Inequality in Carbon Intensity in EU-28: Analysis Based on Club Convergence

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Abstract: This study examines the convergence properties of CO_2 intensity in EU-28 countries, using panel data for the period 1990 to 2016. We use Phillips and Sul's (2007) approach to test for CO_2 intensity convergence and identify convergence clubs. In addition to the EU-28 members, we analyze the EU-15, and the new EU members (EU-new) that joined after 2004, as distinct groups for the periods 1990–2016, 1990–2004, and 2005–2016. Our results show no convergence to a single group among the EU countries during the full and two subsample periods. However, the convergence takes place within five to seven clubs for the EU-28 and within three to five clubs for the EU-15 and EU-new. There is no evidence of all members converging to a single club in either group or the three sub-periods examined. This study highlights the need for adopting new strategies considering club properties and for sustainable growth, which meets the EU-28 environmental regulation standards.

Keywords: Carbon Intensity; Club Convergence; Convergence Test; European Union

JEL Classifications: O13, O47, O5, Q52, C22

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I. Introduction

The most crucial factors for life sustainability are energy and environment. Therefore, energy economists, governmental and non-governmental organizations, and ecologists, have long debated the relationship between environmental quality, energy use, and economic growth, with inconclusive results. Particularly, legislators and ecologists argue that working on reducing CO_2 pollution for better environment hampers the economic growth of countries. However, their opposites argue that policies to reduce the level of irremediable global damage due to anthropogenic emissions of greenhouse gasses are strictly necessary. Therefore, the causal relationship between economic growth and CO_2 emissions were analyzed to determine whether policies—applied or applicable—might slow down sustainability in economic growth. Moreover, greenhouse gas emissions (GHG) from human activities are the primary drivers of economic growth and environmental degradation. Therefore, the increasing threats of climate change and anthropogenic GHG, of which carbon dioxide emissions (CO_2) are the most significant, have been a serious, global, and ongoing concern for several decades. Unfortunately, global GHG shows fluctuations and a pattern of sharp increases in the last two decades. Economic structure and activities as well as energy intensities are claimed to be the key factors of increased GHG globally. Furthermore, increasing global integration and asymmetries between economies boost global GHG emissions and worsen environmental degradation and global climate change. Therefore, it is of utmost importance to develop policies that focus on environmental, social, and economic differences to mitigate economic asymmetries and anthropogenic GHG, while simultaneously, increasing energy efficiency. To this end, environmental scientists, policymakers, and scientific bodies, attempt to design common international policies to mitigate the pace of global climate change and global warming. The signing of the Kyoto Protocol in 1997, Copenhagen Agreement in 2010, Durban Agreement in 2011, Warsaw Agreement in 2013, and the Paris Agreement in 2015 have emphasized the importance of these common policies. These common international agreements aimed to reduce global greenhouse gasses and increase energy efficiency.

According to the European Environment Agency database (2016), the European Union (EU) is one of the largest GHG emitters and biggest energy consumers in the world. Its carbon emissions in 2014 were recorded at 81% of world emissions, followed by methane, N_2O and F-gasses at 10.6%, 5.6%, and 2.9%, respectively. On the other hand, fuel combustion, transportation, industrial process and product use, agricultural activities and waste management are listed as the top sources of emissions with 55.1%, 23.2%, 8.5%, 9.9%, and 3.3%, respectively (Eurostat, 2016). Hence, EU policy makers consider energy efficiency and climate change policies as the cornerstones for economic growth and sustainable economic development. Thereby, besides signing and obeying all common protocols, for example, the Kyoto Protocol, the EU introduced three systems to meet its commitments to the common policies and its carbon mitigation objectives, that is, the Emission Trading Systems (ETS), Clean Development Mechanism (CDM), and joint implementation (JI). EU-ETS is an EU flagship tool to meet the abatement target of CO_2 in relation to the balance with economic objectives, innovation impacts, investment and price, and profit impact. On the other hand, the EU set inclusionary targets for reducing greenhouse gasses and environmental degradation associated with increasing economic competitiveness, energy efficiency, and the use of renewable energy sources to be accomplished by 2020, 2030, and 2050. The European Commission adopted a new 10-year action plan after the 2020 target to mitigate GHG emissions by 85%–95% by 2050, compared to 1990 levels. Depending on ongoing targets and action plans, the European Commission aimed to decrease the level of CO_2 emissions by 40% and 60% by 2030 and 2040, respectively. However, Korban and Manowska (2011) predictions indicates that asymmetries between economic and social structures will not allow the directives and common policies of the EU to mitigate CO_2 emissions by 20% compared to 1990 levels. Although the European Union pressures each member country to implement the same directives of energy and carbon abatement, its impact on each country is quite different. For instance, Germany, United Kingdom, France, Italy, Poland, and Spain were listed as top emitters compared to the EU-28 member countries. The aggregated share of GHG emissions of the listed countries is 70% of the total EU-28 member countries. Among these countries, the new member countries, Romania (56%) and the Czech Republic (approximately 37%) achieved significant reduction in CO_2 emissions by changing their economic structures while Spain (15%), Portugal (6.4%), and Ireland (3.7%) showed an increasing pattern of emissions. The North–South division within member countries, income inequality, and the difference in Gross Domestic Product (GDP), economic structure, and the level of energy efficiency, reveal a heterogeneous picture among EU-28 member countries for the sources of environmental degradation and global warming. Consequently, the determination of the distribution of state-level CO_2 emissions and its dynamics over time, require inspection. Moreover, an investigation of EU-28 CO_2 emissions necessitates the following questions. Do the country-specific differences in CO_2 emission levels tend to disappear or increase over time? If the observed diminishing disparities in CO_2 emissions level minimized, should the legislators not be worried about the current mitigation scheme? If the disparities tend to continue over time, should the legislators implement strict rules to mitigate the disparities between EU-28 countries and CO_2 emissions to reduce global warming? Are the common policies adequate for achieving the target? Do these policies give the intended reduction in CO_2 emissions for each country?

