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Ecological Footprint Convergence in Emerging Market Economies: Panel Data Analysis[1]

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Abstract

In the fast-growing global landscape, environmental degradation has commenced to be recognized as an outcome of industrialization and globalization. Several indicators associated with environmental degradation are studied in the literature. One of these indicators is the ecological footprint. This indicator is considered an assessment that signifies the biological area utilized to generate the resources necessary for individuals to sustain their existence and assimilate waste. Accordingly, acknowledging the significance of current environmental policies, it is shown as an exceptionally comprehensive indicator. In this article, utilizing the 1990-2022 dataset for selected emerging market economies, the existence of ecological convergence was examined through panel unit root tests. This study found that the ecological footprint in emerging market economies was stable. This finding indicates that there is convergence within these economies to achieve global sustainability.

Keywords: *Ecological Footprint, Environmental Pollution, Emerging Market Economy*

JEL Codes*: E00, Q56, Q57*

INTRODUCTION

It is stressed that ecological degradation has influenced the earth due to influences such as industrialization growth, technological developments, demographic expansion, and urbanization level (Erden Özsoy and Dinç, 2016, p.36). All of these challenges extend the demand for natural resources and, consequently, negatively impact environmental quality.

With the deterioration of environmental quality and its perception as an important problem for countries, national and international conferences, workshops, research and meetings have been organized in recent years on environmental problems, climate changes and global warming. The first international conference on this subject was the United Nations Environment Conference held in Stockholm in 1972. In this conference, it was

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emphasized that there is a need for a partnership on a global scale in order to protect and develop the human environment and to improve environmental problems (Güçlü, 2007, p.68). Another global measure on this issue is the Bruntland Report in 1987. In this report, the concept of sustainable development has been officially brought to the agenda. In addition, issues such as global partnerships for the prevention of poverty, ensuring the control of the population growth rate, and the creation of environmentally sensitive technologies were emphasized (Turan, 2014, p.61). Other global measures and conferences on environmental problems are the Rio Conference (1992), the Istanbul Habitat II Conference (1996), the Kyoto Conference (1997), the Johannesburg Summit (2002), the Rio+ 20 UN Sustainable Development Conference (2012) and the Paris Climate Agreement (2015).

In order to achieve convergence towards reducing the ecological footprint, a multidimensional strategy is needed, including education-based, positive changes in individual and social behavior, technological advances and legal regulations. Policies that encourage waste minimization, sustainable agricultural practices, renewable energy use and energy conservation play a critical role. Advances in technology are expected to make significant contributions to reducing the ecological footprint by making resource use more efficient and generating new solutions for environmental sustainability. In addition, raising awareness of sustainable living through educational activities and awareness activities that can be passed on to future generations can facilitate the adoption of environmentally friendly behaviors (Tillaguango et al., 2021, p1-13).

Among these global measures, the Kyoto Protocol, which was adopted in Kyoto, Japan, in 1997, is known as a step to combat climate change and the environmental problems caused by it. It entered into force in 2005. In this protocol, to which Turkey became a party in 2009, many countries have committed to reducing greenhouse gas emissions (Pata, 2020, p.52).

Throughout the studies on environmental pollution, carbon dioxide emissions have been focused on as a variable. (Salaluddin et al., 2015; Wang et al., 2016; Pata, 2018). However, the increasing environmental problems and the fight against climate crises have made other indicators gain importance. One of these indicators is the ecological footprint indicator (Bucak, 2021, p.2). This indicator was first introduced by Rees (1992) and then considered as a methodological framework through Wackernagel and Rees (1996). This criterion, which has been developed for ecological measurements, is calculated in global hectares. It also shows the biologically fertile water areas and lands needed to eliminate the resulting waste, as well as the production of all the resources consumed with resource management and current technology. The fertile water areas and lands mentioned here are an indicator of the biological capacity required to meet the requirements (Wackenagel et al., 2005, p.4). Biocapacity, on the other hand, is expressed as an indicator that measures a bio-productive supply in a certain area (Forest, Pasture, Arable Land, etc.). An increase in a country's ecological deficit means a decrease in the biological capacity of that country. (Schaefer, et al, 2006, p.5-11). In other words, in a sense, the existence of an ecological deficit and the rise of this deficit shows that our people are unconsciously destroying the environment and that this is

unsustainable.

