Investigating the impact of national income on environmental pollution. International evidence

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Abstract

This paper analyses how national income (per capita real GDP) influences the environmental pollution (per capita CO_2 emissions) using a very heterogenous sample composed by 120 countries during the 2000-2009 period. We firstly apply a panel unit root test suggested by Im et al. (2003) in order to examine the stationarity properties of CO_2 emissions and GDP and then a two-step Generalized Method of Moments (GMM) estimator, paying particular attention to the non-linearity of the national income-environmental pollution relationship, to investigate the existence of a Kuznets curve for CO_2 emissions. Preliminary evidence showing the existence of an inverted U-shaped relationship between national income and environmental pollution, validating the Kutznes's hypothesis, turned out to be measleading once the issue of (non) stationarity has been taken into account. Results also show that as population and industrial output expand, more pressure will be put forth the environment, leading to more emissions, calling for more strict environmental and energy conservation policies.

Keywords: National income; Environmental pollution; U-shaped relationship; Kutznes's hypothesis

JEL Codes: C12; C13; C23; F18; Q51

1. *Introduction*

Air pollution and its reduction, primarily caused by carbon dioxide (CO_2) emissions into the environment, is recognized as one of the main themes at the heart of the international debate for climate change as well as a major public concern that governments are trying to solve in the agenda of the 21st century policy. In order to reduce greenhouse gases that cause climate change, the growing economy of countries has prompted governments to make interventions through intergovernmental negotiations and binding agreements – one of the most important is represented by Kyoto protocol signed in 1997 – with the idea of providing constraints to the environmental pollutants as well as providing a multi-years emission reduction process and working schedule. Although the concerted effort, global warning and climate change are still ongoing world-wide concerns. As President Barack Obama remarked *"there's one issue that will define the contours of this century more dramatically than any other, and that is the urgent and growing threat of a changing climate"* (United Nations Climate Change Summit, 2014).

The relationship between environmental quality and economic growth has been intensively empirically analyzed over the past two decades; one of the most important and widely supported line of research focused the attention on the emissions-income nexus using the so-called Environmental Kuznets Curve (EKC) concept[1]. More specifically, according to the EKC hypothesis, economic growth can be beneficial to environmental conditions after that the economy has reached a sufficient level of economic growth. Grossman and Krueger (1995) first propose and test the EKC hypothesis arguing that the relationship between environmental pollution and national income follows an inverted U-curve; in other words, pollution levels initially increase as a country develops and then eventually decline. Scale, composition and technique effects could be blamed, according to Antweiler et al. (2001) and Coxhead (2003), to explain this non-linear relationship. Indeed, on one hand pollution increases as the size of the economy increases (scale effect) and as the production structure of an economy moves from being agricolture to more industry focused (composition effect). On the other hand, these two effects are mitigated by the effects of technological changes on environmental quality such that the amount of pollutant emissions per unit of output may decrease due to the higher quality of techniques and to higher energy efficiency levels. Technical progress indeed includes any improvement in the production techniques, which results in less use of inputs and in the adoption of less polluting technologies in the production process of goods; in other words, such advances in technology over time seem to be the main causes of improved environmental quality (Shafic and Bandyopadhyay, 1992). Institutions such as environmental regulations are also improved with increasing per capita income and might play an important role, too.

Over time, an increasing number of studies analysed the economic growth-environmental pollution nexus within the EKC framework, even though the empirical results appear to be very ambiguos and mixed. Following the first empirical evidence of the EKC existence by Grossman and Krueger (1995) and Selden and Song (1995), evidence supporting an inverted U-shaped function for CO_2 emission has been found (Hettige et al. 1992; Cropper and Griffiths, 1994; DeBruyn et al., 1998; Heil and Selden, 2001; Lindmark, 2002; Martinez-Zarzoso and Bengochea-Morancho, 2004; Vollebergh and Kemfert,

[1]Kuznets (1955) predicted that the changing relationship between per capita income and income inequality is an inverted U-shaped curve. As per capita income increases, income inequality also increases at first and then starts declining after a turning point. This relationship between per capita income and income inequality can be represented by a bell-shaped curve. This observed phenomenon is described as the Kuznet curve (KC). In the 1990s and onwards, the KC took on a new existence. There is evidence that the level of environmental degradation and income per capita follows the same inverted U-shaped relationship as does income inequality and income per capita in the original KC. As a result, the Kuznets curve has become a tool for describing the relationship between the measured levels of environmental quality indicators such as CO_2 and income per capita.

2005; Cole, 2005; Galeotti et al., 2006; Jalil and Mahmud, 2009; Narayan and Narayan, 2010; Kasman and Duman, 2015). Part of the literature is, instead, still skeptical of the optimistic view that economic growth naturally leads to improvements in environmental quality, and does not show evidence in favour of the environmental Kutnetz curve (see for instance Kunnas and Myllyntanous, 2007; Halicoglu, 2009; Aslanidis and Iranzo, 2009; Luzzati and Orsini, 2009; Jaunky, 2011). Pollutant emissions have also been found to be monotonically increasing with income levels (Shafik, 1994; Holtz-Eakin and Selden, 1995; Iwata et al. 2011). Mixed evidence has been found by Coondoo and Dinda (2008), Lee et al. (2009), Dutt (2009) and Zanin and Marra (2012). For an extensive and careful review survey of the studies testing the EKC see Stern (2004) and Dinda (2004)[2].

This paper contributes to the literature providing a new international evidence of the nexus between environmental degradation and national income, giving particular attention to the non-linearity of this relationship and to the effect of Kyoto agreement on the estimation. Specifically, a large heterogenous sample consisting of 120 countries has been analysed (see Section 3 for more information about its composition). We firstly test, by using the recent technique suggested by Lind and Mehlum (2010), the existence of the inverted U-shaped between per capita CO_2 emissions and per capita real GDP; this test gives the exact necessary and sufficient conditions for examining the existence of a U-shaped relationship in both finite samples and for a large class of models. Secondly, in order to take into account the issue of (non) stationarity of CO_2 and GPD, and to see whether these variables follow a stationary trend, we apply the panel unit root test suggested by Im et al. (2003). Thirdly, through a two-step Generalized Method of Moments (GMM) estimator proposed by Arellano and Bond (1991), and paying particular attention to the non-linearity of the national income-environmental pollution relationship and to the effect of the Kyoto agreement, we investigate the existence of a Kuznets curve for CO_2 emissions as well as the impact of national income, electric power consumption, trade freedom and urban population on environmental pollution. Finally, in order to check whether different subsamples or panels could affect the results, we repeat the analysis by selecting countries according to their geographical location and income distribution.

To anticipate our results, firstly we find a strong evidence of a nonlinear relationship between national income and environmental pollution, validating the Kutznes's hypothesis; once we have taken into account the (non) stationarity of CO_2 emissions and GDP, no evidence of environmental Kutnets curve has been found, being the relationship between national income and environmental pollution positive and monotone. Results also show that as population and industrial output expand, more pressure will be put forth the environment, leading to more emissions, calling for more strict environmental and energy conservation policies.

The rest of paper is organised as follows. Section 2 introduces the methodology to assess the nexus above described. A description of the data is presented in Section 3, while Sections 4 presents the empirical evidence and some robustness check; finally, Section 5 concludes.

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[2] Although many studies attempt to test the EKC hypothesis, the mixed empirical evidence is also due to the fact that the EKC concept is open to criticism in various directions such as the normal distribution of income (Stern et al., 1996), the fact that causality may run from income to environmental degradation (Arrow et al., 1995), the presence of different outcomes depending on the pollutant in question (Arrow et al., 1995; Lieb, 2003), the methodology used in empirical EKC-studies, like the use of panel data instead of time-series data (List and Gallet, 1999) and various econometric problems in estimation (Müller-Fürstenberger and Wagner, 2007). For a complete review of the major features and critiques behind the EKC concept see Kaika and Zervas (2013a, 2013b).

2. *The Empirical Strategy*

Following the recent empirical literature such as Ang (2007), Iwata et al. (2011) and Ozturk and Acaravci (2010a) and in particular the non linear evidence suggested by the Lind and Mehlum (2010) test, it is plausible to assess the relationship between environmental pollution and national income in linear quadratic form with a view of testing the validity of the EKC hypothesis using the following equation:

$$C_{it} = \alpha_0 + \alpha_1 Y_{it} + \alpha_2 Y_{it}^2 + \alpha_3 Z_{it} + \varepsilon_{it} \qquad (1)$$

where C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement, including carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring); Y is per capita real GDP in constant US dollars, at base year 2000; Z is the vector of exogenous variables composed by: Electric Power Consumption (Z_1) - see Ang 2007; Halicioglu, 2009; Jalil and Mahmud, 2009; Ozturk and Acaravci, 2010b; Saabori and Sulaiman, 2013; Trade Freedom (Z_2) - see Jalil and Mahmud, 2009; Sharma, 2011); and Urban Population (Z_3) - see Sharma, 2011[3]. Finally ε_{i_t} is the error term.