Notably, a developing country, China, was placed as the top CO_2 emitter, followed by the United States, India, Russia, Japan, Germany, Korea, Canada, Iran, and Saudi Arabia; the CO_2 emissions of these countries represent 75% of global CO_2 emissions. This study analyzes the patterns and inter-temporal dynamics of CO_2 emissions EU-28 countries, and classifies them into homogenous groups. To this end, we employed the club convergence method (PS) by Phillips and Sul (2007) to assort member countries depending on country-specific CO_2 features to investigate the existence of unique or different equilibriums. The PS method accounts for cross-section dependence through common factor analysis and evaluates the convergence process depending on the inter-temporal dynamics of GHG emissions of each member country. Consequently, we evaluated the convergence dynamics of EU-28, EU-15, and EU-new member countries for three different periods as follows: 1990-2016, 1990-2004, and 2005-2016. We divide the full sample period (1990-2016) into two different periods as per the number of observations for each period, to obtain convergence dynamics, and test whether the convergence dynamics changed after the fifth enlargement process of the EU. In particular, by testing for convergence and searching for possible club-specific features, we hope to help policymakers develop separate policies for each club to minimize their energy intensity levels for sustainable economic growth, depending on each club's economic features.

This study makes a three-fold contribution to the existing literature: (i) It attempts to classify the EU-28 members into different clubs as per their inter-temporal dynamics of CO_2 emissions intensities and find the different steady state levels for EU-28, EU-15, and EU-new members for the identified time periods (1990-2016, 1990-2004, 2005-2016). This may lead to different club-specific policies to unify all countries in the long run, and achieve environmental and energy targets in 2030 and 2050. (ii) The methodology employed helps account for spatial heterogeneity in the series, focusing on different steady state levels for countries with the same characteristics in terms of CO_2 intensity, and gives robust results in the presence of heterogeneity and non-stationary. Lastly, it emphasizes the asymmetric reductions in CO_2 emission intensity levels, the magnitude of the effect of common policies, their contributions to the EU 10-year targets, and the diversity between the founding members and newly participating countries.

The rest of this paper is organized as follows: Section-II discusses key related studies and Section-III presents the data and econometric method. Section-IV comments on empirical results, while Section-V concludes.

II. Literature Review

Recently, global warming and global climate change have become the most important topic in all developed and developing countries, with considerable discussion on GHG emissions and its environmental effects in energy and environmental economics. Many studies have attempted to find the drivers of these anthropogenic GHGs, particularly for CO_2 emissions. Popular studies in this field examine causality issues and use the Environmental Kuznets curve (EKC) model to test the direct relationship between gross domestic product and pollutant emissions (Haseeb et al., 2018; Park et al., 2018; Montasser et al., 2018; Huang, 2018; Farhani and Ozturk, 2015; Begum et al., 2015; Heidari et al., 2015; Ozcan 2013). This motivated energy and environmental economists and policymakers to focus on the convergence of these pollutants (see Li and Lin, 2013; Yavuz and Yilanci, 2013; Criado and Grether, 2011). All these studies have relied on the conventional stationarity of GHGs emissions (time series and/or panel) by employing unit root tests such as beta, sigma, and stochastic convergence techniques. These tests also captured the "catch up effect," and were later classified in relative (conditional) and absolute (unconditional) terms. An important issue in these analyses is judging whether the shocks in pollutant emission patterns are permanent. Thus, by studying the behavior of the series (stationary or non-stationary/convergence or divergence), policymakers, and environmental and energy economists can provide country-specific guidance and policies to reduce environmental degradation and overcome global warming under the rules and regulations of the common policies, e.g., the Kyoto Protocol (see Lee and Chang, 2008; Solarin, 2014). Therefore, to design appropriate policies, it is necessary to examine and understand the trends in and behavior of pollutants although a large number of studies on convergence or divergence are ultimately inconclusive. For example, Aldy (2006) provided evidence of divergence in terms of per capita CO_2 emissions among 88 countries during the 1960-2000 period. Nguyen-Van (2005) also investigated the per capita CO_2 emissions and presented mixed results for a sample of hundred industrialized countries. Moreover, Barassi et al. (2008) reached the same conclusion for OECD countries during the period 1950-2002. Ezcura (2007) examined the regional distribution of CO_2 emissions for 87 selected countries and concluded that the regional disparities of these countries were increasing over the period 1960-1999. Furthermore, Camarero et al. (2013) generated a new index, called the carbonization index, and showed that there is no single steady-state level for the countries considered in his study.

