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RESEARCH ARTICLE

Does globalization matter for ecological footprint in Turkey? Evidence from dual adjustment approach

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Abstract
The main aim of this paper is to explore the role of globalization on ecological footprint in Turkey while controlling energy consumption, economic growth, and trade openness. To achieve this objective, we employ dual adjustment approach. The main novelty of the dual adjustment approach is that the method offers another path to the cointegration analysis by relaxing the implicit assumption of the singular adjustment in cointegration analysis. The findings clearly reveal that (i) in the long run, globalization impacts ecological footprint positively and (ii) trade openness reduces ecological footprint in the short run, while ecological footprint is negatively affected by GDP growth in both the short and the long run. In terms of policy implications, this study suggests that in order to improve the environmental quality, Turkey should adopt such policies that encourage energy consumers to shift toward renewable energy. Moreover, the government should take necessary steps to diversify the overall energy mix toward renewable energy.

Keywords Ecological footprint · Globalization · Economic growth · Energy consumption · Trade openness · Turkey

Introduction

The most significant ecological issue humankind has encountered to date is global warming. This development would have catastrophic effects on the environment, economies, and human life in the absence of effective regulation. Anthropogenic behavior and activity are the effect of climate change, and global warming is primarily induced by CO_2 emissions (Ahmed et al. 2019). Increased global understanding of environmental concerns has contributed to foreign initiatives including the Kyoto Protocol and the Paris Agreement being coordinated by the intergovernmental bodies. The principal priorities can be described as lowering global emissions levels and providing economies with sustainable economic growth (Kirikkaleli 2020). In addition, environmental economic experts in advanced and emerging nations such as Adebayo (2020), Wang et al. (2019), Shahbaz et al. (2019), Awosusi et al. (2020), Saidi and Hammami (2015), Adebayo and Akinsola (2021), Alola and Kirikkaleli (2019), Adedoyin et al. (2020), Muhammad (2019), and Odugbesan and Adebayo (2020) have long been investigating economic factors that affect environmental pollution. In the literature, other factors influence environmental degradation such as trade openness, FDI inflows, energy usage, financial development, economic growth, and other factors including political and institutional variables. Over the years, several research have

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been conducted to investigate the interconnection between globalization indices and environmental degradation (ecological footprint) (Figge et al. 2017; Godil et al. 2020; Yilanci and Gorus 2020; Ahmed et al. 2019; Leal et al. 2020). Economic globalization is described as the process of the global collaboration between nations according to Kohler (2004). This partnership typically includes commerce, cross-border collaboration, and financial operations. Admittedly, globalization, including social, political, and economic globalization, may take a number of forms. Nevertheless, only economic globalization and its two key elements, trade and financial globalization, is included in this study. The effect globalization has on the level of emissions may be either negative or positive in economics literature. On the one hand, as economic globalization rises with growing globalization of trade, trade barriers reduce and trading practices expand in the economy. Economic activity and level of output may also lead to improvement in an economy (Leal et al. 2020). The amount of emission then increases as oil is utilized as input for manufacturing process. Some of this effect of globalization in trade is termed a "scale-effect." On the other hand, further free trading creates a shift in the nature of the market. There may be a switch in the economy from preindustrial and industrial economies to environmentally sustainable service-based economies. Therefore, in the economy, there is a systemic shift due to globalization of trade, which may reduce environmental degradation (Ahmed et al. 2019). On the other hand, as the growth in the globalization of the market expands, the financial cap declines, with capital transactions and interaction between nations progressing. There are two potential consequences of rising financial globalization on the quality of the environment in the host nation. Firstly, the environmental quality may worsen if multinational corporations invest in dirty industries in the host nation which have ecological regulations that are lower than in the home nation. Therefore, this kind of expenditure creates a more toxic environment in the receiver nation (Cole 2004). Secondly, the quality of environment in the host nation can improve with the transfer of technology from international firms if multinational corporations have environmentally friendly operations (Zarsky 1999). In addition, the connection between globalization and ecological footprint may be reversed. It is suggested that an ecological footprint shift may contribute to further world trading or financial conditions. A change in demand may render policymakers able to participate in foreign investment and trade negotiations to address the needs of people (Rudolph and Figge 2017). We chose Turkey for our analysis, as Turkey is Europe's third highest CO_2 emission nation. Additionally, the export and import share of goods and services of GDP are 24.61% and 32.43%, respectively, whereas current account deficits are about 3.7% of the GDP in the same year (World Bank 2020). Over the years, external energy dependency has been the primary cause of current account issues in Turkey. As an emerging economy, Turkey has intensified energy demands in every sector (Kalmaz and Kirikkaleli 2019). Turkey is characterized by rising energy demand and an increase in CO_2 pollution that is heavily reliant on importation of energy supplies, which represents a significant cause of current account deficits for several years. Energy usage produces GHG, primarily CO_2 pollution with over 80% of Turkey's overall GHG Ersoy and Ugurlu (2020). Turkey must therefore transform national environmental policies, in specific policies on lowering CO_2 emissions, stressing the significance of this research. Examining the linkage between globalization and ecological footprint of Turkey utilizing annual data between 1985 and 2017, we add to established literature. None of the prior research has so far investigated the impacts of globalization on the ecological footprint utilizing the dual adjustment approach. The fundamental innovation of the dual adjustment approach is that the approach offers an alternative to the cointegration analysis, which relaxes the implicit presumption of the singular adjustment in the cointegration analysis. The globalization index utilized also encompasses various facets of globalization, economic, social, and political. Moreover, in order to catch integration order and structural break simultaneously, we utilized the Zivot and Andrew unit root test suggested by Zivot and Andrews (1992). The rest of the study is structured as follows: (i) "Literature review" discusses summary of related studies; (ii) "Model specification, data, and methodology" addresses data description, model formulation, and econometric approach; (iii) "Discussion" discusses empirical findings; (iv) "Conclusion and policy implications" entails conclusion and policy path.

