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Original Articles

Convergence of per capita ecological footprint among the ASEAN-5 countries: Evidence from a non-linear panel unit root test

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ABSTRACT

This study aims to investigate the convergence of the per capita ecological footprint among the Association of Southeast Asian Nations (ASEAN-5) countries by using panel data for the period 1961 to 2016. To this end, the two-regime threshold autoregressive (TAR) panel unit root test is performed. First, we conclude that the ecological footprint of ASEAN-5 countries is nonlinear. Then, we determine that the transition country between the two regimes is Vietnam. Our empirical results reveal that divergence exists in the second regime and absolute convergence in the first. The second regime constitutes approximately 80% of the sample. Consequently, this result provides strong support for the absolute convergence of the per capita ecological footprint in Indonesia, Malaysia, the Philippines, Thailand and Vietnam. Therefore, common policies should be implemented to prevent environmental degradation in the ASEAN-5 countries.

1. Introduction

Environmental degradation on the one hand adversely affects both human health and various macroeconomic indicators such as labor productivity and sustainable growth. On the other hand, the feedback relationship between the increasing population and income is a major obstacle to the growth of countries without also compromising environmental quality (Danish et al., 2019). As the population increases, the use of natural resources and environmental pollution increase. Because of this two-way relationship between economic indicators and environmental degradation, it is essential to eliminate environmental problems as much as possible and to ensure sustainable growth.

Today global warming and climate change are among the most significant environmental problems. The most important factor causing these two phenomena is regarded as greenhouse gas (GHG) emissions. Global warming increases with the higher GHG emissions, which in turn leads to climate change. Therefore, an increase in GHG emissions should be prevented. Greenhouse gas emissions caused by individual activities affect everyone living in the global environment. Thus, climate change is a common problem (Cooper, 2018). Scientists and political and economic decision-makers are aware of the importance of taking measures to reduce GHG emissions in the atmosphere (Presno et al., 2018). In the coming years, strict and comprehensive environmental regulations are needed to curb the harmful effects of GHG emissions (Haider and Akram, 2019a). Many meetings and conferences have been organized to prevent increases in GHG emissions and thus global warming. The most popular multilateral commitment is the Kyoto Protocol (Burnett, 2016). The Kyoto Protocol defines six gases responsible for GHG emissions: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) (Ahmed et al., 2017). The Kyoto Protocol rules require countries to reduce CO_2 and five other GHG emissions compared to 1990 levels (Lee and Chang, 2008). Among these gases, CO_2 emissions have the largest share in GHG emissions. Carbon dioxide emissions account for more than 70% of GHG emissions globally and are considered one of the main drivers of global warming. Besides, these emissions have been reported as the most crucial indicator of environmental pollution associated with human activities. Therefore, the interaction between CO_2 emissions and economic indicators has been investigated using various hypotheses, such as the environmental Kuznets curve (EKC), the pollution haven and the pollution halo. In addition to these hypotheses, the stationary properties of environmental pollution indicators have recently been tested by researchers.

The EKC hypothesis introduced by Grossman and Krueger (1991) shows that as the income per capita level increases, environmental degradation will rise, but after a certain turning point of income per capita, environmental quality will start to increase. This hypothesis

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implies that there is an inverted U-shaped relationship between income per capita and the indicator of environmental impact and that economic growth will reduce the environmental pollution (Stern, 2004). At the same time, the view that economic growth will provide environmental improvement after a certain turning point continues to be discussed in many studies. It has been demonstrated in various studies that developing countries have not yet reached the turning point (see, for example, Sugiawan and Managi, 2016; Pata, 2018). Therefore, as the income level increases, environmental pollution continues to increase in developing countries. Developed countries, on the other hand, can be more successful in reducing environmental pollution with their high income levels exceeding the turning point and developed cleaner technologies. Brock and Taylor (2003) associate the convergence of environmental pollution indicators with the EKC hypothesis. The Environmental Catch-up hypothesis developed by the authors implies that in the poorer countries, there is more environmental pollution than the rich ones, and that the pollution between the rich and poor countries is diverge over time. The reason for this differentiation is the capital level of countries in their initial situation. When developing countries start to use environmental technologies with the increase in income level, the difference between environmental quality in rich and poor countries will decrease and environmental pollution indicators will converge. Moreover, the EKC states that countries will converge in terms of both economic and environmental quality. Although economic growth initially causes environmental damage, it will eventually help to improve environmental quality (Bimonte, 2009). According to Stern (2017), the convergence hypothesis suggests that pollution falls more rapidly in countries with high levels of pollution than in countries with low levels. If the rich countries initially have high pollution levels in contrast to the low pollution in poor countries, the outcome is similar to the EKC. Contrary to the EKC hypothesis has been tested in many studies, the literature on the convergence of pollution is limited (Tiwari and Mishra, 2017).