Based on EKC hypothesis values of α_1 and α_2 indicate different functional forms:

- $\alpha_1 = \alpha_2 = 0$ indicates a level relationship;
- $\alpha_1 < 0$ and $\alpha_2 = 0$ indicates a monotonically decreasing linear relationship;
- $\alpha_1 > 0$ and $\alpha_2 = 0$, indicates a monotonically increasing linear relationship;
- $\alpha 1 > 0$ and $\alpha_2 > 0$, represents U-shaped relationship and
- $\alpha 1 < 0$ and $\alpha_2 > 0$, indicates an inverted U-shaped relationship, hence the EKC.

In the last case, per capita emissions is $Y^* = -\alpha_1/2\alpha_2$. If the variable Y is measured in logs, then exp(Y) will yield the monetary value representing the turning point or the peak of the EKC. In order to analyse how national income influences environmental pollution, we use the two-step generalized method of moment (GMM) estimator developed by Arellano and Bond (1991) with Windmeijer (2005) corrected standard error in a balanced panel context composed by 120 countries (see for instance Sharma, 2011).[4] The use of panel ordinary least squares (OLS) estimator (with fixed and random effects) is problematic due to the correlation between lagged dependent variable and error term. In this study this problem has solved by using the Arellano and Bond (1991) approach taking the first differences in the regression model. The instruments in

[3] Electric power consumpation measures the production of power plants and combined heat and power plants less trasmission, distribution, and transformation losses and own use by heat and power plants. The trade freedom score is based on two inputs: The trade-weighted average tariff rate, Non-tariff barriers (NTBs). Weighted average tariffs is a purely quantitative measure and accounts for the basic calculation of the score. The presence of NTBs in a country affects its trade freedom score by incurring a penalty of up to 20 percentage points, or one-fifth of the maximum score. The country's trade freedom ranges between 0 and 100, where 100 represents the maximum degree of trade freedom. Urban population (Source: World Bank) refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects.

[4] The GMM technique allow to overcome an important econometric issue due to the omitted variable bias (Stern, 2004) which concerns three sub-subjects: differences between the parameters of the random-effects and fixed-effects models (using a Hausman test), differences between the estimated coefficients in different sub-samples and the tests for serial correlation.

levels are not included because the GMM estimator suffers from the problem of weak instruments when the variance ratio of the individual effects to the disturbance is large, as could be in our case (see Blundell and Bond, 1998; Hayakawa, 2007; Bun and Windmeijer, 2010). As suggested by the procedure to test the unit root developed by Im et al. (2003), almost all variables do not follow a stationary trend in their level form (see section 5 for more details on this test). Then all variables are measured in growth form in order to make stationary trend.[5] The model is then described as follows:

$$\Delta C_{it} = \alpha_0 + \alpha_1 \Delta Y_{it} + \alpha_2 \Delta Y_{it}^2 + \alpha_3 \Delta Z_{it} + \varepsilon_{it} \tag{2}$$

where Δ denotes the first difference in order to obtain the variables in growth form. Moreover, one of the main advantages of this estimator consists in dealing with the endogeneity problems between CO_2 emission and real GDP, including lagged differences as instruments for real GDP, and in presenting good fit especially when N is large and T is small, as in our case. As usual, the correctness of the model is checked with the Sargan test of over-identifying restrictions for validity of instruments, while the Arellano–Bond test is used for testing autocorrelation between error terms over time[6].

3. Data Source and Variables

We extract all information about CO_2 emissions (C) (metric tons per capita) from Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads), per capita real GDP (Y) (constant 2000 US$) from Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html), Electric Power Consumption (Z_1) (kWh per capita) and Urban Population (Z_3) (% of total) from World Bank (Group, 2012, 19-05-2014; ; http://data.worldbank.org/data-catalog/world-development-indicators) and finally Trade Freedom (Z_2) from Heritage Foundation (http://www.heritage.org/index/exploreI). Data refers to the 2000–2009 period comprising 120 countries (see Table 1 for more details about descriptive statistics of the variables).

[Insert Table 1 around here]

The specific countries selected for this study and the timeframe was dictated by data availability and the need for a balanced panel. In order to provide a good explanation about the composition of the sample, these countries are clustered in the following way: (i) by geographical location and (ii) by income distribution[7].

According to the first stratification, we have seven clusters such as:

REG_1: East Asia and Pacific (11.67 % of our sample) (Australia, Cambodia, China, Indonesia, Japan, Korea, Noth

[5] The early EKC-estimations involve potentially non-stationary variables which must satisfy the cointegration property, otherwise regressions may be "spurious" (Aslanidis and Iranzo, 2009). In fact, the GDP series alone, is a non- stationary variable (I(1) process). The presence of non-stationary series invalidates the use of standard unit root tests and cointegration techniques in a time-series or a panel context, so any findings obtained in such studies are highly questionable (Müller-Fürstenberger and Wagner, 2007). If unit root tests indicate a unit root in each series then all series should be integrated of the same order. Lee and Lee (2009), estimate that the series of real GDP and CO_2 emissions are a mixture of stationary and non-stationary series, so panel root tests can lead to misleading inferences while cointegration analysis is perhaps an inappropriate method (Lee and Lee, 2009).

[6] All the empirical tests and estimations have been performed using the STATA 13 software.

[7] The sub-samples are constructed following the OECD definition.

Korea, South Malaysia, Mongolia, Myanmar, New Zealand, Philippines, Singapore, Thailand);

REG_2: Europe and Central Asia (36.67 % of our sample) (Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Greece, Hungary, Iceland, Ireland, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slavakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan);

REG_3: Latin America and Caribbean (18.33 % of our sample) (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela);

REG_4: Middle East and North Africa (14.17 % of our sample) (Bahrain, Egypt, Iran, Israel, Jordan, Kuwait, Lebanon, Libya, Malta, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Arab Emirates United);

REG_5: North America (1.67 % of our sample) (Canada, United States);

REG_6: South Asia (4.17 % of our sample) (Bangladesh, India, Nepal, Pakistan, Sri Lanka);

REG_7: Sub Saharan Africa (13.33 % of our sample) (Botswana, Cameroon, Congo, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Kenya, Mozambique, Namibia, Nigeria, Senegal, South Africa, Tanzania, Zambia, Zimbabwe).

According to the second stratification, we have five clusters such as:

INC_1: High Income – OECD (25 % of our sample) (Australia, Austria, Belgium. Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South of Korea, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slavakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, Uzbekistan, United States);

INC_2: High Income – non OECD (12.5 % of our sample) (Bahrain, Croatia, Cyprus, Kuwait, Latvia, Lithuania, Malta, Oman, Qatar, Russia, Saudi Arabia, Singapore, Trinidad and Tobago, United Arab Emirates, Uruguay);

INC_3: Low Income (10 % of our sample) (Bangladesh, Cambodia, Ethiopia, Haiti, Kenya, North Korea, Mozambique, Myanmar, Nepal, Tajikistan, Tanzania, Zimbabwe);

INC_4: Lower middle income (23.3 % of our sample) (Armenia, Bolivia, Cameroon, Congo, Cote d'Ivoire, Egypt, El Salvador, Georgia, Gnana, Guatemala, Honduras, India, Indonesia, Kyrgyzstan, Moldova, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Senegal, Sri Lanka, Syria, Ukraine, Uzbekistan, Zambia);

INC_5: Upper middle income (29.7 % of our sample) (Albania, Algeria, Argentina, Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, China, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Gabon, Hungary, Iran, Jamaica, Jordan, Kazakhastan, Lebanon, Libya, Malaysia, Mexico, Namibia, Panama, Peru, Romania, South Africa, Thailand, Tunisia, Turkey, Turkmenistan, Venezuela).

As expected, we can notice that groups that present higher values with respect to per capita CO_2 emissions, real per capita GDP and the vector of (Z) (electric power consumption, trade freedom and urban population) are REG_5 (for geographical localisation, i.e. North America) and INC_1 (for income distribution, i.e. High income - OECD). On the other side, the groups that present lower values are REG_6 (for geographical localisation, i.e. South Asia) and INC_3 (for income distribution, i.e.