Literature review

Globalization has transformed the globe over the last few decades, and nations are connected socially, politically, and economically. These social, political, and economic factors affect the environment, although in the prior study, there is little focus on the connection between globalization and ecological footprint. Dreher et al. (2008) is one of the early studies, which explores the effect of globalization on environmental indices. Using 100 nations and yearly data between 1970 and 2000, the investigators explored the interconnection between globalization and environmental degradation. On one side, the empirical findings demonstrate that globalization deteriorates water pollution and air pollution. On the other side, the increase in economic globalization, whereas increasing production of round wood results in a reduction of the level of sulfur dioxide (SO_2) and biochemical oxygen consumption. Therefore, the forests in the nations studied have been ravaged by economic globalization. Various variables for the environmental condition including CO_2, SO_2, spores, and deforestation are utilized as the proxy in the empirical literature. Nevertheless, ecological footprint and its elements have been widely used as an environmental deterioration measure in recent years. Thus, we review the literature in this analysis on the linkage between globalization and ecological footprint. Using 171 nations, Figge et al. (2017) explored the link between globalization and ecological footprint. The authors used multivariate regression, and findings reveal that economic globalization induces increased use and imports with ecological footprint. Rudolph and Figge (2017) utilize data between 1981 and 2009 to examine the interconnection between globalization and ecological footprint in 146 nations. The empirical findings reveal that the ecological footprint of a more global economy with respect to imports, consumption, exports, and output is higher. Moreover, the causality test reveals that the economic globalization Granger causes ecology footprint, while no evidence of causality was found from ecology footprint to globalization. Also using data between 1990 and 2016, Kassouri and Altıntaş (2020) reveal that there is a positive link between ecological footprint and globalization in oil-exporting economies. Nevertheless, in a non-oil-exporting MENA nation, there is no evidence of interconnection between these variables. In addition, Saud et al. (2020) investigate the impact of globalization on ecological footprint, carbon footprint, and CO_2 emissions in 49 countries over the period between 1990 and 2014. The findings reveal that the upsurge in the globalization level enhances environmental quality. Also, there is evidence of feedback causality between environmental pollution indicators and globalization. The study of Kassouri and Altıntaş (2020) reveal that globalization deteriorated the environment in oil-exporting nations between 1990 and 2016. Nevertheless, no evidence of significant link was found between globalization and ecological footprint in non-oil-exporting nations in the MENA economies. In addition, using 49 economies between 1990 and 2014, Saud et al. (2020) investigated the effect of globalization on carbon footprint, CO_2 emissions, and ecological footprint. The findings reveal that increasing the degree of globalization tends to boost the efficiency of the environment in the studied countries. Also, the result supports a feedback causality between globalization and environmental emissions indices. In Turkey, Apaydın (2020) explores the interconnection between globalization and ecological footprint between 1980 and 2014. Empirical findings suggest that these factors are shifting together over the long term. Furthermore, the rise in the globalization index causes an increase in ecological footprint consumption. This implies that an increase in globalization leads to a decrease in the quality of the environment. Defiantly, Bilgili et al.'s (2020) results suggest that growing economic globalization improves quality of the environment. In Malaysia, Ahmed et al. (2019) explored the interconnection between globalization and ecological footprint utilizing yearly data spanning between 1971 and 2014. In order to establish this relationship, the investigators