In contrast, Strazicich and List (2003) employed stochastic and conditional convergence techniques and examined 21 OECD countries' CO2 emissions. They found strong evidence of convergence for the period of 1960-1997. Similarly, Westerlund and Basher (2008) examined 16 industrialized countries and found strong support for stochastic conditional convergence for the period 1870-2002. Furthermore, Romero-Avila (2008) found evidence in support of convergence among 23 industrialized countries for the 1960-2002 period by using panel unit root tests, while Herrerias (2012) reached the same conclusion for the selected 25 EU countries for the 1920-2007 period. Likewise, Jobert et al. (2010) examined the same issue for selected EU countries and focused on the absolute convergence in terms of per capita CO_2 emissions using data for the period of 1971-2006. They documented that the speed of convergence differs across the members and, thus, they suggested to identify different groups within studied EU member states. Moreover, Yavuz and Yilanci (2013) (G7 countries), Christidou et al. (2013) (selected 36 countries), Acaravci and Erdogan (2016) (World's 7 region) and Acaravci and Lindmark (2017) (OECD countries) employed several methods and obtained evidence in support of the convergence of CO_2 emissions across different selected countries over their different study periods. In the same line, Acar and Lindmark (2016), Nguyen-Van (2005) and Stegman (2005) obtained evidence both on the divergence and convergence of CO_2 emission on various countries.

There are several reasons for these mixed findings, for instance, the use of different time spans and/or different conventional econometric techniques, and ignoring the behavior of the series. Thus, the findings may provide inconsistent and specious results about the hypothesis of convergence. Therefore, Quah (1993,1996,1997) and later Durlauf et al. (2005) have both cogently criticized the econometric methods used in the literature and argue that there is no single steady state level as suggested in the neoclassical theory. Furthermore, they also argue that the neoclassical-based approaches ignore the fact that several countries may modify their positions over time. Thus, expecting single steady-state convergence may lead to the ignorance of country spillover effects such as environmental degradation or GHG emissions depending on the diversity within countries and regions that have different growth processes, different energy production compositions of renewable and non-renewable forms, and different composition of energy use. Therefore, many studies investigating the convergence-divergence issue employ the Phillips and Sul (2009) methodology that considers the convergence issue among countries and the homogeneity/heterogeneity of them. For instance, Panopolou and Pantelis (2009) investigated the convergence of CO_2 emission for a total of 128 countries. They found two separate convergence clubs spanning the period of 1960-2003. Moreover, they argue that, there is an evidence of transitions across the two clubs with a tendency of the countries to move from one club to another. Moreover, Herrerias (2013) investigated the convergence issue for 162 countries over 1980-2009 and presented the strong evidence of club convergence. Wang et al. (2014) analyzed CO_2 emissions convergence depending on the diversity in China provinces. They found different steady-state points for the period of 1995-2011. Similarly, Burnet (2016) applied the same approach for per capita aggregate CO_2 emissions for the states of the US over the 1960-2010 period and identified 23 states that comprised 3 clubs and 25 diverging states, while Apergis and Payne (2017) investigated 3 homogenous clubs within the states of the US with respect to CO_2 emissions intensity. Additionally, Ulucak and Apergis (2018) confirmed convergence of the per capita ecological footprint by using club-clustering approach in the EU countries spanning the period from 1961 to 2013. The findings show significant evidence of different convergence clubs. Recently, Yu et al. (2018) and Liu et al.(2018) found evidence of multiple homogenous clubs in terms of CO_2 emissions convergence for 24 industrial sectors and 285 cities in China.

This study assorts the behavior and inter-temporal dynamics of EU-28 CO_2 emissions, as well as the "catch up effect" of the series, into separate clubs that follow the same common environmental targets and convene at different steady state points. Accordingly, this study employed the newly developed PS methodology, which deliberates that some countries, regions, states, or sectors belong to a club, moving from a position of disequilibrium to their club-specific equilibrium level.

III. Data and Empirical Methodology

We obtained the annual data for CO_2 emissions intensity from the World Bank World Development Indicators for European Union-28 member countries, spanning 1990 to 2016. The period of the data is restricted by the availability. The selected countries under investigation are as follows: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Spain, Slovakia, Slovenia, Sweden, and the United Kingdom. We chose to investigate the EU-28 countries due to their high environmental standards globally and their common policies. Carbon dioxide emission intensity refers to the kilogram of emitted CO_2 gasses per kilogram of oil equivalent energy use for production. In other words, it is an emission rate of CO_2 relative to the intensity of a specific activity, or an industrial production process. The concept of convergence, in terms of CO_2, means becoming equal in terms of the level of environmental degradation, while divergence implies decoupling among countries. Here, it is important to consider the behavior and dynamics of the CO_2 emissions pattern of each country as well as their geographical factors, volume of economic activities, and energy use and resources. Therefore, countries may diverge overall but can converge into clubs or attain certain equilibrium. Therefore, the common environmental policies of the EU for achieving the EU-2020, 2030, and 2050 targets may fail. Therefore, Phillips and Sul(2009) recommended the club convergence technique to avoid a single equilibrium level and checking different equilibriums for investigated samples. In other words, PS classifies the countries, states, industries, or regions for different groups or clubs. Moreover, PS has several advantages as follows:

1. It considers the full sample average and measures its relative convergence.
2. PS considers gradually converging series and gradual changes in series, while panel unit root tests do not.
3. PS accounts for the presence of slowly approaching series in the long run equilibrium, while indicates a nonlinear process.
4. PS does not rely on stationarity or panel unit root testing (Apergis and Payne, 2017).
5. PS allows country specific heterogeneity and gives robust results in the presence of heterogeneity and non-stationarity (Burnett, 2016).
6. It is formulated as a nonlinear time varying factor model and named as log t-test.