It is a major shortcoming that countries only focus on reducing CO_2 emissions and ignore other pollution sources (Ozcan et al., 2019). Beyond CO_2 emissions, forestry soil, mining and oil stocks put nature under enormous pressure (Solarin, 2019). The effect of environmental pollutants other than CO_2 emissions on climate change is also important. Therefore, more reliable findings and policy recommendations can be obtained with a cumulative index that includes as many specific environmental pollution indicators as possible. In this regard, a footprint is a popular way of expressing the burden of human activities and their impact on global sustainability (UNEP/SETAC, 2009). There are many footprints, such as the carbon footprint, the water footprint, the emission footprint, the energy footprint, the nitrogen footprint, the biodiversity footprint, the phosphorus footprint, the waste footprint, the social footprint, the financial footprint, the economic footprint, the exergy footprint, the chemical footprint and the ecological footprint (Cucek et al., 2012). The ecological footprint (hereafter EF) was initially proposed by Rees (1992) and developed by Wachernagel and Rees (1996). The EF is an indicator of human demand on natural resources and services and comprises six footprint sub-components: cropland, grazing land, forest products, fishing grounds, built-up land, and the carbon footprint (Galli et al., 2012; Isman et al., 2018). By combining these six footprint subcomponents, the EF responds to how much nature countries have and how much they use productive areas in the nature (Bilgili and Ulucak, 2018a). In this way, it can comprehensively address environmental problems. The carbon footprint accounts for more than half of the EF. Therefore, this footprint also strongly reflects the effects of GHG emissions. Moreover, the EF is an indicator that measures how much of the renewable capacity of the biosphere is used by the human economy (Monfreda et al., 2004). The EF measurements that ensure the ecological balance of countries for a sustainable future indicate the pressure of humans on the environment and the factors that cause it (Aydin et al., 2019). In addition, the EF can measure both the ecological cost of goods and services offered to the human population by land and the maximum population-carrying capacity of a given area (Mcdonald and Patterson, 2004). This comprehensive and composite index expresses anthropogenic pressure on the environment (Solarin, 2019). In other words, the EF represents environmental limits and the extent to which people exceed these limits. The EF monitors the cumulative effects of many environmental factors, such as CO_2 emissions, fish consumption, and land use changes. Thus, this indicator can be used to understand environmental consequences (Galli et al., 2012).

The EF and biological capacity values can be used to measure sustainability (Galli et al., 2012). These two indicators are expressed in units of world average bioproductive area, namely global hectares (gha). Each gha represents an equal amount of biological efficiency (Monfreda et al., 2004). When the EF exceeds the biocapacity of a given area, ecological deficit occurs. For more than 40 years, the EF has been larger than the world can sustain. In other words, the existing fertile land is not sufficient to meet the food and habitat needs of humans and also to absorb CO_2 emissions (McLellan et al., 2014). The total and per capita anthropogenic footprints have not been sustainable since approximately 1970 (Toth and Szigeti, 2016). For the first time in the world, the capacity to meet people's demands was exceeded in the mid-1970 s, and this ecological deficit continues to increase every year (Bilgili et al., 2019). Inadequate biocapacity to meet people's demands poses a threat to sustainable development.

The Association of South East Asian Nations (ASEAN-5) refers to a group of five countries (Indonesia, Malaysia, the Philippines, Thailand and Vietnam) aiming to ensure peace, economic cooperation and sociocultural development among Southeast Asian countries. Among the ASEAN countries, Malaysia (constant 2010 US$11,219) had the highest per capita GDP in 2016, followed by Thailand (US$5,911), Indonesia (US$3,968), the Philippines (US$2,743) and Vietnam (US$1,752). Together these countries constitute 3% of the world economy. In the same year, the ASEAN-5 countries achieved economic growth rates of between 3.35% and 6.88%. Vietnam has the highest growth rate and Thailand the lowest (World Bank, 2019). While these high growth rates have been realized, environmental pollution has also increased. The EF is increasing rapidly in these countries. People's pressure on nature is increasing every year. In 2016, all five countries had ecological deficits. These deficits are quite high compared to previous years. Therefore, it is essential to examine the stochastic properties of EF in the ASEAN-5 countries. Fig. 1 illustrates the country-based per capita EF and per capita biocapacity (BC) values.

The EF has increased significantly in all countries, especially after 1985. Malaysia, which has the highest per capita income level, is rapidly consuming natural resources. The EF of Malaysia is more than the sum of the EF of Thailand and the Philippines. The EF of Thailand, which has the second highest per capita income, and Vietnam, which has the highest economic growth rate, are also higher than those of the remaining two countries. On the one hand, it is obvious that there is a relationship between the economic development level of countries and their EF. On the other hand, biocapacity appears to be declining rapidly in Indonesia and Malaysia. Nevertheless, these two countries still have the highest biocapacity. Thailand and Vietnam have followed a similar course in terms of biocapacity during the period under analysis. In the Philippines, the ecological deficit emerged after 1964. The ecological deficits of Malaysia (1.66 gha) and Thailand (1.30 gha) are higher than those of the remaining countries. This indicates that the two countries with the highest per capita income put more pressure on nature and suffer from major environmental problems.