Low income). The descriptive statistics provided in Table 1 are useful in order to understand if our empirical evidence are influenced by these groups. See Figures 1 and 2 for a graphical representation of per capita CO_2 emissions and real capita GDP according to the country geographical location and income distribution.

[Insert Figures 1 and 2 around here]

4. Empirical Evidence

4.1. Is the EKC hypothesis satisfied?

The empirical analysis aims to verify how per capita real GDP (constant 2000 US$) influences per capita CO_2 emissions during the 2000-2009 period, paying particular attention to the non-linearity of their relationship and to the effects of the Kyoto agreement, and more specifically to investigate the existence of a Kuznets curve for CO_2 emissions as well as the impact of national income, electric power consumption, trade freedom and urban population on environmental pollution

Firstly, by using the technique suggested by Lind and Mehlum (2010), we test the existence of the inverted U-shaped[8] between per capita CO_2 emissions and per capita real GDP, also including other determinants explaining CO_2 emissions in the model (electric power consumpation, trade freedom and urban population) and time trend in order to control for the unobservable exogenous effects (see Tables 2 and 3).

[Insert Tables 2 and 3 around here]

More specifically, Table 2 (results do not change when the timing is included) presents the test both for the entire sample and by excluding different subsamples according to the country geographical location; Table 3, instead, lists the test for different sub-samples by excluding countries according to their income distribution. Overall the data validates the existence of the inverted U-shaped between environmental pollution and national income (we reject the H_0: Monotone or U shape); in order to take this into account, we use both per capita real GDP and the square of per capita real GDP.

Then, we proceed to analyse the relationship between environmental pollution and national income by employing the GMM technique (see Tables 4 and 5), including in the regression other determinants of CO_2 emissions such as electric power consumption, trade freedom and urban population. We start to describe the results considering the entire sample, without Kyoto dummy (assuming value 1 after 2005, 0 otherwise), including the square of per capita real GDP (see column A of Table 4) in order allow for the non-linearity suggested by Lind and Mehlum (2010) test[9]. It is important to underline that the presence of non-stationarity among data has not been expolored so far, therefore all variables are measured in their level form as showed in equation 1 above.

[Insert Table 4 around here]

Results validate the existence of an inverted U-Shaped between per capita CO_2 emissions and per capita real GDP confirming the empirical evidence showed, for instance, by Martinez-Zarzoso and Bengochea-Morancho, 2004; Vollebergh and Kemfert, 2005; Cole, 2005; Galeotti et al., 2006; in other words, in the first phase the increase of GDP tends to increase

[8] Lind and Mehlum (2010) tests for the following hypotheses: H_1: Inverse U shape; H_0: Monotone or U shape.
[9] Results without the use of square of per capita GDP are available on request.

CO_2 emissions. In the second phase, the increase in GDP reduces CO_2 emissions. We rationalise this evidence because the increase in GDP produces greater technical progress. A greater degree of technology, especially in the field of environmental patents, reduces CO_2 emissions. As Kaika and Zervas (2013a) pointed out, the economic growth process lead to a more equitable income distribution, improving the relative position of the median citizen; as a consequence, public attention to the environment degradation increases as well as more suitable environmental regulations are imposed on the economy. With regard to the determinants of CO_2 emissions, the empirical evidence shows that the use of electric power consumption (Z_1) has a positive but not statistically significant effect on the CO_2 emissions. Trade freedom (Z_2), instead, has a positive and statistically insignificant impact on the CO_2 emissions confirming that an EKC-pattern may appear as a result of international trade, on the extent that trade openess helps the expansion of an economy through increased production of (pollution-intensive) goods to support its exports. Finally, the urban population (Z_3) has found to have a negative but not statistically significant influence on the CO_2 emissions. In all regression, the Arellano–Bond test results vouch in most cases for the appropriateness of the 1st-order autoregressive specification. The Sargan tests are also insignificant, validating the robustness of our evidence. Results are confirmed when the Kyoto dummy has been included (see column AA of Table 4) which, as expected, has a negative and statistically significant detrimental effect on CO2 emissions.

In order to check whether different subsamples or panels could affect the results, we repeat the analysis by selecting countries according to their geographical location and income distribution (see columns A_1-A_7 and AA_1-AA_7 in Table 4 and columns B_1-B_5 and BB_1-BB_5 in Table 5). Specifically considering the sample with KYOTO dummy, including the square of per capita real GDP and selecting the countries according to their geographical area (see columns AA_1-AA_7 in Table 4), we find that especially excluding REG_2 (Europe and Central Asia), REG_3 (Latin America and Caribbean), REG_6 (South Asia) and REG_7 (Sub Saharan Africa), real per capita GDP loses its statistical significance effect on the environmental pollution. So, the empirical evidence suggests that these regions are important drivers in explaining CO_2 emissions. We then select countries according to their income distribution and test whether estimates are affected; in other words, this exercise allows us to understand how areas with high income could affect the results; indeed, as pointed out by Cantore and Padilla (2010), differences in GDP per capita between rich and poor regions are significant determinants of emission distribution among countries. Regression including the square of real GDP, without KYOTO (see columns B_1-B_5 in Table 5) and with Kyoto dummy (see columns BB_1-BB_5 in Table 5), show the existence of the inverted U-Shaped between per capita CO_2 emissions and per capita real GDP only when OECD-high income countries (INC_1) are excluded form the sample (see columns B_1 and BB_1 in table 5), suggesting that those countries seem to be strong drivers of CO_2 emissions.

[Insert Table 5 around here]

4.2. Results of the Im et al. (2003) test

So far, the empirical evidence confirms the existence of an inverted U-shaped relationship between national income and environmental pollution, validating the Kutznes's hypothesis. However, as suggested by Lee and Lee (2009), do not take into account the issue of (non) stationarity of CO_2 emissions and GDP could lead to misleading results and to inappropriate conclusions even though the questions is still debated in the existing literature; indeed, by using the panel unit root test procedure of Im et al. (2003), previous studies have concluded that GDP and CO_2 emissions in a panel data framework are

best characterized as a unit root, thus supporting the use of a panel cointegration structure for the estimation of the long-run nexus between GDP and emissions (Perman and Stern, 2003; Dinda and Coondoo, 2006; Richmond and Kaufmann, 2006; Omri et al. 2014). The non-stationarity in both per capita real GDP and CO_2 emission levels has also been found by using Dickey and Fuller (1979) test (see for instance Friedl and Getzner, 2003; Kanjilal and Ghosh, 2002). See Strazicich and List (2003), instead, for a different result supporting a stationary series where shocks to a country's relative per capita CO_2 emissions have temporary effects and per capita emissions stochastically converge (by using Im et al. 2003 test). The same evidence in favour of stationarity has also been found by Lee and Chang (2008), Chang and Lee (2008). Nguyen-Van (2005), by applying non-parametric methods, found evidence that industrial countries show a convergence pattern, but little evidence for the developing countries. See also Lee and Lee (2009) who apply the unit-root test of the panel seemingly unrelated regressions augmented Dickey–Fuller (SURADF) developed by Breuer et al. (2001) finding that real GDP and CO_2 emissions in the countries analyzed are a mixture of I (0) and I (1) processes.
Therefore, by using the panel unit root test proposed by Im et al. (2003), we check whether the variables follow a stationary trend, in which the optimal lags of the variables are identified using the Akaike information criterion. The objective is to decide which variables should enter in the proposed model in growth form and which variables should enter the model in their level form. The results of the unit root test for different subsamples or panels are summarized in Tables 6 and 7, excluding and including time trend for demeaining data.

[Insert Tables 6 and 7 around here]

In order to give more credit to our findings, the same test is also performed by different subsamples or panels, i.e. excluding countries belonging to the same geographical location or region and countries having the same income distribution. Almost in all cases, it can be notice that for all variables the unit root null hypothesis is not rejected; this is true especially when time trend is not included, which we consider our beanchmark estimation (see the first column in Table 6). This implies that all variables are not stationary (conforming the empirical evidence showed by Perman and Stern, 2003; Dinda and Coondoo, 2006; Richmond and Kaufmann, 2006) and they have to enter in the proposed model in growth form. For more clarification, the test is also performed taking variables in growth form. As expected the variables in growth form follow a stationary trend[10].

4.3. Is the EKC hypothesis confirmed?

We proceed to analyse the relationship between environmental pollution and national income employng the GMM technique (see Tables 8 and 9), where variables are taken in growth form as suggested by the Im et al. (2003) unit root test (see Tables 6 and 7). Again, we include in the regression other determinants of CO_2 emissions such as electric power consumption, trade freedom and urban population. We start to describe the results considering the entire sample, without Kyoto dummy (assuming value 1 after 2005, 0 otherwise), including the square of per capita real GDP (see column C in Table 8) in order to include the non-linearity suggested by Lind and Mehlum (2010) test.