The first step in the log t-test is to decompose panel data variable into two time varying components.

$$y_{it} = r_{it} u_t \tag{1}$$

where y_{it} denotes the panel data variable, for N, $i = 1,2,3, \ldots N$, number of countries and T, $t = 1,2,3, \ldots T$, is the time dimension. Here, u_t indicates the common factor across identified countries and represents the aggregate common movements of the panel data variable, which is CO_2 emission intensity. Moreover, r_{it} is the idiosyncratic component symbolizing individual transition factors and measures the idiosyncratic distance between the common factor u_t and the systematic part of the panel data. It is supposed that r_{it} converges to some limiting value r_i for each country.

Considering the hypothesis of convergence, the mean difference between r_{it} and r_i reduces over time, at a rate proportional to

$$\frac{1}{t^{\alpha} \log(t+1)} \tag{2}$$

for $\alpha \geq 0$ and $r_i = r$ for each investigated country. This process helps in finding the convergence, by analyzing whether factor loadings r_{it} converge. Subsequently, the transition path, h_{it}, is calculated as follows:

$$h_{it} = \frac{\log y_{it}}{\overline{\log g_t}} \tag{3}$$

Here, $\overline{\log g_t}$ presents the log values for CO_2 emissions intensity for each country. By employing equation (3), the ratio of the cross-sectional variation (H_1/H_t) can be calculated using:

$$H_t = \frac{1}{N} \sum_{i=1}^{N} (h_{it} - 1)^2 \tag{4}$$

The variations for each investigated country can be calculated through equation (4), which represents the distance of the panel from the common limit. Therefore, we establish the null and alternative hypothesis for convergence or divergence for each country as follows:

Null hypothesis: $r_i = r$ with $\alpha \geq 0$
Alternative hypothesis: $r_i \neq r$ for any i and $\alpha < 0$

The following equation tests the hypothesis in a statistical framework:

$$\log(H_1/H_t) - 2\log L(t) = c + b\log t + u_t \tag{5}$$

for $[\tau T], [\tau T]+1, \ldots, T$ with $\tau > 0$. Here, $L(t) = \log(t)$ and τ indicates a discarded fraction from the investigated panel, which is default by PS to be 0.3. We calculate standard errors using a consistent estimator of heteroskedasticity and autocorrelation for the long-term variance of the residual. On the other hand, as the one-sided *t*-test result is less than -1.65, we concluded that the null hypothesis is rejected at the 5% significance level for the full sample. Thus, if the full sample does not converge at the 5% significance level, we test the convergence of subgroups of clubs. Here, we employ a clustering procedure to determine the number of clubs and their members. This procedure contains the following steps.

Step 1: Ordering. The members in the panel will be ordered depending upon the last observations in descending order.
Step 2: Forming All Possible Core Groups: To form the optimal core cluster size, k^*, PS tries to maximize the $\log(t)$ statistics $t_k = t(G_k)$, where $N > k \geq 2$. Hereby, we denote G_g for the sub-group, which comprises the k highest countries. Moreover, $k^* = \text{argmax}\,(t_k)$ set as criterion, on conditional basis $\min(t_k)$ greater than -1.65. If this condition does not hold, the last member country will be eliminated from the clusters and a new group will be formed. This process will continue until it identifies the core cluster.
Step 3: Sieve Individuals for club membership: Once the core cluster is identified, the rest of the countries will be eliminated to join the core cluster by repeating the $\log(t)$ statistics. Adding a new country at a time to the cluster and employing the $\log(t)$ test to obtain t_s for membership, $t_s > c^*$, where c^* is the critical value. PS suggested setting the c^* to 0, when the size of the sample is not greater or equal to 50. Subsequently, the first cluster is defined; the $\log(t)$ statistics will be enforced to the cluster to ensure that condition t_b is greater than -1.65. Otherwise, it will necessary to increase the critical value of c, that is, c^*.
Step-4: Stopping Procedure: Once the null hypothesis is rejected, stop forming the additional subgroups. Once $t_k > -1.65$, we assume that the remaining countries, states, regions, or industries diverge.