Fig. 2 represents the per capita EF and per capita biocapacity in the ASEAN-5 countries. After 1991, the countries have continuously created an ecological deficit. In these countries, the EF increased by approximately 120% over 56 years. In the same period, biological capacity decreased by half. The ecological deficit decreased to 5.26 gha in 2016. The EF almost doubled in the same period. This indicates that humans put serious pressure on nature in the ASEAN-5 countries and

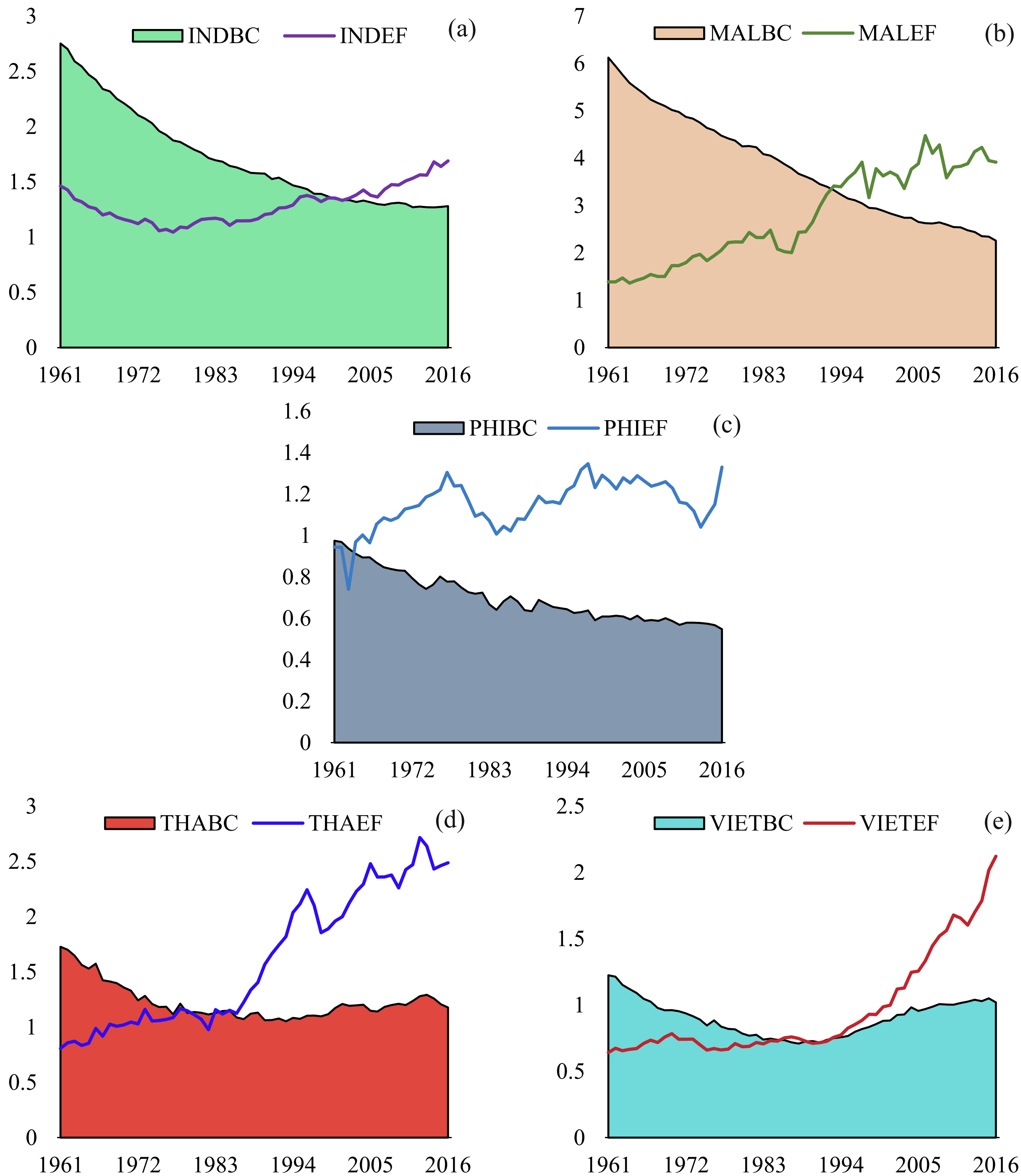

Fig. 1. County specific per capita ecological footprint and per capita biocapacity (gha).

the problem needs to be corrected by taking various measures.

