment then influencing most EU Directives) and consolidates in the 90's. Within the EU, the established innovation scoreboard (European Commission, 2009) places Italy, Spain, Greece and Portugal as moderate innovators, and Germany, Sweden, Denmark, Finland (Norway instead presenting a low index) and UK as leaders. R&D figures also shows a strong divide between northern and southern EU countries.

Turning the head to a more global picture, we note that considering again climate friendly patent trends (1978-2006) (Dechezlepretre et al., 2011), while Japan, Germany and the US rank first in terms of patenting activity (EU27 weights 27%), it must be noted that EU weights more than North America and Japan if one looks at inventions that are patented internationally (capturing innovation quality and diffusion.[7] Germany is now first with 22%, UK 6%, US 13%).

Considering energy use per GDP terms, we note that a decrease has been observed for main and richest OECD countries, with even US and Norway leading the path. Japan, US and main EU countries are strongly correlated over 1973-1998. Somewhat differently, we note that energy efficiency of fossil fuel production awards the northern EU (but also Italy, having historically high energy prices) with respect to Canada and the US. Differences are nevertheless less striking compared to policy and innovation, mainly between northern and southern EU countries. The fuel input mix is also relevant, with the coal share significantly reducing energy efficiency and knowledge accumulation (patents) increasing it (Verdolini et al., 2010). The observation of coal and renewable shares highlights further differences, over a period that was characterised by a shrinking of coal and an increase of gas, oil and renewable shares in world primary energy supply. The change in coal-based energy use over 1970-2001 (International Energy Agency energy balances sources) is of -26% for OECD Europe and +90% for OECD North America (comparable in GDP terms), with meaningful details for our reasoning (Australia +130%, US +81%, Canada +82%. The EU witnesses striking different performance (Austria -18%, UK -56%, France -66%, Germany -41%, while 'developing EU countries' such Spain +112% and Greece +600%. We also mention exceptions in the North like Denmark historical reliance on coal, + 92%, Sweden +30%).

Data on emissions are from the database on global, regional, and national fossil fuel CO2 emissions prepared for the US Department of Energy's Carbon Dioxide Information Analysis Centre (CDIAC). For our study, we use the subset of emissions data that matches the available time series on GDP per capita[8] on the basis of joint availability, series continuity, and country definitions.

This resulted in a sample which covers a long time period which is suitable for a policy oriented analysis which aims at providing insights on the structural long term differences. The time series plot of the variables under study are shown in figures 1-3.

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[7] As they note the overall picture hides differences: "Differences are striking: while Germany and Japan follow the general trend described previously; US innovation efforts have remained stable since the end of the 1980s. The trend of innovation in the US seems to closely follow oil prices, which suggests a limited influence of environmental and climate policies". Also "The second period starts in 1990 and is characterized by a decoupling between innovation and oil prices. While innovation steadily increases during the 1990s, oil prices remain relatively stable until 2003".

[8] Data on GDP per capita in 1990 International 'Geary-Khamis' dollars are from the database managed by the OECD.

