



Does globalization increase the ecological footprint? Empirical evidence from Malaysia

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Abstract

This study focuses to investigate the relationship between globalization and the ecological footprint for Malaysia from 1971 to 2014. The results of the Bayer and Hanck cointegration test and the ARDL bound test show the existence of cointegration among variables. The findings disclose that globalization is not a significant determinant of the ecological footprint; however, it significantly increases the ecological carbon footprint. Energy consumption and economic growth stimulate the ecological footprint and carbon footprint in Malaysia. Population density reduces the ecological footprint and carbon footprint. Further, financial development mitigates the ecological footprint. The causality results disclose the feedback hypothesis between energy consumption and economic growth in the long run and short run.

Keywords Ecological footprint · Ecological carbon footprint · Globalization · Malaysia · Bayer and Hanck test · ARDL

Introduction

Environmental scientists have reached a consensus that increased level of greenhouse gases in the atmosphere disrupt the environment, resulting in climate change. CO₂ emissions are regarded as the foremost contributor to the greenhouse gases and a major

driver behind global climate change. Indeed, anthropogenic activities severely impact the global environment but CO₂ emissions merely reflect the impact of energy consumption (Al-Mulali and Ozturk 2015) and it cannot be considered a holistic indicator of the anthropogenic pressure on our ecosystem. Alternatively, the ecological footprint of consumption, introduced by Wackernagel and Rees (1996), is a comprehensive tool to analyze the effect of human activities on nature.

The ecological footprint measures the effect of human consumption on nature. It tracks the pressure of human demands in terms of cropland (area needed for food), grazing land (area needed for livestock), forest (for paper and wood production), build-up land (area needed for infrastructure and housing), CO₂ footprint (forest needed for CO₂ absorption), and ocean (required for seafood production). According to Ewing et al. (2010), human consumption has exceeded the production of resources (biocapacity) and we are facing a major challenge of overshoot. This supply–demand crunch can degrade Earth's production capacity, accumulate greenhouse gases and waste, deplete resources, and even destroy our ecosystem. Increasing number of recent environmental studies have employed the ecological footprint to measure the consequences of human demand because of its comprehensive nature and the ability to capture the indirect and direct impact of production and consumption (Charfeddine 2017; Uddin et al. 2017; Hassan et al. 2018; Solarin et al. 2018; Ulucak and Bilgili 2018; Danish et al. 2019).

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This study aims to examine the relationship between globalization and the ecological footprint for Malaysia for the period 1971 to 2014. Globalization is defined as a shift from self-constrained and isolated national economies with trade and investment barriers, regulations, and cultural differences to a more integrated, interdependent global economy (Hill 2007). The unprecedented economic, political, and social integration between nations over the past few decades has both negative and positive effects on the environment. The economic aspects of globalization may influence the environment through trade and foreign direct investment channels. For instance, foreign investors may employ sophisticated technology while starting or expanding their business ventures which will improve the environmental quality by reducing energy consumption. The use of innovative technology reduces resource consumption and decreases the cost of production which eventually forces domestic businesses to adopt cleaner technology. Conversely, if foreign firms rely on conventional or obsolete technology, it further deteriorates environmental quality (Shahbaz et al. 2016a). The influence of globalization on the environment through trade openness is explained in terms of scale, composition, and technique effect. If the scale effect dominates, globalization will boost energy consumption and emission through a surge in economic activities. The composition effect of globalization brings structural changes in the economy. The gradual shift from an agriculture-based economy to an industrial-based economy and finally to a more knowledge-based service economy reduces environmental problems. Lastly, the technique effect of globalization improves environmental quality as trade openness and capital inflows help to import more innovative environmental-friendly technology (Zhang et al. 2017; Shahbaz et al. 2018c; Danish et al. 2018a). Besides, Lemos and Agrawal (2006) argue that globalization stimulates human demand by interconnecting far-flung markets resulting in an upsurge in resource consumption, depletion, and waste generation.

The social aspects of the globalization bridge the gap between people by international mobility, personal contacts, and exposure to the global media. Access to international news, the Internet, and other sources brings environmental awareness. The information about the negative aspects of production and consumption helps people to adopt a sustainable lifestyle (Rudolph and Figge 2017). The global environmental awareness may stimulate pro-environmental practices such as recycling, water saving, energy conservation, and use of renewable energy products. Finally, political globalization increases the participation of countries to global environmental agreements and bindings. Compliance with international standards improves environmental quality as international standards require countries to reduce energy consumption and emissions. However, according to Shahbaz et al. (2016a), the difference in economic interest may cause certain

disagreements and some countries may politicize such issues to avoid global governance.

The literature focusing on the linkage between globalization and the environment reports diverse findings (Dreher et al. 2008; Martens and Raza 2010; Doytch and Uctum 2016; Shahbaz et al. 2016b, 2018a, b; Figge et al. 2017; Kwabena Twerefou et al. 2017; Rudolph and Figge 2017; Xu et al. 2018; You and Lv 2018; Lv and Xu 2018). Moreover, the majority of these studies used panel data, CO₂ emission as an environmental proxy, and results do not follow any pattern. Evidently, theoretical background and previous literature report both positive and negative consequences of globalization on the environment; therefore, the impact of globalization is expected to vary across countries. Under such a situation, it is imperative to focus on country-specific studies to determine a profound relationship.

We selected Malaysia for our study because Malaysia is one of the most globalized countries in Southeast Asia. Its score on KOF index of globalization is 78.14 out of 100 which is higher than some major regional economies, such as China (62.02), Japan (72.26), Korea (67.03), and India (52.38). Malaysia introduced a liberal development plan in 1990 which interconnected it with the world resulting in an opening up of domestic markets, increasing movement of people, boosting foreign investment, and trade inflows (Peow 2011). On the political side of globalization, Malaysia is a party to the Kyoto protocol to UNFCCC, Convention on Biological Diversity (CBD), and other agreements. The average annual GDP growth rate of Malaysia has been more than 6% for the period 1971 to 2015, and trade performance and foreign direct investment were the key contributors to this enormous growth (Bekhet and Othman 2018). However, this increase in economic activities has raised the consumption of resources, for instance, energy, food, infrastructure, and water. Consequently, the ecological footprint of Malaysia has increased by more than 140 percent for the period 1971 to 2014, while for the same period the availability of resources, indicated by the biocapacity, has reduced by more than 50%, resulting in an ecological deficit of 85%. Our study investigates the major factors behind this surge in human demands while focusing on the role of globalization.

We contribute to the existing literature by analyzing the effect of globalization (KOF index) on the ecological footprint for Malaysia over the period 1971 to 2014. To the best of our knowledge, none of the studies have so far investigated the impact of globalization on the environment in Malaysia. In addition to the ecological footprint, we use the ecological carbon footprint as an additional environmental proxy to investigate a more in-depth relationship between globalization and the ecological footprint since carbon footprint is an integral component of the ecological footprint. In disaggregate analysis, we investigate the effect of economic, political, and social globalization on the ecological footprint. Moreover, we

control some other important factors, such as energy consumption, economic growth, population density, and financial development because of their important role in influencing human demands. The Bayer and Hanck cointegration method and the ARDL bound test are employed for cointegration analysis and dummy variables are included to account for the effects of the structural breaks in the data.

The remaining part of this paper is in the following order. Section 2 provides a brief review of the literature. In Section 3, model construction, variables, data sources, and econometric methodology are discussed. Section 4 contains results and discussion. Section 5 provides policies and conclusion.

Literature review

Over the past few decades, globalization has changed the world and the countries are economically, socially, and politically interlinked. These economic, social, and political aspects influence the natural environment but the relationship between globalization and the ecological footprint has not gained much attention in the previous literature.

However, in a recent study, Figge et al. (2017) explore the relationship between globalization (KOF index) and the ecological footprint using panel data of 171 countries. The authors argue that the impact of globalization on the environment varies according to the political, economic, and social dimensions. The results suggest that economic globalization stimulates the ecological footprint of consumption and social globalization reduces the ecological footprint of consumption. Moreover, the overall globalization and political globalization have no significant effect on the ecological footprint of consumption. Similarly, Figge et al. (2017) investigate the effect of globalization on the ecological footprint for a panel of 171 countries by using an alternative proxy (MGI index) for globalization. The findings indicate a positive impact of globalization on the ecological footprint. Further, a disaggregate analysis reveals that all aspects of globalization degrade the environment except the political dimension which mitigates environmental degradation.

Apart from this, some other studies have examined the relationship between globalization and other environmental indicators. For instance, Dreher et al. (2008) analyze the consequences of globalization against different environmental proxies, such as CO₂ emissions, sulfur, round wood production, and water pollution. The results generated by panel regression models reveal that globalization (KOF index) mitigates water pollution and sulfur dioxide; however, it does not influence round wood production and CO₂ emissions. In disaggregate analysis, the findings support a positive impact of social globalization on emission levels, a negative relationship between water pollution and political globalization, and a positive relationship between economic globalization and round

wood production. The overall results are highly ambiguous and inconclusive.