In the literature on environmental economics, the number of studies dealing with the ecological consequences of individuals' activities towards the environment has recently started to attract attention and research. However, in general, most of the studies dealing with environmental degradation have focused on issues such as the Environmental Kuznet Hypothesis and the Pollution Shelter Hypothesis. In the economic literature, convergence is stated as an approach that suggests that the gap between low-income countries and high-income countries in neoclassical growth theory will close over time (Barro and Salai Martin, 1992, p.225), and it is stated that the issue of convergence has gained importance as a research area that has not been applied to the field of environmental convergence in determining environmental climate change strategies over time (Strazicich and List, 2003, p.265).

The course and convergence trends of pollutant emissions are of great importance for predicting the future of environmental degradation and developing effective climate policies in both developed and developing countries. As a matter of fact, long-term climate change scenarios and most of the international environmental obligations are based on the assumption that pollutant emissions will converge over time. In this context, analyzing whether countries' environmental performances are converging or not can contribute to the formulation of more effective and targeted environmental policies against global warming (Belloc and Molina, 2022:2).

In today's world, environmental problems are increasing in certain countries and country groups. In particular, factors such as industrialization, rapid population growth, and urbanization cause environmental destruction. Since the focus is on rapid economic growth and industrialization process in developing countries, this situation leads to an increase in the ecological footprint indicator. In this study, which is considered in line with this perspective, ecological footprint convergence was investigated for selected emerging market economies, and the data for the period 1990-2022 were examined using the panel unit root test.

When the studies in the literature are examined from a holistic perspective, it is seen that carbon emission convergence has become the focus rather than ecological convergence. In addition, determining whether ecological footprint convergence exists in emerging market economies, which have an important position in global trade with their high production capacity and rapid growth rates, is of critical importance in terms of environmental and economic policies to be developed. It is thought that the study will fill the gap in the literature both on a variable basis and on a country basis. This study is based on four main sections. In the first part, the introduction and the second part include studies (literature) that test ecological footprint stability. The third chapter presents the theoretical background of the study. In the fourth part, the data set and methodology were introduced, and the study was terminated by making comments and suggestions in the light of econometric findings.

LITERATURE REVIEW

It can be noted that scholarly and scientific investigations referring to environmental economics have gathered considerable attention in recent years as the significance of the environment and ecological conditions has increased. In many empirical analyses within the reviewed articles of environmental economics literature, it has been concluded that carbon emissions are largely utilized. Notwithstanding this, it has been noted that studies employing the ecological footprint variable to determine stationarity and convergence among nations are limited. Thus, it is suggested that this study attempts to riches the literature in this regard.

It can be found that the first analysis evaluating the stationarity of carbon emissions within the academic was published by Strazicich and List (2003). It examined the 1960-1997 temporal data gathering for 21 industrialized economies utilizing the panel data methodology. In the results, it was suggested that carbon emissions displayed stability. One of the earlier analyses studying the stationarity of carbon emissions was analyzed by Lee and Chang (2008). In the research, in which the data gathering for the period 1960-2000 was employed for 21 OECD countries, convergence was noted in 7 countries and deviation in 14 nations was observed. In scholarly works such as Romero and Asilla (2008), Westerlund ve Basher (2008), Lee and Chang(2009), Panopoulou & Pantelidis (2009) Yavuz and Yılancı (2013), Christidou vd.,(2013), Solarin (2014), Wang, vd.(2016), Burnet (2016),Tiwari et al.(2016), Apergis and Payne (2017), Yu vd., (2018), Emir vd.(2019), Churchill et al.(2020), Apergis and Payne(2020), Topalli (2021), Payne and Apergis(2021), Apeaning and Labaran (2024) the convergence of carbon dioxide emissions was evaluated employing diverse cross-country groups and econometric methodologies

On the other side, upon reviewing studies that utilize ecological footprint, the first study was conducted by Ulucak and Lin (2017), which analyzed the stability of the ecological footprint of the United States during the period of 1961-2012. In their conclusions, they highlighted that the ecological footprint is not static. Additional studies that evaluating ecological footprint convergence are summarized in the following table (Table 1).