employed ARDL bounds test and the Hanck cointegration test as a robustness check. The empirical findings reveal that globalization triggers ecological carbon footprint. Furthermore, GDP growth and energy have a positive impact on carbon footprint and ecological footprint. However, globalization and the ecological footprint do not have a significant relationship. Using data stretching from 1995 to 2017, Leal et al. (2020) investigated the nexus between globalization and environmental performance in emerging and advanced economies. The investigators aim to investigate the EKC hypothesis in both economies. The findings revealed an inverted U-shaped curve, which indicates that globalization enhances environmental quality in advanced economies. Contrarily, in emerging economies, there is evidence of a U-shaped curve, which indicates that globalization is deteriorating the environment. Employing yearly data between 1981 and 2016, Yilanci and Gorus (2020) examined the predictive power of globalization on ecological footprint using the MENA nations[1] as a case study. The study employed the panel causality test, and findings revealed that ecological footprint Granger causes financial, economic, and trade globalization. In addition, the predictive capacity of financial globalization in MENA nations is observed to forecast more values of environmental deterioration. Ahmad et al. (2020) explored the impact of economic growth, natural resources, and technological innovations on ecological footprint in emerging economies using dataset from 1984 to 2016. The results show that natural resources and economic growth exert positive impact on ecological footprint, whereas technological innovations enhance environmental quality. In addition, the study also confirms the EKC hypothesis. Jianqiang et al. (2020) used a group of seven (G7) to examine the linkage among natural resources, financial development, energy prices, and research and development. The investigators used recent panel econometric techniques to capture these interactions. The empirical outcomes reveal that natural resources enhance financial development, while energy price deteriorates financial development. In addition, research and development exerts a positive impact on financial development. Hao et al. (2020) explored the linkage between green growth and environmental sustainability in G7 using CS-ARDL. The outcomes show that linear and non-linear green growths enhance environmental quality. Using 30 Chinese provinces, Shen et al. (2020) explores the impact of financial development, natural resource rent, and energy consumption on environmental sustainability. In order to establish this linkage, the investigators used CS-ARDL estimator. The empirical outcomes show that green investments enhance the quality of the environment, while natural resource rent harms the environmental quality. Umar et al. (2020) investigated the interaction among financial development, economic growth,

[1] Middle East and North Africa countries

innovation, transportation, and environmental sustainability in China using dataset between 1971 and 2018. The investigators utilized wavelet coherence, and findings show that innovation can predict a significant variation of environmental sustainability. Usman et al. (2020) explored the impact of globalization on ecological footprint in the USA using quarterly data between 1985 Q1 and 2014 Q4. The investigators also incorporate renewable energy and financial development as determinants of ecological footprint. The study employed the MAKI cointegration and ARDL techniques to explore this linkage. The empirical findings revealed that globalization and financial development exert ecological footprint positively, while GDP growth and renewable energy affect ecological footprint negatively in the long run.

Model specification, data, and methodology

Theoretical framework and model specification

This paper explores the role of globalization (GI) on ecological footprint (EF) while controlling income (GDP), energy usage (EC), and trade openness (TO) in the case of Turkey. Following Khan et al. (2020), the model specification for this study given as

$$\mathrm{LEF}_t = \beta_1 \mathrm{LGI}_t + \beta_2 \mathrm{LEC}_t + \beta_3 \mathrm{LGDP}_t + \beta_4 \mathrm{LTO}_t + \varepsilon_t \quad (1)$$