In contrast, Lv and Xu (2018) report a negative relationship between economic globalization and CO₂ emission for a panel of 15 countries by using panel estimation techniques robust against heterogeneity and cross-sectional dependence for the period 1970–2012. Similarly, You and Lv (2018) suggest a negative association between globalization and CO₂ emissions for a panel of 83 countries. Conversely, Kwabena Twerefou et al. (2017) examine the linkage between globalization and CO₂ emissions using GMM methodology for a panel of 36 African countries. The findings of this study disclose that globalization degrades the environment in selected African countries. Likewise, Shahbaz et al. (2018a) investigate the effect of globalization on CO₂ emissions for a panel of 25 developed countries. Interestingly, the findings unveil a positive influence of globalization on emissions in developed economies. Salahuddin et al. (2018) examine the impact of globalization on CO₂ emissions for 44 SSA countries using panel estimation techniques. The findings disclose an insignificant effect of globalization on CO₂ emissions and a positive effect of urbanization on CO₂ emissions. Martens and Raza (2010) use the Maastricht Globalization Index (MGI) to investigate the sustainability of globalization against different sustainability indexes. They report a variation in the relationship of globalization against different sustainability indexes and could not reach a consensus. Doytch and Uctum (2016) measure the globalization in terms of FDI inflow and analyze the effect of sectoral FDI on CO₂ emission by using panel methodology. The authors argue that the negative and positive effects of FDI vary across income level and economic sectors.

Besides, a few studies have used time series data to examine the relationship between globalization and CO₂ emissions. For example, Shahbaz et al. (2015) report a positive effect of globalization on CO₂ emissions in India. In addition, economic growth, financial development, and energy consumption increase CO₂ emissions. Similarly, Shahbaz et al. (2018a) confirm a positive impact of globalization, economic growth, and energy consumption on CO₂ emissions in Japan. However, Shahbaz et al. (2016b) find variations in the effect of globalization for 19 African countries. The findings disclose mixed results pertaining to the impact of globalization on CO₂ emissions and the existence of the EKC. Xu et al. (2018) argue that globalization has no significant influence on CO₂ emission in Saudi Arabia and energy consumption is the main driver of CO₂ emission.

Summing up, scholars have analyzed the effect of globalization on different environmental indicators and the results vary across countries. Globalization has economic, political, and social dimensions with both positive and negative effects. Majority of the previous studies used panel data with inconclusive findings. Moreover, the relationship between

globalization and the ecological footprint has not been focused by researchers and the previous results lack any pattern. Under this situation, the objective of this study is to examine the relationship between globalization and the ecological footprint for Malaysia from 1971 to 2014.

Model construction and econometric methodology

Model construction

The aim of current research is to examine the relationship between globalization and the ecological footprint for the period 1971 to 2014. The ecological footprint of consumption is an environmental indicator which measures the productive land and ocean needed to support human consumption and to assimilate its waste, given prevalent technology and management practices (Rudolph and Figge 2015). We also used the ecological carbon footprint as an additional dependent variable which is more related to air pollution. National footprint accounts measure the ecological carbon footprint in terms of forest land required to absorb CO₂ emissions. The main focus of the study is to analyze the relationship between globalization and the ecological footprint and the use of the ecological carbon footprint is just to better understand this relationship since carbon footprint is an integral part of the ecological footprint.

Globalization has three dimensions, namely, economic, political, and social. The ecological effects of economic globalization are generally explained in terms of foreign direct investment and trade openness. Economic globalization can improve the environment by structural transformation of economy and adoption of efficient cleaner technology especially in high-income countries with strict environmental laws. On the contrary, foreign investment inflows degrade the environment in low- and middle-income countries with relaxed environmental laws causing a race to the bottom which is also known as a pollution heaven hypothesis (Doytch and Uctum 2016; Zhang et al. 2017).

We included some control variables in the model, for instance, economic growth, energy consumption, population density, and financial development, because these variables are significant contributors to the ecological pressure in the previous literature. Economic growth is the basic driver of human demands for natural resources, for instance, food, water, housing, energy, and others. Both energy consumption and economic growth are the major contributors to the ecological footprint (Al-Mulali and Ozturk 2015; Uddin et al. 2017; Solarin et al. 2018).

We also included population density as a control variable which is measured as people per square kilometer of land. Population density has both positive and negative effects on the environment. According to Liu et al. (2017), population density has played a key role in changing the emissions level in China. In the less-developed areas, the rise in population

density increases environmental problems due to the construction and maintenance of public infrastructures, such as electrical installations, roads, sewage system, education, health, and others. However, in a developed region, increase in population density may reduce environmental issues because of innovative technology, economies of scales, and energy efficiency. Sapkota and Bastola (2017) suggest that population density increases pollution level because in densely populated areas pollution-intensive plants are less viable and less likely to be opposed.

Financial development is another important factor which can affect the environment negatively or positively. For instance Baloch et al. (2019b) used financial development as potential indicator and found that financial development contributes to environmental degradation. Financial development may increase environmental problems (Hafeez et al. 2018; Baloch et al. 2019a) by supporting the manufacturing sector. In contrast, financial development may improve the environment by boosting research and development and technological advancement (Shahbaz et al. 2013). Shahbaz et al. (2016a) disclose a short-run causality from globalization to financial development and a feedback effect between globalization and financial development in the long run. Uddin et al. (2017) report that financial development reduces the ecological footprint, whereas Charfeddine (2017) suggests that financial development increases the ecological footprint.

On the basis of the above theoretical discussion, we developed the following model to study the linkage between globalization and the ecological footprint.

$$\begin{aligned} \text{LogFP}_t = & \phi_o + \phi_{EG}\text{LogEG}_t + \phi_E\text{LogE}_t + \phi_{PD}\text{LogPD}_t \\ & + \phi_{GL}\text{LogGL}_t + \phi_{FID}\text{LogFID}_t + \mu_t \end{aligned} \quad (1)$$

where FP is the ecological footprint of consumption (global hectares (gha) per person), EG is the economic growth (per capita constant 2010 US dollars), E is the energy consumption (per capita kg of oil equivalent), PD is the population density (people per square km of land area), GL is the globalization (overall KOF index), FID is the financial development (domestic credit to private sectors percentage of GDP), and μ_t is the residual term. Moreover, all the variables stated in Eq. 1 are in logarithm form. The first model is developed to analyze the relationship between overall globalization and the ecological footprint of consumption. In disaggregate analysis, we examined the effect of economic, social, and political globalization on the ecological footprint separately by using the following three models.

$$\begin{aligned} \text{LogFP}_t = & \sigma_o + \sigma_{EG}\text{LogEG}_t + \sigma_E\text{LogE}_t + \sigma_{PD}\text{LogPD}_t \\ & + \sigma_{GL}\text{LogEGL}_t + \sigma_{FID}\text{LogFID}_t + \mu_t \end{aligned} \quad (2)$$

$$\begin{aligned} \text{LogFP}_t &= \sigma_o + \sigma_{EG}\text{LogEG}_t + \sigma_E\text{LogE}_t + \sigma_{PD}\text{LogPD}_t \\ &+ \sigma_{GL}\text{LogSGL}_t + \sigma_{FID}\text{LogFID}_t + \mu_t \end{aligned} \quad (3)$$

$$\begin{aligned} \text{LogCFP}_t &= \sigma_o + \sigma_{EG}\text{LogEG}_t + \sigma_E\text{LogE}_t + \sigma_{PD}\text{LogPD}_t \\ &+ \sigma_{GL}\text{LogPGL}_t + \sigma_{FID}\text{LogFID}_t + \mu_t \end{aligned} \quad (4)$$

where LogEGL, LogSGL, and LogPGL refer to the economic, social, and political globalization.

Lastly, we constructed model 5 to study the relationship between our independent variables and the ecological carbon footprint.

$$\begin{aligned} \text{LogCFP}_t &= \sigma_o + \sigma_{EG}\text{LogEG}_t + \sigma_E\text{LogE}_t + \sigma_{PD}\text{LogPD}_t \\ &+ \sigma_{GL}\text{LogGL}_t + \sigma_{FID}\text{LogFID}_t + \mu_t \end{aligned} \quad (5)$$

This study covers the data from 1971 to 2014 and the time span depends upon the availability of data for certain variables. The 2017 version of KOF index by Dreher (2006) is used as a measure of globalization which is considered to be the most extensive and reliable measure on globalization. The KOF index was developed at the KOF Swiss Economic Institute. The aggregate KOF index includes all three dimensions of globalization namely economic, social, and political. This data source also provides separate indices for economic, social, and political globalization. The KOF index calculates economic globalization index on the basis of actual flows of trade, foreign direct investment, income paid to foreign nationals, portfolio investments, and restrictions (import barriers, tariff rates, taxes on international trade, etc.). Social globalization index is based on personal contacts, informational flows, and cultural proximity. Political globalization index is based on embassies in countries, international treaties, membership in international institutions, and participation in international missions. The version 2017 of the KOF index provides data over the time span 1970 to 2014¹. The other indices of globalization are generally available for either some specific group of countries or specific time period (Rudolph and Figge 2017).

