**Does Convergence Really Matter for the Environment? An Application Based on Club Convergence and on the Ecological Footprint Concept for the EU Countries**

**Abstract**

The ecological footprint has currently become a highly popular environmental performance indicator. It provides the basis for setting goals, identifying options for action, and tracking progress toward stated goals. This paper investigates the convergence of the per capita ecological footprint by employing the annual data for the case of the European Union countries, spanning the period 1961 to 2013. The methodology follows the club clustering approach and the empirical findings document the presence of certain convergent clubs. These empirical results clarify the differences in terms of environmental quality, as well as the awareness strategies the EU members in each club need to follow.

**Keywords**: environmental convergence; ecological footprint;club convergence; environmental policy

**1. Introduction**

Convergence studies have attracted great attention in many areas of the macroeconomic theory, especially since the seminal work of Barro and Sala-i-Martin (1992). There are lot of convergence implications using various empirical methodologies, such as time series, cross-section and panel data. In relevance to these studies, the common ground is convergence regression through an economic growth equation within the context of the neo-classical growth theory developed by Solow (1956). These studies differ across the variables they search running from commodity prices to public expenditures on health, military, educational, to fiscal and monetary variables, foreign trade, tourism and energy consumption (Bukenya and Labys, 2005; Wang, 2009; Claustre et al., 2010; Apergis et al., 2013; Pjesky, 2013; Mishra and Smyth, 2014; Solarin and Lean, 2014; Su et al. 2014; Apergis, 2015; Ioana-Laura 2015; Hao et al., 2015; Lau et al., 2016; Chen et al., 2016 ). However, the studies that focus on threats, like global warming and climate change and or environmental convergence, which seriously affect the world have been receiving great attention.

There are primarily three reasons that can explain why countries converge in terms of environmental values. The first one is in relevance to the environmental catch-up hypothesis recommended by Brock and Taylor (2003). According to this hypothesis, it refers to the convergence of environmental quality between the rich and the poor countries at a point in time, which is fundamentally explained through the Environmental Kuznet's Curve (EKC) which highliths that at the initial stage of economic growth, it makes environmental quality worse, and, that, at a later stage of economic growth enhances environmental quality only after per capita income reaches a threshold (Brock and Taylor, 2003). According to the EKC, the countries which reach a spesific income level, reduce their emissions. As long as this is true, rises in income will get emissions per capita closer to each other. This is exactly what a convergence implies with regard to the EKC (Strazicich and List, 2003b). Second, such convergence is based on global mitigation efforts in order to stop global warming and climate change under the guidence of Intergovernmental Panel on Climate Chance, IPCC, and international agreements, like that of the Kyoto Protocol (Aldy, 2006). Finally, the initial levels of pollution emissions, emissions intensity, or concentrations, are associated with slower growth in parallel with growth convergence (Stern, 2015). Such potential expectations provided in the relevant literature have led to the investigation of environmental convergence.

The contribution of this manuscript is twofold: First, the current literature is mostly based on per capita carbon dioxide emissions and does not consider any environmental degradation variables. Therefore, the relevant observations should also focus on resource stocks, such as soil stocks, forestry stocks, mining stocks, and oil stocks (Arrow et al. 1995; Stern 2015). Therefore, this study makes use of the ecological footprint concept, developed by Wachernagel & Rees (1996), as a comprehensive environmental degradation variable (i.e. Bartelmus, 2008; Caviglia-Harris et al., 2009; Kitzes and Wackernagel, 2009; Wiedmann and Barrett, 2010; Ozturk et al. 2016), and (ii) the majority of the relevant literature consider a unit root approach or growth regressions to reach the conclusion on whether convergence is verified for their samples. However, pollution or the environmental degradation has spillover effects across regions or countries. Furthermore, certain countries have similar dynamics and conditions with regard to the drivers of environmental quality. Thus, convergence may be verified across countries with similar conditions, such as the growth process, the dependence on environmental resources, changes in the composition of energy production between renewables and nonrenewables, and changes in the composition of energy consumption. To this end, the study uses the club convergence approach developed by Phillips and Sul (2007), which considers that certain countries, states, sectors, or regions that belong to a club move from disequilibrium positions to their club-specific steady-state positions. The remaining of the manuscript is organised as follows. Convergence issues and their impact on the environment are explained in Section 2, while a brief literature review on environmental convergence is discussed in Section 3. Section 4 describes the data set, as well as the empirical methodology used, while estimation results are reported in Section 5. Finally, Section 6 concludes.