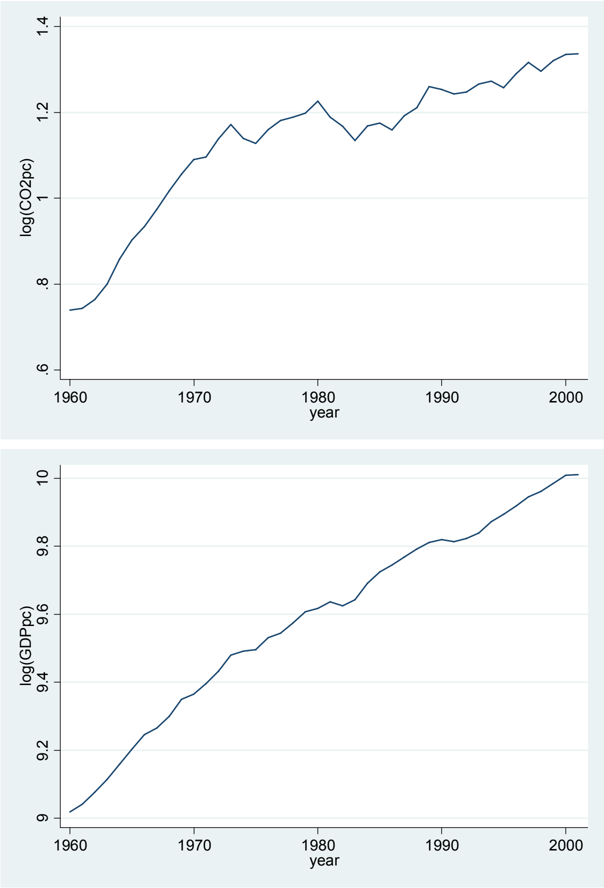

Figure 1. Umbrella group

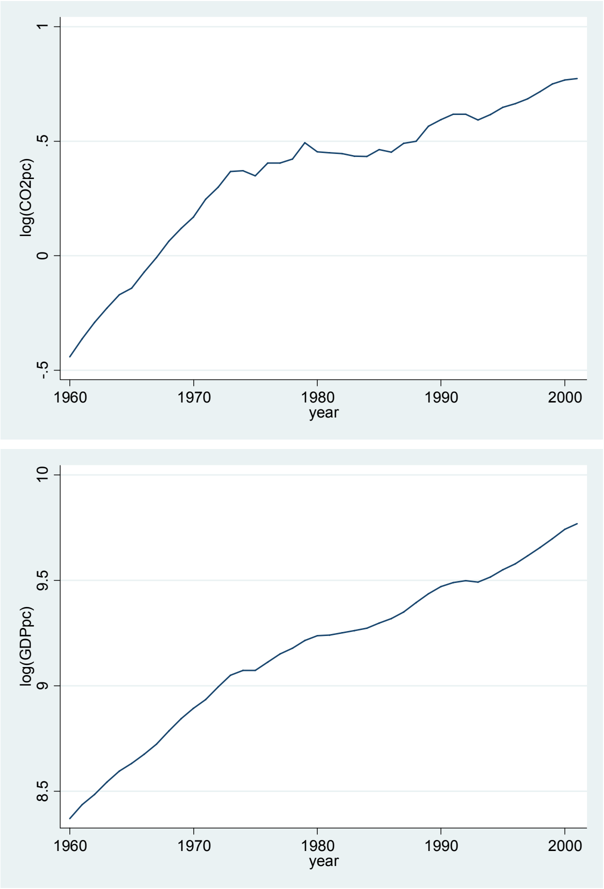

Figure 2. EU-South group

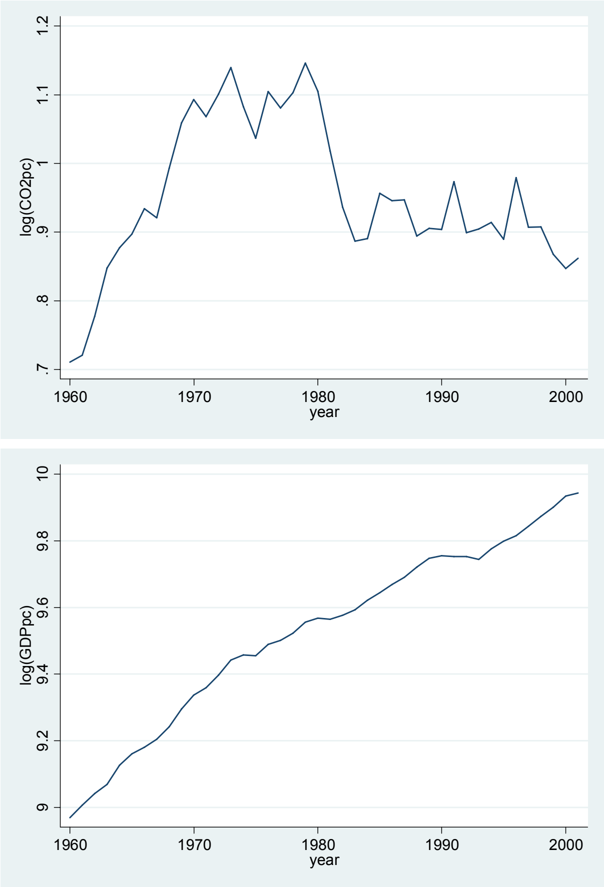

Figure 3. EU-North group

4. Econometric analysis

4.1. Preliminary integration tests

Before estimating the model, a preliminary statistical analysis is conducted in order to detect the order of integration of the variables. We perform the Augmented Dickey-Fuller (ADF) test as a benchmark including a linear time trend in the auxiliary regression and setting the lag order (p) using the AIC starting from an AR(5) model. The ADF tests provide evidence favouring the unit root hypothesis for all the time series.

It is worth noting, however, that since Neslon and Plosser's (1982) seminal work, many econometricians have shown that, for many economic time series, standard unit root tests fail to reject the null hypothesis of a unit root. We therefore conduct other tests, as follows.

First, since unit roots tests applied to time series of moderate sample size may suffer from size distortion, we simulate the p-value of the ADF test on the basis of a AR(p) Gaussian model. Second, we follow Kwiatkowski et al. (1992) who argue that the standard unit root tests are not very powerful against relevant alternatives and propose the so called KPSS test in which the unit root is the null hypothesis to be tested. When we simulate the p-value of the ADF or apply the KPSS test (in table 1) we cannot cross-validate the results of the ADF test for all of the time series under consideration since both tests indicate that the variables are stationary.