We collected the data for our dependent variables, the ecological footprint, and the ecological carbon footprint, from the website of global footprint network. GFN has developed the ecological footprint which is a reliable tool to measure environmental pressure exerted by human activities on our ecosystem for consumption as well as waste absorption. It has applied its measurement to over 200 nations and to the entire globe. It provides valuable information to international organization and governments to restrain misuse of our limited natural resources. The calculation of the ecological footprint

involves measuring the effect of human activities on six types of land².

The data for financial development, population density, energy consumption, and economic growth are collected from WDI (World Development Indicators)³. The world development indicators provide globally comparable high-quality statistics. The database of the World Bank contains almost 1600 indicators (time series) for nearly 217 economies and over 40 country groups. Table 1 contains detailed information about variables and their measurement.

Econometric methodology

In this study, we employed two cointegration methods, namely the Bayer–Hanck cointegration approach and the ARDL bound testing approach following Danish et al. (2017) and Danish and Baloch (2018). There are various cointegration approaches available in the previous literature, such as Engle and Granger (1987), Johansen (1988) cointegration test, Banerjee et al. (1998), and Johansen and Juselius (1990). However, these cointegration methods have many limitations. For instance, Engle and Granger cointegration method is based on two steps and an error in one step can carry over to the next step eventually causing biased estimations (Shahbaz et al. 2016a). Johansen and Juselius (1990) cointegration approach is based on the single equation and it requires a uniform order of integration I(1) and large sample size. Moreover, the availability of many cointegration techniques often leave a user indecisive pertaining to the selection of a suitable cointegration approach since the outcomes of cointegration tests can differ.

Bayer and Hanck (2013) proposed a combined cointegration approach which overcomes some weaknesses of cointegration methods by combining four different cointegration tests. This test provides reliable and uniform results as compared to individual cointegration tests. This method computes a Fisher statistics by combining probability values of Boswijk (1994), Johansen (1991), Engle and Granger (1987), and Banerjee et al. (1998) cointegration tests. The decision for the presence of cointegration is made by comparing the calculated Fisher statistics with the critical values provided by Bayer and Hanck (2013). If the critical values are less than the Fisher statistics, it indicates the presence of cointegration (rejection of the null hypothesis).

After employing the Bayer and Hanck test, we applied the ARDL bound testing approach (Pesaran et al. 2001). We preferred the bound testing approach over other cointegration techniques

¹ For more information about computation of index and weight assigned to variables see <https://www.kof.ethz.ch/en/>

² Cropland (area needed for food), grazing land (area needed for livestock), forest (for paper and wood production), build-up land (area needed for infrastructure and housing), CO₂ footprint (forest needed for CO₂ and other waste absorption), and ocean (required for seafood production). For more detail about computation of the ecological footprint, see <https://www.footprintnetwork.org/>.

³ The WDI indicators are available at <http://datatopics.worldbank.org/world-development-indicators/> (Accessed on February, 15 2019).

Table 1 Variables and descriptive statistics

Variables	Definitions and measurement									
Ecological footprint of consumption (LogFP)	The productive (water and land) area required to support human consumption and its waste assimilation. Measured in global hectares (gha) per person.									
Ecological carbon footprint (LogCFP)	Forest land required to absorb CO ₂ emissions measured in global hectares (gha) per person.									
Economic growth (LogEG)	Gross domestic product of a country is divided by the mid-year population. Measured as constant 2010 US dollars.									
Energy consumption (LogE)	Total energy consumption indicates consumption of primary energy before transformation to end-use fuels. It is measured as energy use per capita kilogram of oil equivalent.									
Population density (LogPD)	Mid-year population of a country divided by land area in square kilometers. Measured as people per square kilometer of land area.									
Globalization (LogGL)	Overall KOF Index of Globalization including economic, social, and political globalization.									
Economic globalization (logEGL)	Economic globalization index is calculated on the basis of actual flows of trade, foreign direct investment, portfolio investments, and restrictions, for instance import barriers, tariff rates, taxes on international trade, etc.									
Social globalization (logSGL)	Social globalization index is based on personal contacts, informational flows, and cultural proximity.									
Political globalization (logPGL)	Political globalization index is based on embassies in countries, international treaties, membership in international institutions, and participations in international missions.									
Financial development (LogFID)	Domestic credit to private sector includes financial resources provided by financial corporations to private sector measured as percentage of GDP.									
Descriptive statistics	LogEP	LogCFP	LogEG	LogE	LogPD	LogGL	LogEGL	LogSGL	LogPGL	LogFID
Mean	0.4784	0.0092	3.7040	3.1462	1.7582	1.7741	1.8355	1.7007	1.7662	1.9024
Median	0.5233	0.1399	3.7253	3.1987	1.7678	1.7677	1.8259	1.6642	1.8133	2.0065
Maximum	0.6637	0.4479	4.0169	3.4723	1.9638	1.8982	1.9080	1.8874	1.9226	2.2000
Minimum	0.2546	− 0.7336	3.3136	2.7189	1.5272	1.6041	1.7626	1.4731	1.4749	1.3533
Std. deviation	0.1267	0.3525	0.2068	0.2415	0.1352	0.1033	0.0437	0.1615	0.1380	0.2386

because it offers several advantages. In this study, we have a small sample size of 44 years (1971 to 2014) and the ARDL approach provides robust estimates for small sample size (Pesaran et al. 2001). The ARDL method does not require a uniform order of integration and it can be applied as long as no variable is integrated at 1(2) (Charfeddine et al. 2018). This methodology uses a simple linear transformation to estimate short-run and long-run dynamics simultaneously and the error correction term captures the speed of convergence (Danish et al. 2018b). Moreover, the ARDL bound testing approach is free from autocorrelation and an appropriate lag length selection removes the issue of endogeneity (Ali et al. 2017). Before proceeding to the ARDL, we applied various unit root tests to ensure that no variable is integrated at 1(2). The unrestricted error correction model of the ARDL is given below:

$$\begin{aligned}
 \Delta(\text{LogFP})_t &= \sigma_o + \sigma_{DM}DM + \sum_{k=1}^p \phi_{1k} \Delta(\text{LogFP})_{t-k} \\
 &+ \sum_{k=0}^p \phi_{2k} \Delta(\text{LogEG})_{t-k} + \sum_{k=0}^p \phi_{3k} \Delta(\text{LogE})_{t-k} + \sum_{k=0}^p \phi_{4k} \Delta(\text{LogPD})_{t-k} \\
 &+ \sum_{k=0}^p \phi_{5k} \Delta(\text{LogGL})_{t-k} + \sum_{k=0}^p \phi_{6k} \Delta(\text{LogFID})_{t-k} + \beta_{FP}(\text{LogFP})_{t-1} \quad (6) \\
 &+ \beta_{EG}(\text{LogEG})_{t-1} + \beta_E(\text{LogE})_{t-1} + \beta_{PD}(\text{LogPD})_{t-1} \\
 &+ \beta_{GLB}(\text{LogGL})_{t-1} + \beta_{FID}(\text{LogFID})_{t-1} + \varepsilon_t
 \end{aligned}$$

where the short-run portion of the equation is articulated with (\sum) sign and ϕ_1 to ϕ_5 represent the short-run parameters of the equation. The long-run parameters are expressed by β_{FP} , β_{EG} , β_E , β_{PD} , β_{GLB} , and β_{FID} . DM is the dummy variable used for the structural break in the ecological footprint and ε_t is the error term. The null hypothesis of no cointegration ($H_0 : \beta_{FP} = \beta_{EG} = \beta_E = \beta_{PD} = \beta_{GLB} = \beta_{FID} = 0$) is tested against the alternative of cointegration ($H_1 : \beta_{FP} \neq \beta_{EG} \neq \beta_E \neq \beta_{PD} \neq \beta_{GLB} \neq \beta_{FID} \neq 0$). The existence of the long-run equilibrium relationship is confirmed if the F-statistics generated by the bound test is greater than the upper critical bound (UCB) of Narayan (2005) or Pesaran et al. (2001). Conversely, if the lower critical bounds (LCB) exceed the F-statistics, it implies no cointegration. Lastly, if the F-statistic value lies between the UCB and LCB, the decision is made on the basis of error correction term. In this study, we compared the computed F-statistics with the critical bounds of Narayan (2005) which are generally preferred in the case of small sample. Moreover, the optimum lag length 2 is used under Akaike Information Criteria (AIC). The unrestricted error correction model to analyze the effect of economic, social, and political globalization is given below.