IV. Empirical Results

We perform a graphical analysis of the convergence issue for the CO_2 emissions intensity of EU-28 countries. First, we examined the relative transition path of CO_2 emissions intensity of EU-28 countries to visually decide whether the investigated group of countries converges at one steady state level. However, as is obvious in Figure 1, the countries have many ascents and descents relative to the transition of CO_2 emissions intensity, and show decoupling from each other. Moreover, during the period under investigation, we observed average annual growth of CO_2 emissions intensity in Belgium, Croatia, Cyprus, Ireland, Netherlands, Poland, Portugal, Romania, and Spain. In the remaining EU-28 member countries, the CO_2 emissions intensity shows a decreasing pattern. However, in recent years, the smallest average annual decrease in CO_2 emissions intensities were in Germany, Luxembourg, Malta, the Slovak Republic, and the United Kingdom. Instances of highest decrease were observed in Estonia, Finland, Greece, and Slovenia. These differences were mostly related to economic activities or structures, economic transition enforcements, technological advancement, and the differences in the growth rates of the economies. On the other hand, the fluctuations were mostly observed after the fifth enlargement process of the EU, possibly due to enforcement for membership or pursuit of standards. Thus, we employed the PS method to further investigate the different steady states for the members who share a common trend for different time periods. In addition, we also wanted to check if the enlargement process has significant effects on the dynamics of convergence for countries during their transition terms. Moreover, we employed this test for EU-15 and EU-new member countries for the periods under investigation to observe their inter-temporal dynamics and the behavior related to CO_2 emissions intensity.