Table 1: Literature Review on Ecological Footprint Convergence

Author(s)- Year	Period/Country(s)	Method	Finding
Bilgili ve Ulucak(2018)	1961-2014/G-20 countries	Panel KPSS Unit Root Test	There is convergence
Bilgili-Ulucak(2019)	1961-2014/60 Countries	Panel KPSS Unit Root Test	There is deviation in Africa-America-Europe.
Solarin (2019)	1961-2013/27 OECD Country	RALS-LM Unit Root Corporal	While there was convergence in 13 countries, deviation was found in 12 countries.
Solarin vd. (2019)	1961-2014-92 countries	Panel Unit Root Test	There is convergence
Haider – Akram (2019)	1961-2014/77 countries	Phillps and Sul method	Findings supporting the club convergence hypothesis have been obtained.
Özcan et al. (2019)	1961-2013/Low-Middle-High income countries	Panel CSR Unit Root Testing	It has been found that there is ecological footprint convergence.
Pata (2020)	191-2016/N-11 Countries	Hadri-Kurozumi (2012) and Lee and Tieslau (2019) panel unit root tests	It shows that the ecological footprint per capita in N11 countries is converging
Yılancı and Pata(2020)	ASEAN 5-Countries/1961-2016	TAR Unit Root Test	The convergence hypothesis is found to be valid.
Tillaguango (2021)	1990-2016/16 Latin American Country	Logistics Regression Analysis	Findings supporting the existence of club convergence have been obtained.
Işık et al.(2021)	1961-2016/USMCA Countries	TAR Unit Root Test	It has been found that there is ecological footprint convergence.
Belloc and Morina (2022)	African Countries/1970-2018	Panel Club Convergence Test	There is not findings were obtained to support the existence of convergence
Yılancı vd.(2022)	G-7 /1961-2016	Panel Fourier Threshold Unıt root test	It has been determined that there is convergence in ecological footprint and carbon footprint.
Cabaş (2023)	1961-2018/Newly Industrialized Countries	Panel Fourier Unit Root Test	On the basis of countries, China, India, Thailand, Malaysia and Turkey, the per capita ecological footprint is unit-rooted, It has been stationary for Brazil, Mexico, Argentina, the Philippines and South Africa
Bayraktar et al.(2023)	1992-2017/BRICS-T	Panel Fourier Unit Root Test	When we look at the countries individually, it was obtained that the ecological footprint converged in Russia and Turkey according to the ADF test, in China and Russia according to the Fourier ADF test, and in Brazil and China according to the Fractional Fourier Frequency test.
Çelik et al.(2023)	ECCAS ve ECOVAS Countries/1961-2017	Panel Unit Root Test	As a result of unit root analysis, it was determined that the convergence was valid
Aragundade vd.(2023)	189 Countries/1990-2017	Panel Club Convergence Test	It has been determined that convergence is valid in the findings obtained.
Gomez and Rodrigez (2024)	ABD Countries/1990-2022	Panel Club Convergence Test	There is findings were obtained to support the existence of convergence

Source: Created by the authors.

When the literature on convergence analyses is examined, it is noteworthy that the vast majority of studies focus on carbon emissions. However, in some studies, ecological footprint, certain greenhouse gases or various combinations of these gases are also included in the scope of the analysis. It is seen that different countries and country groups have been studied. There is no complete consensus on the convergence of ecological footprint

findings. It can be said that the use of different methods, variables and countries has an effect on this.

