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RESEARCH ARTICLE

Determinants of the ecological footprint in Thailand: the influences of tourism, trade openness, and population density

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Abstract
This paper investigates the impact of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprints in Thailand over the period from 1974 to 2016. We applied the augmented Dickey–Fuller and Zivot–Andrews unit root tests to check the stationary properties of the data. The ARDL bounding test approach and VECM Granger causality were used to investigate (i) the long-run and short-run effects and (ii) directions of such effects respectively. The long-run results showed that economic growth, energy consumption, and trade openness have positive relationships with the ecological footprint, while tourism and population density are negatively associated with the ecological footprint in Thailand. The results of VECM Granger causality confirmed that the bidirectional causality (i) between tourism and population density in the long run and (ii) between trade openness and population density in the short run. Furthermore, the unidirectional causality runs from the ecological footprint, economic growth, energy consumption, and trade openness to tourism and population density in the long run. The country policy combined with economic growth, energy consumption, tourism, international trade, and population density perspectives need to be revisited towards sustainable development by mitigating the effects of these variables on environmental depletion especially the ecological footprint.

Keywords Tourism · Trade openness · Population density · Ecological footprint · ARDL

Introduction

Along the country's growth path, ecological quality depreciates speedily due to human consumption and activities. These growths of population, tourism, and economic activities result in continuing either direct resources and energy consumption or indirect disrupting life-sustaining ecosystems that will lead to environmental degradation (Remoundou and Koundouri 2009). The ecological footprint, proposed by Rees (1992), is widely used as a proxy for environmental degradation to determine the degree of environmental degradation in the current decade (Solarin and Bello 2018; Destek and Sarkodie 2019; Zafar et al. 2019). The ecological footprint is preferred because it represents an aggregate indicator that combines the process of both production and consumption activities (Solarin and Bello 2018; Ulucak and Bilgili 2018), while CO_2 emission and other environmental indicators are a portion of environmental degradation (Destek and Sarkodie 2019).

At the early stages of the ecological footprint research, many scholars focused on measuring the size of the ecological footprint (Andersson and Lindroth 2001; Gössling et al. 2002; Hunter 2002; Hunter and Shaw 2007; Castellani and Sala 2008; Lin et al. 2018). The attention of the study of impacts of the economic growth, energy use, population dynamics, and several other notable factors on the ecological footprint has been a concern across the globe in the late 2000s (Bello et al. 2018; Destek et al. 2018; Sarkodie 2018; Alola et al. 2019; Danish and Wang 2019a; Destek and Sarkodie 2019; Ozcan et al. 2019; Wang and Dong 2019). Besides the benefit of tourism on the economic growth, tourism has also shown a very significant impact on the environmental degradation; it accounted for 5% in the greenhouse gas emissions especially CO_2 through consumption, transportation, accommodation,

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and tourism activities (Peeters and Dubois 2010; Gössling and Peeters 2015). In addition, tourism has been found to increase CO_2 in some countries (Katircioglu 2014; Zaman et al. 2016). However, tourism was also found to reduce CO_2 in some developed countries (Balsalobre-Lorente et al. 2019a) and the ecological footprint in some regions (Ozturk et al. 2016; Katircioglu et al. 2018; Kongbuamai et al. 2020).

Tourism is expected to grow annually as the world's largest industry in the twenty-first century, and it added roughly 10.4% and 9.9% to the world's GDP and employment respectively (WTTC 2018). Currently, more than 1.4 billion international tourists were recorded in 2018 (UNWTO 2019); however, the number of tourists is forecasted to 1.8 billion by 2030 (UNWTO 2011). This huge tourism sector requires huge consumptions of resources, goods, services, and energy (Danish and Wang 2019b). These number of tourists would increase the rate of consumption in the destinations as well as the population density (Balsalobre-Lorente et al. 2019a, 2020). The international trade could help to balance between the demand of tourists and local population with the supply of goods and services in the destination countries. Furthermore, the huge tourist inflow will generate income and increase economic activities for a country (Brida et al. 2014; Comerio and Strozzi 2018). These above human activities and mobility will contribute to the negative impacts on the ecological footprint (Gössling et al. 2002) as well as greenhouse gas emissions (Lenzen et al. 2018).

Based on the above study, there are limited numbers of studies dealing with the relationship between the ecological footprint and tourism (Ozturk et al. 2016; Katircioglu et al. 2018; Kongbuamai et al. 2020), and these studies employed the econometric method of panel data analysis, while extensive works of literature have studied the relationship between the tourism and CO_2 (Alam and Paramati 2017; Dogan and Aslan 2017; Paramati et al. 2017a; Azam et al. 2018; Wang and Wang 2018; Danish and Wang 2019b; Zhang and Liu 2019). These studies showed the evidence of mixed results between tourism and CO_2 nexus, both positive and negative relationships were found in different countries.

Thailand is one of the top world tourist destinations (rank 9th), and Thailand hosted more than 35.4 million international arrivals in 2017 which is half proportion to its population (UNWTO 2018). Furthermore, the international tourism receipt is ranked 4th in the world after the USA, Spain, and France (UNWTO 2018). Tourism's income directly contributed more than 21.1% to Thailand's GDP in 2017 (UNWTO 2018), and the tourism sector created more than 15.5% of total employment in 2017 (WTTC 2018). The primary energy sectors of Thailand are fossil fuels, coal, and natural gas, while less than 15% of the total energy consumption comes from the renewable energy sector in 2018 (Thailand Ministry of Energy 2019). Prominent in export-oriented countries, the export sector contributes about 66.8% to Thailand's GDP in 2018 (World Bank 2019). This international trade has contributed rapidly to Thailand's economic growth. Furthermore, Thailand is an ecological deficit country that deficit 1.3 global hectare (gha) in 2016 (Global Footprint Network 2019). From the current scenario, Thailand is one of the countries that have the growth potential in many aspects especially the tourism sector.

Therefore, this study aims to investigate the impact of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprint in Thailand. To complete this research objective, the current study employs the time series analysis. The set of econometric methods, including the augmented Dickey–Fuller (ADF), Zivot–Andrews unit root test, vector autoregressive (VAR) lag order selection criteria, autoregressive distributed lag (ARDL) bounding test approach, and vector error correction model (VECM) Granger causality approach, have been applied in this study to inclusively investigate the long-run and short-run relationships and directions among these variables.

For analyzing the long-run and short-run relationships, the ARDL bounding test was suggested as an appropriate method in the time series data (Jalil et al. 2013; Shahbaz et al. 2016; Danish et al. 2019a). The ARDL bounding test has an advantage because (i) it can remove the problem associated with missing variables and autocorrelation; (ii) it also can analyze the relationship of mixed-order of integration; (iii) it provides the consistent results in small sample sizes; and (iv) it can estimate the result even the explanatory variables are endogenous (Pesaran and Shin 1997; Pesaran et al. 2001). Furthermore, the VECM Granger causality test is appropriate to find the causality relationships in the time series analysis, as it was suggested (i) it can define both long-run and short-run causal relationship by accommodating structural breaks and (ii) it imposes additional restriction due to the existence of cointegrated in the data (Shahbaz et al. 2012, 2019; Alam et al. 2015; Ohlan 2017; Bello et al. 2018; Liu and Bae 2018).