Table 2 Results of the KPSS, ADF, and Dickey–Fuller GLS tests

Variables	KPSS		Augmented Dickey–Fuller (ADF)				Dickey–Fuller GLS	
	At level	Difference	AT level	Difference		AT Level	Difference	
	LM-stat. values		T-statistic	Prob.	T-statistic	Prob.	T-statistic	
LogEF	0.7990***	0.0682	− 2.6463	0.2630	− 7.6995***	0.0000	− 2.6836	− 7.8944***
LogCFP	0.81134***	0.1450	− 1.3689	0.5881	− 6.8018***	0.0000	− 2.0210	− 6.5554***
LogEG	0.8415***	0.2005	− 2.2268	0.4633	− 5.7029***	0.0001	− 1.8735	− 5.7955***
LogE	0.8280***	0.2139	− 1.8389	0.6682	− 7.0333***	0.0000	− 2.0076	− 6.8198***
LogPD	0.8415***	0.5147	− 2.2503	0.4486	− 4.5431***	0.0050	− 1.6151	− 5.2074***
LogGL	0.8197***	0.3051	− 0.4449	0.9825	− 6.7353***	0.000	− 0.9328	− 6.5620***
LogEGL	0.8253***	0.0988	− 2.7262	0.2323	− 6.5200***	0.0000	− 2.1837	− 6.3942***
LogSGL	0.7883***	0.1346	− 1.4290	0.8379	− 6.0166***	0.0001	− 1.5721	− 6.0489***
LogPGL	0.8208***	0.3195	− 2.0049	0.5822	− 6.7320***	0.0000	− 1.6971	− 6.9014***
LogFID	0.9301***	0.3917	− 1.4818	0.8205	− 6.2487***	0.0000	− 1.6550	− 6.3768***

In KPSS test, the alternative hypothesis is non-stationary and the critical values at 10%, 5%, and 1% levels are 0.347, 0.463, and 0.739, respectively For more details about critical values of Kwiatkowski–Phillips–Schmidt–Shin unit root test, see Kwiatkowski et al. (1992)

Critical values of Dickey–Fuller GLS are − 3.770 (1%), − 3.190 (5%), and − 2.890 (10%)

***Significance at 1% level

$$\begin{aligned} \Delta(\text{LogFP})_t &= \phi_o + \phi_{DM}DM + \sum_{k=1}^p \sigma_{1k} \Delta(\text{LogFP})_{t-k} \\ &+ \sum_{k=0}^p \sigma_{2k} \Delta(\text{LogEG})_{t-k} + \sum_{k=0}^p \sigma_{3k} \Delta(\text{LogE})_{t-k} + \sum_{k=0}^p \sigma_{4k} \Delta(\text{LogPD})_{t-k} \\ &+ \sum_{k=0}^p \sigma_{5k} \Delta(\text{LogGL})_{t-k} + \sum_{k=0}^p \sigma_{6k} \Delta(\text{LogFID})_{t-k} + \delta_{FP}(\text{LogFP})_{t-1} \quad (7) \\ &+ \vartheta_{EG}(\text{LogEG})_{t-1} + \vartheta_E(\text{LogE})_{t-1} + \vartheta_{PD}(\text{LogPD})_{t-1} \\ &+ \vartheta_{GL}(\text{LogGL})_{t-1} + \vartheta_{FID}(\text{LogFID})_{t-1} + \varepsilon_t \end{aligned}$$

$$\begin{aligned} \Delta(\text{LogCFP})_t &= \phi_o + \phi_{DM}DM + \sum_{k=1}^p \sigma_{1k} \Delta(\text{LogCFP})_{t-k} \\ &+ \sum_{k=0}^p \sigma_{2k} \Delta(\text{LogEG})_{t-k} + \sum_{k=0}^p \sigma_{3k} \Delta(\text{LogE})_{t-k} + \sum_{k=0}^p \sigma_{4k} \Delta(\text{LogPD})_{t-k} \\ &+ \sum_{k=0}^p \sigma_{5k} \Delta(\text{LogGL})_{t-k} + \sum_{k=0}^p \sigma_{6k} \Delta(\text{LogFID})_{t-k} + \delta_{CFP}(\text{LogCFP})_{t-1} \quad (8) \\ &+ \vartheta_{EG}(\text{LogEG})_{t-1} + \vartheta_E(\text{LogE})_{t-1} + \vartheta_{PD}(\text{LogPD})_{t-1} \\ &+ \vartheta_{GL}(\text{LogGL})_{t-1} + \vartheta_{FID}(\text{LogFID})_{t-1} + \varepsilon_t \end{aligned}$$

where i denotes the economic globalization, social globalization, and political globalization. We analyzed the second model with economic globalization, and third and fourth models with social and political globalization, respectively. The ARDL model with the ecological carbon footprint (LogCFP) as a dependent variable is given below:

After estimating the long-run and short-run dynamics, we conducted some diagnostic tests to check serial correlation, functional form, and heteroscedasticity problem. Further, the cumulative sum (CUSUM) and the CUSUMSQ tests are employed to analyze the stability of the models.

Table 3 Zivot and Andrews unit root tests with structural breaks

Variables	Levels		Difference	
	t -stat	Structural break year	t -stat	Structural break year
LogEF	− 4.1222	1990	− 8.5409***	1988
LogCFP	− 3.0740	1990	− 6.4663***	1988
LogEG	− 3.3159	1991	− 6.2382***	1998
LogE	− 3.3071	2007	− 6.6283***	1991
LogPD	0.7847	1984	− 4.6044*	1982
LogGL	− 1.3632	2007	− 7.6629***	1988
LogEGL	− 3.7571	1997	− 7.2561***	2001
LogSGL	− 2.4659	2007	− 6.5725***	1982
LogPGL	− 3.8808	1988	− 8.0017***	1988
LogFID	− 2.8492	2000	− 6.6295***	1987

***Rejection of null at 1% level of significance

*Rejection of null at 10% level of significance

Table 4 Combined cointegration test of Bayer and Hanck

Estimated models	EG-JOH	EG-JOH-BO-BDM	Decision
(LogFP/LogEG, LogE, LogPD, LogGL, LogFID)	55.7780***	67.4801***	yes
(LogFP/LogEG, LogE, LogPD, LogEGL, LogFID)	12.7237**	26.4781**	Yes
(LogFP/LogEG, LogE, LogPD, LogSGL, LogFID)	12.9341**	23.7894**	Yes
(LogFP/LogEG, LogE, LogPD, LogPGL, LogFID)	17.5560**	22.7205**	Yes
(LogCFP/LogEG, LogE, LogPD, LogGL, LogFID)	23.6498**	55.8859***	yes
Critical regions			
1% level	15.701	29.850	
5% level	10.419	19.888	
10% level	8.276	15.804	

Critical values are taken from Bayer and Hanck (2013)

***Rejection of the null at 1% significance level

**Rejection of the null at 5% significance level

Results and discussion

Table 1 provides some descriptive statistics after transforming the variables into logarithm form over the period 1971 to 2014. The summary statistics include information about mean, median, minimum, maximum, and standard deviation. The ecological footprint per person ranges from 0.52 to 0.66 with an average of 0.47. The globalization ranges from 1.76 to 1.89 with a mean value of 1.77.

Unit root analysis

First of all, we applied unit root tests to check the level of integration. It is imperative to select a suitable econometric

methodology and to avoid spurious regression. We used the Kwiatkowski Phillips Schmidt Shin (KPSS), Dickey–Fuller generalized least squares (DF–GLS), and Augmented Dickey–Fuller (ADF) unit root tests to examine whether our variables are stationary. The ADF and DF–GLS test have the null hypothesis of non-stationary and the alternative hypothesis of stationary. Unlike the ADF and DF–GLS tests, the KPSS test has the null hypothesis of stationary. The results of the ADF, DF–GLS, and KPSS tests are reported in Table 2. The results show that the null hypothesis cannot be rejected at levels for all variables under the DF–GLS and ADF tests. It means that our variables have a unit root at levels. However, the null hypothesis is rejected at levels under the KPSS test. Nevertheless, the KPSS test has the null hypothesis of

Table 5 Results of the ARDL bound test

Models under investigation	Bound test		Diagnostic tests statistics		
	F-stat	Lags	Ramsey RESET test	ARCH test	LM test
(LogFP/LogEG, LogE, LogPd, LogGL, LogFID)	4.6944**	(1,2,0,0,0)	0.3009 [0.7654]	0.1512 [0.6906]	0.4070 [0.5742]
(LogFP/LogEG, LogE, LogPd, LogEGL, LogFID)	4.9056**	(1,2,0,0,0)	0.20812 [0.6514]	0.2537 [0.6067]	0.59983 [0.4460]
(LogFP/LogEG, LogE, LogPd, LogSGL, LogFID)	4.4964**	(1,2,0,0,0)	1.7186 [0.6813]	0.1551 [0.6869]	0.36821 [0.6046]
(LogFP/LogEG, LogE, LogPd, LogPGL, LogFID)	4.5515**	(1,2,0,0,0)	0.0298 [0.8640]	0.1679 [0.6750]	0.5455 [0.4785]
(LogCFP/LogEG, LogE, LogPd, LogGL, LogFID)	3.4867*	(1,0,0,0,0)	1.2542 [0.2734]	1.1437 [0.2799]	0.0785 [0.7810]
Critical regions	LCB 1(0)	UCB 1(1)			
1% significance level	3.657	5.256			
5% significance level	2.734	3.920			
10% significance level	2.306	3.353			