THEORETICAL FRAMEWORK

Ecological deterioration is considered one of the factors that significantly affect the quality of an individual's life and the sustainability of economic growth. Recently, the large accumulation of greenhouse gas emissions in the atmosphere elevates ecological degradation to a high level of concern in both developed and developing countries. It is notable that the industrialization process, which occurs through the utilization of non-renewable energy in the majority of countries, harms ecological degradation in these countries and negatively impacts economic progress (Solarin, 2019, p.6167).

Convergence theory is dependent on the convergence analysis of growth dynamics, which Solow (1956) evaluated within the context of the Neo-Classical Growth Model. This theory proposes that developing countries can catch up with developed nations (Bayraktar et al., 2023, p.325). This theoretical framework, which supposes that low-income countries will achieve accelerated growth compared to high-income countries, additionally suggests that the growth rate of any country is inversely correlated with the initial per capita income level in this country. It is also highlighted that low-income countries will grow more than high-income countries over the long term and that investments in physical capital will yield significant efficacy (Üzümcü & Ayyıldız, 2022, p.29; Abdioğlu and Uysal, 2013, p.85).

By reviewing literature, convergence is categorized into beta (β) and sigma (σ) convergences. As a comprehensive definition, β convergence is examined to discover whether the relatively low-income country will grow at a rate higher than the growth rate of high-income countries and whether it can catch up with the countries with high-income levels. σ convergence, conversely, focuses on the distribution of income among countries. In addition to these classifications of convergence, it is emphasized that there exist various forms of convergence including micro and macro convergence, conditional and unconditional convergence, stochastic and deterministic convergence, convergence in growth rates and convergence in income levels, conditional convergence, and club convergence (for climate club’s countries) (Ceylan, 2010, p.53).

From an economic perspective, convergence analyses are typically studied within the framework of income convergence. Nevertheless, recently, convergence analyses have been conducted concerning various economic and social indicators. One such indicator is environmental convergence. Therefore, based on the abovementioned convergence classifications, it is argued that environmental convergence is examined in a manner affiliated to economic convergence. In other words, the assumption that the actual environmental quality of countries will align over time is defined as "environmental convergence" (Brock & Taylor 2003, p.2).

For a studied country, the convergence in this context is outlined as the per capita carbon dioxide emissions equalizing over time. Besides, the concept of divergence is recognized as the increasing disparity of carbon

dioxide emissions among countries over time. Consequently, the phenomenon of convergence or divergence regarding such emissions has been explained in the literature accordingly. The significant consideration here is the reality that countries may be moved towards a specific stationary state due to economic and geographical factors or the accumulation of energy resources (Herrerias, 2013, p.1141). Furthermore, when econometric research studies convergence, convergence is observed in some countries while divergence is observed in others. This process gives insights regarding the feasibility of implementing environmental policies.

On the other hand, in order to achieve sustainable development goals, the theory of convergence has started to be discussed in the literature as environmental convergence. Environmental convergence is characterized as a theory based on examining whether environmental policies progressively become similar over time. For the first time, Strazicich and List (2003) tested the convergence analysis of carbon dioxide emissions for 21 industrialized countries. Over time, the ecological footprint indicator began to be included in the convergence analysis. Because the ecological footprint is expressed as one of the main indicators of environmental pollution, which represents sustainability. Compared to other indicators of environmental pollution, the ecological footprint indicator is a more comprehensive indicator. The ecological footprint is considered as an indicator that deals with total production and consumption instead of consumption and production activities that only cause carbon dioxide emissions. It is stated that environmental pollution indicators, especially ecological footprint convergence, may affect international climate agreements (Bayraktar et al., 2023, p.63026).