Moreover, the failure of the ADF tests to reject the unit root null hypothesis could be due to breaks or non-linearities in the trend function. The idea that a time series can be stationary around a breaking deterministic linear trend, as in Zivot and Andrews (1992) and Perron (1989), was generalised by Park and Choi (1988), Outliaris et al. (1989) and Bierens (1997), who introduced the notion of integration around a deterministic non-linear trend. The notion of non-linear trend stationarity can usefully be applied to the emissions series which is clearly non-linear.

Here, we focus on the Bierens (1997) revised non-linear Dickey-Fuller test. Let denote the Chebishev polynomial as $P_{0,t},\dots,P_{m,t}$ where $P_{0,t}$ equals to 1, $P_{1,t}$ is a linear trend and $P_{2,t},\dots,P_{m,t}$ are cosine functions, the augmented Dickey Fuller test is based on the following auxiliary regression model:

$$\Delta z_t = \alpha z_{t-1} + \sum_{j=1}^{p} \phi_j \Delta z_{t-j} + \theta^T P_{t,n}^m + \varepsilon_t . \qquad (6)$$

Bierens (1997) considers the null unit root hypothesis with drift against the alternative of non-linear trend stationarity, and develops several test statistics:

- $\hat{t}(m)$ is the t-statistic of the estimated coefficient $\hat{\alpha}$
- $\hat{A}(m) = \dfrac{n\hat{\alpha}}{\left|1-\sum_{j=1}^{p}\hat{\phi}_j\right|}$

Since these two tests do not take account of all the available information, Bierens proposes two other tests $\hat{F}(m)$ and $\hat{T}(m)$ for the joint hypothesis that $\hat{\alpha}$ and the last m components of the parameter vector θ are zero. The $\hat{F}(m)$ is a conventional F-test whereas $\hat{T}(m)$ is a χ^2 test based on non-conventional testing principles (for more details, see Camarero and Ordonez, 2008).

Since all the CO2 series appear to have a clear nonlinear shape, we conducted, for such variables, the non-linear ADF test on the basis of the auxiliary regression (6). The lag lag length p has been choosen as for the astandard ADF, i.e. using the AIC starting from an AR(5) and in order to correct for the sise distortion we simulate the critical values using wild bootstrap[9] based on 2000 replications.

The Chebishev time polynomial order m, should be ideally settled in such a way that it provides the best approximation of the non linear trend under the alternative hypothesis. For instance, Bierens (1997) using century and highly nonlinear series, uses two values for m, 10 and 20. From a practical viewpoint, the choice of m is difficult because if a too low order is specified, the tests may lack power due to specification error, but, at the opposite, if the researcher specifies a to high order, the tests may lack power from estimating superfluous parameters. Since the exact magnitude of such opposite effects is not known we have performed the test with m ranging from 3 to 20.

Results in table 2 indicate some striking features. The tests behave similarly for the Umbrella and the southern Europe countries for which the emission series have a low degree of non linearity. For both groups, settling a low value for m is enough for getting stationary series. Indeed, for $m=3$ or 4 the $\hat{t}(m)$ and $\hat{A}(m)$ test reject (right side rejection) the null non stationarity hypothesis but the $\hat{F}(m)$ and $\hat{T}(m)$ test does not reject. The $\hat{t}(m)$ and $\hat{A}(m)$ tests indicate that the process is either (linear trend) stationary or nonlinear trend stationary. In the first case the

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[9] Draw the model errors from normal distribution with zero mean and variance the squared OLS residuals.

$F(m)$ and $T(m)$ test should not reject, and in the second case it should. Therefore, it is possible to conclude that the emission series are, for Umbrella and EU South, nonlinear trend stationary[10]. For the northern Europe the emission series presents a higher level of nonlinearity and similar results with respect to those obtained for the other groups are found for an average level of m (9 and 11)[11].

In summary, after taking into account of : i) the possible size distortion by simulating the p-values, ii) the way the test is conducted by adopting the KPSS test in which the unit root is the null hypothesis to be tested and, iii) by allowing nonlinearities in the trend function (which appears to be very important in the CO2 series), we can conclude that the series are stationary and thus we can follow our analysis without reoccurring to first differencing.