Critical values are obtained from Narayan (2005) case II: restricted intercept and no trend

For diagnostic tests, F-stat values are reported with relevant *p* values in the brackets

Optimum Lags 2 under AIC are used to compute the results of the bound test for model 1 to model 4 (SBC optimum lag length 1 is used for model 5 where CFP is a dependent variable)

**5% level of significance

*10% level of significance

Table 6 Long-run and short-run results

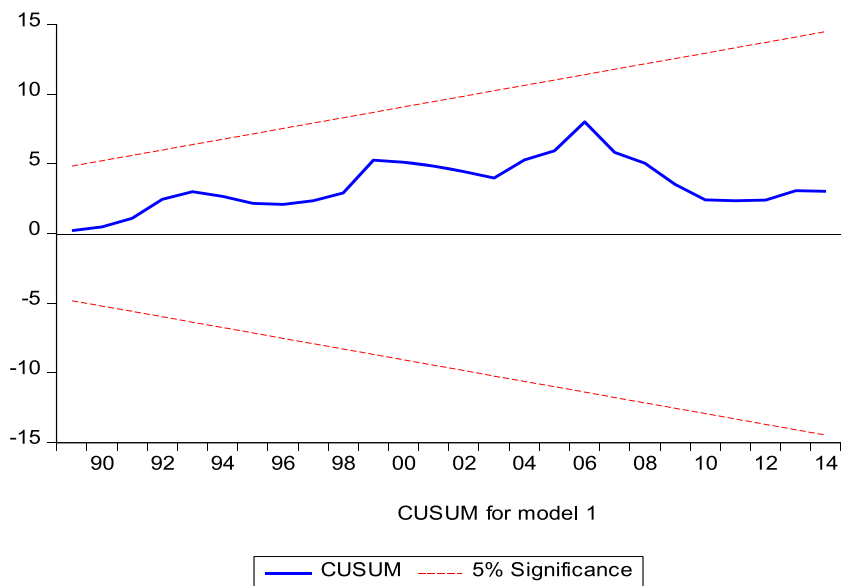
Dependent variables = (1) Ecological footprint of consumption (logFP) for model 1 to model 4
 =(2) Ecological carbon footprint (LogCFP) for model 5

Variables	Long-run results					Short-run results					
	Model 1	Model 2	Model 3	Model 4	Model 5	Variables	Model 1	Model 2	Model 3	Model 4	Model 5
LogEG	1.4870*** [0.0000]	1.4221*** [0.0000]	1.4713*** [0.0000]	1.4823*** [0.0000]	1.9134*** [0.0004]	LogEG	1.6251*** [0.0000]	1.6923*** [0.0000]	1.6543*** [0.0000]	1.6774*** [0.0000]	0.2554 [0.3753]
LogE	0.3451** [0.0204]	0.3484** [0.0168]	0.3384** [0.0225]	0.3563** [0.0187]	1.2691*** [0.0015]	LogE	0.1305 [0.2589]	0.1346 [0.2188]	0.0956 [0.3934]	0.1085 [0.3584]	0.6303* [0.0859]
LogPD	-2.0112*** [0.0000]	-2.0693 [0.0000]	-2.0031*** [0.0000]	-2.0424*** [0.0000]	-2.8381*** [0.0004]	LogPD	-0.0952 [0.6050]	-0.1650 [0.3436]	-0.2072 [0.2967]	0.1085 [0.3584]	-0.9393* [0.0989]
LogGL (overall)	-0.1164 [0.6596]	-	-	-	0.2500** [0.0259]	LogGL	-0.1155 [0.1810]	-	-	-	-0.5722 [0.3428]
LogEGL (economic)	-	0.2381 [0.4919]	-	-	-	LogEGL	-	0.0480 [0.1409]	-	-	-
LogSGL (Social)	-	-	-0.0491 [0.5987]	-	-	LogSGL	-	-	-0.0676 [0.3660]	-	-
LogPGL (Political)	-	-	-	-0.0784 [0.6643]	-	LogPGL	-	-	-	-0.1327 [0.4929]	-
LogFID	-0.1127*** [0.008000]	-0.11161*** [0.0062]	-0.1089** [0.0127]	-0.11167*** [0.0070]	-0.0465 [0.6141]	LogFid	-0.0275 [0.3590]	-0.0317 [0.2855]	-0.0344 [0.2977]	-0.0161 [0.5968]	-0.1277 [0.1668]
DM	-0.0876*** [0.0001]	-0.0861*** [0.0001]	-0.0852*** [0.0001]	-0.0913*** [0.0007]	-0.1030** [0.0156]	DM	-0.0665*** [0.0018]	-0.0686*** [0.0009]	-0.0663*** [0.0021]	-0.0637*** [0.0035]	-0.0974 [0.1158]
C	-2.1175*** [0.0000]	-2.4255*** [0.0000]	-2.1839*** [0.0000]	-2.1396*** [0.0000]	-5.6705*** [0.0000]	cointEq(- 1)	-0.8038*** [0.0000]	-0.9147 [0.0000]	-0.8430*** [0.0000]	-0.8271*** [0.0001]	-0.6478*** [0.0048]
R-Square	0.9836	0.9837	0.9836	0.9835	0.9857						
Adjusted R ²	0.9789	0.9791	0.9790	0.9789	0.9828						
DW Stat	2.0868	2.1628	2.0858	2.1125	2.0443						
F-Statistics	213.307 [0.0000]	215.166 [0.0000]	213.905 [0.0000]	213.227 [0.0000]	345.7533 [0.0000]						

***Significance at 1% level

**Significance at 5% level

Fig. 1. CUSUM for model 1



stationary; therefore, the rejection of the null hypothesis implies non-stationary. The results of all unit root tests reveal that our variables are stationary at first difference. However, these unit root tests do not provide information about any possible structural break in the data series. Shahbaz et al. (2014) argue that the results of traditional unit root tests are not reliable in the presence of structural breaks.

In the next step, we applied Zivot and Andrews structural break unit root test which also provides information about structural breaks in the data. The results are reported in Table 3. All variables are stationary at first difference with one structural break. The ecological footprint of consumption and the ecological carbon footprint are stationary at first difference with a structural break in 1988. This structural break

can be the consequence of the environmental quality order of 1987 which was introduced by the Malaysian government to reduce the environmental problems caused by industrial development projects (Department of Environment 2010; Shahbaz et al. 2013). We included a dummy variable to account for this structural break in the data series. The overall results of the structural break unit root test are similar to the outcomes of conventional unit root tests.

The Bayer and Hanck cointegration method

The variables under investigation are stationary at $I(1)$; therefore, we can proceed to check the cointegration between variables. We applied the Bayer and Hanck cointegration tests