The subject of convergence is based on Solow's (1956) neoclassical growth model. According to the neoclassical growth model, the income gap between high-income and low-income countries narrows over time due to diminishing returns to scale. This phenomenon, called "economic convergence" in the literature, has been tested in numerous studies (see, for example, Barro and Sala-i-Martin, 1992; Mankiw et al., 1992). Environmental convergence is a new research field analogous to economic convergence (Nguyen-Van, 2005). The models used in the preparation of climate change strategies are based on the convergence assumption. Therefore, investigating the stochastic behavior of the EF is crucial for policymakers to develop effective environmental protection policies.

Convergence of environmental quality among countries is important to prevent climate change (Haider and Akram, 2019a). The convergence of EF is a key issue for policymakers to equalize environmental pollution responsibility among all countries. In this respect, few researchers have used unit root tests to investigate whether shocks to the EF are permanent or transitory. The lack of EF convergence research makes it difficult for countries to undertake joint commitments to reduce environmental pollution. The stochastic behavior and dynamic changes in EF will help regulate sustainable policies (Bilgili et al., 2019). Determining the convergence of pollution indicators such as CO_2 emissions and EF in countries allows researchers and administrators to

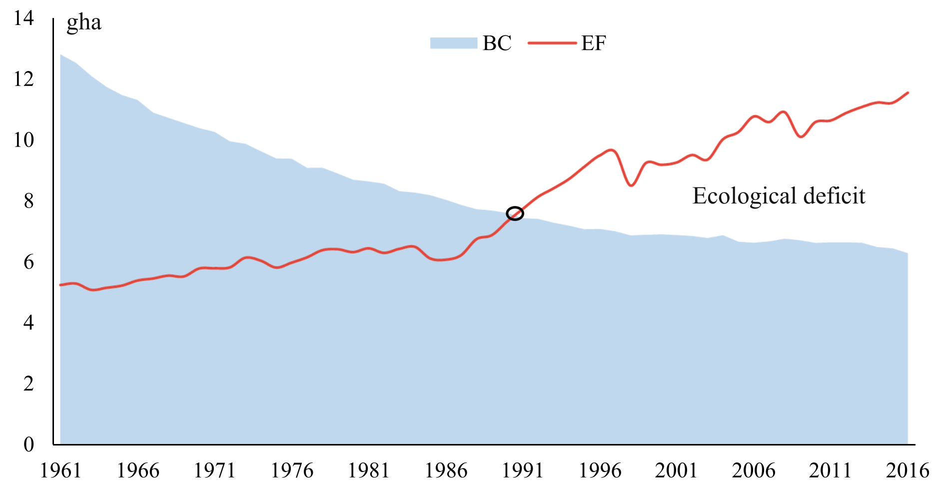

Fig. 2. Per capita ecological footprint and per capita biocapacity in ASEAN-5 countries.

observe the effectiveness, speed and success of environmental policies (Bilgili and Ulucak, 2018a,b). The convergence of EF can be expressed as the reduction of environmental pollution difference among countries. Over time, if countries with a high per capita EF reduces this environmental indicator and countries with a low per capita EF increases or maintains their pollution, there will be convergence among countries. If the EF is stationary, the effect of shocks will be temporary, and this series will be stochastically converged to the mean value once the impacts of the shocks disappear. By comparison, if the effect of shocks is permanent, then the series will diverge from the average.

The contribution of this study is threefold: First, this paper examines the convergence of EF per capita, a more comprehensive indicator than CO_2 emissions. Second, we perform a nonlinear panel unit root test for the first time with regard to this environmental pollution indicator. Using Beyaert and Camacho (2008)'s TAR panel unit root test, we can decide whether convergence of EF is absolute or relative. Most of the previous studies were performed with linear time series or panel unit root tests. In these studies, nonlinear properties of environmental pollution can be neglected. Third, this is the first research to test the convergence of EF among the ASEAN-5 countries. For all these reasons, we expect that the study will contribute to the current literature.

In the first section of the study, the main features of the EF and environmental degradation in the ASEAN-5 countries were discussed. The remainder of the paper is structured as follows. The next section presents the empirical literature review on the convergence hypothesis for environmental pollution indicators such as CO_2 emissions and EF. Then the third section describes the econometric strategy. The data used in this paper and the empirical results are reported in the fourth section. The final section presents the conclusions and policy recommendations.

2. Literature review

It is important to analyze the factors affecting environmental pollution and to determine whether this pollution is a permanent or temporary phenomenon. To this end, researchers have tried to specify the factors affecting environmental pollution indicators by using cointegration, causality, regression and unit root analyses and tested the convergence of these indicators among the countries.