The remaining sections of this paper are organized and second section reveals the existing literature; the third section presents data and model applied; the fourth section is aimed at results discussion, and the last (fifth) section provides conclusion and policy implications.

Literature review

The tourism-led growth hypothesis and the environment

The study of tourism and economic growth nexus was carried out since the 1970s, but the tourism-led growth (TLG) hypothesis was not expressly defined (Brida et al. 2014, 2016). Until 2002, Balaguer and Cantavella-Jordá (2002) developed the tourism-led growth (TLG) hypothesis to examine the relationship between economic growth and tourism. The TLG hypothesis was developed from the export-led growth hypothesis (Balaguer and Cantavella-Jordá 2002). Currently, the study on tourism and economic growth nexus reached more than 364 publications globally (Nunkoo et al. 2019). The TLG hypothesis nowadays is one of the major studies in tourism and economics nexus (tourism economics) (Pablo-Romero and Molina 2013; Brida et al. 2014, 2016; Nunkoo et al. 2019).

After Simon Kuznets purposed the environmental Kuznets curve (EKC) hypothesis in 1995 (Kuznets 1995), it widely used as the framework to investigate the relationship between economic growth and the environment (Kuznets 1995).

The EKC hypothesis has been combined with the TLG hypothesis; it is called the tourism-induced EKC hypothesis. The tourism-induced EKC hypothesis introduced that tourism helps to improve the environment quality (Katircioğlu 2014; Ozturk et al. 2016). The tourism-induced EKC hypothesis is still used in many studies in different countries and regions on various environment's indicator of CO_2 (Katircioğlu 2014; de Vita et al. 2015; Zhang and Gao 2016; Alam and Paramati 2017; Paramati et al. 2017a; Shakouri et al. 2017; Azam et al. 2018; Bella 2018; Wang and Wang 2018; Balsalobre-Lorente et al. 2019a; Danish and Wang 2019b; Gao et al. 2019; Qureshi et al. 2019; Zhang and Liu 2019) and the ecological footprint (Ozturk et al. 2016; Katircioglu et al. 2018; Qureshi et al. 2019; Kongbuamai et al. 2020).

Although the EKC approach may generate the multicollinearity between GDP and square of GDP (Al-Mulali et al. 2016), consequently, many studies examine tourism–environment relations without the EKC approach. Several studies have shown the effect of tourism on the environment's indicator of CO_2 without using the EKC approach in different regions and countries (Lee and Brahmasrene 2013; Katircioglu 2014; Dogan and Aslan 2017; Paramati et al. 2017b).

Hence, there is an obvious limitation of tourism impacts on the ecological footprint; one can only study the limited literature (Ozturk et al. 2016; Katircioglu et al. 2018; Kongbuamai et al. 2020). Therefore, this study is to investigate the impact of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprint in Thailand without using the EKC approach. There are many determinants of the ecological footprint which have been discussed in the literature. We have divided the literature into a pairwise nexus, which is presented in the section below.

Tourism and the ecological footprint nexus

According to The World Travel & Tourism Council (WTTC 2018), the tourism sector generates about 10% of the total world revenues. At the same time, this industry counts about 10% of the world's ecological footprint (Wackernagel and Yount 2000).

The effect of tourism on the ecological footprint has been carried out using the panel data analysis. Firstly, Ozturk et al. (2016) have employed the EKC hypothesis with the generalized method of moments (GMM) and system panel GMM to examine the relationship between the ecological footprint and GDP from tourism in 144 countries; the result showed that the EKC hypothesis (inverted U-shape) between the ecological footprint and the GDP from tourism, especially in the upper-middle- and high-income countries.

Furthermore, Katircioglu et al. (2018) carried out the role of tourism development in the ecological footprint quality in the world top 10 tourist destinations by using the tourism-induced EKC hypothesis with the panel random-effects (RE) method for 1995–2014, the findings show that the coefficients of tourist arrivals, the tourism receipts, the tourism expenditures, and tourism index are negatively significant associated with the ecological footprint. It implied that tourism development improved the levels of environmental degradation (the ecological footprint) in top tourist countries.

Lastly, there is also a study from Kongbuamai et al. (2020) that confirmed tourism helps to reduce the ecological footprint in ASEAN countries (negative relationship), and they employed the Driscoll–Kraay panel regression model and Dumitrescu–Hurlin panel causality test for the panel data from 1995 to 2016.

Trade openness and the ecological footprint nexus

The relationship between trade openness and the ecological footprint nexus has been studied by various researchers. Different studies reported positive as well as the negative impact of trade openness on the ecological footprint. For example, Charfeddine (2017) studied Qatar for the period 1970–2015 by using the Markov switching equilibrium correction model; the results show that a positive relationship between trade openness and the ecological footprint. Ulucak and Bilgili (2018) employed the models of continuously updated fully modified (CUP-FM) and continuously updated bias-corrected (CUP-BC) models for the high-, middle-, and low-income countries between 1961 and 2013, and it reveals that trade openness leads the ecological footprint to increase in each income group countries. Imamoglu (2018) employed the dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and ARDL bounding test approaches to investigate Turkey from 1970 to 2014 period. This study found a significant positive impact of trade volume on the ecological footprint.

On the contrary, some studies reported a negative impact of trade openness on the ecological footprint. For example, Mrabet et al. (2017) mentioned that trade openness contributed a negative impact on Qatar's ecological footprint in the long run by using the ARDL bounding test approach (the data between 1980 and 2011). Destek et al. (2018) employed DOLS and FMOLS to investigate the European Union (EU) countries of the data from 1980 to 2013; trade openness decreases the ecological footprint in the majority of EU countries. Alola et al. (2019) used the panel pooled mean group-autoregressive distributive lag (PMG-ARDL) model to investigate EU countries from 1997 to 2014, and a negative relationship between trade openness and the ecological footprint was found in the long run. Furthermore, trade openness was also found as a negative impact on the ecological footprint in the 24 Organization for Economic Co-operation and Development (OECD) countries by Destek and Sinha (2020); they used mean group (MG), FMOLS-MG, and DOLS-MG tests for the data from 1980 to 2014, while Ahmed and Wang (2019) found an insignificant effect of trade openness on the ecological footprint in India (the long run) using the ARDL bounding test, and the VECM Granger causality test.

Population density and the ecological footprint nexus

Aşıcı and Acar (2016) showed that there is a negative relationship between population density and the domestic production ecological footprint for a panel of 116 countries during the period of 2004–2008 using the panel fixed effects (FE) regression method. In the similar results, a negative relationship is found between population density and the non-carbon import ecological footprint with low magnitude in 87 countries, but the population density has no effect on the non-carbon domestic production ecological footprint during the period 2004–2010 according to the FE and RE model (Aşıcı and Acar 2018). In addition, Dogan et al. (2020) found that the population growth contributes a negative impact on the ecological footprint in BRICST (Brazil, Russia, India, China, South Africa, Turkey) using the FMOLS and the DOLS and the augmented mean group (AMG) estimators (data 1980–2014).