Fig. 2. CUSUMSQ for model 1

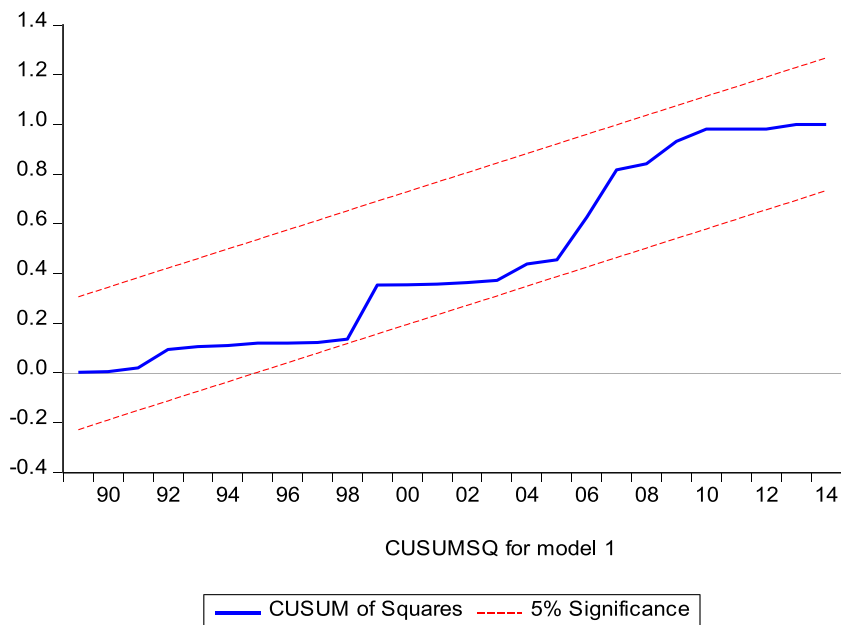
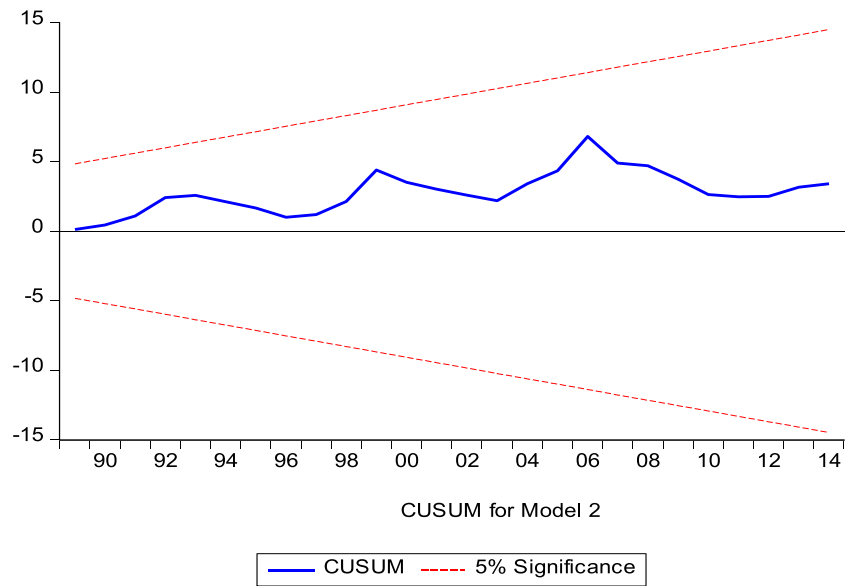


Fig. 3. CUSUM for Model 2



and the results are reported in Table 3. In the first model, both Fisher statistics (EG-JOH and EG-JOH-BO-BDM) are greater than the 1% critical values. It implies that the ecological footprint of consumption (logFP), economic growth (LogEG), energy consumption (LogE), population density (LogPD), globalization (logGL), and financial development (LogFID) are cointegrated at 1% level of significance. We replaced the total globalization with economic globalization, social globalization, and political globalization in the second, third, and fourth models, respectively. The Fisher statistics for the next three model are greater than the 5% critical values. Similarly, model 5 with the ecological carbon footprint as dependent variable shows cointegration between variables. The overall

results of Bayer and Hanck cointegration test reveal cointegration among variables in all five models.

The ARDL bound test

We verified these results by using the ARDL bound test which generates reliable results even for small sample size and fractional integration (mixed integration 1(0) and 1(1)). The results reported in Table 4 suggest that F-statistic is greater than the critical values of Narayan (2005) at 5% significance level for the first four models which indicates the rejection of the null hypothesis. Likewise, the null hypothesis is rejected for model 5 at the 10% significance level. The results of the

Fig. 4. CUSUMSQ for Model 2

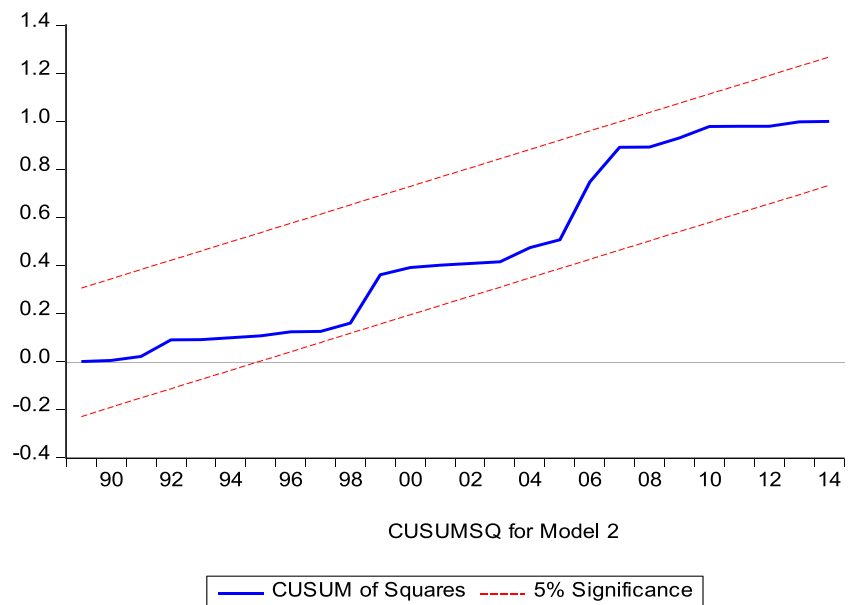
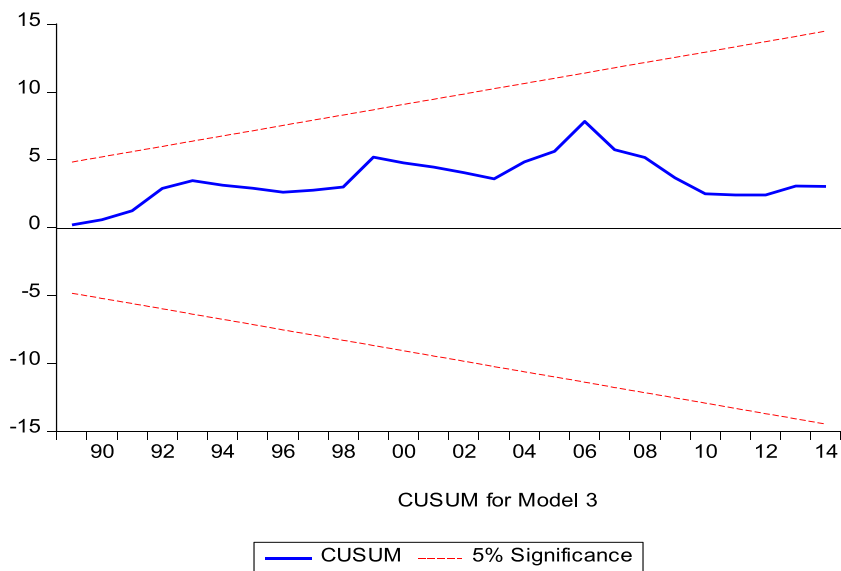


Fig. 5. CUSUM for Model 3



bound test disclose cointegration between variables in all models. These findings are consistent with our previous results of the Bayer and Hanck cointegration approach.

The long-run and short-run results

The results of both cointegration tests are quite similar and our variables are cointegrated; thus, we can proceed to investigate the long-run and short-run impact of each regressor on the ecological footprint. For this purpose, we applied the ARDL approach which uses a single reduced form equation to compute both the long-run and short-run results. The long-run results are presented in the left portion of Table 6.

We used five models to investigate the relationship between globalization and the environment. The first model shows the impact of overall globalization on the ecological footprint. The disaggregate analysis in models 2, 3, and 4

determine the impacts of economic, social, and political globalization on the ecological footprint. Moreover, the last model (model 5) analyzes the effect of globalization on the ecological carbon footprint.

In the first model, the coefficient of total globalization (logGL) is insignificant which indicates that total globalization has no significant impact on the ecological footprint in the long run. Likewise, the coefficients of economic globalization (logEGL), social globalization (LogSGL), and political globalization (LogPGL) are insignificant in the second, third, and fourth models, respectively. These results clearly indicate that total globalization, as well as economic, social, and political dimensions, has no significant impact on the ecological footprint of consumption in the long run. These outcomes suggest that globalization in Malaysia has not reached a level where it could influence the ecological footprint of consumption. The findings of