The ecological footprint indicator calculates the biological capacity required for the production of goods and services consumed by individuals living in a country, as well as the capacity required for nature to absorb pollutants resulting from these activities. In this respect, the Ecological Footprint (EFP) index assesses human-induced environmental damage in a broader framework and reflects environmental impacts in a more holistic manner compared to indicators that focus only on CO_2 emissions. Ecological footprint convergence is based on the fact that global consumption and waste generation patterns are not sustainable and that the world's natural resources are limited. Since high-income countries generally have a larger ecological footprint, they adopt more sustainability-oriented practices, increase efficiency by reducing resource use, and contribute to legal and institutional initiatives in this field by supporting environmental regulations. On the other hand, although low-income countries have a smaller ecological footprint, it is observed that they tend to increase their resource consumption in order to increase their living standards (Apaydın et al., 2021, p.53379-53393; Kazemzadeh vd., 2022, p.1-5).

In conclusion, it is suggested that the ecological footprint convergence will result in the existing environmental pollution discrepancy among countries to reduce over time. In other words, it is underscored that there will be a convergence among countries over time. In this process, it is emphasized that it is essential to study the stationary

characteristics of the ecological footprint utilizing diverse methodologies for various countries groups (Yılancı & Pata, 2020, p.106178).

EMPIRICAL FINDINGS

Data Set

In this article, the stationarity of the ecological footprint convergence for selected emerging market economies (Argentina, Brazil, China, India, Indonesia, Chile, Thailand, Mexico, South Africa, Turkey) was examined utilizing a panel unit root test for the period of 1990-2022. The ecological footprint variable was obtained from the Global Footprint Network repository.

Methodology and Findings

Methodology

- **Cross-Section Dependency Tests**

In the context of panel data analysis, the assessment of cross-sectional dependence and the evaluation of homogeneity among the units constituting the variables are crucial for determining the appropriate tests to be employed in both the estimation methodology and the stationarity examination. This is due to the fact that in scenarios characterized by cross-sectional dependency, it is necessary to apply second-generation panel unit root tests, whereas in the absence of cross-sectional dependency, first-generation panel unit root tests are utilized.

In this article, prior to the execution of the unit root analysis, an examination of cross-sectional dependence and homogeneity conditions was conducted, leading to the determination of the most suitable unit root test. A multitude of cross-sectional dependency tests are employed within the realm of panel data analysis. Among these, the Breusch-Pagan (1980) LM test, alongside the CD and CD_{LM} tests formulated by Pesaran (2004), as well as the LMadj test established by Pesaran et al., is noteworthy. The mathematical equations of these tests are delineated in equations (1), (2), (3) and (4) as follows:

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\rho_{ij}^2 \qquad \sim X^2N\,(N\text{-}1)/2 \qquad (1)$$

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}i^2 j-1) \qquad \sim N(0,1) \qquad (2)$$

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{P}_{ij}\right. \qquad (3)$$

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\frac{(T-k)\rho^2 ij-\upsilon_{Tij}}{\sqrt{v}2_{Tij}} \qquad \sim N\,(0,\,1) \qquad (4)$$

In all three of these tests, T represents the time dimension in the panel and N represents the unit dimension. Here,

k is the number of regressors, μ_{Tij} and v^2_{ij} are the mean and variance of (T-k) ρ^2_{ij}, respectively (Pesaran et al., 2008: 108).It is stated that in cases where cross-sectional dependence is not taken into account, erroneous parameters may be revealed with estimates tested with traditional panel estimators (Chudik and Pesaran, 2013, p.2). In order to eliminate this situation, the above tests should be applied. In this context, it is essential to determine the cross-sectional dependence for variables and the model. The zero hypothesis of the cross-sectional dependence test is established as "H_0: There is no intersectional dependence". When the H_0 hypothesis is accepted, the first-generation panel unit root tests should be preferred, and when it is rejected, the second-generation panel unit root tests should be preferred (Baltagi, 2008, p.284).