Table 1. ADF with simulated p values and KPSS

Variable	ADF		KPSS	
	Test	Simulated p value	test	conclusion
Log (CO2PC)_Umbrella	-2.0737	0.0450	0.1324	H0 Not rejected at 5%
Log (GDPPC)_Umbrella	-1.8599	0.0300	0.1443	H0 Not rejected at 5%
Log (CO2PC)_nord	-2.4812	0.0550	0.1313	H0 Not rejected at 5%
Log (GDPPC)_nord	-2.3175	0.0390	0.1401	H0 Not rejected at 5%
Log (CO2PC)_sud	-2.4199	0.0410	0.1339	H0 Not rejected at 5%
Log (GDPPC)_sud	-2.2334	0.0395	0.1332	H0 Not rejected at 5%

Note: Since unit roots tests applied to time series of moderate sample size may suffer from size distortion we simulate the p-value of the test on the basis of a AR Gaussian model for y(t)-y(t-1) ADF: p choosen withn AIC starting from AR(5)

KPSS: Null hypothesis H0: z(t) = c + d.t + u(t), where u(t) is a zero-mean stationary process and c and d are constants.
Alternative hypothesis H1: z(t) is a unit root process with drift: z(t) = z(t-1) + c + u(t)
The KPSS test employs a Newey-West type variance estimator of the long-run variance of u(t)

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[10] It is worth to note for high level of m (higher than 15) the tests give the same results. For the Umbrella, when m=20, we should conclude that the series are trend stationary.

[11] in one case, for m=17 we should conclude that this series is trend stationary.

Table 2. BIERENS NONLINEAR ADF

			Simulated p value																		
Variable	p	Test type		m=3	m=4	m=5	m=6	m=7	m=8	m=9	m=10	m=11	m=12	m=13	m=14	m=15	m=16	m=17	m=18	m=19	m=20
Log(CO2PC)_Umbrella	0	t		0.9810	0.9880	0.4670	0.6540	0.6550	0.4250	0.7200	0.8160	0.3730	0.4030	0.3900	0.7000	0.7820	0.7620	0.8790	0.9509	0.9900	0.9990
		A		0.9630	0.9850	0.4880	0.6520	0.6980	0.6420	0.6570	0.8800	0.4270	0.5290	0.5300	0.7260	0.8200	0.8000	0.9150	0.9573	0.9840	0.9990
		F		0.6970	0.4750	0.9490	0.8520	0.8000	0.8500	0.7350	0.7444	0.9080	0.8500	0.8760	0.6290	0.5140	0.4630	0.3730	0.1782	0.0790	0.0330
		T		0.8630	0.7650	0.9950	0.9780	0.9350	0.9400	0.9460	0.9550	0.9660	0.9440	0.9650	0.8710	0.8190	0.7710	0.7500	0.6382	0.5300	0.5700
Log (CO2PC)_nord	0	t		0.8880	0.8940	0.8640	0.6720	0.7060	0.5840	0.9160	0.4760	0.9130	0.7370	0.8110	0.4080	0.5630	0.2470	0.0960	0.1530	0.2787	0.3210
		A		0.8160	0.7840	0.7790	0.6770	0.7130	0.0860	0.9270	0.8440	0.9070	0.6330	0.8500	0.6930	0.4000	0.5150	0.2060	0.2360	0.2867	0.3680
		F		0.6040	0.4150	0.4090	0.5520	0.4670	0.4840	0.1360	0.6340	0.4210	0.4310	0.4500	0.7240	0.6920	0.8910	0.9030	0.8650	0.7713	0.7130
		T		0.7610	0.6420	0.6350	0.8290	0.7190	0.4660	0.4640	0.7060	0.6700	0.6180	0.7580	0.8000	0.7710	0.9350	0.9150	0.8640	0.7980	0.7410
Log (CO2PC)_sud	2	t		0.9950	0.9800	0.2260	0.5280	0.6220	0.8710	0.8980	0.9220	0.8700	0.8410	0.6990	0.5890	0.9860	0.9780	0.9890	0.9770	0.9527	0.9550
		A		0.9860	0.9650	0.2110	0.2000	0.1810	0.6720	0.4660	0.7850	0.3090	0.2380	0.2780	0.1810	0.9580	0.8180	0.3990	0.0420	0.0640	0.0540
		F		0.3180	0.1050	0.8770	0.7070	0.4750	0.5140	0.3710	0.2900	0.3370	0.1960	0.3700	0.5470	0.5530	0.3530	0.2120	0.1320	0.1653	0.1680
		T		0.8620	0.8130	0.9440	0.9190	0.7900	0.6890	0.5750	0.5580	0.6770	0.5800	0.5240	0.5660	0.4990	0.5160	0.6060	0.5280	0.6000	0.5670

4.2. Intervention analysis on carbon Kuznets curves

4.2.1. The Rio 1992 convention

The parameters' estimates for three main groups are in table 3. Real and fitted values are plotted in fig. 4-6. We adopt a maximum likelihood estimation approach (ARIMA procedure available with SAS 9.2). Model specification search has been performed by using a general-to-specific procedure (backward selection).