**2. Convergence issues**

The discussion on convergence has been initiated with that on the neo-classical growth theory developed by Solow (1956). One of the most critical assumptions of the Solow growth model is the presence of diminishing returns, implying that the marginal product of capital is large when the capital stock is small and that it is small when the capital stock is large by considering the Inada (1963) conditions, symbolised by and . This critical assumption leads to test convergence within an economy or across economies by modelling a negative correlation between initial income levels and subsequent growth rates. This negative correlation has been tested by growth-initial level regressions, i.e. the -convergence approach. The presence of this negative coefficient states that countries with less capital stocks tend to grow faster than those with more capital given that the presence of diminishing returns to capital come into play as the economy grows (Barro and Sala-i-Martin, 1992). Considering that the Solow model is based on a Cobb-Douglass production function, including capital, labor and total factor productivity, economic growth turns out to be a function of the initial levels of the capital stock, labur and total factor productivity, as well as the saving rate, the growth rate of population and the growth rate of technology. One may emprically document that poor countries are expected to catch up the rich countries in the long run when each component of this growth (accounting) function shares the same characteristics across all countries (Baumol, 1986). However, these growth components are not the same across all countries in the real world. Hence, convergence is potential across countries with the same conditions in terms of factors which affect economic growth (Kormendi and Meguire, 1985; De Long, 1988; Grier and Tullock, 1989). Moreover, due to the presence of increasing returns as supported by the endogeneous growth theories, the income gap between poor and rich countries may widen (Romer, 1986). These arguments necessiate that the initial conditions and basic dynamics of economic growth should be regarded for the process of country selection in the convergence analysis (Durlauf and Johnson, 1995; Galor, 1996). This approach is the so called conditional convergence, with each individual economy possessing a particular steady state equilibrium which attempts to approach. Similarly, if economies are grouped by common characteristics (Durlauf and Johnson, 1995), each group is expected to illustrate the same steady state equilibrium, which also attempts to approach. According to the sigma -convergence, introduced by (Quah 1993; Friedman 1992), the series under investigation have a decreasing behavior in the cross-sectional variation. In other words, it focuses on the dispersion of the cross-sectional growth distribution (Islam, 2003).

A great number of papers have used various unit root tests to provide evidence on convergence. Brock and Taylor (2010) transformed the Solow (1956) model into an environmental growth model by amending it with carbon emissions and showed the presence of convergence in the frame of growth equations. Their study has an important place within the environmental convergence literature. In their study, the motion equation of emissions is defined as: , where it is asssumed that every economic activity, *F,* produces unit of pollution, while the pollution abatement, , is a strictly concave function of total economic activity, *F,* and the economy’s efforts at abatement, *FA*. The above equation is rearranged with a common factor, , and rewritten as: . When is used instead of and combined with the Solow model, the output equation yields: *Y = [1-]F.* Then, the Solow model is transformed into a ‘green’ Solow model as follows:

(1)

(2)

Next, they use Equation 3 to define the growth of emissions per capita as a negative function of the technological progress in abatement () and a positive function of growth in per capita income in order to derivate the emissions convergence equation:

(3)

In the following step, three applications are applied to transform the emissions per capita equation into a convergence equation. First, both the emissions per capita, and the growth rate of income per capita, are determined over a discrete time period of size *N* by their average log changes. In that sense, Equation 3 turns to be:

(4)

where is the growth rate of technological progress in abatement.