- **Homogeneity Tests**

The homogeneity test is recognized as an additional primary test that takes consideration after the assessment of horizontal cross-sectional dependence. According to Swamy (1970), this homogeneity test for slopes is estimated upon the distribution of individual slope estimations obtained from a suitable pooled estimator. It has been suggested that Swamy's test, affiliated with the F test, was formulated for panel data where the number of cross-sectional N values is less than the value of T (Akçacı and Yılmaz, 2021, p.390). The hypotheses associated with the Swamy test are as follows:

H_0: Slope coefficients are homogeneous.

H_1: Slope coefficients are heterogeneous.

- **Unit Root Test**

Prior to applying an econometric estimation, it is essential to determine whether the series intended for utilization possess stationary characteristics through the application of unit root tests; this is crucial for preemptively addressing the issue of spurious regression and for deriving economically significant econometric findings (Tarı, 2015, p.544). Given the presence of cross-sectional dependence, as identified in the following section of this article, the stationarity of the series, which fulfils the T>N condition and aligns with the structure of the panel data framework, was evaluated using the MADF unit root test, a recognized second-generation panel unit root testing method. The MADF unit root test is classified as a second-generation panel unit root testing methodology and is recognized as a test formulated by Taylor and Sarro (1998), based on the ADF test. The calculation of the MADF unit root test is conducted as follows (Yerdelen Tatoğlu, 2020, p.80):

$$MADF=\frac{(t-\Psi\hat{\beta})\Psi\left[Z'(\wedge^{-1}\otimes I_T)^{-1}\right]\Psi(t-\Psi\hat{\beta})N(T-k-1)}{(Y-Z\hat{\beta})'(\hat{\wedge}^{-1}\otimes I_T)(Y-Z\hat{\beta})} \quad (5)$$

Here $\hat{\beta}$ and $\hat{\wedge}$, according to the equation, $\hat{\beta}$ and $\hat{\wedge}$ are expressed as consistent estimators, and the MADF unit root test shows that it has a distribution of X^2 squares with N degrees of freedom (Yerdelen Tatoğlu, 2020, p.81). In

this study, MADF unit root test and Pesaran (2007) CADF-CIPS unit root test was used because it satisfies the T>N condition and has a cross-sectional dependency.

The Cross-sectional Augmented Dickey-Fuller (CADF) unit root test, developed by Paseran (2007) while considering cross-sectional dependencies among units, suggested the formulation of an enhanced test by integrating the lagged values of unit means alongside the first differences of units within the framework of the Augmented Dickey-Fuller (ADF) test. This methodology has been labeled as the Cross-sectional Augmented Dickey-Fuller (CADF) test (Yerdelen Tatoğlu, 2020, p.84). In standing out from established panel unit root tests that rely on simple averages of CADF statistics, this test is predicated upon the t-bar statistic introduced by Im, Pesaran, and Shin (2003) for the individual CADF statistics. Consequently, different asymptotic results are obtained for both individual CADF statistics and the mean test represented as the Cross-sectional Im, Pesaran, and Shin (CIPS) test (Pesaran, 2007: 266). While the CADF test is enhanced to determine stationarity at the unit level, the CIPS test is aimed to examining the stationarity of the panel (Gençoğlu et al., 2020, p.1289). Simply, the CADF test can be presented as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + c\ \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \qquad (6)$$

As mentioned above, determining the stationarity of the values for each cross-section utilizing the CADF test presents considerable challenges. Thus, CIPS statistics are considered for each individual section. Initially, the CADF test is conducted, then, the validity of the null hypothesis can be evaluated through the application of CIPS statistics across the entire panel.

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \qquad (7)$$

The data presented in the figure relating to the CIPS statistics is a result of calculating the average values of the t-statistics related to the lagged variables (Pesaran, 2007, p.265-312).

Findings

- **Cross-Section Dependency Results**

In this article, the LM test developed by Breusch-Pagan (1980), which gives effective results for T>N, and the Pesaran (2004) CD test, which gives more effective results in both T>N and T<N situations, were preferred as the cross-sectional dependency test. The cross-sectional dependency test results are shown in Table 2 in the following:

Table 2: Cross-Section Dependency Test Results

Test	Breusch- Pagan LM	Pesaran CD_{LM}
Statistic Value	452.96	43.003

Probability Value	0.000	0.000

Source: Created by the authors.