As far as EU north countries are concerned, when the model is estimated without interventions, both the linear and the quadratic GDP are significant, producing an expected bell-shaped curve. Various scholars have recently observed EKC for such countries which actually are being compliant with Kyoto targets (Galeotti et al., 2009; Musolesi et al., 2010). It is currently of higher interest to investigate more on income and time components of the EKC. In fact, in the model which also contains the interventions, only the linear term of per capita income is significant and positive. Concerning the 'interventions', a negative and highly significant coefficient emerges in association to the trend change after 1992.

The Umbrella and EU-south groups are instead quite similar with regard to the income-environment relationship: first, EKC shapes present a quadratic path with a turning point outside the range of observed values, secondly, the coefficient, representing the trend change λ, is always significant, but positive. The evidence highlights the fact that 1992 Framework Convention did not have a negative effect on their emissions' level.

The positive sign is not totally unexpected insofar even recent data show that most EU south countries have experienced an increase in emissions in the 1998-2008 periods after Kyoto (EEA, 2008) and are still far from being compliant to reduction with respect to 1990 levels

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Overall, we note that the model based on the ramp function is preferred and that the cubic GDP term is never significant. We do believe that this outcome is coherent with the history of the past years: as far as countries with 'proactive' early moving behavior (the nordic ones), they seemingly reacted (Andersen and Ekins, 2009, Andersen, 2011; Ekins and Speck, 2011) well before 1997. The UK as well adopted low carbon service oriented reshifting of the economy well before 1997. In countries where the time series availability of emissions sector data is good (e.g. Italy, Spain) some recent studies has proved that Kyoto was not a significant break overall for the economy, with some sectors even showing increase in emissions, possibly due to a 'back to coal' strategy and decreasing green investments (Marin and Mazzanti, 2011).

4.2.2. Energy shocks

Following the application of the automatic outliers selection procedure another structural break is detected. It is a permanent-gradual shift in the early eighty's (1980) that occurred (only) for the EU North group. This is modelled combining a step function with an exponential transfer function. Thus we introduce a second intervention

$$\psi_t^{s80} = step\_1980_t = \begin{cases} 1, \text{ if } t \geq 1980 \\ 0, \text{ otherwise} \end{cases},$$

$$\Upsilon_2 = [\omega_{80}\mathbf{B}/\left(1-\delta_{80}\mathbf{B}\right)]\psi_t^{s80} \tag{7}$$

and thus, for EU North, the final specification is:

$$y_t = \theta_0 + \theta_1 x_t + \Upsilon_1 + [\omega_{80}\mathbf{B}/1-\delta_{80}\mathbf{B}]\psi_t^{s80} + \varepsilon_t \tag{8}$$

where Υ_1 is alternatively equals to $[\omega\mathbf{B}/\left(1-\delta\mathbf{B}\right)]\psi_t^{s}$ and $\lambda\psi_t^{r}$. The change occurred after 1980 is measured by the parameters ω_{80} and δ_{80} indicating the magnitude of the impact and its decay pattern.

The estimates of ω_{80} appeared to be <0 while that of δ_{80} is <1, indicating a negative nonlinear and highly significant break's path.
The statistical 1980 break can refer to and be economically explained by the second oil shock (namely 1979), with all the consequential effects on the post-recession (1981-82) restructuration phase of advanced economies, beginning around early 80's, which was characterised by efforts towards higher energy efficiency in Northern EU.
For the Umbrella Group, a transitory-abrupt change is also detected in the mid eighty's (1983-87). Therefore the corresponding input is:

$$\psi_t^{s8387} = step\_198387_t = \begin{cases} 1, \text{ if } 1983 \le t \le 1987 \\ 0, \text{ otherwise} \end{cases},$$
$$\Upsilon_2 = \tau \psi_t^{s8387} \tag{9}$$

where τ measures the magnitude of the average impact and the preferred specification for the Umbrella is:

$$y_t = \theta_0 + \theta_1 x_t + \theta_2 x_t^2 + \Upsilon_1 + \tau \psi_t^{s8387} + \varepsilon_t \tag{10}$$

whereas the final specificaton for the EU-south group is

$$y_t = \theta_0 + \theta_1 x_t + \theta_2 x_t^2 + \Upsilon_1 + \varepsilon_t \tag{11}$$

where, as stated before, all the model selection procedures indicate that for the three groups under study, for the first intervention, the ramp function $\Upsilon_1 = \lambda \psi_t^r$ beats the first-order step function $\Upsilon_1 = [\omega \mathbf{B} / (1 - \delta \mathbf{B})] \psi_t^s$.