Economic growth and the ecological footprint nexus

Economic growth has been incorporated in many studies to investigate its effect on the ecological footprint, both positive and negative relationships between the economic growth and ecological footprint were confirmed in various studies and countries. Imamoglu (2018) employed the DOLS, FMOLS, and ARDL bounding test approaches to investigate Turkey from 1970 to 2014 period; a highly positive impact of formal and informal economies on the ecological footprints were found in the long run. Danish et at. (2019a) applied the ARDL bounding test to study Pakistan from 1971 to 2014; the results showed a positive impact of economic growth on the ecological footprint. Wang and Dong (2019) employed 14 sub-Saharan Africa (SSA) countries over 1990–2014 using the AMG; the AMG estimator indicates that economic growth exerts positive effects on the ecological footprint in the SSA countries. Alola et al. (2019) used the PMG-ARDL approach to investigate EU countries from 1997 to 2014; the economic growth exerts a positive impact on the ecological footprint in both the short run and long run. Lastly, Ahmed et al. (2020) used the CUP-FM and CUP-BC in the study on G7 countries (data 1971–2014), and economic growth has been found as a positive impact on the ecological footprint in these countries.

On the other hand, economic growth also found to reduce the ecological footprint and it has been confirmed in several countries and regions. Several studies confirmed that economic growth help to reduce the ecological footprint after reaching some stage of economic development according to the EKC approach for example in BRICS countries (Danish et at. 2019b), MINT (Mexico, Indonesia, Nigeria, and Turkey) countries (Balsalobre-Lorente et al. 2019b), India (Ahmed and Wang 2019), Israel (Gormus and Aydin 2020), ASEAN countries (Kongbuamai et al. 2020), Turkey (Sharif et al. 2020), Pakistan (Aziz et al. 2020), and EU (Altıntaş and Kassouri 2020).

Nevertheless, Sarkodie et al. (2019) found the dynamic relationship between the economic growth and the ecological footprint using the dynamic autoregressive distributed lag simulations; this study was confirmed that the economic growth (with the positive shock) decreases ecological footprint, while the economic growth (with the negative shock) increases ecological footprint in the long run for Australia (data from 1970 to 2017).

Energy consumption and the ecological footprint nexus

Several authors included energy consumption into their study models of the ecological footprint. For example, Charfeddine (2017), Katircioglu et al. (2018), Sarkodie (2018), Imamoglu (2018), Destek and Sarkodie (2019), Wang and Dong (2019), Alola et al. (2019), Ahmed and Wang (2019), Zafar et al. (2019), and Ahmed et al. (2020) found a positive relationship between energy consumption and the ecological footprint. Furthermore, Sharif et al. (2020) confirmed that the non-renewable energy has a positive impact on the ecological footprint in the long run on each quantile for Turkey using the quantile autoregressive lagged (QARDL) approach for the data from 1965Q1-2017Q4. In addition, Destek and Sinha (2020) and Kongbuamai et al. (2020) also reported the positive relationship between energy consumption and the ecological footprint in OECD and ASEAN countries respectively.

On the other hand, energy consumption was also found to be a negative relationship with the ecological footprint, especially the renewable energy in the EU countries (Destek et al. 2018), Malaysia (Bello et al. 2018), 14 SSA countries (Wang and Dong 2019), and Europe (Alola et al. 2019). The negative relationship between renewable energy and the ecological footprint was also found in OECD by Destek and Sinha (2020) and Turkey by Sharif et al. (2020). Furthermore, Danish et at. (2019b) employed the FMOLS and DOLS for the study of BRICS countries (data 1992–2016), and renewable energy consumption has confirmed a negative impact on the ecological footprint. Balsalobre-Lorente et al. (2019a, b) also confirmed a negative relationship between renewable energy consumption the ecological footprint by using FMOLS and DOLS in MINT (Mexico, Indonesia, Nigeria, and Turkey) countries (data 1990–2013). Gormus and Aydin (2020) used the MG and AMG estimators to conduct the study on the top 10 innovative economies (data 1990–2015), and renewable energy consumption was found to have a negative impact on the ecological footprint in Denmark, Germany, the Netherland, and the USA. In addition, Aziz et al. (2020) also confirmed that renewable energy consumption has significant negative impacts on the ecological footprints in the long run for Pakistan. Lastly, Altıntaş and Kassouri (2020) confirmed the statistically negative impact of renewable energy on the ecological footprint in 14 EU countries using the interactive fixed effects (IFE) method and the dynamic common correlated effects (D-CCE) approach (data 1990–2014).

Based on the existing literature review, the research gap of the study between tourism and the ecological footprint in Thailand needs to be explored. Therefore, this study aims to investigate the impact of tourism together with economic growth, energy consumption, trade openness, and population density on the ecological footprint in Thailand. Specifically, there are rare studies available that used time series data in this issue. The data set and econometric methodology will assist to reach consistent and efficient estimators, which is explained in the section below.

Data and econometric method

Data

This study uses time series data (annual data) of Thailand from 1974 to 2016. One dependent variable is the ecological footprint (EF)—a proxy of environmental quality. Three independent variables have been used, namely, tourism—the number of international tourists (T), trade openness (TRADE), and population density (PD)—a proxy of human dynamic. Furthermore, two control variables were employed including GDP per capita—a proxy for economic growth—and energy use (ENG)—a proxy for energy consumption. The ecological footprint represents the nature capacity associated with human activities of consumption and production, which is measured as a global hectare (gha) per person, (Danish et at. 2019a; Ozcan et al. 2019). The GDP is collected as the GDP per capita (in constant 2010 US dollars), and energy use (kg of oil equivalent per capita) is taken as energy consumption variable. The number of people is the unit of the number of international tourists (T). For trade openness (TRADE) representing the share of total trade value (export + import) in the GDP, a percentage is used as a unit. Population density is measured in the unit of people per square kilometer of land area. The data of the ecological footprint was derived from the database of the Global Footprint Network (2019). GDP, ENG, TRADE, and PD were collected from the world development indicators (World Bank 2019), while tourism data (T) was collected from the Tourism Authority of Thailand (TAT) (1995) which combined the world development indicators (World Bank 2019).

Model construction

To investigate the effect of the GDP per capita, energy consumption, the number of international tourists, trade openness, and population density on the ecological footprint in Thailand, the empirical economic equation is specified as follows:

$$\mathrm{EF} = f(\mathrm{GDP}, \mathrm{ENG}, \mathrm{T}, \mathrm{TRADE}, \mathrm{PD}) \quad (1)$$

where EF (the ecological footprint) is a function of GDP per capita (GDP), energy consumption (ENG), international tourists (T), trade openness (TRADE), and population density (PD).