Recently, several studies have empirically tested convergence in CO_2 emissions. Strazicich and List (2003) conducted the first empirical work to test CO_2 convergence for 21 industrialized countries covering the period 1960 to 1997. They concluded that CO_2 emissions have indeed converged. Following that study, the following research studies have been conducted, all obtaining similar results: Aldy (2006) for 23 OECD countries; Westerlund and Basher (2008) for 16 developed and 12 developing countries; Lee et al. (2008) for 21 OECD countries; Romero-Avila (2008) for 23 OECD countries; Panopoulou and Pantelidis (2009) for 128 countries; Brock and Taylor (2010) for 173 countries; Jobert et al. (2010) for 22 European countries; Barassi et al. (2011) for 13 out of 18 OECD countries; Huang and Meng (2013) for China's 30 provinces; Li and Lin (2013) for 110 countries; Yavuz and Yilanci (2013) for the G7 countries; Solarin (2014) for 39 African countries; Acaravci and Erdogan (2016) for the seven regions of the world; Acar and Lindmark (2017) for 28 OECD countries; Sun et al. (2016) for the ten largest economies in 2016; Tiwari and Mishra (2017) for 18 Asian countries; Presno et al. (2018) for 28 OECD countries; Erdogan and Acaravci (2019) for 28 OECD countries; and Solarin (2019) for 12 of 27 OECD countries.

Contrary to these studies, the following research studies reached the opposite conclusion, namely that CO_2 emissions have diverged: Nguyen-Van (2005) for 100 countries; Aldy (2006) for a global sample of 88 countries; Aldy (2007) for the U.S. states; Barassi et al. (2008) for 21 OECD countries; Lee and Chang (2008) for 14 out of 21 OECD countries; Nourry (2009) for 127 countries; Ordás Criado and Grether (2011) for 166 world areas; Herrerias (2013) for 162 countries; Li et al. (2014) for 38 out of the 50 U.S. states; Ahmed et al. (2017) for 124 of 162 countries; and Kounetas (2018) for 23 European countries.

Previous studies in the literature on the convergence of CO_2 emissions have yielded mixed findings. Rather than CO_2 emissions, a limited number of studies have examined the convergence of EF. In other words, EF convergence has recently become the subject of an interesting research field. Ulucak and Lin (2017), Solarin and Bello (2018), and Yilanci et al. (2019) have analyzed whether shocks to the EF are temporary or permanent. Yilanci et al. (2019) determined that only the fishing ground footprint has a unit root and that the other five EF components are stationary. In the other two studies, the authors concluded that EF generally follow a non-stationary process.

In a study that analyzes the convergence of EF, Bilgili and Ulucak (2018b) applied the bootstrap-based panel Kwiatkowski–-Phillips–Schmidt–Shin (KPSS) test with structural breaks and a club convergence test for G20 countries covering the period 1961 to 2014. Their findings support stochastic and deterministic convergence in per capita EF. Ulucak and Apergis (2018) investigated convergence clubs in terms of EF for 20 European Union countries using data covering 1961 to 2013 and evidence for convergence for only a small number of clubs. Bilgili et al. (2019) tested EF convergence across 15 countries on four continents from 1961 to 2014. They utilized the panel KPSS unit root test and found that EF has converged in African, American and European countries but not in Asian countries. Haider and Akram (2019b) utilized panel club convergence approach from 1961 to 2014 for a sample of 77 countries. They did not find convergence for full sample.

However, they concluded that there are two significant club convergences for the EF and carbon footprint. Ozcan et al. (2019) performed several panel unit root tests over the period 1961 to 2013, and found evidence of convergence in EF for all high-income countries and for about half of low-income and upper-middle-income economies. They also concluded that EF has diverged in lower-middle-income countries. By comparison, Solarin (2019) examined convergence in CO_2 emissions, carbon footprints, and EF among 27 OECD countries for the period 1961 to 2013. He performed the residual augmented least squares with Lagrange multiplier (RALS-LM) unit root test and found strong evidence of EF convergence in 13 out of 27 countries. Solarin et al. (2019) used EF data and its six components for 92 countries over the period 1961 to 2014 and conducted a combination of two convergence club approaches. Their findings indicate that there are ten convergence clubs for EF and four convergence clubs for built-up footprints.

The results obtained by these studies vary according to the method used, the country group analyzed, and the time period. Moreover, few studies tested the convergence of EF. For these reasons, it is crucial to test the stationary properties of EF for different country groups with various methods.

3. Econometric methodology

Studies that examine the convergence of ecological indicators generally approach the convergence process as uniform (see, among others, Barassi et al., 2008; Lee et al., 2008; Kiran Baygin, 2017), but in some cases, the indicators converge only if certain conditions are met, and diverge otherwise. To deal with the possibility of heterogeneous cases of convergence, we employ the econometric methodology of Beyaert and Camacho (2008). Following this methodology, we first test the null hypothesis of linearity in the panel data; in the case of rejection of the null hypothesis, we move to the second stage where we test the stationarity of the panel data in a two-regime threshold model framework.