Fig. 6. CUSUMSQ for model 3

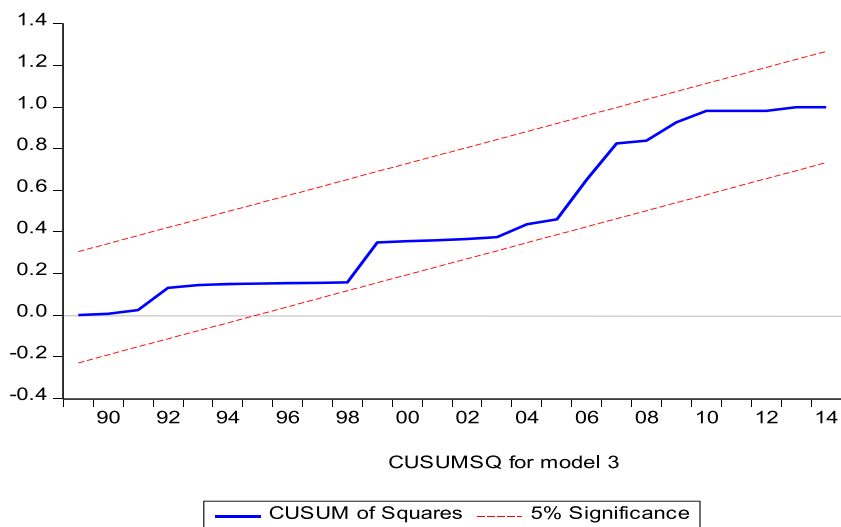
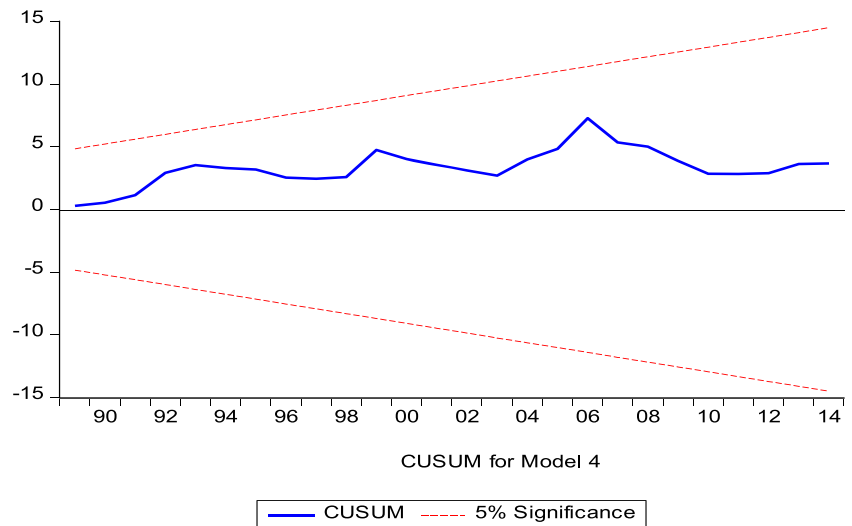


Fig. 7. CUSUM for Model 4



the insignificant relationship between total globalization and the ecological footprint, and political globalization and the ecological footprint of consumption, are consistent with those of Figge et al. (2017). Further, Xu et al. (2018) and Dreher et al. (2008) have also found an insignificant relationship between globalization and CO₂ emissions.

Conversely, the coefficient of globalization is significant at 5% level of significance in model 5 which shows that globalization increases the ecological carbon footprint. A 1% increase in GLB will increase CFP by 0.25%. The reason for this variation in the result is based on the fact that the ecological footprint is a global environmental indicator, while the ecological carbon footprint is a local indicator which mainly relates to the use of energy and consequential air pollution. This result implies that globalization influences the air components of the ecological footprint more than the land and water components. It is

an indication of scale effect and pollution heaven effect (race to the bottom) considering the fact that Malaysia has achieved the average annual GDP growth rate of more than 6% for the period 1971 to 2015 largely due to its trade performance and foreign investment (Bekhet and Othman 2018). These results are supported by Shahbaz et al. (2015) and Shahbaz et al. (2018a) who report that globalization increases CO₂ emissions by stimulating energy consumption.

The coefficient of economic growth (logEG) is significant in all five models in the long-run. A 1% percent increase in EG will increase the FP by 1.48%, 1.42%, 1.47%, and 1.48% in the first, second, third, and fourth models, respectively. Also, the coefficient of EG in model 5 indicates a positive effect of globalization on the carbon footprint. Malaysia has experienced tremendous economic development over the past few decades and an upsurge in the

Fig. 8. CUSUMSQ for model 4

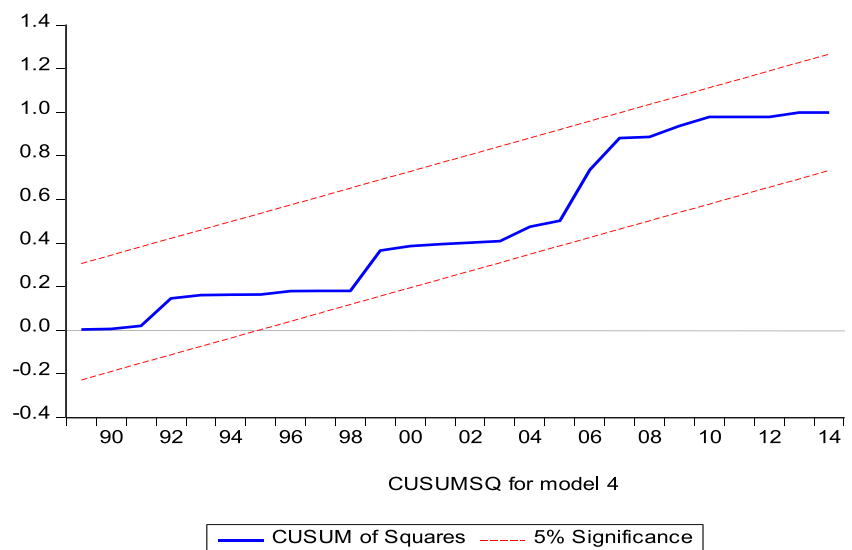


Table 7 VECM results

Results of short-run causality							Long-run causality Coefficients
T-statistics [<i>p</i> values]							[<i>p</i> values]
	LogFP	LogEG	LogE	LogPD	LogGL	LogFID	ECM(− 1)
LogFP	–	7.0634*** [0.0000]	1.3020 [0.1929]	0.1619 [0.8714]	0.5811 [0.5612]	– 1.1350 [0.2563]	– 0.6188*** [0.0003]
LogEG	5.6121*** [0.0000]	–	1.8179* [0.0691]	– 0.6989 [0.4846]	1.3270 [0.1845]	0.8264 [0.4086]	– 0.4781*** [0.0003]
LogE	1.0177 [0.3088]	1.2015*** [0.0096]	–	0.7624 [0.4458]	– 1.3888 [0.1649]	1.6431 [0.1004]	– 0.6835*** [0.0000]
LogPD	0.5364 [0.5917]	– 0.6516 [0.5146]	0.8929 [0.3719]	–	1.6341 [0.1014]	0.6642 [0.5066]	0.0245 [0.4553]
LogGL	– 0.0880 [0.9298]	0.8071 [0.4196]	– 0.6000 [0.5485]	1.3963 [0.1626]	–	0.6168 [0.5373]	– 0.1981 [0.1228]
LogFID	– 1.2085 [0.2268]	– 0.1758 [0.8604]	– 1.6690* [0.0951]	– 5.5956*** [0.0094]	– 2.1561** [0.0311]	–	– 0.3337*** [0.0007]

*Significance at 10% level

**Significance at 5% level

***Significance at 1% level

income level stimulates the ecological footprint by triggering a rise in the use of energy, food, infrastructure, transportation, and other resources. This result is in agreement with Solarin and Al-Mulali (2018) and Uddin et al. (2017) who report a positive association between GDP and the ecological footprint.

Similarly, the coefficient of LogE is significant which discloses dominant evidence of a positive impact of energy consumption on the ecological footprint and carbon footprint. This outcome is in line with Al-Mulali and Ozturk (2015), Solarin and Al-Mulali (2018), Charfeddine and Mrabet (2017), and Charfeddine (2017). This result is explicable because Malaysia has transformed from an agro-based country to an industrial- and service-based economy with a large dependence on energy. The average energy consumption growth rate of Malaysia was between 6 and 7% in industrial, transportation, and residential sectors over the past 4 decades. Furthermore, fossil fuels, such as oil, gas, and coal, dominate the energy mix (Bekhet and Othman 2018). The literature has reached on a consensus that fossil fuels degrade the environment by causing enormous pollution in air and water, biodiversity loss, and waste generation.

The coefficient of population density (logPD) is significant and negative. A 1% increase in PD will reduce the FP and the carbon footprint (CFP) by 2.01% and 2.83% in model 1 and model 5. The impact of population density is also negative in our disaggregate analysis. This negative relationship is supported by Liddle (2014) who report a negative effect of population density on energy and emissions. Likewise, Liu et al. (2017) argue that high population density improves the environment by promoting scaling effect, which causes

technological innovation and resource efficiency in economic activities and public services, such as, sewage disposal, water supply, heating, sanitation, and others. The population density of Malaysia has increased by more than 170% from 1971 to 2014. This enormous surge in population density contributes negatively to the ecological footprint.

Lastly, financial development reduces the ecological footprint of consumption and this negative relationship between financial development and the ecological footprint is consistent in the first four models. The negative relationship between financial development and the ecological footprint is supported by Uddin et al. (2017). Furthermore, Dogan and Seker (2016) and Shahbaz et al. (2013) also report a negative effect of financial development on emissions. This outcome suggests that the financial sector of Malaysia contributes negatively to the ecological footprint by supporting research and development, promoting the adoption of cleaner technology, and providing funds to environmental projects. However, financial development has insignificant effect on the carbon footprint in model 5. The difference in results can be explained on the ground that the ecological footprint of consumption is a more general proxy and it captures all direct and indirect effects of financial development as compared to the carbon footprint. The dummy variable (DM) used for structural break caused by environmental quality order 1987 is significant with a negative sign in all models. The environmental quality order was introduced to reduce environmental issues caused by industrial development projects. Our results indicate a mitigating effect of environmental quality order on the ecological footprint and carbon footprint.