The validity of the cross-sectional dependency assumption illustrates that an economic shock in one country significantly influences the economies of other countries (Bayrakdar and Soyyiğit, 2020, p.53). Analyzing the findings presented in Table 2, it was found that a cross-sectional dependency exists regarding the ecological footprint within emerging market economies, as evidenced by both sets of test results. The implementation of cross-sectional dependency confirms that the first condition is appropriate for the implementation of the second-generation panel unit root test.

- **Homogeneity Test Results**

The findings of the Swamy S test conducted in this article are summarized in Table 3. The assumption of heterogeneity indicates that countries maintain their unique characteristics.

Table 3: Swamy S Homogeneity Test Result

Swamy S Testi	Chi-Square Test Statistic Value	Probability Value
	4144.75	0.000

Source: Created by the authors.

According to the results of the Swamy S test as presented in Table 3, the Chi-Square probability value falls below the significance level set at 0.05, and the null hypothesis positing "the parameters exhibit homogeneity" is consequently dismissed, thus leading to the acceptance of the alternative hypothesis. This indicates a heterogeneous distribution within the dataset. Hence, the identified heterogeneity confirms that the required condition is fulfilled for the implementation of the second-generation panel unit root analysis.

- **Unit Root Test**

Based on the findings obtained from the cross-sectional dependency and homogeneity tests within Emerging Market Economies, it was found that the second-generation panel unit root test should be implemented. The outcomes relating to the stationarity evaluation of ecological footprint convergence across Emerging Market Economies are presented in Table 4. and Tablo 5.

Table 4.:MADF Unit Root Test Result

Ecological Footprint Variable (LFOOT) at the Level			
Obs	Lags	MADF	About 5%
32	1	82.913	25.898

Source: Created by the authors.

Table 4 Upon presenting the results of the MADF unit root analysis, it is evident that the delay length has been

established as 1. According to the MADF unit root test results, the MADF test statistic is greater than the given 5% critical value. Consequently, at the 95% confidence level, the null hypothesis H_0 was rejected, leading to the conclusion that our series exhibits stationarity. This scenario explains that it is feasible to forecast future values predicated on the historical values of the ecological footprint observed in each country and that shocks affecting the relevant variable prompt a temporary impact.

Table 5: Pesaran (2007) CIPS Unit Root Test Results

	CIPS Statistics
Variable	Level Values
Ecological Footprint Variable (LFOOT) at the Level	-5.716
	Critical Values
%1	-2.55
%5	-2.33
%10	-2.21

Source: Created by the authors.

If the statistical value resulting from the CIPS unit root test exceeds any of the thresholds established at the 10%, 5%, and 1% significance levels in absolute values, this indicates a rejection of the null hypothesis, thereby considering the series as stationary. Therefore, given that the absolute value of the CIPS test statistic for the LFOOT variable exceeds the critical values at the 10%, 5%, and 1% confidence levels, it can be concluded that the variable exhibits stationarity at the specified level

In conclusion, the results from both the MADF unit root test and the CIPS unit root test confirm the findings relating to convergence. Also, the results yielded by both unit root tests support the convergence of the ecological footprint within the Emerging Market Economies during the studied period.

CONCLUSION AND EVALUATION

The economic development aims that countries attempt to achieve growth to enhance welfare standards, resulting in a constant escalation in fossil fuel consumption. Consequently, this phenomenon engenders the challenges associated with climate change and global warming, thereby exacerbating environmental pollution. A principal metric of environmental pollution is identified as carbon emissions.