All variables were subsequently changed into natural logarithm forms, which suggested to evade the problem of dynamic properties in the data series (Paramati et al. 2017a, b) and capture growth effects (Katircioglu 2014; Nathan et al. 2016; Zaman et al. 2016; Katircioglu et al. 2018). Therefore, we rewrite Eq. (1) in natural logarithm as shown below:

$$\begin{aligned} \mathrm{lnEF}_t = {} & \beta_0 + \beta_1 \mathrm{lnGDP}_t + \beta_2 \mathrm{lnENG}_t + \beta_3 \mathrm{lnT}_t \\ & + \beta_4 \mathrm{lnTRADE}_t + \beta_5 \mathrm{lnPD}_t + \varepsilon_t \end{aligned} \quad (2)$$

where lnEF is the ecological footprint, lnGDP is the GDP per capita, lnENG is the energy consumption, lnT is the number of international tourists, lnTRADE is the trade openness, and lnPD is the population density. The coefficients β_i, $i = 1, 2, \ldots, 5$ indicate the long-run elasticity estimates of the ecological footprint with respect to real GDP per capita, energy consumption, number of international tourists, trade openness, and population density respectively. t represents a time frame ($t = 1, 2, 3, \ldots, 47$) of the study, and the stochastic error term indicated as ε.

Both economic growth and energy consumption contributed impact on environmental degradation especially in low-income countries (Aşıcı and Acar 2016; Danish and Wang 2019a). Thailand is one of the upper-middle-income countries and massively relies on more than 75% conventional energy (fossil flue, natural gas, and coal) (Thailand Ministry of Energy 2019). This conventional energy is an engine for driving economic growth. Therefore, this could lead to a harmful environment in Thailand, the expected signs of β_1 and β_2 are positive.

The number of international tourists is used in this study, the number of international tourists, and activities affected the environmental degradation and the domestic ecological footprint through their consumption and activities. Hunter (2002) suggested that tourists required different ecological demands. Therefore, the β_3 is set as a positive sign which tourists would increase the environmental depletion in Thailand.

Trade openness leads to import or export of the ecological footprint through the transfer of goods and services (Andersson and Lindroth 2001). The trade openness was confirmed to reduce the ecological footprint especially in the upper-middle- and high-income countries (Aşıcı and Acar 2016; Ozturk et al. 2016). Furthermore, Thailand is an export-oriented country. Therefore, β_4 is expected as a negative sign.

Lastly, the population density was suggested to improve the accessibility of services and promote resource use efficiency (Chen et al. 2008), and Thailand's population density is not too high compared to other big cities in the world and Thailand has a high population density in few cities. Therefore, the expected sign of β_5 is negative.

Econometric strategy

This study employs the time series analyzing technique to analyze the impact of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprint in Thailand. The ADF, Zivot–Andrews unit root test, VAR lag order selection criteria, ARDL bounding test approach, and VECM Granger causality approach have been used to test the correlation, stationary, cointegration, relationship, and causality for the purpose of efficient and reliable. The econometric strategy is presented below.

We first employed the correlation test to investigate the dependence relations among multiple variables. The results show the correlation coefficients of each variable with the others. If the correlation value is "0" or closer to "0," it states no correlation or very weak correlation respectively. Similarly, a correlation value of "1" reflects a strong positive relationship and a "− 1" value means a strong negative relationship (Wooldridge 2015).

Second, we applied the ADF and Zivot–Andrews unit root tests to check the unit root properties. A unit root test helps to identify the non-stationary and possesses a unit root of the time series variables (Wooldridge 2015). Since all the conventional unit root tests such as ADF, DF-GLS, and PP tests fail to identify the presence of a structural break in the data set. Therefore, we used the Zivot–Andrew unit root test to investigate a structural break (Zivot and Andrews 1992). The structural breaks in the data are identified which could lead to biases in the estimation (Allaro et al. 2011). The Zivot–Andrew test conveys the structural breaks on any point, if any, and also estimates the unit root properties on different levels (Zivot and Andrews 1992).

After the unit root test, we applied the VAR model combined the effect of previous years and disturbances of observed variables containing zero means. The VAR facilitates to form a data series of every individual variable by incorporating its historical values (Wooldridge 2015). This VAR model helps to examine all the series regarding the order of integration. After the VAR model, we need to check the long-run and short-run relationships. For exploring these relationships, we used the ARDL bounding test model presented by Pesaran and Shin in 1997 (Pesaran and Shin 1997) and further extended by Pesaran et al. in 2001 (Pesaran et al. 2001). The ARDL bounding test approach to cointegration estimation provides an unbiased and efficient result for both the long-run and short-run analyses (Jalil et al. 2013; Shahbaz et al. 2016; Danish et at. 2019a). This estimation removed the problem associated with missing variables and autocorrelation, with a small sample size of variables. Furthermore, the ARDL bounding test approach can also distinguish dependent and explanatory variables and analyze the relationship of mixed-order of integration, i.e., $I(0)$ and $I(1)$ in the variables (Pesaran and Shin 1997; Pesaran et al. 2001). The ARDL bounding test representation of selected variables is specified below in Eq. (3):

$$\begin{aligned}\Delta \ln \mathrm{EP} = {} & c_0 + \sum_{i=1}^{p} \beta_1 \Delta \mathrm{EF}_{t-r} + \sum_{i=0}^{q} \beta_2 \Delta \mathrm{GDP}_{t-r} \\ & + \sum_{i=0}^{r} \beta_3 \Delta \mathrm{ENG}_{t-r} + \sum_{i=0}^{s} \beta_4 \Delta \mathrm{T}_{t=r} \\ & + \sum_{i-0}^{t} \beta_5 \Delta \mathrm{TRADE}_{t-r} + \sum_{i=0}^{u} \beta_6 \Delta \mathrm{PD}_{t-r} \\ & + \lambda_1 \ln \mathrm{EF}_{t-1} + \lambda_2 \ln \mathrm{GDP}_{t-1} + \lambda_3 \ln \mathrm{ENG}_{t-1} \\ & + \lambda_4 \ln \mathrm{T}_{t-1} + \lambda_5 \ln \mathrm{TRADE}_{t-1} + \lambda_6 \ln \mathrm{PD}_{t-1} \\ & + \varepsilon_t \end{aligned} \quad (3)$$

where the Δ is the first difference operator, the p, q, r, s, t and u denoted lag length, and coefficients are presented through β. Long-run relationships can be represented through two hypotheses. First, the null hypothesis states the absence of cointegration that can be written as $(H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 = 0)$ and the second alternative hypothesis that states the presence of cointegration between variables $(H_0: \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \neq 0)$. Later, the Johansen cointegration is used to test and verify the robustness of the ARDL bounding test. The presence of cointegration enables to estimate the long-run coefficients using Eq. (4).