The short-run results are stated in the right portion of Table 6. Globalization has no significant effect on the ecological footprint and the ecological carbon footprint in the short run. Economic growth increases the ecological footprint in the short run and this finding is consistent with our long-run results. Energy consumption increases the carbon footprint in the short run, and it is not surprising since carbon footprint mainly captures the effect of energy consumption. Population density reduces the carbon footprint in the short run as well. Besides, all other variables are insignificant in the short run indicating their insignificant role in influencing the ecological footprint in the short run. The dummy variable (DM) is negative and significant in model 1 to model 4 which suggests a negative impact of environmental quality order 1987 on the ecological footprint. The coefficients of lagged error correction terms are negative and significant which validate the cointegration between variables in all five models. The elasticity of coefficients 0.80, 0.91, 0.84, 0.82, and 0.64 indicates a quick adjustment to the long-run equilibrium in the first, second, third, fourth, and fifth models, respectively.

We performed some diagnostic test to assure that our models do not suffer from serial correlation, heteroskedasticity, and miss-specified functional form issues. The results reported in the right portion of Table 5 and in the bottom of Table 6 reveal that the probability values (in brackets) for the LM test are not below 0.10 in any case. Thus, our models have no serial correlation problem. Similarly, the results of the ARCH test disclose no heteroskedasticity, and the results of Ramsey RESET test indicate that all four models are correctly specified. In addition, the values of DW Statistics reported in Table 6 are around 2 which further assure that the models are free from residual correlation.

In addition to the diagnostic tests, we investigated the stability of our models by performing the cumulative sum of recursive residuals tests. The plots for CUSUM are within the critical bounds. Likewise, the plots for CUSUMsq are within the critical bounds for all models. The CUSUM and CUSUMsq tests (Fig. 1, 2, 3, 4, 5, 6, 7, 8) validate the constancy of the parameters.

Causality analysis

Finally, we employed the vector error correction model to analyze the direction of causality between variables under investigation. We performed the causality test only for model 1 with overall globalization. The following Vector Error Correction Model is used to examine the causal linkage between variables.

$$\begin{aligned}
 (1-L) \begin{bmatrix} \text{LogFP}_t \\ \text{LogEG}_t \\ \text{LogE}_t \\ \text{LogPD}_t \\ \text{LogGL}_t \\ \text{LogFID}_t \end{bmatrix} &= \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \\ \varphi_5 \\ \varphi_6 \end{bmatrix} \\
 + \sum_{i=1}^p (1-L) \begin{bmatrix} \theta_{11i} & \phi_{12i} & \phi_{13i} & \phi_{14i} & \phi_{15i} & \phi_{16i} \\ \phi_{21i} & \phi_{22i} & \phi_{23i} & \phi_{24i} & \phi_{25i} & \phi_{26i} \\ \phi_{31i} & \phi_{32i} & \phi_{33i} & \phi_{34i} & \phi_{35i} & \phi_{36i} \\ \phi_{41i} & \phi_{42i} & \phi_{43i} & \phi_{44i} & \phi_{45i} & \phi_{46i} \\ \phi_{51i} & \phi_{52i} & \phi_{53i} & \phi_{54i} & \phi_{55i} & \phi_{56i} \\ \phi_{61i} & \phi_{62i} & \phi_{63i} & \phi_{64i} & \phi_{65i} & \phi_{66i} \end{bmatrix} \begin{bmatrix} \text{LogFP}_{t-1} \\ \text{LogEG}_{t-1} \\ \text{LogE}_{t-1} \\ \text{LogPD}_{t-1} \\ \text{LogGL}_{t-1} \\ \text{LogFID}_{t-1} \end{bmatrix} \\
 + \begin{bmatrix} \sigma \\ \rho \\ \beta \\ \delta \\ \gamma \\ \lambda \end{bmatrix} \text{ECT}_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \\ \varepsilon_{6t} \end{bmatrix}
 \end{aligned} \tag{9}$$

where ε_{1t} to ε_{6t} are error terms, $(1-L)$ denotes difference operator, and ECT_{t-1} refers to the lagged error correction term. The significance of the ECT indicates the long-run casualty and the value of its coefficients shows the speed of adjustment.

The causality results are reported in Table 7. The lagged error correction term is significant and negative for Eq. 1 (ecological footprint), Eq. 2 (economic growth), Eq. 3 (energy consumption), and Eq. 6 (financial development). These negatively significant coefficients of ECT suggest long-run bidirectional causality between these variables (logFP, LogEG, LogE, and LogFID), and unidirectional causality from population density and globalization to these variable.

In the long run, the feedback effect is found between economic growth and the ecological footprint. This result is consistent with Charfeddine and Mrabet (2017) for MENA countries and Charfeddine (2017) for Qatar. The feedback effect is an indication of interdependence between the ecological footprint and economic growth; therefore, the policies to mitigate the ecological footprint should be formulated keeping in view a possible adverse effect on economic growth. Likewise, the feedback effect is found between economic growth and energy consumption. Charfeddine et al. (2018) argue that the causality between economic growth and energy consumption significantly influence the effect of policies. This bidirectional causality indicates that energy consumption boost economic growth and high economic growth, in turn, upsurges energy use. The policymakers should consider this bidirectional relationship in formulating environmental policies. This finding is supported by Shahbaz et al. (2013) and Saboori and Sulaiman (2013) for Malaysia; however, it is against Ali et al. (2017) who report a unidirectional causality from economic growth to energy consumption for Malaysia. Bidirectional causality is found between energy consumption and the ecological footprint and between financial development and the ecological footprint. Bidirectional

causality is also found between energy consumption and financial development which is in consonance with Shahbaz et al. (2013). Further, population density and globalization Granger cause the ecological footprint, economic growth, and energy consumption without any feedback.

The short-run results provide evidence of bidirectional causality between economic growth and the ecological footprint and between energy consumption and the ecological footprint. Similar short-run results have been reported by Charfeddine and Mrabet (2017) for MENA countries. The bidirectional causality between economic growth and energy consumption validates the existence of a feedback hypothesis for Malaysia in the short run as well. Moreover, energy consumption, globalization, and population density Granger cause financial development.

Conclusion and policies

Conclusion

Numerous scholars have examined the drivers behind environmental degradation for Malaysia but the relationship between globalization and environment is not studied yet. The previous literature pertaining to the relationship between globalization and the environment focuses on panel data and the results are controversial. To address this issue, we examined the relationship between globalization and the environment for Malaysia using the ecological footprint of consumption and the ecological carbon footprint as dependent variables. We analyzed the time series data from 1971 to 2014 by employing cointegration and causality approach. Our results of the Bayer and Hanck and the ARDL bound test show cointegration between variables in all five models. The findings of the study highlight that globalization has no significant effect on the ecological footprint; however, it increases the ecological carbon footprint. Energy consumption and economic growth are the major drivers of the ecological footprint and carbon footprint. Population density reduces the ecological footprint and carbon footprint. In addition, financial development mitigates the ecological footprint. Our causality estimates disclose the feedback hypothesis between energy consumption and economic growth in the long run and short run which is an indication that energy consumption stimulates economic growth and growth level also influences energy use. Further, the feedback effect has also been found between economic growth and the ecological footprint, between energy consumption and the ecological footprint, and between financial development and the ecological footprint.

Policy recommendations

Globalization is not a significant determinant of the ecological footprint under the current economic situation but it

stimulates the ecological carbon footprint. Under this situation, the policymakers should formulate policies to analyze environmental viability of foreign investment and actions should be taken against the businesses that use outdated dirty technology. Moreover, foreign investors should be encouraged to use cleaner technology and invest in cleaner energy projects by offering special incentives. The social interaction with other nations should be enhanced and national media should be used to promote environmental awareness.

The causality between economic growth and energy consumption is bidirectional which indicates that energy conservation is not viable for Malaysia. The use of renewable energy can be increased to replace excessive reliance on fossil fuels. Renewable energy provides a vital opportunity to reduce dependence on energy imports and improves environmental footprints (Kahia et al. 2017). The financial development decreases the ecological footprint (FP) which has important policy implications. The financial sector can play a vital role by providing funds for the use of green technology to new ventures and also to the existing businesses for the replacement of outdated technology. Environment policies should also focus on increasing public awareness to use renewable energy products and adopt a less-resource-intensive lifestyle since the overextraction of resources increases the ecological footprint. Moreover, population density should be increased to reduce urban sprawls and achieve the benefits of scaling effect. Future studies should analyze the relationship between population density and the environment by using some regional data since the management of population density may provide a good option to reduce the ecological footprint in Malaysia.

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