In the following application, the discrete *N* period growth rate of income per capita near the model’s steady state is determined (Mankiw et al., 1992; Barro, 1991) in order to eliminate income growth:

|  |  |
| --- | --- |
|  | (5) |

where *b* is a constant term and is the speed of convergence in the Solow growth model. The speed of convergence is determined as: , where is the output elasticity of capital, is the growth rate of labor, is the growth rate of technology, and denotes the depreciation rate.

Next, income growth in Equation 4 is replaced by Equation 5 through considering: from Equation 3 and a convergence equation of emissions per capita is generated across *i* countries to a constant, , while the initial period of emissions per capita in the panel regression form with an error term

(6)

**3. Literature review**

The research on environmental convergence has been a widespread subject of many empirical studies that have followed different methodologies used in the relevant literature. Certain estimation methodologies range from time series analyses to panel data or cross section analyses, as well as different notations of convergence have been also analysed. The results support different conclusions on whether emissions emitted by countries converge or not. The findings seem to be in favor of convergence, implying that emissions are expected to reach the same size across countries. A number of novel studies focusing on the convergence issue are shown in Table 1, which briefly summurizes them based on certain criteria, such as the sample period, the country invlolved, the methodology followed, and the type of variables included.

| **Table 1.** Literature review on environmental convergence | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Author/s** | **Period** | **Country** | **Methodology** | **Variable** | **Emprical Findings** |
| List (1999) | 1929-1994 | U.S. States | Time series unit root | SO2, NO2 | Some evidence for convergence |
| Lanne and Liski (2004) | 1870-2028 | 16 countries | Panel unit root with structural breaks | CO2 | No evidence |
| Strazicich and List (2003) | 1960-1997 | 21 countries | cross section and Panel unit root proposed by Im et al ( 2003) | CO2 | Stochastic conditinaol convergence |
| Nguyen Van (2005) | 1966-1996 | 100 countries | non-parametric approach based on distribution analysis | CO2 | Convergence for industrialized ones but divergence for full samples |
| Aldy (2006) | 1960-2000 | 88 countries | DF-GLS Unit root, Markov chain transition matrix analysis | CO2 | Stochastic convergence for 13 out of 88. Divergence for Forecasts of long-run emissions. |
| Aldy (2007) | 1960-1999 | U.S. States | Panel unit root proposed by Im et al ( 2003), Markov chain transition matrix analysis | CO2 | No evidence for consumption CO2  Divergence for production CO2 |
| Ezcurra (2007) | 1960-1999 | 87 countries | non-parametric approach based on the spatial distribution analysis | CO2 | Evidence for convergence |
| Romero-Ávila (2008) | 1960-2002 | 23 industrialized countries | Panel unit root test with structural breaks | CO2 | Stochastic and deterministic convergence |
| Lee and Chang (2008) | 1960-2000 | 21 OECD countries | SURADF panel unit root | CO2 | Stochastic and β-convergence for 7 out of 21, divergence for 14 out of 21 countries |
| Camarero et al. (2008) | 1971-2002 | OECD countries | Data Envelopment Analysis, sequential multivariate approach, SURADF unit root | EPI\* | Evidence for convergence |
| Westerlund and Basher (2008) | 1870-2002 | 16 developed, 12 developing countries | Panel unit root proposed by Hadri (2000) and Im et al ( 2003) | CO2 | Stochastic conditional convergence |
| Panopoulou and Pantelidis (2009) | 1960-2003 | 128 countries | Phillips and Sul (2007) Panel club convergence test | CO2 | Evidence for club convergence |
| Brock and Taylor (2010) | 1960-1998 | 173 countries | cross-sectional approach | CO2 | Conditional convergence |
| Yavuz and Yilanci (2013) | 1960-2005 | G7 countries | TAR panel unit root | CO2 | Convergence for regime 1, divergence for regime 2, conditional convergence |
| Herrerias (2013) | 1980-2009 | 162 countries | Phillips and Sul (2007) Panel club convergence and Pair-wise unit root test | CO2 from Fossils | Club convergence for a large group, divergence for pair-wise unit root |
| Christidou et al. (2013) | 1870-2006 | 36 countries | Linear and non-linear panel unit root tests | CO2 | Convergence in non-linear form |
| Li and Lin (2013) | 1971-2008 | 110 countries | Panel GMM | CO2 | Absolute convergence |
| Huang and Meng (2013) | 1985-2008 | Provinces of China | Spatial econometrics models | CO2 | Evidence for convergence |
| Li et al. (2014) | 1990-2010 | 50 U.S. States | Sequential panel selection method proposed by Chortareas and Kapetanios (2009) | CO2 | Convergence for 12 states  Divergence for 38 states |
| Wang et al. (2014) | 1995-2011 | Provinces of China | Phillips and Sul (2007) Panel club convergence test | CO2 | Convergence for Clubs  Divergence for whole sample |
| Presno et al. 2015) | 1901-2009 | 28 OECD countries | Non-linear stationarity test proposed by (Presno et al. (2014) | CO2 | Stochastic and β-convergence in linear form, stochastic convergense in non-linear form |
| Burnett (2016) | 1960-2010 | U.S. States | Phillips and Sul (2007) Panel club convergence test and panel data estimators | CO2 | Club convergence and conditional β-convergence for 26 states, divergence for others, |
| Tiwari et al. (2016) | 1960-2009 | 35 Sub-Saharan Countries | Non-linear time series and panel unit root tests proposed by (Becker et al (2006), Ucar and Omay (2009) | CO2 | Stochastic convergence for 27 countries in time series form and 15 countries in panel form |
| Ahmed et al. (2016) | 1960-2010 | 162 countries | Wavelet unit root proposed by Fan and Gençay (2010) | CO2 | Convergence for 38 countries, divergence for 124 countries |
| Acaravcı and Erdogan (2016) | 1960-2011 | 7 regions of the World | Panel unit root test proposed by Pesaran (2007) and Carrion-i-Silvestre et al.( 2005) | CO2 | Stochastic conditional convergence for regions |
| Acar and Lindmark (2016) | 1950-2010 | 86 Countries | Growth regression | CO2 | Mixed results |
| Apergis and Payne (2017) | 1980-2013 | U.S. States | Phillips and Sul (2007) Panel club convergence test | CO2 | Club convergence for some states, divergence for some |
| Acar and Lindmark (2017) | 1970-2010 | OECD | Growth regression | CO2 | Evidence for convergence |