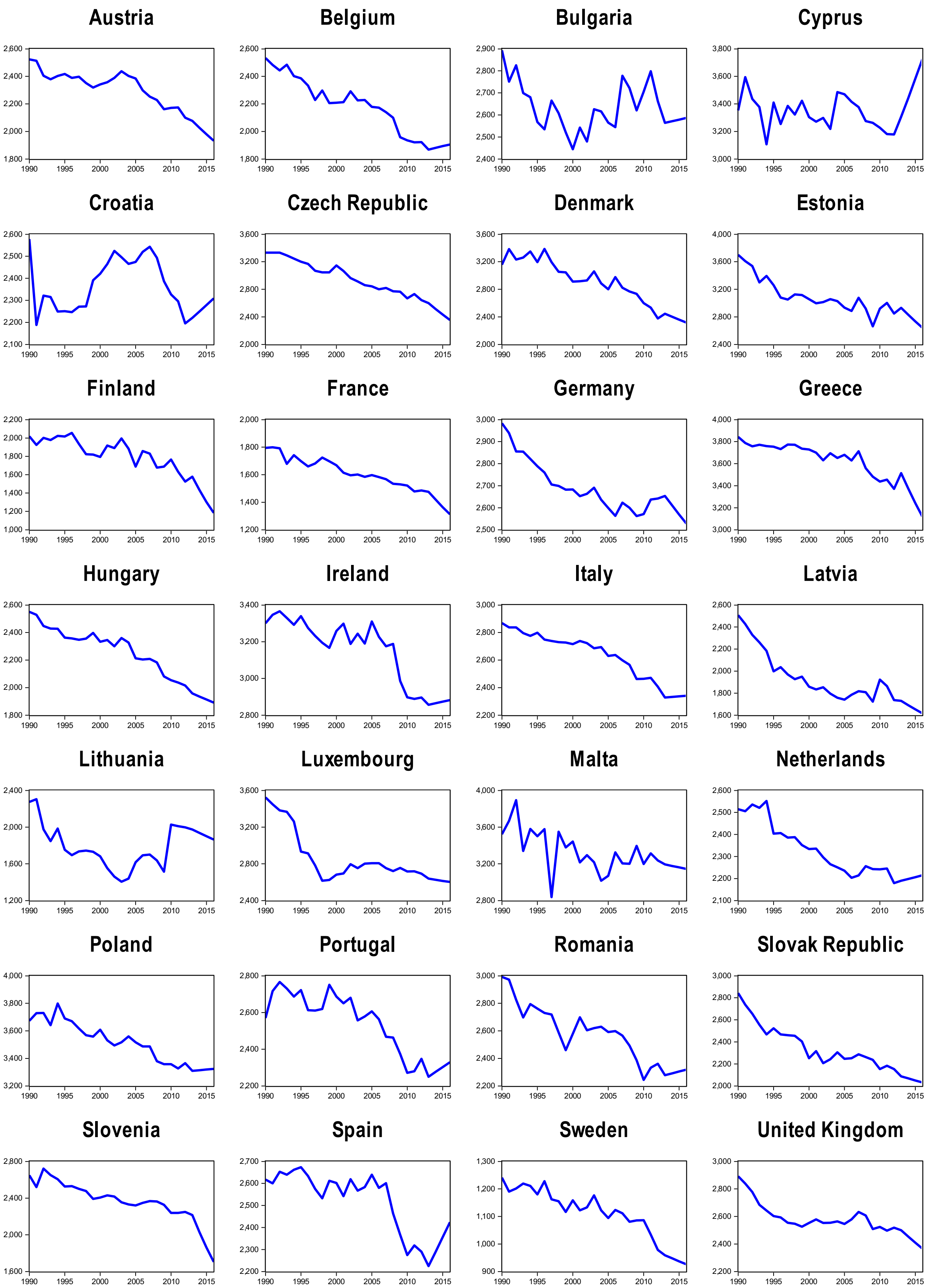

Figure 1: CO_2 Emissions Intensity of EU-28 countries

4.1 Full Sample Club Convergence

As we observed decoupled trends in Figure 1, we employed the Phillips and Sul (2007) methodology to find several steady state levels and classify the homogenous group of countries. Table 1 illustrates the findings of log *t*-tests of club convergence methodology for CO_2 emissions intensity of EU-28 countries. For all identified periods (1990-2016, 1990-2004, and 2005-2016), we found one-sided t-statistics at less than the critical level. Thus, the null hypothesis of convergence of full sample at unity is rejected at the 5% significance level. Therefore, we employed the clustering procedure. To this end, for 1990-2016, we identified five different groups of countries that consist of 5,8,8,4, and 2 members, respectively. Furthermore, one country, namely Sweden, was categorized as the non-convergent country among others. The first club has the highest convergence speed of CO_2 emissions intensity and consists of Cyprus, Greece, Lithuania, Malta, and Poland. Moreover, the second club, which has lower speed than the first club but a higher speed than the third, fourth, and fifth convergence clubs, consists of Bulgaria, Croatia, Czech Republic, Estonia, Germany, Ireland, Luxembourg, and the United Kingdom, followed by other countries with different convergence speeds. Finland and France were classified as the last group members and have the lowest convergence speed for environmental remediation. On the other hand, when the analysis was repeated, considering the fifth enlargement process, before 2005, the diversification in transition patterns and the dynamics of CO_2 intensity was higher than after the enlargement process. For 1990-2004, decoupling among countries was high and we obtained seven groups of countries. However, this reduces to six after the enlargement process, perhaps due to EU enforcement of environmental issues, common policies, and the economic integration/advancement of countries. We analyzed the possibility of transition of member countries from one club to another or merging of clubs for the time period under investigation. This allows us to observe the countries that share common long-run trends and transition dynamics.

No clubs merge in the 1990-2016 period; however, the second and third club merged for the 1990-2004 period, and the number of clubs decrease to six, while we observe the same situation after the enlargement period (see from Table 1). This implies the presence of a larger subgroup of the combined clubs related to CO_2 emissions intensity. Moreover, the results from the club convergence methodology clarify the differences in the environmental quality of the countries, as well as the environmental awareness in each club. Lastly, we observe that club 1 has older and less efficient industrial infrastructure in terms of environment than other clubs. In other words, club 1 members emit higher CO_2 per unit of energy consumed.

Table 1: Convergence Clubs of CO_2 Intensity for EU-28

Periods	log *t* test		Convergence Clubs Before Merging								
	Coeff.	**t-stat**	**No of Clubs**	**Club 1**	**Club 2**	**Club 3**	**Club 4**	**Club 5**	**Club 6**	**Club 7**	**Not Convergent Group**
1990-2016	-0.961	-51.635	5	**Coeff: 0.036** **t-stat: 0.347** Cyprus, Greece, Lithuania, Malta, Poland	**Coeff: 0.174** **t-stat: 5.919** Bulgaria, Croatia, Czech Republic, Estonia, Germany, Ireland, Luxembourg, United Kingdom	**Coeff: 0.225** **t-stat: 2.447** Austria, Denmark, Italy, Netherlands, Portugal, Romania, Slovak Republic, Spain	**Coeff: 0.155** **t-stat: 1.027** Belgium, Hungary, Latvia, Slovenia	**Coeff: 4.146** **t-stat: 2.618** Finland, France			Sweden
1990-2004	-1.071	-155.496	7	**Coeff: 0.035** **t-stat: 0.333** Cyprus, Poland	**Coeff: 0.001** **t-stat: 0.016** Croatia, Ireland, Malta	**Coeff: 0.258** **t-stat: 2.765** Czech Republic, Denmark, Estonia, Italy, Portugal, Spain	**Coeff: 0.325** **t-stat: 4.824** Austria, Bulgaria, Germany, Hungary, Luxembourg, Romania, United Kingdom	**Coeff: 0.687** **t-stat: 8.047** Belgium, Netherlands, Slovak Republic	**Coeff: -0.490** **t-stat: -0.311** Finland, Latvia	**Coeff: -2.325** **t-stat: -1.366** France, Lithuania	**Coeff: -0.944** **t-stat: -48.155** Greece, Slovenia, Sweden
2005-2016	-1.239	-261.878	6	**Coeff: 1.623** **t-stat: 8.525** Greece, Malta, Poland	**Coeff: 0.056** **t-stat: 0.568** Bulgaria, Estonia, Germany, Ireland, Lithuania	**Coeff: 0.460** **t-stat: 2.794** Czech Republic, Netherlands, United Kingdom	**Coeff: 1.409** **t-stat: 4.984** Croatia, Denmark, Italy, Portugal, Romania, Spain	**Coeff: 0.060** **t-stat: 0.604** Austria, Belgium, Hungary, Latvia, Slovenia	**Coeff: 3.968** **t-stat: 1.549** Finland, France		**Coeff: -1.298** **t-stat: -155.252** Cyprus, Luxembourg, Slovak Republic, Sweden
Convergence Clubs After Merging											
1990-2016	No Clubs can be merged										
1990-2004				**Coeff: 0.035** **t-stat: 0.333** Cyprus, Poland	**Coeff: -0.008** **t-stat: -0.109** Croatia, Czech Republic, Denmark, Estonia, Ireland, Italy, Malta, Portugal, Spain	**Coeff: 0.325** **t-stat: 4.824** Austria, Bulgaria, Germany, Hungary, Luxembourg, Romania, United Kingdom	**Coeff: 0.687** **t-stat: 8.047** Belgium, Netherlands, Slovak Republic	**Coeff: -0.490** **t-stat: -0.311** Finland, Latvia	**Coeff: -2.325** **t-stat: -1.366** France, Lithuania		**Coeff:-0.944** **t-stat: -48.155** Greece, Slovenia, Sweden