$$\Delta \ln \mathrm{EP}_t = c_0 + \sum_{k=1}^{p} \beta_1 \Delta \ln \mathrm{EF}_{t-k} + \sum_{k=0}^{q} \beta_2 \Delta \ln \mathrm{GDP}_{t-k} + \sum_{k=0}^{r} \beta_3 \Delta \mathrm{ENG}_{t-k} + \sum_{k=0}^{s} \beta_4 \Delta T_{t-k} + \sum_{k=0}^{t} \beta_5 \Delta \mathrm{TRADE}_{t-k} + \sum_{k=0}^{u} \beta_6 \Delta \mathrm{PD}_{t-k} + \mu_t \quad (4)$$

where Δ is the first difference operator, $\beta_{1,\ 2,\ 3,\ 4,\ 5,\ 6}$ denotes the long-run coefficients, $\beta_{p,\ q,\ r,\ s,\ t,\ u}$ denotes the short-run coefficients, c_0 denotes a constant term, μ denotes a noise error term, and μ_t denotes the structural break. We can derive the short-run dynamics of study variables by using the following error correction models (ECM) Eq. (5):

$$\Delta \ln \mathrm{EF}_t = c_0 + \sum_{k=1}^{p} \beta_1 \Delta \ln \mathrm{EF}_{t-k} + \sum_{k=0}^{q} \beta_2 \Delta \ln \mathrm{GDP}_{t-k} + \sum_{k=0}^{r} \beta_3 \Delta \mathrm{ENG}_{t-k} + \sum_{k=0}^{s} \beta_4 \Delta \mathrm{T}_{t-k} + \sum_{k=0}^{t} \beta_5 \Delta \mathrm{TRADE}_{t-k} + \sum_{k=0}^{u} \beta_6 \Delta \mathrm{PD}_{t-k} + \kappa \mathrm{ECT}_{t-1} + \mu_t, \quad (5)$$

where ECT_{t-1} represents the error correction term which defines the adjustment of speed to long-run equilibrium if any shock happens. As a standard, the value of ECT_{t-1} should be statistically significant and negative in order to reach again at the long-run equilibrium point (Rafindadi and Ozturk 2016). The set of robustness test, Ramsey RESET test, LM, Breusch–Pagen Godfrey, and CUSUM is applied to test the robustness of the long-run and short-run estimations.

After confirmation of cointegration in the variables by the Johansen cointegration and ARDL bounding test approach to cointegration, the long-run and short-run causality among the variables were identified by the VECM Granger causality test, which is not possible in ARDL bounding test. This VECM Granger causality functioned as past values of one series (x_t) which predict the future values of another series (y_t) by controlling past values of y_t (Wooldridge 2015). The VECM Granger causality estimation is appropriate for the variables which are integrated at the same order (Ohlan 2017). After knowing the data stationary, the long-run and short-run causal directions between these variables can further proceed through the VECM Granger causality, which is formulated as Eq. (6):

$$\begin{bmatrix} \Delta \ln \mathrm{EF}_t \\ \Delta \ln \mathrm{GDP}_t \\ \Delta \ln \mathrm{ENG}_t \\ \Delta \ln \mathrm{T}_t \\ \Delta \ln \mathrm{TRADE}_t \\ \Delta \ln \mathrm{PD}_t \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \delta_4 \\ \delta_5 \\ \delta_6 \end{bmatrix} + \sum_{p-1}^{q} \begin{bmatrix} \theta_{11p} & \theta_{12p} & \theta_{13p} & \theta_{14p} & \theta_{15p} & \theta_{16p} \\ \theta_{21p} & \theta_{22p} & \theta_{23p} & \theta_{24p} & \theta_{25p} & \theta_{26p} \\ \theta_{31p} & \theta_{32p} & \theta_{33p} & \theta_{34p} & \theta_{35p} & \theta_{36p} \\ \theta_{41p} & \theta_{42p} & \theta_{43p} & \theta_{44p} & \theta_{45p} & \theta_{46p} \\ \theta_{51p} & \theta_{52p} & \theta_{53p} & \theta_{54p} & \theta_{55p} & \theta_{56p} \\ \theta_{61p} & \theta_{62p} & \theta_{63p} & \theta_{64p} & \theta_{65p} & \theta_{66p} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} \mathrm{ECT}_{it-1} + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \\ \mu_{5t} \\ \mu_{6t} \end{bmatrix} \quad (6)$$

where Δ denotes the operator of the first difference, p shows the lag length, and μ means the residuals. The results of the study are presented in continuity in the following section.

Empirical results

This study first tests the correlation between the variables. Table 1 summarizes a correlation matrix for all variables in order to indicate the degree of linear dependence between sets of variables. The significant correlation is observed, and the ecological footprint positively correlated with GDP per capita, energy consumption, tourism, trade openness, and population density.

Before applying the ARDL bounding test, we need to check the stationary properties. All the data series must be stationary on “0” or “1st” different levels. The ADF and Zivot–Andrews unit root tests were used to find the stationary properties of the data. Furthermore, the Zivot–Andrews unit root test also helps in pointing out a single unknown structural break in the series (Zivot and Andrews 1992). The results of both unit root tests are presented in Table 2.

The finding from both the ADF and Zivot–Andrews unit root tests shows that variables are stationary at the first difference level. The structural breaks exist in the years 1991, 1996, 1984, and 1987 according to the Zivot–Andrews unit root tests; it indicated that economic structure and policy changes in Thailand which occurred in those years. For example, the structural break of 1996–1997 recalls the Asian financial crisis that severely harmed the Thai economy and the rest of Asia. Therefore, the ARDL bounding test is applied to extend further results.

Next, we checked the lag order before performing the ARDL bounding test. To do this, we applied the VAR lag order selection criteria test. For this purpose, we utilized the Schwarz information criterion (SIC), and we selected the lag order 1 as suggested by SIC in Table 3.

After we confirmed the stationary of the data, the ARDL bound testing technique has been used to find the cointegration among variables. The ARDL bound testing approach to cointegration exhibited the results in Table 4, and the long-run cointegration is confirmed in this ecological footprint model. If our estimated F statistic value is higher than the standard critical bounds, then we reject the null hypothesis (no cointegration).

Table 1 Correlation matrix

	lnEF	lnGDP	lnENG	lnT	lnTRADE	lnPD
lnEF	1.000					
lnGDP	0.173630	1.000				
lnENG	0.281478	0.465686	1.000			
lnT	0.305134	0.518146	0.835610	1.000		
lnTRADE	0.135508	0.219970	0.358823	0.396675	1.000	
lnPD	0.047044	0.079600	0.129829	0.144097	0.061054	1.000

The results show that our F statistic value is 8.510 which is higher than the upper critical bound. It means we hereby reject the null hypothesis concluding that there is long-run cointegration among our model variables at 1% significance level.

Furthermore, we also applied the Johansen cointegration test which is appropriate to test the robustness of the ARDL bounding test. Table 5 presents the results of the Johansen cointegration.

The result of the Johansen cointegration test reveals that we had three cointegrating vectors when GDP, energy consumption, international tourists, trade openness, and population density were used as dependent variables.