\*environmental performance indicator calculated by the authors

We can definitely highlight that panel unit root test methodologies have been frequently used to test convergence across countries. Their results favor the rejection of a unit root, implying the presence of conditional convergence (Islam, 2003).

**4. Data and methodology**

Annual data on the ecological footprint per capita in the case of the EU countries are obtained from the Global Footprint Network, spanning the period from 1961 to 2013. The countries under investigation are: Luxembourg, Belgium, Sweden, Finland, Austria, Denmark, Irland, Germany, Netherland, United Kingdom, France, Italy, Poland, Greece, Spain, Portugal, Cyprus, Hungary, Bulgaria, and Romania. The remaining EU countries have been excluded due to data unavailability. The analysis focuses on the EU countries since the EU has adopted some of the highest environmental standards on a global basis, as well as common environmental policies. The ecological footprint refers to how much of the environment is demanded by people (Wackernagel 2002). It answers the question of how much the regenerative biological capacity of the planet is demanded by certain human activities, such as resources consumption and goods and services production (Kitzes and Wackernagel 2009). The ecological footprint has turned to be one of the most popular and widespread indicators for sustainability assessment and resource management, since it provides a basis for setting goals, identifying options for action, and tracking progress toward stated goals (Mancini et al. 2017; Ulucak and Lin 2017; Borucke et al. 2013). The concept of convergence in terms of the ecological footprint implies that per capita values of the environmental degradation are getting more equal, while the presence of a divergence status implies the differentiation across countries. The critical point here is considering certain possibilities, such as geographical factors, the volume of economis activities, and energy resources or consumption. In this respect, countries may diverge as a whole, but they can converge into clubs or a spesific steady state. Therefore, a common environmental policy across all countries may fail (Herrerias 2013). Phillips and Sul (2007) recommend a club convergence test (PS test, hereafter) to avoid the possibilities mentioned above. The PS methodology, named as the *log t test*, classifies countries into convergence groups or clubs. Several advantages come to the forefront by applying this methodology: (i) it measures the relative convergence of cross-sectional averages, (ii) panel unit root test may yield that series have a unit root for the gradually converging series, while the PS methodology outperforms it, since it considers gradual changes, (iii) the methodology may yield the presence of cointegration if the series are slowly approaching a long-run equilibrum or indicate a non-linear process; in this case, standard cointegration tests may reject the presence of a cointegrating association., (iv) panel unit root tests are imposed by stationarity properties of each cross section. The general result for the panel may be stationary or non-stationary if very few sections in the panel are strongly stationary or non-stationary (Kurozumi et al. 2013). However, the PS procedure does not rely on the unit root testing (Apergis and Payne 2017), (v) the PS test is formulated as a non-linear time-varying factor model and it allows individual heterogeneities, while it is robust under the presence of heterogeneity and stationarity of the series under investigation (Burnett 2016).