2005-2016				**Coeff: 1.623** **t-stat: 8.525** Greece, Malta, Poland	**Coeff: -0.042** **t-stat: -0.525** Bulgaria, Czech Republic, Estonia, Germany, Ireland, Lithuania, Netherlands, United Kingdom	**Coeff: 1.409** **t-stat: 4.984** Croatia, Denmark, Italy, Portugal, Romania, Spain	**Coeff: 0.060** **t-stat: 0.604** Austria, Belgium, Hungary, Latvia, Slovenia	**Coeff: 3.968** **t-stat: 1.549** Finland, France			**Coeff:-1.298** **t-stat:-155.252** Cyprus, Luxembourg, Slovak Republic, Sweden

4.2. EU-15 and EU-new Sub-Group Club Convergence Relative to CO_2 Intensity

We employ the initial classifications for the EU-15 and EU-new member countries based upon the log t algorithm. Table 1 lists the members of each corresponding club. Depending on the test results for each club, the coefficients on the log t term are negative and statistically insignificant. Thus, we conclude that for the identified time periods, each club converges at different steady state points and has diverging CO_2 emissions intensity. On the other hand, the results indicate that the heterogeneity of behavior of CO_2 emissions intensity among EU-15 countries is consistent in the long run and none of the clubs merge. On the contrary, the heterogonous behavior of CO_2 emissions intensity among EU-new member countries disappears slightly in the long term, and many countries move from one club to another or the clubs merge. This may be due to technological improvements, development in economic structure or performance, imposing strict regulations to achieve EU standards, role of internalization, and compliance with international agreement obligations for environment and economic issues during their transition term. However, the degree of intra-distribution mobility among the clubs is quite low and limited. It seems that most countries tended to stay in their original club before and after the fifth enlargement term. Consequently, we can say that heterogeneity within EU-15 and EU-new members as well as between both groups continues after the fifth enlargement period (see Table 2).

Table 2: Convergence clubs of EU-15 and EU-new Member Countries

Periods	Log t test		Convergence Clubs Before Merging						
	Coeff.	t-stat	No of Clubs	Club 1	Club 2	Club 3	Club 4	Club 5	Not Convergent Group
EU-15 Countries before merge									
1990-2016	-1.007	-68.059	3	**Coeff: 0.243** **t-stat: 2.207** Germany, Ireland, Luxembourg, United Kingdom	**Coeff: 0.384** **t-stat: 4.327** Austria, Denmark, Italy, Netherlands, Portugal, Spain	**Coeff: 4.146** **t-stat: 2.618** Finland, France			**Coeff: -0.893** **t-stat: -307.818** Belgium, Greece, Sweden
1990-2004	-0.923	-53.451	1	**Coeff: 0.026** **t-stat: 0.452** Austria, Denmark, Germany, Italy, Luxembourg, Portugal, Spain, United Kingdom					**Coeff: -0.971** **t-stat: -54.818** Belgium, Finland, France, Greece, Ireland, Netherlands, Sweden
2005-2016	-1.233	-150.967	3	**Coeff: 0.543** **t-stat: 4.054** Germany, Ireland, Luxembourg	**Coeff: 0.680** **t-stat: 6.129** Denmark, Italy, Netherlands, Portugal, Spain, United Kingdom	**Coeff: 3.968** **t-stat: 1.549** Finland, France			**Coeff: -1.105** **t-stat: -53.507** Austria, Belgium, Greece, Sweden
EU-New member Countries before merge									
1990-2016	-0.744	-33.438	5	**Coeff: 2.639** **t-stat: 2.649** Cyprus, Poland	**Coeff: 0.625** **t-stat: 4.504** Bulgaria, Czech Republic, Estonia, Lithuania	**Coeff: 6.856** **t-stat: 10.205** Croatia, Romania	**Coeff: 1.013** **t-stat: 1.109** Slovak Republic, Slovenia	**Coeff: 0.165** **t-stat: 0.957** Hungary, Latvia	Malta
1990-2004	-1.40	-198.129	4	**Coeff: 0.035** **t-stat: 0.333** Cyprus, Poland	**Coeff: 0.59** **t-stat: 4.001** Croatia, Czech Republic, Estonia	**Coeff: 0.349** **t-stat: 2.652** Bulgaria, Romania	**Coeff: 1.733** **t-stat: 4.674** Hungary, Slovenia		**Coeff: -1.495** **t-stat: -615.845** Latvia, Lithuania, Malta, Slovak Republic