According to the Johansen cointegration test, the results show that both the trace statistics and the maximum eigenvalue are significant. Therefore, this confirmed that ecological footprint is cointegrated with economic growth, energy consumption, tourism, trade openness, and population density in Thailand in the long run.

Table 2 The unit root test

ADF unit root test				
	Level	*p* value	First difference	*p* value
lnEF	− 0.798349	0.9577	− 5.490395***	0.0003
lnGDP	− 1.850683	0.6614	− 3.663953***	0.0085
lnENG	− 0.482575	0.9805	− 3.630970***	0.0091
lnT	− 2.151190	0.5033	− 6.126419***	0.000
lnTRADE	− 1.368505	0.8558	− 6.532828***	0.000
lnPD	− 1.557976	0.4926	− 4.066387***	0.0033
Zivot–Andrews unit root test				
	Level	Break year	First difference	Break year
lnEF	− 1.9941	2006	− 6.0898***	1991
lnGDP	− 3.4253	1995	− 4.6491**	1996
lnENG	− 3.6918	2004	− 6.1165***	1984
lnT	− 3.2595	2010	− 5.9862***	1991
lnTRADE	− 3.0755	2009	− 7.5403***	1987
lnPD	− 3.4832	2000	− 4.4774**	1987

***, **, and * represent 1%, 5%, and 10% significance levels respectively

Long-run and short-run estimations

After cointegration among the variables has been confirmed, the long-run and short-run relationships were purposed to estimate the impacts of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprint using the ARDL bounding test approach. The long-run and short-run results are presented in Table 6.

In the long run, this study highlighted a negative significant relationship of tourism (number of international tourists) on the ecological footprint which a 1% increase in the number of international tourists that causes a reduction of 0.123% in the ecological footprint in Thailand. The growth of tourism in Thailand under this investigation confirmed no deterioration in the environmental quality (the ecological footprint) in Thailand. This finding is in parallel with the results from Ozturk et al. (2016) for 144 countries, Katircioglu et al. (2018) for the top ten destination countries, and Kongbuamai et al. (2020) for ASEAN countries.

Eventually, this increased number of tourists led to an increase in the population density and consumption in the tourism destination, whereas tourism in Thailand developed to be environment friendly following the current global concern of sustainable tourism. Thailand presently promotes the environmental concern for tourists through multi-campaigns and advertisement as well as alternative tourism, i.e., the community-based tourism and eco-tourism. This environmental concern for tourists accelerates resource use efficiency, eco-friendly product consumption, and reducing pollutions.

Nevertheless, the tourism income of Thailand contributes more than 21% of GDP (UNWTO 2018); therefore, the government of Thailand can collect taxes and deposits it into the environmental fund to improve Thailand's environmental quality (Thailand Ministry of Natural Resources and Environment 2018). Furthermore, the environmental concern also promotes on the tourism service providers (hotel, restaurant, transportation, and destination) in Thailand. These tourism service providers offer eco-friendly goods and services

Table 3 VAR lag order selection criteria

lag	LogL	LR	FPE	AIC	SIC	HQ
0	267.8779	NA	8.29E−14	− 13.0939	− 12.8406	− 13.0023
1	618.2414	578.0997	1.26E−20	− 28.8121	− 27.0387*	− 28.1709
2	690.4972	97.54543	2.34E−21	− 30.6249	− 27.3316	− 29.4341
3	798.3868	113.2841*	9.12E−23*	− 34.21934*	− 29.40604	− 32.47900*

***, **, and * represent 1%, 5%, and 10% significance levels respectively

and actively participated in different environment-friendly schemes such as the green hotel certificate by the ministry of natural resources and environment, the green leaf certificate by the Green Leaf Foundation, and green destination certificate by the Global Sustainable Tourism Council. To do this, these tourism service providers actively work with the government organization and international agencies to promote and develop their business and products which improve efficiency and reduce pollution.

Furthermore, the coefficient on population density is also negative and statistically significant to Thailand's ecological footprint in the long run. The result confirmed that such an increased 1% in population density led to a decrease in Thailand's ecological footprint by 1.402%. The estimated coefficient of population density is the highest among all the coefficients; this attests that population density is the main proportion among these variables.

Currently, the population density of Thailand was 135.89 people per square kilometer of land area in 2018 (World Bank 2019) and only a few big cities have high population density (National Statistical Office of Thailand 2020). In Thailand, population density has a negative relationship to the ecological footprint; this is because the population's consumption is highly dependent on natural products as well as plentiful resources currently available, which are capable of handling the balance within the ecosystem. Our results are similar to those of Aşıcı and Acar (2016) for 116 countries (the domestic production ecological footprint), Aşıcı and Acar (2018) for 87 countries (the non-carbon import ecological footprint), and Dogan et al. (2020) for BRICST (the ecological footprint).

As such, it has been suggested that population density will improve the accessibility of services and promote resource use efficiency (Chen et al. 2008), and Thailand's natural resources were observed as increasing trends for several decades, especially in the 1990s and 2000s (World Bank 2019). These negative impacts of tourism and population density on the ecological footprint are justified through the pertinent level of natural resources and resource use efficiency in Thailand.

However, the findings of the study exhibited that GDP per capita, energy consumption, and trade openness have a significant and positive impact on the ecological footprint in the long run for Thailand.

For the GDP per capita, an increase of 1% of Thailand's economic growth leads to an increase of 0.300% of its ecological footprint. This result implied vast developments in various sectors of Thailand's economy, leading to the growth of economic activities. It also accelerated energy consumption and resource consumptions which lead to an increase in the level of environmental degradation (the ecological footprint). This result is in accordance with the results of for the 27 highest emitting countries (Uddin et al. 2017), for the EU countries (Alola et al. 2019), for 14 SSA countries (Wang and Dong 2019), for G7 countries (Ahmed et al. 2020), for Qatar (Mrabet et al. 2017), for Turkey (Imamoglu 2018), for Pakistan (Danish et at. 2019a), and for the USA (Zafar et al. 2019) in the long run.

It is in contrast with the finding that economic growth helps to improve the environmental degradation (the ecological footprint) after some economic growth level, which is confirmed in BRICS countries (Danish et at. 2019b), MINT countries (Balsalobre-Lorente et al. 2019b), ASEAN countries (Kongbuamai et al. 2020), EU (Altıntaş and Kassouri 2020), Israel (Gormus and Aydin 2020), India (Ahmed and Wang 2019), Turkey (Sharif et al. 2020), and Pakistan (Aziz et al. 2020) in the long run.