4.3. Comments

Overall, it seems that the absolute delinking experienced by Northern EU countries is not attributable to 'income related factors' along a typical EKC adage, but is more the outcome of path-breaking reactions to policy shocks and other exogenous 'energy events'. These include the 'climate change Rio convention', the 'Iranian revolution' and associated second oil price shock and the recession in the early 1980s[12]. Analyses confirm that different (groups of) advanced countries reacted differently to market and policy events. The dynamics is explained mostly - in the case of absolute decoupling - by discrete changes rather than by a smooth reshaping of the income-carbon relationship.
Panopoulou and Pantelidis (2009) show that the oil crisis affected carbon 'club' convergence in per capita carbon emissions. Their study on clubs and structural similarity over time shows that while convergence at world level, among all countries, was significant in 1960-85, it was not significant in 1975-2003. Events matter and appear to influence the succeeding income-

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[12] Although the second break in the early 1990s may also be due to the Iraq war causing friction in the oil markets, we believe that the Rio convention was the event that changed the market and policy behavior of northern EU countries more than anything else.

environment relationship. Panopoulou and Pantelidis identified four clubs that can be aggregated into two macro clubs (advanced and not advanced economies), with the EU countries converging in the steady state, which does not contradict but rather complements the present analysis, which has a different focus. We provide evidence that, along the dynamics, even quite similar advanced countries may diverge, that shock events may matter, and that heterogeneity between and within groups is peculiar and worthy of analysis.

The Northern EU countries seem to have taken earlier actions to achieve economic restructuring and environmental policy implementation (see figures A1 and A2 in the appendix for a general picture within the EU)[13]. Since most (innovative and composition effects related) efforts were already in place in 1997, this may partially explain their strong support of the Kyoto targets,.

For example, the UK embarked on a de-carbonization program through a rapid shift from industry to services, and became the leader for climate change policy; Germany and the Scandinavian countries combined policy actions with investment in green technologies. This relative success is not irreversible however. For example, the UK, the current climate change leader of political debates and the main driver of the Northern EU TP in CKC, is experiencing 0.5% annual cuts having exploited the above mentioned benefits of the economy reshuffling towards services and the 'dash for gas' options. The current 20-20-20 EU strategy and further 'policy cuts' on CO2 emissions (-50% in the EU and -80% in the UK by 2050) could present possibilities for new 'exogenous events'. In the meantime, the Southern EU countries, including G8 members such as Italy, seem to be resisting the introduction of stringent carbon policies based on the rather insufficient US administration proposal for a carbon policy target. A key question is whether we are moving towards convergence - or even divergence - in emissions/income ratios between world areas.

Fig. 4 – Intervention analysis. Real and fitted values, Umbrella

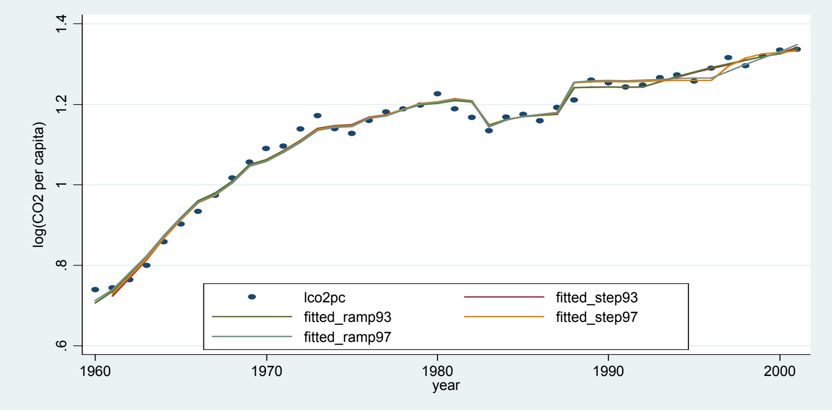
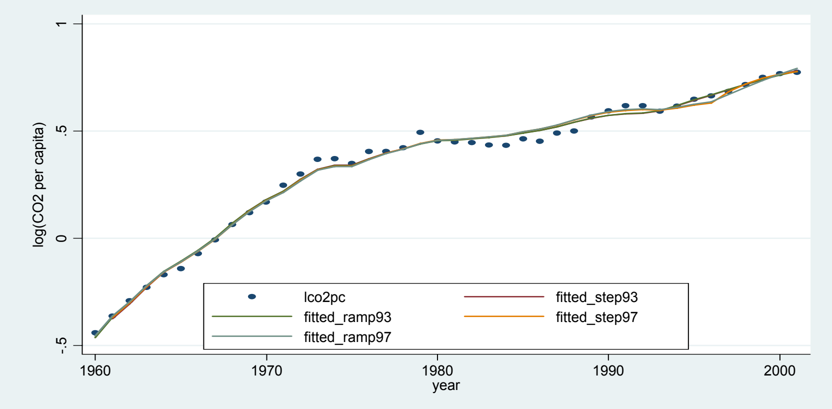


Fig. 5 - Intervention analysis. Real and fitted values, EU south



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[13] Iwata et al. (2010) comment on the role of Nuclear energy for EKC achievements in France.