2005-2016	-1.165	-145.772	4	**Coeff: 0.308** **t-stat: 3.716** Malta, Poland	**Coeff: 0.076** **t-stat: 0.648** Bulgaria, Estonia	**Coeff: 0.860** **t-stat: 4.198** Czech Republic, Lithuania, Romania	**Coeff: 0.302** **t-stat: 2.200** Hungary, Latvia, Slovenia		**Coeff: -1.626** **t-stat: -202.527** Croatia, Cyprus, Czech Slovak Republic
EU-15 Convergence Clubs After Merging									
1990-2016	No Clubs can be merged								
1990-2004	No Clubs can be merged								
2005-2016	No Clubs can be merged								
EU-new members Convergence Clubs After Merging									
1990-2016				**Coeff:-0.048** **t-stat:-0.484** Bulgaria, Cyprus, Czech Republic, Estonia, Lithuania	**Coeff: 6.856** **t-stat: 10.205** Croatia, Romania	**Coeff: 1.013** **t-stat: 1.109** Slovak Republic, Slovenia	**Coeff: 0.165** **t-stat: 0.957** Hungary, Latvia		Malta
1990-2004				**Coeff: 0.035** **t-stat: 0.333** Cyprus, Poland	**Coeff: 0.264** **t-stat: 2.542** Bulgaria, Croatia, Czech Republic, Estonia, Romania	**Coeff: 1.733** **t-stat: 4.674** Hungary, Slovenia			**Coeff: -1.495** **t-stat: -615.845** Latvia, Lithuania, Malta, Slovak Republic
2005-2016				**Coeff: 0.308** **t-stat: 3.716** Malta, Poland	**Coeff: 0.007** **t-stat: 0.090** Bulgaria, Czech Republic, Estonia, Lithuania, Romania	**Coeff: 0.302** **t-stat: 2.200** Hungary, Latvia, Slovenia			**Coeff: -1.626** **t-stat: -202.527** Croatia, Cyprus, Slovak Republic

V. Conclusion

The literature has still not paid full attention to the consequences of anthropogenic GHGs emissions on the environment. The few studies primarily focus on the intensity level of CO_2 emissions by considering a single steady state point. Thus, these papers obtain ambiguous and mixed results. Therefore, this study put forth and employed the club clustering methodological approach in the case of EU-28 member states.

This study contributes to the existing literature in terms of convergence evaluation aspects on the existence of different steady state points or convergence clubs of EU-28 member states, rather than the presence of an overall or regional single convergence level during time spans investigated (1990-2016, 1990-2004, and 2005-2016). With this, the rejection of the null hypothesis (overall convergence) leads us to identify some clubs that tend to different equilibrium levels within the EU-28, EU-15, and EU new member countries. We identified a relative convergence within the identified clubs as five to seven convergence clubs, depending on the investigated time periods at the country level. However, three to five convergence clubs were identified in terms of categorical level (EU-15, EU-new members).

For the case of the EU, carbon emissions continue to be quite high due to the massive dependence on fossil fuels for energy generation to support sustained economic graowth. Due to the large emissions, the environment continues to degrade with no reduction in sight. It is almost impossible to implement a direct solution that would effectively reduce the amount of energy intensity because of how much the apparently homogenous region depends on the current level of energy usage. In the EU, there is an ongoing process of energy transitions through common agreements, i.e. Kyoto Protocol and Paris Agreement, in order to reduce energy consumption, CO_2 emission, and environmental degradation by 20% as well as reducing global temperature by 1.5°C. To this end, the carbon reduction roadmap was designed while focusing on increasing energy efficiency through rapid reduction in energy demand, comprehensive electrification of energy supply, replacing fossil fuel consumption with renewable energy sources etc. However, social and political roadblocks, such as political paralysis and denials; financial, governance and implementation constraints; inequitable wealth distributions and social dependences prevent rapid de-carbonization within the EU. Therefore, our findings carry significant policy implications for environmental degradation. Accordingly, the EU must first accelerate the enforcements through agreements as well as implement some strict regulations in order to achieve a low carbon economy. Secondly, depending on the economic and energy dependency, the EU should strengthen economic capacity by producing goods and services with lower energy requirement and CO_2 emissions. Moreover, the member states should change the structure of the electricity sector and diversify energy sources in order to generate more efficient electricity for the industry and households. This will cause to gain institutional thickness and capacity to have less energy intensity in electricity generation. Thus, political leaders, investors, and environmentalist should promote and subsidize the cost of installing renewable energy sources along with providing accommodation and subsidies for entities that are investing into research and development of eco-friendly technologies. Furthermore, the governments and legislators should introduce stricter regulations on fossil fuel dependent technologies through common agreements that also contribute to mitigating carbon emissions and environmental degradation. In other words, both consumers and producers should be encouraged to adapt environmental friendly technologies and energy conserving procedures that contribute to sustainable economic growth and maintain high qualitative environmental standards. Additionally, the EU should continue to protect vulnerable communities from the ravages of degradation. Thus, it should increase CO_2 emission permit prices and expanding such policies into covering all greenhouse gasses i.e. methane and nitrous oxide, including shipping and air transport. Moreover, since energy related CO_2 emission is measured as 80% of total emission and transportation sector has the highest share depending on continuous increase in road transportation that is triggered by growing trade volumes, the EU should develop policy on fuel switching to biofuels or other renewable energy sources and introduce more energy efficient technologies to the citizens.

In contrast, depending on heterogeneous characteristics of the EU-member countries, there is a need to adopt new strategies that consider the homogenous clubs' properties and contribute to sustainable economic growth processes, which also sustain the environmental standards. Thus, the club convergence assessment helps us recommend further consideration of environmental degradation and club specific policies to reduce heterogeneity among countries and gather them into one club to develop more effective common policies to reach the target.

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