We employ the following panel data model in Eq. (1) to examine the existence of convergence among the EF of the ASEAN-5 countries:

$$\Delta f_{n,t} = \left[\delta_n^I + \rho_n^I f_{n,t-1} + \sum_{i=1}^{p} \phi_{n,i}^I \Delta f_{n,t-i}\right] I_{\{Z_{t-1} < \lambda\}} + \left[\delta_n^{II} + \rho_n^{II} f_{n,t-1} + \sum_{i=1}^{p} \phi_{n,i}^{II} \Delta f_{n,t-i}\right] I_{\{Z_{t-1} \geqslant \lambda\}} + \varepsilon_{n,t} \quad (1)$$

where n = 1,...,N, and t = 1,...,T. We define the variable $f_{n,t}$ as $f_{n,t} = e_{n,t} - \bar{e}_t$, where $e_{n,t}$, and $\bar{e}_t$ indicate the log of the EF, and the cross-country average of $e_{n,t}$ at time t, respectively. $I_{\{X\}}$ is an indicator which takes value 1, when the condition $z_{t-1} < \lambda$ is fulfilled, and zero otherwise. So, if the condition is met, then Eq. (1) becomes $\Delta f_{n,t} = \delta_n^I + \rho_n^I f_{n,t-1} + \sum_{i=1}^{p} \phi_{n,i}^I \Delta f_{n,t-i} + \varepsilon_{n,t}$ and the dynamics of the EF stand in Regime I; however, if the condition is not fulfilled, then Eq. (1) becomes $\Delta f_{n,t} = \delta_n^{II} + \rho_n^{II} f_{n,t-1} + \sum_{i=1}^{p} \phi_{n,i}^{II} \Delta f_{n,t-i} + \varepsilon_{n,t}$ and the process of convergence takes place in Regime II. λ is called the threshold parameter, while z_{t-1} is the threshold variable. We obtain z_t by using the formulae $z_t = f_{m,t} - f_{m,t-d}$, so it is obvious that the switch from one regime to another is related to the change rate of the EF of country j, in the last d periods. The values of parameters λ, m, and d can be estimated using feasible generalized least squares (see Beyaert and Camacho, 2008).

In the first step of the analysis, we test the null hypothesis of linearity ($H_{0,1}$: $\delta_n^I = \delta_n^{II}$, $\rho_n^I = \rho_n^{II}$, $\phi_{n,i}^I = \phi_{n,i}^{II}$) using the likelihood ratio test. Since the test does not follow a standard distribution, the critical values are obtained using bootstrap simulations. In the case of non-rejection of the null hypothesis, we estimate the linear model suggested by Evans and Karras (1996). If the null hypothesis is rejected, the next step consists of testing convergence in a nonlinear framework. The null hypothesis $H_{0,2}$: $\rho_n^I = \rho_n^{II} = 0$ assumes the divergence in both regimes. Alternatively, convergence can take place in both regimes $H_{A,2}$: $\rho_n^I < 0, \rho_n^{II} < 0 \forall_n$ or partial convergence can happen whenever the countries converge under one regime, but not another, that is $H_{A,2_a}$: $\rho_n^I < 0, \rho_n^{II} = 0 \forall_n$ or $H_{A,2}$: $\rho_n^I = 0, \rho_n^{II} < 0 \forall_n$. The t-statistics are used to test the hypotheses. The last step of the analysis consists of determining the type of convergence (absolute vs. conditional) for the regime under which the null hypothesis of divergence is rejected. The necessary critical values are obtained using bootstrap simulations.

4. Data and empirical results

This study tests the convergence of per capita EF (measured in global hectare) of the ASEAN-5 countries over the period 1961 to 2016. The dataset was retrieved from Global Footprint Network.[1] We present the descriptive statistics for this dataset in Table 1.

Malaysia has the highest mean of EF among the five countries, while Vietnam has the lowest. Interestingly, only the EF of Indonesia seems distributed normally. The EF of the Philippines is negatively skewed and leptokurtic, while Vietnam's EF data are highly positively skewed and also leptokurtic. The EF data of the remaining countries are platykurtic, since the value of kurtosis is less than 3.

The time path of log of the EF of the ASEAN-5 countries is depicted in Fig. 3. At first glance, a visual inspection of Fig. 3 reveals that there is an increase in all series over time. However, especially after 1985, there seems to be a convergence of these series to each other.