[Insert Table 8 around here]

[10] For the sake of brevity the results are not reported and are availble on request.

Differently from before, once we have taken into account that all variables are not stationary, no evidence of environmental Kuznets curve has been found, being the relationship between national income and environmental pollution positive and monotone; in other words, we find that the coefficient of the linear GDP term to be always positive and significant, while the coefficient of quadratic term is statistically insignificant. This result is in line with the part of the literature which is skeptical of the optimistic view that economic growth naturally leads to improvements in environmental quality. See, for instance, Kunnas and Myllyntanous (2007) who did not find a steady decline of these emissions, although the carbon dioxide emissions from energy production increased at the beginning of the period and Halicioglu (2009) who found a stable carbon emission function. The findings from the work of Shafik (1994), Holtz-Eakin and Selden (1995) and Iwata et al. (2011) show that pollutant emissions are monotonically increasing with income levels. Jaunky (2011) found that the long run income elasticity does not provide evidence of an EKC; Luzzati and Orsini (2009) found no support in favour of the energy-EKC hypothesis as well as Aslanidis and Iranzo (2009) did not find any evidence in favour of carbon dioxide emissions environmental Kutnetz curve. Overall, these results confirms that the empirical evidence on this relationship seems to be very mixed[11].

Regarding the determinants of CO_2 emissions, now we find that the use of electric power consumption (Z_1) has a positive and statistically significant effect on the CO_2 emissions, meaning that an increase in the use of energy boosts pollution. This confirms the effect of technology and structural changes on CO_2 emissions over time due to the evolution of energy intensity (see Lantz and Feng, 2006; Tol et al., 2009). Indeed, when dealing with energy, most EKC empirical evidence shows a positive relationship among CO_2 emissions, energy and economic growth (see Richmond and Kauffmann, 2006; Luzzati and Orsini, 2009). Althought some authors show that an EKC-pattern may appear as a result of international trade (see for instance Kearsley and Riddel, 2010), arguing that trade openness helps the expansion of an economy through increased production of (pollution-intensive) goods to support its exports, our results show that the trade freedom (Z_2) has a negative and statistically significant impact on the CO_2 emissions. This result is in line with the recent literature concerning international context (Sharma, 2011) and it is inconsistent with the Hecksher-Ohlin trade theory, which perceived trade to result in greater consumption and production of goods and services leading to greater pollution. Finally, the urban population (Z_3) has found to have a positive and statistically significant influence on the CO_2 emissions. This means that the increase of the population contributes to increase the level of pollution; indeed, as the population becomes more urbanised, it exerts pressure on urban resources and environment leads to more pollution (see Li and Yao, 2009; Kahn and Schwartz, 2008). Again, in all regression, the Arellano–Bond test results vouch in most cases for the appropriateness of the 1st-order autoregressive specification. The Sargan tests are also insignificant, validating the robustness of our evidence.

4.4. Do geographical location and income distribution affect the results?

The main concern is that our findings could be influenced by the high level of heterogeneity of the sample. In order to see whether our results are sample dependent, we exclude countries according to (i) geographical location and (ii) income

[11] Among others, the studies by Lindmark (2002), Cole (2004), Jalil and Mahmud (2009), Narayan and Narayan (2010) support the EKC hypothesis. Mixed evidence has bee found by Coondoo and Dinda (2008), Lee et al. (2009) and Dutt (2009).

distribution[12]. Therefore, we analyze how different subsamples or panels could affect the empirical evidence (see Section 4 for more details on the stratification of the countries).

Starting from the sample without KYOTO dummy, including the square of per capita real GDP and selecting the countries according to their geographical area, we find that especially excluding REG_2 (Europe and Central Asia) and REG_3 (Latin America and Caribbean), real per capita GDP and other determinants lose their statistical significance effect on the environmental pollution (see columns C_1-C_7 in Table 8). The same result is obtained even including KYOTO (see columns CC_1-CC_7 in Table 8). So, the empirical evidence suggests that these regions are important drivers in explaining CO_2 emissions.

We then select countries according to their income distribution and test whether estimates are affected; as above, we firstly consider the regression including the square of real GDP, without KYOTO (see columns D_1-D_5 in Table 9) and with Kyoto (see columns DD_1-DD_5 in Table 9) dummy.

[Insert Table 9 around here]

The analysis shows that especially excluding INC_1 (high income: OECD), INC_4 (lower middle income) and INC_5 (upper middle income), real GDP and the other determinants do not produce significant effects on the estimates. This means that the countries that belong to these groups have very strong effects on CO_2 emissions.

5. Conclusions

The global warming is one of the main problems that policy makers are trying to solve. At this point investigating which determinants influence environmental pollution, particularly national income, remains one of the main topics in the environmental literature. This reason motivate us to analyse the relationship between per capita CO_2 emissions and per capita real GDP using an interesting international sample consisting of 120 countries during the 2000-2009 period and employing the GMM estimator proposed by Arellano and Bond (1991) with Windmeijer (2005) corrected standard error. Because there is a high heterogeneity in our sample, we include in our regression other determinants of CO_2 emissions used in the environmental literature, such as electric power consumption, trade freedom and urban population. In this way we are able to check which determinants have a greater impact on CO_2 emissions. All variables are used in growth form as confirmed by Im et al. (2003) unit root test. We also test the national income-environmental pollution U-shaped relationship using the procedure suggested by Lind and Mehlum (2010). This test gives the exact necessary and sufficient conditions for the test of a U shaped in both finite samples and for a large class of models. Finally, the GMM technique is used in order to assess how per capita real GDP and the other determinants affect per capita CO_2 emissions.

Preliminary evidence showing the existence of an inverted U-shaped relationship between national income and environmental pollution, validating the Kutznes's hypothesis, has been showed to be measleading once the issue of (non) stationarity has been taken into account through a panel unit root test. Indeed, once we have taken into account that all variables are not stationary, no evidence of environmental Kuznets curve has been found, being the relationship between

[12] Another option would have been running the analysis either on each region (i.e. only on REG_1, REG_2, and so on) or on each income cluster (i.e. only on INC_1, ONC_2, and so on) in order to better explore differences among countries located in different areas and among high, middle and low income coutnries, but the observations were not enough to perform the GMM estimation correctly.

national income and environmental pollution positive and monotone. Moreover, both electric power consumption and urban population have a positive and statistically significan effect on CO_2 emissions, leading to greater pollution. This means that as population and industrial output expand, more pressure will be put forth the environment, leading to more emissions. As suggested by Sharma (2011), more strict environmental and energy policies will need to be taken into account. The advent of Kyoto Protocol has a beneficial effect on the reduction of CO_2 emissions. Finally, in order to check whether a different sample composition affects our finding, we firstly exclude alternatively countries belonging to the same geographical location and then countries having the same income distribution. We show that especially countries belonging to the Europe and Central Asia and Latin America and Caribbean influence the results as well as countries that belong to OECD high income, lower-middle income and upper-middle income groups.

Overall, the econometric results lead to the first conclusion that the potential benefits of GDP growth on natural environment, if exist, are not present in the years considered in the analysis, implying that economic growth per se will not reduce energy use or emissions that cause global climate change. Secondly, it appears evident that the presence of a unit root in the income and emission levels have crucial implications for the economic modeling of the income–emissions nexus and for the investigation of the environmental Kutnetz curve existence.