The starting point of the test for a panel data variable , where *i= 1….N* and *t=1….T*, with *N* being the number of countries in the panel and *T* is the time dimension. Using for the log of the ecological footprint per capita, it is decomposed into two time-varying components:

(7)

where is the common factor across countries in the panel and represents the aggregate common action of , i.e. the ecological footprint, but it could be any common variable that has an effect on it, such as CO2, fossil fuels and others. is the idiosyncratic component and represents individual transitions factors that measure the idiosyncratic distance between the common factor and the systematic part of . It is assumed that converges to some limiting value for each country. Considering the convergence hypothesis, the average difference between and decreases over time at a rate proportional to log(t+1)) for and for each country. This procedure enables us to determine convergence by testing whether factor loadings converge. Then, the transition path is calculated as the cross section average of the log per capita values for the series as follows:

(8)

Having applied Equation 8, the cross sectional variaton ratio is constructed as in Equation 9 below:

(9)

Each cross sectional variance is calculated through Equation 9 which indicates the distance of the panel from the common limit. Then, the null (and alternative) hypothesis of convergence (and non-convergence) for each section or country is established as:

Using the *Log t* regression in Equation 10, these hypotheses can be statistically tested:

for (10)

where and symbolises a discarded fraction from the sample and it is recommended by Phillips and Sul (2007) to be . Standard errors are calculated using a heteroskedasticity and autocorrelation consistent estimator for the long-run variance of the resduals. The t-test is performed and the null hypothesis is rejected at the five percent significance level if the one-sided t test is less than -1,65. This null hypothesis defines relative/conditional convergence, while it is analogous with the conditional sigma convergence for the case of panel data (Phillips and Sul, 2007). If the convergence can not be verified for the full sample, it should be investigated for the cases of sub-groups or clubs. To this end, a clustering procedure proposed by Phillips and Sul (2007) is performed to determine the number of those clubs. Firstly, countries in the panel are ordered by the last observation. Then, the first *k* highest countries are selected to form the sub-group *GK* for some , and the *log t test* is run in order to calculate the convergence test statistics for this sub-group, while the core group size is determined by maximizing the test statistics of the sub-group over *k*. Having determined the sub-groups, if we denote the complementary set of the core group , the remaining countries are individually added to and the *log t test* is rerun. If the *t statistic* is grater than *c*, where *c* is some chosen critical value discussed by the authors in the frame of Monte Carlo experiments, the added section is included into the convergence club. This procedure is repeated for the remaining countries to sieve each country for club membership and to form the first convergence club.