Here, $\mathrm{LEF}_{i,\ t}$ is for ecological footprint, which is measured by CO_2 emissions; $\mathrm{LGI}_{i,\ t}$ is the natural log of globalization; $\mathrm{LEC}_{i,\ t}$ is the natural log of energy usage; $\mathrm{LGDP}_{i,\ t}$ is the natural log of GDP; $\mathrm{LTO}_{i,\ t}$ is the natural log of trade openness, and $\varepsilon_{i,\ t}$ is for the error term. Control variables include LEC, LGDP, and LTO. Furthermore, the natural logarithms of all the variables used are taken to reduce skewness. Following Liddle (2018), Destek and Sarkodie (2019), and Khan et al. (2020), we include GI in the empirical model of EF. Globalization, by increasing the flow of goods and services, has increased the competition and hence poses a severe threat to the environment. Hence, we expect a positive impact of GI on EF, i.e., $\left(\beta_1 = \frac{\partial \mathrm{LEF}}{\partial \mathrm{LGI}} > 0\right)$. Following Lee and Min (2015) and Khan et al. (2020), we include energy consumption in the empirical model of ecological footprint. An increase in energy consumption presents a serious threat to the environment due to the increased demand for fossil fuels. Hence, we expect a positive impact of energy consumption on EF, i.e., $\left(\beta_2 = \frac{\partial \mathrm{LEF}}{\partial \mathrm{LEC}} > 0\right)$. Following Apergis and Ozturk (2015), Zhang and Da (2015), and Hasanov et al. (2018), we include GDP in the empirical model of ecological footprint. It is widely recognized that GDP is positively related with EF, meaning that environmental sustainability may be negatively affected by economic activities. An increase in economic activities leads to an increased demand for fossil fuels, which deteriorates the environmental sustainability. Hence, we expect a positive impact of economic activities (GDP) on EF, i.e., $\left(\beta_3 = \frac{\partial \mathrm{LEF}}{\partial \mathrm{LGDP}} > 0\right)$. Following Wang et al. (2020) and Khan et al. (2020), we include trade openness in the empirical model of ecological footprint. We expect a positive impact of trade openness on EF, i.e., $\left(\beta_4 = \frac{\partial \mathrm{LEF}}{\partial \mathrm{LTO}} > 0\right)$. The units and variables source are depicted in Table 1 below:

Analytical techniques

Unit root tests

The main aim of this study is to check the long-run relationship among variables presented in model 1. However, before

Table 1 Variable units and sources

Variable	Description	Units	Sources
$\mathrm{EF}_{i,\ t}$	Ecological footprint (CO_2 Emissions)	Metric tons of CO_2	Global Carbon Atlas (GSA 2019); http://www.globalcarbonatlas.org/en/CO2-emissions
$\mathrm{GI}_{i,\ t}$	Economic globalization index	Index based on FDI, trade, and portfolio investment	Gygli et al. (2019): revised KOF globalization index (https://doi.org/10.1007/s11558-019-09344-2_
$\mathrm{GDP}_{i,\ t}$	Gross domestic product	Constant US dollars, 2010	Word Development Indicators (WDI 2019); https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
$\mathrm{TO}_{i,\ t}$	Trade openness	Percentage of GDP	Word Development Indicators (WDI 2019); https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions
$\mathrm{EC}_{i,\ t}$	Energy consumption	Percentage of total final energy consumption	WDI 2019; https://databank.worldbank.org/source/world-development-indicators#advancedDownloadOptions

employing cointegration techniques, it is imperative to identify the stationarity of the variables. This study uses the DF-GLS unit root test in order to check the stationarity of series. However, the reliability of the conventual technique such as DF-GLS reduces with structural breaks. Hence, this study utilizes Zivot and Andrews (1992) (ZA) structural breaks unit root test. In the ZA unit root test, the time of structural break is ascertained endogenously. The ZA test allows one structural break for each series. The ZA model endogenizes one structural break in a series (x_t) as follows:

$$H0: x_t = \mu + x_{t-1} + e_t$$
$$x_t = \widehat{\mu} + \widehat{\theta}\, DU_t\left(\widehat{T}_b\right) + \widehat{\beta}\, t + \widehat{\gamma}\, DT_t\left(\widehat{T}_b\right) + \widehat{\alpha} x_{t-1} + \sum_{j=1}^{k} \widehat{c}_j \Delta x_{t-j} + \widehat{e}_t \quad (2)$$

This test equation harbors the likelihood of a shift in the intercept as well as a trend break.