Table 4 Results of the ARDL bounding test approach

Model	ln EF = *f*(ln GDP, ln ENG, ln T, ln TRADE, ln PD)
Bound test-*F* statistics	8.510199
Significance	1%
Lower 1(0) bound	3.74
Upper 1(1) bound	5.06

Table 5 Results of the Johansen cointegration

Hypothesis	Trace statistics	Maximum eigenvalue
$R=0$	174.9000***	70.46057***
$R\leq 1$	104.4394***	43.67746**
$R\leq 2$	60.76194*	24.6514
$R\leq 3$	36.11053	16.35387

***, **, and * represent 1%, 5%, and 10% significance levels respectively

Furthermore, a 1% increase in Thailand's energy consumption leads to an increase of 1.096% in the ecological footprint in the long run. This implies that energy consumption is one of the major reasons for environmental degradation in Thailand. As such, Thailand is one of the upper-middle-income countries and massively relies on more than 75% conventional energy (fossil flue, natural gas, and coal) (Thailand Ministry of Energy 2019). This could lead to harm on the environment in Thailand. Also, this energy consumption is a fundamental requirement for the growth-goal objective of the country. This result also matches with the studies of Al-Mulali et al. (2015) for 93 countries; Katircioglu et al. (2018) for the top 10 tourist destinations; Destek and Sarkodie (2019) for 11 newly industrialized countries, especially in China, India, Mexico, Singapore, and Thailand; Danish and Wang 2019a) for the Next-11 countries; Charfeddine and Mrabet (2017) for the 15 MENA; Ahmed et al. (2020) for G7 countries; Destek and Sinha (2020) for OECD countries; Kongbuamai et al. (2020) for ASEAN countries; Zafar et al. (2019) for the USA; and Sharif et al. (2020) for Turkey in the long run.

Nevertheless, the contrast results of the negative relationship between energy consumption (renewable energy) and the ecological footprint are also confirmed in the EU countries (Destek et al. 2018), Malaysia (Bello et al. 2018), 14 SSA countries (Wang and Dong 2019), Europe (Alola et al. 2019), OECD countries (Destek and Sinha 2020), BRICS countries (Danish et at. 2019b), MINT countries (Balsalobre-Lorente et al. 2019b), Denmark, Germany, the Netherland, and the USA (Gormus and Aydin 2020), Pakistan (Aziz et al. 2020), and Turkey (Sharif et al. 2020) in the long run.

Lastly, trade openness positively contributes to the ecological footprint in Thailand. When there is a 1% rise in trade openness, it increases 0.188% of the ecological footprint in the long run. This result implied that Thailand's international

Table 6 Long-run and short-run estimations

	Coefficient	Std. error	*t* statistic	Prob.
Long-run estimations				
lnGDP	0.300078	0.121146	2.477006**	0.0184
lnENG	1.096937	0.152158	7.209174***	0.0000
lnT	− 0.12365	0.049527	− 2.49659**	0.0175
lnTRADE	0.188314	0.033271	5.659939***	0.0000
lnPD	− 1.40249	0.656063	− 2.13774**	0.0398
C	3.808432	1.372694	2.774423***	0.0089
Short-run estimations				
D(lnGDP)	0.388305	0.128622	3.018963***	0.0048
D(lnENG)	0.527975	0.104054	5.074051***	0.000
D(lnT)	− 0.1600	0.061343	− 2.60831**	0.0134
D(lnTRADE)	0.243681	0.088013	2.768703***	0.009
D(lnPD)	− 1.81484	0.379317	− 4.7845***	0.000
CointEq (− 1)	− 0.77279	0.235364	− 3.28339***	0.0024
Sensitivity analysis	*F* statistics	*p* value		
Ramsey RESET test	0.475154	0.4956		
LM	0.377435	0.7699		
Breusch–Pagan–Godfrey	0.039699	0.9611		
R^2	0.98979			
Adj-R^2	0.987688			
F statistics	470.8573			
DW	2.123528			

***, **, and * represent 1%, 5%, and 10% significance levels respectively trade increases environmental degradation (the ecological footprint), whereas Thailand is an export-oriented country and it requires substantial resources and energy as primary materials in the production chain. The more their export increases, the more resource extraction and energy use that increased the rate of environmental degradation. This is in accordance with the results from Al-Mulali et al. (2015) for 93 countries; Aşıcı and Acar (2016) for116 countries; Charfeddine (2017) for Qatar; Ulucak and Bilgili (2018) for 45 countries; and Imamoglu (2018) for Turkey. On the contrary, this result is not in the same direction with the studies from Mrabet et al. (2017) for Qatar; Destek et al. (2018) for the EU countries; Alola et al. (2019) for the EU countries; and Destek and Sinha (2020) for the OECD countries.

In the short run, the results are also in a similar direction to the long-run results. Tourism and population density are negative relations to the ecological footprint in Thailand, while the economic growth, energy consumption, and trade openness positively contribute to the ecological footprint (Table 6).

Table 6 also includes some tests for the reliability of the model. We used the LM, Breusch–Pagan, and Ramsey RESET tests to verify the reliability of our model. The result confirmed that our model is fit and reliable. We also used CUSUM and CUSUM of squares to check the robustness of our model. Figures 1 and 2 depict that our model is robust because the blue line is within the red line boundary.

VECM Granger causality results

The ARDL bounding test model does not inform about the direction relationships (the long run or short run). For this purpose, we applied the VECM Granger causality test which helps in conveying the direction of relationships (causal relation). In order to formulate a comprehensive economic policy, we need to know the direction of any causal relationship.

The VECM Granger causality results for long run and short run (causal relation) among the economic growth (GDP), energy consumption (ENG), tourism (T), trade openness (TRADE), population density (PD), and the ecological footprint (EF) are reported in Table 7.

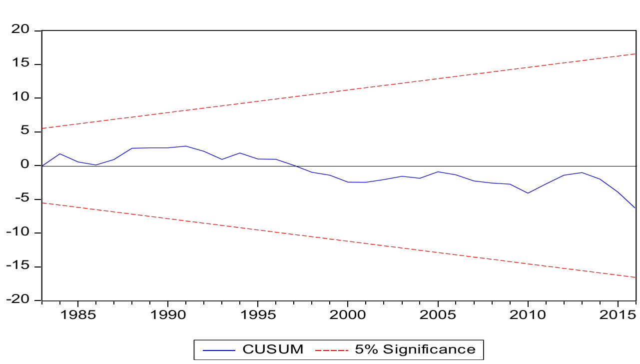

Fig. 1 Plot of CUSUM

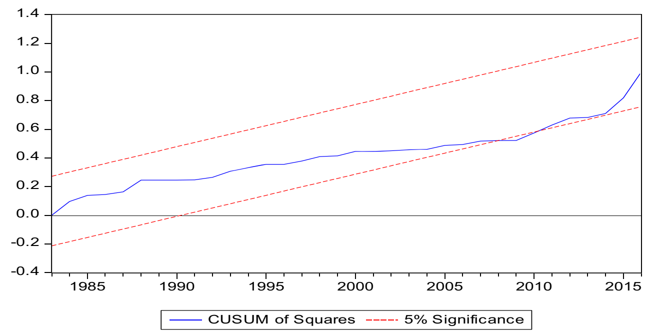

Fig. 2 Plot of CUSUM of squares

The VECM Granger causality results show that the tourism Granger affects population density in the long run, which suggested that the bidirectional causality is found between tourism and the population density in the long run. In the long run, the results also show (i) unidirectional causality running from EF, GDP, ENG, and TRADE to T and (ii) the unidirectional causality running from EF, GDP, ENG, and TRADE to PD in Thailand. However, we found neutral causality between the ecological footprint and economic growth and between energy consumption and the ecological footprint.