**5. Emprical results**

Table 2 illustrates the findings of the club convergence methodology for the ecological footprint. In the case where the one-sided t statistic is < -1,65, the null hypothesis of convergence is rejected at the five percent significance level. Given that the t-statistics turn out to be positive for the cases of the first and third clubs, the null hypothesis can not be rejected (Phillips and Sul, 2007). The rows indicate the findings of the club-clustering procedure for the first convergent club, the second convergent club and the third convergent club, respectively, wherein the full-sample convergence test rejects the null hypothesis of the environmental degradation convergence. The first club includes Greece and Cyprus, the second club consists of Austria, Spain, Portugal, Netherland and Italy, and, finally, the third club involves the remaining of the EU countries, i.e. the U.K., Ireland, Belgium, Sweden, Romania, Luxemburg, Hungary, Germany, France, Findland, Denmark, Bulgaria and Poland.

Table 2.PS club convergence test results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| First Convergence  Club | Greece  Cyprus | |  | *coefficient* | *t statistics* |
| *Constant* | -2.579 | -1.262 |
| *Log t* | 0.766 | 1.312 |
| Second Convergence Club | Austria, Spain, Portugal, Netherland, Italy | |  | *coefficient* | *t statistics* |
| *Constant* | -5.145 | -7.724 |
| *Log t* | -0.228 | -1.201 |
| Third Convergence  Club | Belgium, United Kingdom, Sweden, Romania, Luxembourg, Ireland, Hungary, Germany, France, Finland, Denmark, Bulgaria, Poland | |  | *coefficient* | *t statistics* |
| *Constant* | -7.166 | -13.038 |
| *Log t* | 0.795 | 5.066 |
| Club merging statistics | |  | | *coefficient* | *t statistics* |
| Club 1 + Club2 | | -0.065 | -7.230 |
| Club 1 + Club 3 | | 0.360 | 4.514 |
| Club 2 + Club 3 | | -0.112 | -6.157 |

Phillips and Sul (2009) recommend to rerun the *log t* test across the subclubs to observe evidence in

support of merging clubs into larger clubs. Having determined three convergent clubs, club merging statistics, also shown in Table 2, reveal the failure to reject the null of convergence for the first and the third club, implying the presence of a larger subgroup of the combined clubs. Empirical outputs from the club convergence test clarify the differences in the environmental quality, as well as the awareness strategies for the EU members in each club.

As a transition check, per capita footprint movements of the countries under analysis are depicted by Fig. 1. While each country has lots of descents and ascents, Luxembourg draws the attention at first glance since it has the largest footprint. Apart from Luxemourg, other countries have continued to reach similar a size. More specifically, Denmark has experienced a great success in reducing its own footprint per capita, while it was the second country after Luxembourg until 2005 it reduced this process steadily since the peak year of 1976. In Fig. 2. countries are ordered by their last year observation with a pie chart. From Fig. 2 we can see the size of the ecological footprint for each country by the year 2013. The gradation from largest to the smallest goes as follows: Luxembourg, Belgium, Sweden, Finland, Austria, Denmark, Irland, Germany, Netherland, UK, France, Italy, Poland, Greece, Spain, Portugal, Cyprus, Hungary, Bulgaria, and Romania.

Fig. 1: General outlook of per capita ecological footprint for the countries

Fig. 2: Per capita ecological footprint values for 2013

**Conclusion**

The literture has not paid yet full attention on the ecological consequences of human activities. The few studies in the relevant literature primarily focus on water and air pollutants or consider only a substantially divergent range of sustainability indices. In that sense these few studies have come up with mixed and ambiguous results. This paper, however, put forward and employed the concept of the ecological footprint as a comprehensive indicator to assess convergence issues. The analysis employed the club clustering methodological approach for the case of the EU countries, with the empirical results highlighting the presence of a (small) number of convergence clubs.

These findings carry significant policy implications, mainly for producers, consumers and energy and environmental regulators. In particular, both consumers and producers need to adopt new strategies that highly contribute to a sustainable growth process that significantly maintains high qualitative environmental standards. Such strategies call for new directions and forms of the impact of globalization on production patterns, new lifestyle patterns and the source of energy consumption. The ignorance of the role of the ecological footprint in the health of our ecosystems will potentially result in un-intended and undesirable effects for our future. Therefore, it is substantially crucial to embrace the positive aspects of globalization, while mitigating the associated risks of an increasingly interconnected world in terms of energy and environmental issues.

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