Dual adjustment approach

The present study employs the dual adjustment approach which is proposed by Ismihan (2019). The benchmark case for the dual adjustment approach is the standard Engle-Granger (EG) cointegration method. Hence, this study uses both dual adjustment approach and EG cointegration approach. The main novelty of the dual adjustment approach is that the method gives an alternative to the cointegration analysis relaxing the implicit assumption of the singular adjustment in cointegration analysis. As advised by White and Granger (2011) and Ismihan (2019), we follow the indirect method and use the Hodrick-Prescott (HP) filter to measure the trend and permanent component of the variables. Scilicet, HP is the favored method of decomposition in the current analysis for numerous motives mentioned previously, but this does not certainly mean that it is superior to others. Thus, the dual adjustment approach permits the present study to use other popular filters which are Baxter-King filter (BK) (suggested by Baxter and King (1999)), Ravn and Uhlig 2002 (RU), and Christiano and Fitzgerald (CF) filters (suggested by Christiano and ve Fitzgerald 2003).

Following Ismihan (2019), by employing the stepwise methodology of the dual adjustment approach, the first phase in the dual adjustment approach is to decompose the variable in two distinct components. The HP approach is the superior method for the decomposition. However, by utilizing the HP method, the choice of the smoothing parameter is the most important step. The λ value for the frequency of data is 100 in the case of the HP approach. However, RU proposes the value of 6.25 in the case of annual data. Hence, this study uses two different values of λ, i.e., 100 and 6.25. The study also uses BK and CF for the choice of the smoothing parameter. Moreover, the study uses the critical values of EG approach in the case of Co-HP trend analysis. The Co-HP trend analysis has two steps. The following equation is estimated via OLS method in first step:

$$\mathrm{LEF}_t = \beta_0 + \beta_1 \mathrm{LGI}_t^l + \beta_2 \mathrm{LEC}_t^l + \beta_1 \mathrm{LGDP}_t^l + \beta_1 \mathrm{LTO}_t^l + \varepsilon_t \quad (3)$$

where LGI_t^l, LEC_t^l, LGDP_t^l, *and* LTO_t^l are the HP trend of variables GI, LEC, LGDP, and LTO, and u is the error term. The following equation is estimated in the second step:

$$\Delta\mu + \gamma\mu_{t-1} + e_t \quad (4)$$

where $\gamma = p-1$. The null hypothesis of no common HP trend is rejected if $\gamma = 0$, which implies that the residuals are non-stationary. In order to analyze the short-run relationship, the following equation is estimated by employing OLS method:

$$\mathrm{LEF}_t^s = \beta_0 + \beta_1 \mathrm{LGI}_t^s + \beta_2 \mathrm{LEC}_t^s + \beta_1 \mathrm{LGDP}_t^s + \beta_1 \mathrm{LTO}_t^s + \varepsilon_t \quad (5)$$

where, LEF_t^s, LGI_t^s, LEC_t^s, LGDP_t^s, *and* LTO_t^s are HP filtered gap components. After confirmation of cointegration and common HP trend, FMOLS and DOLS methods are utilized in order to estimate the long-run coefficients of variables presented in model 1.

Discussion

The brief description of the variables utilized is presented in Table 2. The insignificant values of Jarque-Bera suggest that the data is normally distributed. Except for variable trade openness (TO), the standard deviations of all other variables are low. The values of Kurtosis show that the distributions are too peaked for all variables. Moreover, the values of skewness confirm a substantially skewed distribution for all variables except GDP.

Table 2 Descriptive Statistics

	LEF	LEC	LGDP	LGI	TO
Mean	8.145	2.996	11.600	3.808	35.056
Median	8.144	2.990	11.598	3.910	36.207
Max	8.426	3.231	12.050	4.267	54.970
Min	7.807	2.718	11.168	3.110	9.100
SD	0.182	0.138	0.250	0.360	14.036
Skewness	− 0.142	− 0.076	0.076	− 0.468	− 0.433
Kurtosis	1.852	1.999	1.931	1.814	1.820
JB	2.739	2.006	2.281	4.471	4.200
Prob	0.254	0.367	0.320	0.107	0.122

Table 3 ADF-GLS test

	LEF	LEC	LGLOB	LGDP	TO
t-statistic	− 4.889**	− 2.878	− 0.739	− 2.656	− 2.521
	Δ LEF	Δ LEng	Δ LGlob	Δ LGdp	Δ TO
t-statistic	− 9.993**	− 6441**	− 6.389**	− 6.508**	− 6.185**