As the first step of the panel threshold autoregressive (TAR) unit root methodology, we test the linearity of the panel data using the Wald test and report the test results in the first row of Table 2. We compute two bootstrap p-values: the restricted p-value, used for the data that has a unit root, and the unrestricted p-value, used for the stationary data, since we do not have a priori information about the stationarity of the data. Since both of the p-values are lower than traditional critical levels, these findings support the evidence of nonlinearity for the EF series. The grid search reveals Vietnam as the transition country between regimes, that is, the progress of Vietnam's EF determines the shift from one regime to the other. Delay parameter (d) is found as 2, so the transition variable is $z_t = f\_{Vietnam,t} - f_{Vietnam,t--2}$ and the threshold parameter is estimated at −4.903. Regime I refers to the years in which the relative growth rate of the per capita EF of Vietnam to the average growth rate of the per capita EF of the ASEAN-5 countries is below –4.903 percentage points, and this regime includes 19.23% of the sample, while Regime II corresponds to the years in which the rate is above the −4.903, and 80.77% of the sample constitutes Regime II.

On the one hand, the test results for convergence provide evidence of convergence only for Regime II, since the p-value is smaller than the traditional significance levels only in this regime, that is, there is partial

Table 1
Descriptive statistics.

Countries	Indonesia	Malaysia	Philippines	Thailand	Vietnam
Mean	1.293	2.773	1.149	1.604	0.961
Median	1.272	2.465	1.156	1.370	0.751
Maximum	1.690	4.478	1.346	2.717	2.122
Minimum	1.044	1.363	0.741	0.808	0.642
Std. Dev.	0.165	0.985	0.117	0.615	0.394
Skewness	0.591	0.073	−0.811	0.296	1.417
Kurtosis	2.574	1.501	4.096	1.487	3.796
Jarque-Bera	3.684	5.293	8.950	6.160	20.211
Probability	0.158	0.071	0.011	0.046	0.000
Observations	56	56	56	56	56

[1] http://data.footprintnetwork.org

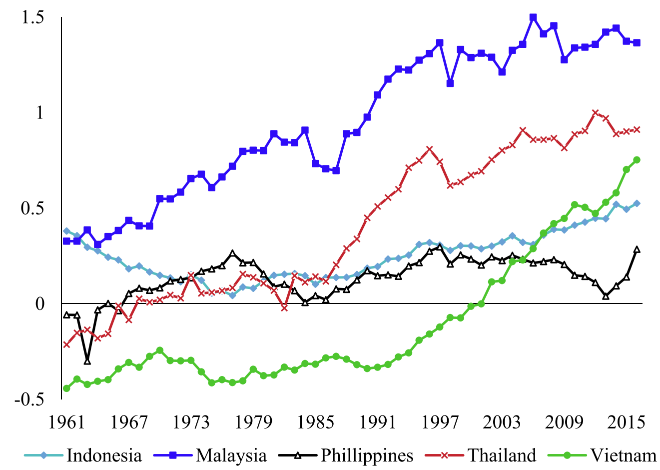

Fig. 3. Logs of ecological footprint per capita for the ASEAN-5 Countries.

convergence for the EF of the ASEAN5 countries. On the other hand, this regime exhibits absolute convergence with a p-value of 0.427. In this case, the initial conditions of countries in terms of environmental pollution are not important for convergence.

The threshold parameter, along with the threshold variable, are illustrated in Fig. 4. Visual examination of the figure provides the insight that when two regimes occur, Regime II dominates the majority of the sample period, and Regime I is effective in only nine years (1972, 1973, 1975, 1976, 1989–1992, and 2013). We can therefore conclude that absolute convergence is valid for the EF of the ASEAN5 countries. The EF of these countries begin to converge after 1993.

5. Discussion

In this section, we discuss the results obtained from this study with other studies. Since joint action against environmental pollution is important, we have tested the convergence of EF in ASEAN-5 countries. Our findings suggest that convergence is valid for the EF among Indonesia, Malaysia, the Philippines, Thailand and Vietnam (given in Table 2). The results of this study are consonance with the findings of Bilgili and Ulucak (2018b), Bilgili et al. (2019), Ozcan et al. (2019), Solarin (2019), and Solarin et al. (2019). It has been proven that EF has converged in some country groups. However, a limited number of studies have been conducted on the convergence of EF. Therefore, it may be early to say that common measures should be taken to reduce environmental pollution worldwide.

On the one hand, our findings show that EF can be reduced through common policies for ASEAN-5 countries. On the other hand, environmental pollution and ecological deficit increase from year to year (shown in Fig. 1. and Fig. 2.). This may be an indication that effective environmental policies are not being implemented in these countries to reduce the EF. For this reason, it can be argued that ASEAN-5 countries need to go further in their policies to reduce environmental pollution.