Carbon dioxide emissions are commonly employed in numerous searches relating to environmental pollution. Nevertheless, this singular variable is deemed not enough for a thorough analysis of environmental pollution. It has been stated that petroleum reserves, mineral extraction, and land utilization also contribute negatively to ecological well-being (Tatar, 2022, p.1027). Consequently, current studies increasingly analyze the ecological footprint indicator, which offers a more holistic approach to identifying environmental pollution.

One of the main issues in the domain of economic development is the convergence hypothesis. The convergence

hypothesis constitutes one of the fundamental assumptions of the Solow growth model. Although this hypothesis was originally characterized as a framework to illustrate income inequalities between countries with high-income levels and those with low-income levels, it has progressively become a hypothesis that explains environmental challenges over time. Environmental convergence illustrates this evolution. In this context, the validity of ecological footprint convergence, which is considered a comprehensive indicator of environmental degradation, is examined in this article utilizing a panel unit root test. The analysis, which employed a dataset covering the period from 1990 to 2022, was employed to discover the existence of ecological footprint convergence among selected emerging market economies. In the study where the MADF unit root test was used, according to the unit root test results, the critical value of the MADF test statistic at the level was greater than 5%. Consequently, at the 95% confidence level, the null hypothesis (H_0) was rejected, leading to the conclusion that the data series exhibits stationarity. In addition, considering that the absolute value of the CIPS test statistic for the LFOOT variable exceeded the critical values at the 10%, 5% and 1% confidence levels, it was determined by this test statistic that the variable was stationary at the level. In other words, it has been concluded that ecological footprint convergence exists within the aforementioned countries.

The findings reveal that the ecological footprint is stable in the countries examined, and therefore, in the long run, these countries converge in their environmental sustainability levels. This result suggests that ecological indicators have converged over time and that these countries have responded similarly to similar environmental policies or external environmental pressures. These findings, which are in line with the studies by Bilgili and Ulucak (2018), Solarin et al. (2019), Özcan et al. (2019) and Yılancı and Pata (2019) in the literature, support that emerging market economies have a certain convergence trend in terms of ecological indicators. These studies also revealed that emerging market economies show a convergence trend in ecological footprint, carbon emissions or environmental sustainability

Minimizing the gap in ecological footprints represents a significant concern for both developing and developed countries. In this regard, it is necessary to mitigate carbon emissions within emerging market economies to avoid environmental degradation. In these countries, it is essential to prioritize the increased utilization of renewable energy sources alongside the implementation of technology-driven policies that facilitate the effective deployment of these resources. Accordingly, it is suggested that environmentally sustainable energy practices be initiated instantly. It is worth mentioning that the reduction of environmental pollution and the establishment of sustainability can only be realized through the adoption of clean energy alternatives. To this end, it is crucial for governments to enhance both the production and consumption of electric vehicles, while simultaneously promoting the utilization of solar and wind energy. Achieving ecological equilibrium for a habitable planet can solely be accomplished through mindful consumption and production practices.

In the light of these findings, emerging market countries are exposed to similar environmental pressures and may experience common sustainability problems in the development process. Therefore, regional cooperation platforms can be established in order to ensure coordination in environmental regulations and practices, increase information sharing and facilitate green technology transfer. In order for countries to maintain ecological balance in sustainable development processes, it may be recommended to adopt sustainable production and consumption models that limit resource use, minimize waste generation and support circular economy. As a matter of fact, policies can be developed to increase resource efficiency especially in transport, industry and agriculture sectors. In sectors with high ecological footprint, environmental taxes should be applied to discourage environmentally damaging activities, while low-carbon production enterprises should be encouraged. Moreover, market-based mechanisms such as carbon markets and emission trading systems should be gradually implemented in this group of countries. Since the ecological footprint is directly related to individual and institutional behavior, educational policies can be implemented to increase environmental awareness and raise awareness for sustainable environmental awareness.

Ultimately, in future research, it is suggested that the ecological footprint convergence may be analyzed through the comparative analysis of individual countries and groups of countries. Within this framework, it becomes feasible to suggest policy recommendations for these countries and country groups, thereby enriching the literature accordingly.

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