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Tables and Figures

Table 1. Descriptive Statistics for the variables included in the analysis (average on 2000-2009)

Variables	*C*	*Y*	Z_1	Z_2	Z_3
All sample (N=120)					
Mean	5.694	13440,54	1.28e+11	71	2.44e+07
Stand Dev	6.641	14609,13	4.38e+11	15	6.40e+07
By geo location					
REG_1 (N=14)					
Mean	5.509	13182,15	3.10e+11	69	6.65e+07
Stand Dev	4.902	12745,82	6.42e+11	21	1.38e+08
REG_2 (N=44)					
Mean	6.804	19136,73	9.06e+10	78	1.21e+07
Stand Dev	3.936	13742,51	1.51e+11	9	1.96e+07
REG_3 (N=22)					
Mean	2.855	6.399	4.26e+10	71	1.93e+07
Stand Dev	4.552	3983,72	8.49e+10	8	3.45e+07
REG_4 (N=17)					
Mean	11156,58	18335,83	4.04e+10	66	1.06e+07
Stand Dev	11503,64	21801,9	4.66e+10	17	1.25e+07
REG_5 (N=2)					
Mean	18056,14	37635,97	2.25e+12	83,6	1.31e+08
Stand Dev	1.373	4.063	1.75e+12	35	1.09e+08
REG_6 (N=5)					
Mean	563	2.096	1.26e+11	52,19	8.45e+07
Stand Dev	364	926	2.12e+11	18	1.24e+08
REG_7 (N=16)					
Mean	960	3003,12	1.82e+10	62	1.07e+07
Stand Dev	1673,19	2976,15	5.22e+10	11	1.51e+07
By income distribution					
INC_1 (N=30)					
Mean	9747,38	29300,55	2.91e+11	82	2.43e+07
Stand Dev	4.192	10630,27	7.14e+11	5	4.54e+07
INC_2 (N=15)					
Mean	14362,26	24899,99	7.98e+10	77	9930186
Stand Dev	11309,31	20506,46	2.05e+11	9	2.60e+07
INC_3 (N=12)					
Mean	473	1.577	7.52e+09	56	9706673
Stand Dev	781	1.019	7.39e+09	21	9119677
INC_4 (N=28)					
Mean	1.340	2.803	4.25e+10	66	2.71e+07
Stand Dev	1410,2	1.303	1.03e+11	15	6.22e+07
INC_5 (N=35)					
Mean	3.778	7.513	1.19e+11	68	3.35e+07
Stand Dev	2.321	2844,6	4.02e+11	12	9.29e+07

Note: C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditsch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang, 2007; Halicioglu et al. 2009; Jalil and Mahmud, 2009; Ozturk et al. 2010; Saabori and Sulaiman, 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma, 2011). N is the sample size evaraged by year.

Table 2. Testing inverted U-shaped of EKC for the entire sample and excluding groups belonging to the same geographical distribution

	All Sample	*NO REG_1*	*NO REG_2*	*NO REG_3*	*NO REG_4*	*NO REG_5*	*NO REG_6*	*NO REG_7*
Without Kyoto								
extreme point	65281.31	65044.53	63639.05	67299.17	37028.34	65967.26	65739.35	67995.08
p-value	0.0000	0,0000	0.0000	0.0000	0.0000	0,0000	0,0000	0,0000
t-value	10.07	9.6	12.15	7.53	16.46	9.31	9.68	8.22
With Kyoto								
extreme point	65281.31	65044.53	63639.05	67299.17	37028.34	65967.26	65739.35	67995.08
p-value	0.0000	0,0000	0.0000	0.000	0,0000	0,0000	0,0000	0,0000
t-value	10.07	9.76	12.15	7.3	16.46	9.31	9.68	8.22

Lind and Mehlum (2010) tests for the following hypotheses: H_1: Inverse U shape; H_0: Monotone or U shape.

Table 3. Testing inverted U-shaped of EKC excluding groups belonging to the same income distribution

	NO INC_1	*NO INC_2*	*NO INC_3*	*NO INC_4*	*NO INC_5*
Without Kyoto					
extreme point	62206.49	37804.49	68154.98	68675.2	64879.37
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
t-value	13.19	13.87	8.08	6,47	11.59
With Kyoto					
extreme point	62260.57	37790.96	68227.41	68771.11	64955.61
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
t-value	13.18	13.88	8.03	6.42	11.53

Lind and Mehlum (2010) tests for the following hypotheses: H_1: Inverse U shape; H_0: Monotone or U shape.

Table 4. Estimating the EK curve for all sample and excluding groups belonging to the same geographical localization

Variable	*All Sample*	*NO REG$_1$*	*NO REG$_2$*	*NO REG$_3$*	*NO REG$_4$*	*NO REG$_5$*	*NO REG$_6$*	*NO REG$_7$*
	A	*A$_1$*	*A$_2$*	*A$_3$*	*A$_4$*	*A$_5$*	*A$_6$*	*A$_7$*
Without Kyoto dummy								
C_{t-1}	0.818***	0.788***	0.809***	0.791***	0.702	0.813***	0.816***	0.821***
	(8.66)	(9.73)	(11.60)	(4.03)	(0.01)	(13.61)	(15.08)	(4.83)
Y	0.0870*	0.131	0.129	0.0432	0.303	0.0829*	0.0878	0.0957
	(2.25)	(1.14)	(1.39)	(0.32)	(0.00)	(2.26)	(1.05)	(0.77)
Y^2	-5.92e-07**	-8.13e-07	-8.13e-07	-2.63e-07	-3.93e-06	-5.49e-07	-5.96e-07	-6.41e-07
	(-3.09)	(-1.27)	(-1.56)	(-0.35)	(-0.00)	(-1.92)	(-1.07)	(-0.82)
Z_1	5.13e-10	1.54e-09	1.64e-09	8.23e-10	-5.86e-10	2.91e-10	1.13e-09	6.47e-10
	(0.72)	(0.41)	(0.41)	(0.28)	(-0.00)	(0.62)	(1.44)	(0.33)
Z_2	5.636***	6.114	5.513	5.563	3.964	5.222***	6.299*	6.251
	(4.90)	(1.44)	(0.42)	(0.48)	(0.00)	(3.99)	(2.35)	(1.59)
Z_3	-0.00000134	-0.00000131	-0.0000202	-0.00000350	0.0000116	0.00000308	-0.00000988	-0.00000305
	(-0.15)	(-0.09)	(-0.18)	(-0.10)	(0.00)	(0.56)	(-0.96)	(-0.14)
Constant	yes	yes	yes	yes	yes	yes	yes	yes
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes
AB (2) test	0,7815	0,7427	0,4241	0,8509	0,9995	0,8051	0,7771	0,7586
Sargan test	0,1711	0,5077	0,9885	0,7023	0,0000	0,2078	0,2625	0,6150
N	960	848	608	784	824	944	920	832
	AA	*AA$_1$*	*AA$_2$*	*AA$_3$*	*AA$_4$*	*AA$_5$*	*AA$_6$*	*AA$_7$*
With Kyoto dummy								
C_{t-1}	0.818***	0.788***	0.809***	0.791***	0.702***	0.813***	0.816***	0.821
	(8.74)	(20.68)	(9.49)	(4.03)	(5.06)	(15.07)	(16.23)	(1.37)
Y	0.0870**	0.131*	0.129	0.0432	0.303**	0.0829**	0.0879	0.0958
	(2.92)	(2.44)	(1.11)	(0.32)	(3.10)	(2.73)	(1.26)	(0.21)
Y^2	-5.92e-07**	-8.14e-07**	-8.13e-07	-2.63e-07	-3.93e-06***	-5.48e-07**	-5.97e-07	-6.41e-07
	(-2.59)	(-2.61)	(-1.20)	(-0.35)	(-6.60)	(-3.25)	(-1.38)	(-0.28)
Z_1	5.13e-10	1.54e-09	1.64e-09	8.23e-10	-6.05e-10	3.02e-10	1.13e-09	6.48e-10
	(0.90)	(1.16)	(0.24)	(0.28)	(-0.37)	(0.30)	(0.90)	(0.01)
Z_2	5.636***	6.100	5.513	5.563	3.982	5.204**	6.308*	6.223
	(4.50)	(0.35)	(0.27)	(0.48)	(1.64)	(3.10)	(2.07)	(0.05)
Z_3	-0.00000134	-0.00000137	-0.0000202	-0.00000350	0.0000119	0.00000296	-0.00000983	-0.00000305
	(-0.18)	(-0.00)	(-0.09)	(-0.10)	(0.57)	(0.26)	(-0.60)	(-0.00)
Kyoto	-335.2**	-333.8	-130.0	-315.0*	-497.1***	-294.2***	-343.7*	-389.0
	(-3.12)	(-1.08)	(-0.34)	(-2.56)	(-5.23)	(-9.30)	(-2.20)	(-0.09)
Constant	yes	yes	yes	yes	yes	yes	yes	yes
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
AB (2) test	0.7816	0.7419	0.4304	0.8509	0.9724	0.8048	0.7768	0.8102
Sargan test	0.1711	0.5842	0.9832	0.7023	0.6468	0.2057	0.2594	0.5732
N	960	848	608	784	824	944	920	832

Note: All equations are estimated through a two-step generalized method moment estimator with Windmeijer (2005) corrected standard error in parentheses. C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011). Δ describes that all variables are in growth form as suggested by Im et al. (2003) test. N is the sample size. Statistics for the Sargan and Arellano–Bond, AR(2), tests are p-values. *, **, *** stand for significant at 10%, 5% and 1%, respectively. Robust standard errors in brackets.