Fig. 6– Intervention analysis. Real and fitted values, EU North

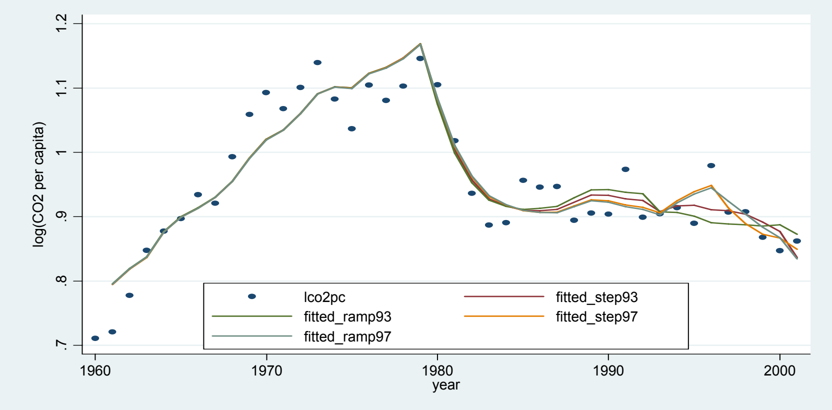

Table 3 – Intervention Analysis.

Specification/param.	θ_0	θ_1	θ_2	θ_3	ω	δ	λ	τ	ω_{80}	δ_{80}	AIC	SBC
UMBRELLA												
CKC_ML	-48.65(00)	9.90(00)	-.49(00)								-161.38	-156.169
Intervention_Step_1993	-79.33(.00)	16.39(.00)	-.83(.00)	-	.013(.01)	1.02(.00)		-.06(.00)			-209.26	-198.98
Intervention_Ramp_1993	-74.91(.00)	15.47(.00)	-.78(.00)	-			.013(.00)	-.06(.00)			-212.03	-203.34
Intervention_Step_1997	-71.65(.00)	14.75(.00)	-.75(.00)	-	.04(.01)	.57(.02)		-.07(.00)			-201.86	-191.57
Intervention_Ramp_1997	-66.66(.00)	13.70(.00)	-.69(.00)	-			.018(.00)	-.07(.00)			-204.88	-196.19
EU_SOUTH												
CKC_ML	-36.01(00)	7.167(00)	-35(00)								-170.76	-165.55
Intervention_Step_1993	-49.95(.00)	10.29(.00)	-.52(.00)	-	.015(.03)	1.02(.00)					-179.53	-170.97
Intervention_Ramp_1993	-47.99(.00)	9.86(.00)	-.50(.00)	-			.014(.00)				-185.75	-178.80
Intervention_Step_1997	-45.00(.00)	9.18(.00)	-.46(.00)	-	.041(.04)	.61(.04)					-174.28	-165.72
Intervention_Ramp_1997	-.43.00(.00)	8.73(.00)	-.43(.00)	-			.020(.00)				-179.72	-172.78
EU_NORTH												
CKC_ML	-108.81(00)	23.17(00)	-1.22(00)								-111.52	-106.308
Intervention_Step_1993	-5.34(.00)	.68(.00)	-	-	-.01(.17)	1.22(.00)			-.10(.00)	.74(.00)	-142.56	-132.28
Intervention_Ramp_1993	-5.32(.00)	.68(.00)	-	-			-.02(.00)		-.10(.00)	.72(.00)	-141.69	-133.40
Intervention_Step_1997	-5.33(.00)	.68(.00)	-	-	-.05(.02)	.81(.00)			-.09(.00)	.77(.00)	-144.73	-134.46
Intervention_Ramp_1997	-5.31(.00)	.68(.00)	-	-			-.04(.00)		-.09(.00)	.77(.00)	-146.07	-137.51

p values in brackets

5. Conclusions

The analysis in this study provides new evidence on carbon Kuznets curves. We add insights from a time related and policy perspective. We shed light on the exogenous factors that might have affected long run carbon-income performance of advanced countries - the only that can eventually present EKC, by using intervention analysis techniques – which might capture market and policy related time events. It is, to our knowledge, the first application of intervention analysis to the realm of EKC. The technique is capable of offering new knowledge on the various factors that might have driven the inverted U shaped income-carbon relationship. It specifically addresses questions regarding the weights of income and time related factors. The latter include time events that are capable of breaking series and cause turning points.