Some results of this study are, however, similar to the result of unidirectional causality running from the economic growth to tourism in Korea (Oh 2005), Cyprus (Katircioglu 2009), Europe (Paramati et al. 2017b), and BRICS countries (Danish and Wang 2019b) in the long run.

In the short run, the VECM Granger causality also shows that (i) bidirectional causality exists between TRADE and PD; (ii) the unidirectional causality running from GDP, ENG, and PD to EF; and (iii) the unidirectional causality running from the ENG and TRADE to T; and, lastly, (iv) the unidirectional causality running from the PD to GDP and ENG.

Conclusion

The ecological footprint is one of the recent debates that has posed the researchers and policy makers to be perplexed. The rising environmental degradation, low capacity of natural resources for regeneration, and rising population are prominent issues nowadays. At the same time, every country is endeavoring for higher economic growth. In such a scenario, this study explores the impact of economic growth, energy consumption, tourism, trade openness, and population density on the ecological footprint in Thailand. Among one of the world-leading tourism destinations, Thailand is a worth-studying country. Its tourism sector currently contributes more than 21% of the GDP which stimulates money circulation, job creation, and investment in the country. This study uses Thailand's annual data from 1974 to 2016. The ADF and Zivot–Andrews unit root tests confirmed that data is stationary at first difference level. The ARDL bounding test approach

Table 7 VECM Granger causality

	ΔlnEF	ΔlnGDP	ΔlnENG	ΔlnT	ΔlnTRADE	ΔlnPD	ECT-1
ΔlnEF	====	3.54971** (0.0392)	7.54925*** (0.0018)	1.16624 (0.3230)	1.33435 (0.2760)	2.74293* (0.0778)	− 0.015222 [− 1.019504]
ΔlnGDP	1.32356 (0.2788)	===	0.83211 (0.4433)	2.15099 (0.1311)	0.80559 (0.4547)	3.78283** (0.0323)	0.009311 [1.181314]
ΔlnENG	1.59960 (0.2160)	1.53971 (0.2282)	==	0.55700 (0.5778)	0.48325 (0.6207)	3.69554** (0.0347)	0.008505 [0.679200]
ΔlnT	0.31024 (0.7352)	0.00555 (0.9945)	3.48608** (0.0413)	===	3.26261** (0.0499)	0.46504 (0.6318)	− 0.038535** [− 2.225822]
ΔlnTRADE	2.16247 (0.1298)	1.84555 (0.1726)	0.27789 (0.7590)	0.71822 (0.4945)	==	3.66667** (0.0355)	0.004039 [0.183484]
ΔlnPD	0.50490 (0.6078)	2.10355 (0.1368)	1.09415 (0.3457)	1.90838 (0.1630)	3.27948** (0.0492)	==	− 0.010040*** [− 5.153532]

Significance means *p*-values, If *p*-values less then 0.001 is 2 percent significance level

Brackets reflect *t* values while parenthesis reflects *p* values

Δ shows the first difference operator; ***, **, and * represent 1%, 5%, and 10% significance levels respectively

confirmed the long-run cointegration among variables. Furthermore, the ARDL bounding test model was also used to investigate the long-run and short-run effects. The empirical findings show that economic growth, energy consumption, and trade openness have positive relationships with the ecological footprint, while tourism and population density contribute significantly in reducing the ecological footprint in the long run. Lastly, we used VECM Granger causality to determine the directions of relationships among concern variables. The results of VECM Granger causality also confirmed the bidirectional causality (i) between tourism and population density in the long run and (ii) between trade openness and population density in the short run. Furthermore, the unidirectional causality runs from the ecological footprint, economic growth, energy consumption, and trade openness to tourism and population density in the long run.

The overall results suggest that the policymakers should revise growth and development policy that incorporate with the economic growth, energy consumption, tourism, trade openness, and population density dimensions in order to mitigate the impacts on environmental degradation (the ecological footprint). The findings on this Thailand's ecological footprint model provide several policy recommendations.

Firstly, Thailand should integrate sustainable development (UNSDGs), green economy into their country's economic and development plans (the National Economic and Social Development Plan (NESDP)) to promote economics in response to social development and the environment.

For energy consumption perspective, Thailand should aim to reduce the use of conventional energy and promote the use of renewable energy, and this may typically remain an alternative for Thailand to mitigate the energy consumption impacts on the environment as suggested by many researchers (Ozturk et al. 2016; Bello et al. 2018; Destek et al. 2018; Hajko et al. 2018; Wang and Dong 2019). Although both conventional and renewable energy devastate the effects on the environment (Abbasi and Abbasi 2000; Dincer 2000; Gill 2005; Akella et al. 2009; Saidur et al. 2011; Popp et al. 2014), Thailand should aim to increase renewable energy by increasing energy efficiency and incorporate advanced technology and innovation in the energy supply chain as suggested by Dincer (2000). Conclusively, a sustainability criterion for renewable energy use can also be an option to elaborate green growth and sustainable development (Popp et al. 2014).

Furthermore, Thailand should, therefore, continue to promote sustainable tourism and green practice as there has been a successful implementation to improve the environmental quality (i.e., the ecological footprint) following the World Tourism Organization, ASEAN tourism guidelines, etc. The number of international tourists was forecasted to increase globally and in Thailand. Therefore, Thailand should incorporate sustainable tourism and green practice to all stakeholders including tourism service providers (supply side) and the tourists (demand side). To do this, firstly, the government should initiate an environmental concern campaign through their sub-organizations and partners such as TAT, Thailand hotel organization, tourist guides, and tourist attractions. Second, the government should provide an incentive to increase environmental awareness for all stakeholders. Lastly, in the society to obtain sustainable tourism practices, the government should emphasize on resource and income equality among the tourism stakeholders as suggested by Sinha et al. (2020).

In addition, Thailand's government should promote the green product and green supply chain for the production of goods and services to eliminate the negative impacts of international trade on the environment. Advanced technology and innovation can be implemented in the export-oriented countries (Thailand) to improve the resource efficiency of the production and supply chain.

The last but not the least, Thailand had an overall population density at 135.89 people per square kilometer of land area in 2018 (World Bank 2019) and had a high population density in a few big cities (National Statistical Office of Thailand 2020). To improve the accessibility of services and promote resource use efficiency regarding population density (Chen et al. 2008), Thailand should reconsider the population structure (population dynamic) and urbanization which integrate the increasing stock of natural resources (de Sherbinin et al. 2007), and control the population density. This suggestion will help to balance between population consumption and resource availability.

For further research, future studies can include variables like natural resources and financial development in the ecological footprint model to explore the role of these variables on the ecological footprint. Second, the advanced econometric methods can be introduced to investigate the non-linear relationships or asymmetric relationships using the quartile ARDL or dynamic ARDL methods, etc. Finally, the tourism-induced EKC can extend the study in other nations or regions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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