Table 5. Estimating the EK curve excluding groups belonging to the same income distribution

Variables	*NO INC$_1$*	*NO INC$_2$*	*NO INC$_3$*	*NO INC$_4$*	*NO INC$_5$*
	B$_1$	*B$_2$*	*B$_3$*	*B$_4$*	*B$_5$*
Without Kyoto dummy					
C_{t-1}	0.800***	0.613	0.819***	0.819	0.805***
	(13.60)	(0.87)	(25.83)	(0.01)	(5.61)
Y	0.111**	0.170	0.0991	0.101	0.0788
	(2.66)	(0.08)	(1.42)	(0.00)	(0.63)
Y^2	-6.55e-07***	-2.37e-06	-6.63e-07*	-6.66e-07	-5.10e-07
	(-3.32)	(-0.12)	(-2.32)	(-0.00)	(-0.69)
Z_1	8.63e-10	1.63e-10	5.75e-10	1.69e-09	1.62e-09
	(0.02)	(0.00)	(0.03)	(0.00)	(0.30)
Z_2	3.171	3.226	6.171	6.828	11.76
	(0.20)	(0.01)	(0.44)	(0.00)	(0.36)
Z_3	-0.00000678	0.00000644	-0.00000196	-0.0000173	-0.00000619
	(-0.02)	(0.01)	(-0.01)	(-0.00)	(-0.11)
Constant	yes	yes	yes	yes	yes
Time Dummies	yes	yes	yes	yes	yes
AB (2) test	0,2496	0,5203	0,7818	0,9986	0,8848
Sargan test	0,8750	0,0029	0,4363	0,0000	0,8667
N	720	840	864	736	680
	BB$_1$	*BB$_2$*	*BB$_3$*	*BB$_4$*	*BB$_5$*
With Kyoto dummy					
C_{t-1}	0.800***	0.613	0.819**	0.820	0.805
	(13.45)	(0.44)	(2.71)	(0.05)	(0.21)
Y	0.111**	0.170	0.0991	0.0993	0.0788
	(3.17)	(0.08)	(0.04)	(0.01)	(0.03)
Y^2	-6.54e-07***	-2.37e-06	-6.63e-07	-6.59e-07	-5.10e-07
	(-3.58)	(-0.11)	(-0.05)	(-0.01)	(-0.03)
Z_1	8.53e-10	1.58e-10	5.75e-10	1.76e-09	1.62e-09
	(0.26)	(0.00)	(0.00)	(0.00)	(0.02)
Z_2	3.193	3.214	6.171	6.906	11.76
	(1.23)	(0.02)	(0.02)	(0.00)	(0.01)
Z_3	-0.00000664	0.00000648	-0.00000196	-0.0000183	-0.00000619
	(-0.21)	(0.00)	(-0.00)	(-0.00)	(-0.00)
Kyoto	-183.1***	-357.7	-391.4	-376.3	-382.5
	(-5.12)	(-0.11)	(-0.05)	(-0.00)	(-0.04)
Constant	yes	yes	yes	yes	yes
Time dummies	yes	yes	yes	yes	yes
AB (2) test	0.2395	0.5912	0.9543	0.9932	0.8848
Sargan test	0.8862	0.0155	0.7764	0.1324	0.8667
N	720	840	864	736	680

Note: All equations are estimated through a two-step generalized method moment estimator with Windmeijer (2005) corrected standard error in parentheses. C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011).*Significant at 10 %. **Significant at 5 %. ***Significant at 1 %. Δ describes that all variables are in growth form as suggested by Im et al. (2003) test. N is the sample size. Statistics for the Sargan and Arellano–Bond, AR(2), tests are p-values. *, **, *** stand for significant at 10%, 5% and 1%, respectively. Robust standard errors in brackets.

Table 6. Im et al. (2003) Unit Toot Test for the entire sample and excluding groups belonging to the same geographical distribution

	Without Trend		*With Trend*		*Without Trend, Demeaning Data*		*With Trend, Demeaning Data*	
W-t-bar	*Statistic*	*p-value*	*Statistic*	*p-value*	*Statistic*	*p-value*	*Statistic*	*p-value*
All Sample								
C	5,6459	1,0000	2,8826	0,9980	3,9292	1,0000	9,8273	1,0000
Y	2,8728	0,9980	0,6060	0,7278	1,1993	0,8848	2,7807	0,9973
Z_1	6,8048	1,0000	4,3532	1,0000	-1,5105	0,0655	9,6580	1,0000
Z_2	/	/	/	/	-4,5469	0,0000	-18,3990	0,0000
Z_3	92,3601	1,0000	-14,5428	0,0000	66,1291	1,0000	5,4890	1,0000
NO REG$_1$								
C	5,3137	1,0000	2,4508	0,9900	3,1726	0,9900	9,1858	1,0000
Y	3,4571	1,0000	0,8029	0,7890	1,3376	0,9095	1,8031	0,9643
Z_1	5,9665	1,0000	3,9128	1,0000	1,2068	0,8863	9,9828	1,0000
Z_2	-1,7398	0,0410	-11,9779	0,0000	-4,8311	0,0000	-18,8087	0,0000
Z_3	91,5336	1,0000	-16,1207	0,0000	80,5701	1,0000	-4,5531	0,0000
NO REG$_2$								
C	3,7300	0,9900	-1,1519	0,1247	1,4084	0,9205	3,1373	0,9900
Y	0,5660	0,7143	-0,0878	0,4650	-0,7898	0,2148	2,6040	0,9954
Z_1	9,1486	1,0000	-0,3726	0,3547	3,9832	1,0000	4,6781	1,0000
Z_2	/	/	/	/	-3,8485	0,0000	-10,7761	0,0000
Z_3	105,1206	1,0000	-15,3825	0,0000	46,5085	1,0000	5,1561	1,0000
NO REG$_3$								
C	6,5282	1,0000	5,4781	1,0000	3,9759	1,0000	7,7068	1,0000
Y	2,7671	0,9972	1,4674	0,9289	0,8942	0,8144	3,2943	0,9995
Z_1	5,3680	1,0000	5,6460	1,0000	-0,9721	0,1655	9,4492	1,0000
Z_2	/	/	/	/	-2,8422	0,0022	-17,9487	0,0000
Z_3	91,0194	1,0000	-15,9226	0,0000	55,9542	1,0000	5,3678	1,0000
NO REG$_4$								
C	5,5864	1,0000	2,5073	0,9939	3,4574	0,9997	10,2106	1,0000
Y	3,1201	0,9991	-0,6851	0,2466	3,2795	0,9995	1,6430	0,9498
Z_1	4,2688	1,0000	4,9004	1,0000	-1,8405	0,0328	8,8133	1,0000
Z_2	/	/	/	/	-6.4862	0,0000	-21,8571	0,0000
Z_3	93,2551	1,0000	-0,9109	0,1812	65,7360	1,0000	15,6554	1,0000
NO REG$_5$								
C	5,2949	1,0000	2,5876	0,9952	3,3992	0,9997	9,7633	1,0000
Y	3,2988	0,9995	0,4167	0,6615	1,4808	0,9307	2,4651	0,9932
Z_1	6,8035	1,0000	4,1569	1,0000	5,1435	1,0000	2,0814	0,9813
Z_2	/	/	/	/	-4,5273	0,0000	-17,7905	0,0000
Z_3	92,6578	1,0000	-14,6295	0,0000	72,7614	1,0000	7,6193	1,0000
NO REG$_6$								
C	4,8053	1,0000	2,7939	0,9974	4,0579	1,0000	8,6746	1,0000
Y	2,1347	0,9836	0,3928	0,6528	1,2105	0,8870	2,7774	0,9973
Z_1	6,2063	1,0000	4,6799	1,0000	-2,4805	0,0066	10,5200	1,0000
Z_2	/	/	/	/	-4,4195	0,0000	-18,5631	0,0000
Z_3	92,9941	1,0000	-14,2437	0,0000	64,1243	1,0000	4,6096	1,0000
NO REG$_7$								
C	5,2485	1,0000	3,5636	0,9998	4,9641	1,0000	7,0353	1,0000
Y	2,9923	0,9986	1,5716	0,9420	0,5368	0,7043	2,8777	0,9980
Z_1	6,7870	1,0000	4,7009	1,0000	-1,8176	0,0346	9,0433	1,0000
Z_2	/	/	/	/	-2,4440	0,0073	-13,2081	0,0000
Z_3	35,5605	1,0000	-17,3295	0,0000	51,0351	1,0000	4,1241	1,0000

Note: C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011). A few values of Z_2 variable are not present due to the insufficient number of time periods to compute W-t-bar.