We find that the Umbrella and EU South groups, which were and still are less favorably disposed to stringent climate policies, have not reacted proactively to historic 'carbon-related' market or policy shocks. We found some robust signs that the absolute delinking associated with the Northern EU countries may be largely due to environmental policy and induced innovation responses to the exogenous shocks that occurred in the 1980s and early 1990s, which is evidence of some path dependency in CKC. It might be that this group of countries took advantage of the oil shocks to restructure their economies and therefore took early action towards achieving 'green' technological competitive advantage. These pre-Kyoto facts largely explain the strong commitment of these countries towards climate change, since they were positioned and already on the track in 1997 to meet targets set with reference to 1990.

The evidence provided in this paper may be an additional example of the fallacy of a simplistic EKC argument to which we suggest precise contents. Although per capita income levels may be comparable, different innovation and policy responses and dynamics can lead to quite different emissions performance. Thus, the way income influences environmental quality cannot be expected to be a timeless relationship. This may provide useful food for thought as we just experienced a quite inconclusive Rio+20 meeting. While we try to set the post Kyoto regulatory framework in face of CO2 emissions that have globally risen by 45% over the past 20 years, we should keep in mind that some countries – highly ranked in economic competitiveness - have succeeded in cutting CO2 and exogenous policy 'shocks' matter. Economic history is characterized by discrete changes and shock events might help restructuring economies faster. Their short run economic costs might well be balanced by net benefits in the long run.

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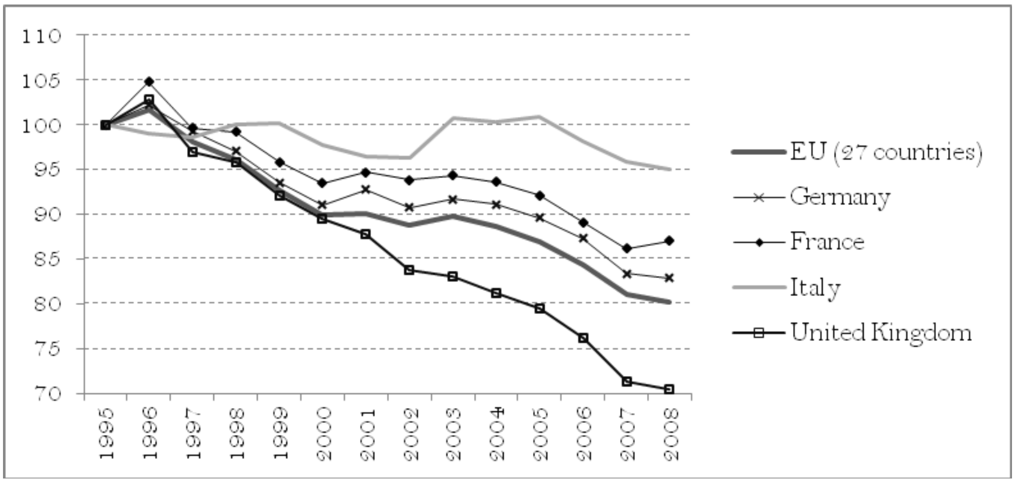
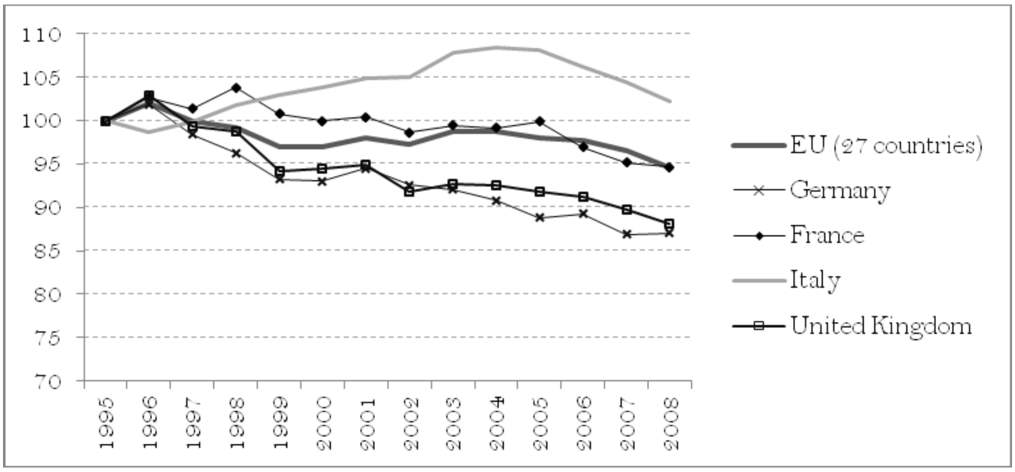
Appendix

Table A1 – Energy Intensity (energy / GDP)



Source: Eurostat

Table A2 – GHG



Source: Eurostat