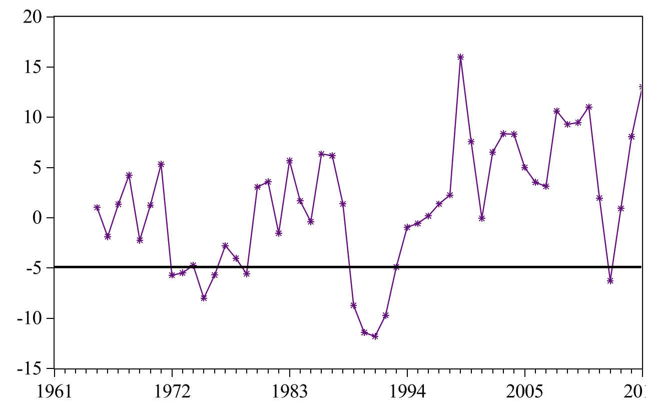

Fig. 4. Threshold variable with the threshold value (-4.903).

6. Conclusion

Today, societies and countries are increasingly concerned and cautious about environmental issues. In this respect, measures that can be taken to prevent environmental pollution are discussed in various national and international meetings and agreements. The main objective of these meetings is to reduce GHG emissions, and particularly CO_2 emissions, in order to combat climate change. However, a more comprehensive indicator is needed to assess environmental pollution. In this context, the EF is a more reliable indicator, because it includes many environmental pollution variables. The EF indicates both natural resources consumed by humans and the reproduction of these resources by nature. Besides, this indicator can be used to determine whether the biocapacity is exceeded. For these reasons, the convergence of EF is an important research topic. As a result of the convergence test of EF, it may be decided that countries will pursue joint or separate policies to combat environmental pollution. In the case of convergence, countries are expected to implement common policies against environmental pollution, whereas in the case of divergence, it is more accurate for countries to follow national policies.

Nearly all studies in the literature on the convergence of EF are based on a linear framework. However, the EF is related to many economic variables and may follow a nonlinear structure. Hence, it will be more accurate to determine whether the EF has a linear structure before testing convergence.

The aim of this study has been to investigate the stationarity properties of the per capita EF in the ASEAN-5 countries. Our empirical study is based on the TAR panel unit root test. Initially, we determined that EF has a nonlinear structure. Then we investigated whether per capita EF in the ASEAN-5 countries is stationary at level. We identified the transition country between the two regimes as Vietnam. We found that EF does not converge in Regime I. However, we cannot reject the null hypothesis that EF converge in Regime II. Meanwhile, the results suggest that there is an absolute convergence in Regime II which constitutes 80.77% of the sample. Therefore, the general findings of the study support convergence of EF, implying the difference in this environmental pollution indicator decreases over time in the ASEAN-5 countries. Since the EF converged, it is possible to forecast the future

Table 2
Results for panel threshold unit root test.

Linearity tests		Transition Country	d	Threshold	% observations in Regime I
Test Statistic: 23.842 Unrestricted bootstrap p-value: 0.029 Restricted bootstrap p-value: 0.027		Vietnam	2	−4.903	19.230
Convergence tests					
Divergence vs convergence			Absolute vs relative convergence		
Regime 1 1.068 (0.857)	Regime II −2.684 (0.017)	Both 8.347 (0.169)	Regime I –	Regime II 4.452 (0.427)	Both -
Partial Convergence in Regime II			*Absolute Convergence in Regime II*		

value of environmental pollution in these countries. Thus, the ASEAN-5 countries can use historical data from their EF to make projections.

Absolute convergence states that the per capita EF of countries converges to one other independently of their initial conditions. The convergence of the EF indicates that markets can actively create equilibrium, and in this case, policymakers need to implement common policies. Reducing EF can be achieved more effectively by implementing international environmental policies. These policies should consider the socioeconomic characteristics of each country.

The underlying determinants of the EF level in a country are technological development, regulations on energy use, deforestation, environmental taxes, international trade, and the scale and composition of the economy. The current level of the EF can be changed as a result of common policies regarding these factors. The common policies implemented after international meetings, conferences, and agreements can help to reduce environmental pollution in the ASEAN-5 countries.

One possible policy implication is that carbon taxes may be imposed in these countries. Another possibility is that environmental and renewable energy sources can be substituted for fossil fuels. By increasing subsidies for the use of renewable energy, people's pressure on the environment and thus EF can be reduced. Closing the technological gap between ASEAN-5 countries, and controlling population size also help to reduce environmental pollution. To this end, environmental research and development investments can be increased. In addition, the same level of production can be achieved by increasing the efficiency in the economy and therefore using fewer natural resources. Moreover, societies should be made aware of the negative consequences of excessive consumption. This awareness can be made through information programs on environmental quality in universities and institutions. These common measures can help reduce the EF in these countries.

In conclusion, this paper offers new research opportunities. In future research, the convergence of EF components such as cropland, grazing land, fishing grounds, built-up land, forest areas and the carbon demand of the ASEAN-5 and other developing country groups can be examined. At the same time, similar research can be conducted with regard to high-income country groups where the EF has a nonlinear structure. In this way, the convergence of the EF can be compared between low-income and high-income countries.

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