Table 7. Im et al. (2003) Unit Root Test excluding groups belonging to the same income distribution

	Without Trend		*With Trend*		*Without Trend, Demeaning Data*		*With Trend, Demeaning Data*	
W-t-bar	*Statistic*	*p-value*	*Statistic*	*p-value*	*Statistic*	*p-value*	*Statistic*	*p-value*
NO INC_1								
C	3,1488	0,9992	0,2365	0,5935	3,0547	0,9989	4,7720	1,0000
Y	3,8481	0,9999	-0,3173	0,3755	0,8241	0,7951	1,2278	0,8902
Z_1	7,8041	1,0000	0,5375	0,7045	7,9400	1,0000	-0,0139	0,4945
Z_2	/	/	/	/	-5,4381	0,0000	-13,9402	0,0000
Z_3	98,3738	1,0000	-13,7054	0,0000	61,6613	1,0000	2,9712	0,9985
NO INC_2								
C	5,2876	1,0000	2,2320	0,9872	5,4904	1,0000	11,6346	1,0000
Y	2,7934	0,9974	0,1597	0,5635	3,1596	0,9992	2,3058	0,9894
Z_1	5,5464	1,0000	4,1356	1,0000	1,2987	0,9030	7,5311	1,0000
Z_2	/	/	/	/	-4,7527	0,0000	-19,3726	0,0000
Z_3	98,6713	1,0000	-4,2498	0,0000	68,5781	1,0000	7,3826	1,0000
NO INC_3								
C	5,0119	1,0000	3,0562	0,9989	4,4760	1,0000	7,6550	1,0000
Y	3,1726	0,9992	1,5859	0,9436	0,3788	0,6476	2,4363	0,9926
Z_1	6,8305	1,0000	4,7501	1,0000	-1,1682	0,1214	9,3309	1,0000
Z_2	-2,3908	0,0084	-11,5081	0,0000	-3,6442	0,0000	-18,4212	0,0000
Z_3	83,2271	1,0000	-15,8447	0,0000	68,0669	1,0000	3,2199	0,9994
NO INC_4								
C	5,1243	1,0000	3,6012	0,9998	4,6122	1,0000	4,7608	1,0000
Y	2,1195	0,9830	0,2909	0,6145	0,3195	0,6253	2,7979	0,9974
Z_1	5,2310	1,0000	4,8698	1,0000	-2,7513	0,0030	8,6975	1,0000
Z_2	/	/	/	/	-4,8263	0,0000	-16,6055	0,0000
Z_3	33,3992	1,0000	-16,1237	0,0000	33,5566	1,0000	3,9207	1,0000
NO INC_5								
C	6,7360	1,0000	3,7862	0,9999	3,4989	0,9998	9,4631	1,0000
Y	0,8024	0,7888	0,9337	0,8248	0,3381	0,6324	3,0202	0,9987
Z_1	4,9986	1,0000	5,1147	1,0000	-0,4711	0,3188	10,6085	1,0000
Z_2	/	/	/	/	-2,9915	0,0014	-12,8313	0,0000
Z_3	99,4881	1,0000	-15,5821	0,0000	55,8029	1,0000	-1,0359	0,1501
INC_H								
C	5.8990	1,0000	5.6678	1.0000	4.5359	1.0000	-0.8677	0.1928
Y	-0.3396	0.3671	2.1698	0.9850	-0.5958	0.2756	0.7164	0.7631
Z_1	2.7085	0.9966	7.1276	1.0000	0.5979	0.7251	0.3874	1.0000
Z_2	2.9141	0.9982	-4.9599	0.0000	-4.6978	0.0000	-10.9693	0.0000
Z_3	12.2445	1.0000	-21.3827	0.0000	8.0530	1.0000	-1.1696	0.1211
INC_{LM}								
C	2.5666	0.9949	-0.7524	0.2259	1.4739	0.9297	2.1823	0.9855
Y	3.8845	0.9999	-0.9295	0.1763	4.2186	1.0000	0.1264	0.5503
Z_1	6.5115	1.0000	-0.0243	0.4903	11.0359	1.0000	-1.3854	0.0830
Z_2	/	/	/	/	-5.4949	0.0000	-14.3798	0.0000
Z_3	107.7908	1.0000	-1.6272	0.0518	61.9501	1.0000	12.9942	1.0000

Note: C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011). A few values of Z_2 variable are not present due to the insufficient number of time periods to compute W-t-bar.

Table 8. Estimating the EK curve for all sample and excluding groups belonging to the same geographical localization

Variable	*All Sample*	*NO REG$_1$*	*NO REG$_2$*	*NO REG$_3$*	*NO REG$_4$*	*NO REG$_5$*	*NO REG$_6$*	*NO REG$_7$*
	C	*C$_1$*	*C$_2$*	*C$_3$*	*C$_4$*	*C$_5$*	*C$_6$*	*C$_7$*
Without Kyoto dummy								
C_{t-1}	0.779***	0.777***	0.836	0.767***	0.694***	0.786***	0.779***	0.783***
	(112.87)	(126.70)	(0.09)	(6.01)	(19.05)	(126.97)	(111.18)	(122.33)
ΔY	0.0237**	0.0220**	0.0471	0.00716	0.141***	0.0216**	0.0226**	0.0332***
	(2.51)	(2.08)	(0.01)	(0.08)	(3.88)	(2.40)	(2.36)	(3.76)
ΔY^2	8.87e-08	1.01e-07	7.13e-08	1.95e-07	-1.12e-06***	1.11e-07*	9.55e-08	3.39e-08
	(1.47)	(1.57)	(0.00)	(0.33)	(-3.22)	(1.88)	(1.56)	(0.59)
ΔZ_1	3.34e-09***	4.61e-09***	2.72e-09	3.44e-09**	3.79e-09***	3.36e-09***	3.32e-09***	3.19e-09***
	(10.89)	(11.10)	(0.01)	(2.41)	(8.04)	(6.16)	(10.76)	(10.47)
ΔZ_2	-2.249***	-2.559***	-0.717	-1.036	-2.674***	-2.019**	-2.675***	-2.610***
	(-2.74)	(-3.01)	(-0.00)	(-0.45)	(-2.63)	(-2.47)	(-3.07)	(-3.03)
ΔZ_3	0.000546***	0.000882***	0.000187	0.000750	0.000507***	0.000581***	0.000553***	0.000461***
	(4.99)	(5.12)	(0.00)	(0.66)	(4.87)	(5.24)	(4.93)	(4.48)
Constant	yes	yes	yes	yes	yes	yes	yes	yes
Time Dummies	yes	yes	yes	yes	yes	yes	yes	yes
AB (2) test	0.6665	0.6131	0.0338	0.9858	0.9261	0.6776	0.6683	0.6571
Sargan test	0.0273	0.1315	0.0000	0.2909	0.1841	0.0340	0.0510	0.1530
N	960	848	608	784	824	944	920	832
	CC	*CC$_1$*	*CC$_2$*	*CC$_3$*	*CC$_4$*	*CC$_5$*	*CC$_6$*	*CC$_7$*
With Kyoto dummy								
C_{t-1}	0.779***	0.777***	0.836	0.767***	0.694***	0.786***	0.779***	0.783***
	(112.87)	(126.70)	(0.10)	(6.01)	(19.05)	(126.97)	(111.18)	(122.33)
ΔY	0.0237**	0.0220**	0.0471	0.00716	0.141***	0.0216**	0.0226**	0.0332***
	(2.51)	(2.08)	(0.01)	(0.08)	(3.88)	(2.40)	(2.36)	(3.76)
ΔY^2	8.87e-08	1.01e-07	7.13e-08	1.95e-07	-1.12e-06***	1.11e-07*	9.55e-08	3.39e-08
	(1.47)	(1.57)	(0.00)	(0.33)	(-3.22)	(1.88)	(1.56)	(0.59)
ΔZ_1	3.34e-09***	4.61e-09***	2.72e-09	3.44e-09**	3.79e-09***	3.36e-09***	3.32e-09***	3.19e-09***
	(10.89)	(11.10)	(0.00)	(2.41)	(8.04)	(6.16)	(10.76)	(10.47)
ΔZ_2	-2.249***	-2.559***	-0.717	-1.036	-2.674***	-2.019**	-2.675***	-2.610***
	(-2.74)	(-3.01)	(-0.00)	(-0.45)	(-2.63)	(-2.47)	(-3.07)	(-3.03)
ΔZ_3	0.000546***	0.000882***	0.000187	0.000750	0.000507***	0.000581***	0.000553***	0.000461***
	(4.99)	(5.12)	(0.00)	(0.66)	(4.87)	(5.24)	(4.93)	(4.48)
Kyoto	-181.8***	-135.9***	57.32	-231.5	-299.4**	-175.4***	-128.2***	-134.5***
	(-6.31)	(-4.11)	(0.00)	(-0.79)	(-2.71)	(-6.10)	(-3.94)	(-4.11)
Constant	yes	yes	yes	yes	yes	yes	yes	yes
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
AB (2) test	0.6665	0.6131	0.2387	0.9858	0.9261	0.6776	0.6683	0.6751
Sargan test	0.0273	0.1315	0.0000	0.2909	0.1841	0.0340	0.0510	0.1530
N	960	848	608	784	824	944	920	832

Note: All equations are estimated through a two-step generalized method moment estimator with Windmeijer (2005) corrected standard error in parentheses. C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; ; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011). Δ describes that all variables are in growth form as suggested by Im et al. (2003) test. N is the sample size. Statistics for the Sargan and Arellano–Bond, AR(2), tests are p-values. *, **, *** stand for significant at 10%, 5% and 1%, respectively. Robust standard errors in brackets.

Table 9. Estimating the EK curve excluding groups belonging to the same income distribution

Variables	*NO INC₁*	*NO INC₂*	*NO INC₃*	*NO INC₄*	*NO INC₅*
	D_1	D_2	D_3	D_4	D_5
Without Kyoto dummy					
C_{t-1}	0.845	0.502***	0.781***	0.779***	0.776***
	(0.20)	(17.37)	(106.85)	(5.40)	(6.94)
ΔY	0.0648	0.0555**	0.0253***	0.0122	0.0290
	(0.02)	(2.12)	(2.61)	(0.11)	(0.27)
ΔY^2	-1.05e-08	-2.29e-07	7.99e-08	1.62e-07	5.40e-08
	(-0.00)	(-0.90)	(1.28)	(0.23)	(0.09)
ΔZ_1	1.79e-09	3.81e-09***	3.18e-09***	3.09e-09	4.77e-09
	(0.00)	(13.67)	(10.69)	(1.19)	(0.39)
ΔZ_2	-1.394	-0.899	-2.935***	-1.829	-2.071
	(-0.00)	(-1.32)	(-3.42)	(-0.38)	(-0.53)
ΔZ_3	0.000684	0.000828***	0.000528***	0.000522	0.000654
	(0.00)	(4.79)	(4.97)	(0.29)	(0.49)
Constant	yes	yes	yes	yes	yes
Time Dummies	yes	yes	yes	yes	yes
AB (2) test	0,1360	0,5122	0,6611	0,6660	0,7619
Sargan test	0,0000	0,1489	0,1157	0,7810	0,9143
N	720	840	864	736	680
	DD_1	DD_2	DD_3	DD_4	DD_5
With Kyoto dummy					
C_{t-1}	0.845	0.502***	0.781***	0.779***	0.776***
	(0.37)	(17.37)	(106.85)	(5.40)	(6.94)
ΔY	0.0648	0.0555**	0.0253***	0.0122	0.0290
	(0.04)	(2.12)	(2.61)	(0.11)	(0.27)
ΔY^2	-1.05e-08	- 2.29e-07	7.99e-08	1.62e-07	5.40e-08
	(-0.00)	(-0.90)	(1.28)	(0.23)	(0.09)
ΔZ_1	1.79e-09	3.81e-09***	3.18e-09***	3.09e-09	4.77e-09
	(0.00)	(13.67)	(10.69)	(1.19)	(0.39)
ΔZ_2	-1.394	-0.899	-2.935***	-1.829	-2.071
	(-0.00)	(-1.32)	(-3.42)	(-0.38)	(-0.53)
ΔZ_3	0.000684	0.000828***	0.000528***	0.000522	0.000654
	(0.01)	(4.79)	(4.97)	(0.29)	(0.49)
Kyoto	-16.13	-192.7***	-134.4***	-229.8	-158.0***
	(-0.00)	(-5.78)	(-3.90)	(-0.95)	(-2.84)
Constant	yes	yes	yes	yes	yes
Time dummies	yes	yes	yes	yes	yes
AB (2) test	0.1360	0.5122	0.6611	0.6660	0.7619
Sargan test	0.0000	0.1489	0.1157	0.7810	0.9143
N	720	840	864	736	680

Note: All equations are estimated through a two-step generalized method moment estimator with Windmeijer (2005) corrected standard error in parentheses. C is per capita CO_2 emissions (Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas faring; Source: Esty et al. (2008, 20-01-2014); http://epi.yale.edu/downloads); Y is per capita real GDP in constant US dollars (at base year 2000; Source: Gleditch (2002, 27-01-2013); http://privatewww.essex.ac.uk/~ksg/exptradegdp.html); Z_1 is the electric power consumption (kWh per capita; Source: World Bank, Group, 2012, 19-05-2014; http://data.worldbank.org/data-catalog/world-development-indicators)) (see Ang 2007; Halicioglu et al. 2009; Jalil et al. 2009; Ozturk et al. 2010; Saabori et al. 2013); Z_2 is the trade freedom (Source: Heritage Foundation, http://www.heritage.org/index/explore) (see Jalil et al. 2009; Sharma 2011); Z_3 is the urban population (% of total; Source: World Bank, Group (2012, 19-05-2014); http://data.worldbank.org/data-catalog/world-development-indicators) (see Sharma 2011).*Significant at 10 %. **Significant at 5 %. ***Significant at 1 %. Δ describes that all variables are in growth form as suggested by Im et al. (2003) test. N is the sample size. Statistics for the Sargan and Arellano–Bond, AR(2), tests are p-values. *, **, *** stand for significant at 10%, 5% and 1%, respectively. Robust standard errors in brackets.

Figure 1. GDP per capita and per capita CO_2 emission distribution by geoegraphical area and by income clusters

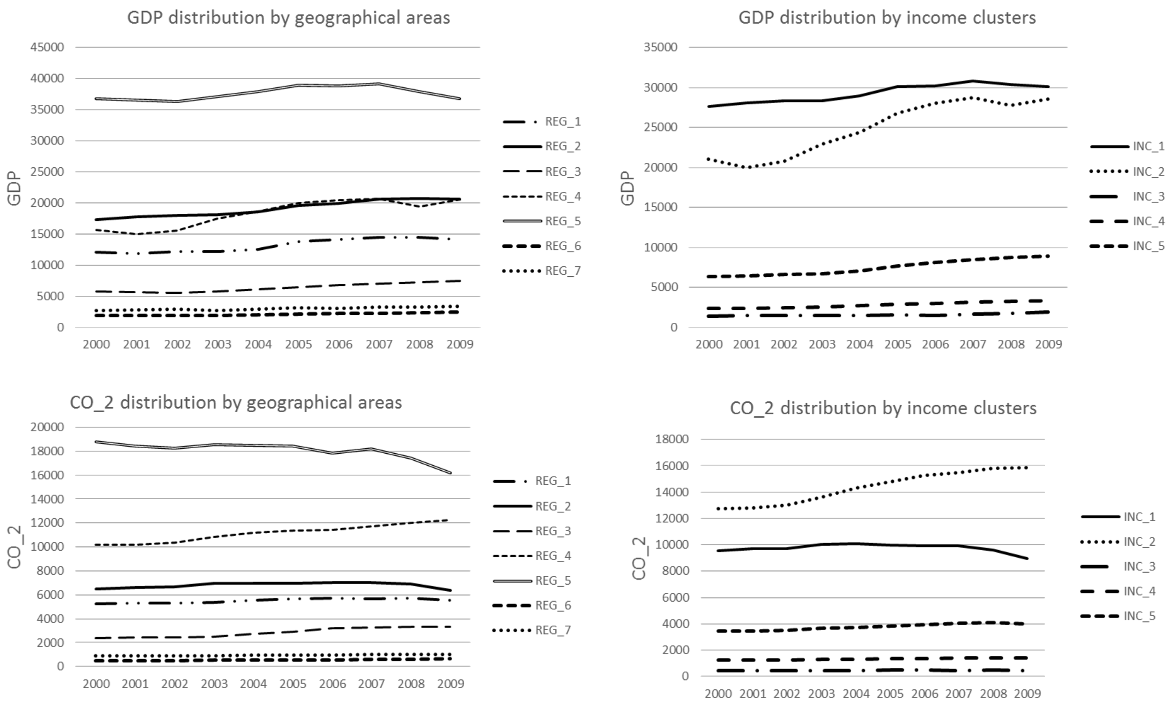

Figure 2. Boxplots of per capita GDP and per capita CO_2 emission by geographical area and by income clusters