Δ stands for the first difference. ** and * illustrate statistical significance at 0.05 and 0.10 levels, respectively

This study employs ADF-GLS unit root test in order to check the stationarity property of each variable (Table 3). The outcomes provide mixed integration orders, i.e., *I*(1) and *I*(0). The variables LEF are stationary at level, while the remaining variables are stationary at first difference. Since we have checked for stationarity properties of each variable, in the next step, we checked for the long-run cointegration of all models. Similarly, the results of ZA unit root test show that except LEF, all variables are integrated of order 1. Hence, both tests confirm that the variables are mix order of integration (Table 4).

The present study employs the dual adjustment approach which is proposed by Ismihan (2019). The main novelty of the dual adjustment approach is that the approach offers another way to cointegration analysis by relaxing the implicit assumption of the singular adjustment in cointegration analysis. As advised by White and Granger (2011) and Ismihan (2019), we follow the indirect method and use the Hodrick-Prescott (HP) filter to measure the trend and permanent component of the variables. Scilicet, HP is the favored method of decomposition in the current analysis for numerous motives mentioned previously, but this does not certainly mean that it is superior to others. Thus, the dual adjustment approach permits the present study to use other popular filters which are Baxter-King filter (BK) (suggested by Baxter and King (1999))) and Ravn and Uhlig 2002 (RU), and Christiano and Fitzgerald (CF) filters (suggested by Christiano and ve Fitzgerald 2003).

Firstly, we test for the presence of Co-HP trend. In all situations, the null hypothesis of no common HP trend is dismissed, i.e., with four distinct smoothing parameters.

Table 4 ZA unit root test

	LEF	LEC	LGLOB	LGDP	TO
t-statistic	− 6.343**	− 4.154	− 3.276	− 3.967	− 3.819
SB	2001	1978	1985	1999	1980
	Δ LEF	Δ LEC	Δ LGlob	Δ LGDP	Δ TO
t-statistic	− 10.857**	−7.308**	−7.475**	−6.757**	−6.234**
SB	1978	1982	1980	1981	1980

Δ stands for the first difference. ** and * illustrate statistical significance at 0.05 and 0.10 levels, respectively. The structural break date is illustrated by SB

Both Engle-Granger CI analysis and Co-HP trend tests in all cases clearly shows that there is a long-run linkage between ecological footprint and globalization, economic growth, trade openness, and energy usage. Hence, this study tests the existence of Co-HP trend. The Co-HP trend is analyzed for four different smoothing parameters such as HP, RU, BK, and CF. The estimated values of parameters obtained from Co-HP trend are consistent with the results obtained from Engle-Granger cointegration analysis. The significant values of EG/Co-HP^{w} enable us to reject the null hypothesis of no cointegration. Hence, there is a common HP trend in all cases of HP, RU, BK, and CF. The results imply that ecological footprint is stationary around the common component of globalization and other control variables (Co-HP trend). The outcomes of λ_{HP}, λ_{RU}, λ_{BK}, and λ_{CF} clearly reveal that globalization has a significant and positive effect on ecological footprint in the long run, meaning that environmental sustainability is negatively affected by globalization in Turkey in the long run. However, we fail to capture any significant effect of globalization on ecological footprint in the short run. Moreover, in the long run, ecological footprint is positively affected by economic growth. The effect of economic growth on ecological footprint also remains effective in the short run as well. The outcomes of λ_{BK} and λ_{CF} also reveal that energy use deteriorates environmental sustainability in the long run. Moreover, in the short run, ecological footprint is negatively affected by trade openness in Turkey. Hence, the results of the dual adjustment approach indicate that the variables ecological footprint, globalization, energy usage, and trade openness are cointegrating. Globalization, energy usage, and trade openness have some roles to play in describing the ecological footprint in Turkey. These outcomes comply with findings of Yilanci and Gorus (2020), Leal et al. (2020), and Usman et al. (2020).

After the cointegration among the variables is confirmed in Table 5, we estimate the long-run coefficient of variables. To serve this purpose, this study uses dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS). The results of long-run estimates are presented in Table 6. In the long run, globalization, GDP, and energy consumption are important factors in explaining ecological footprint. It is evident that except trade openness, all variables are important in explaining ecological footprint in the case of Turkey. To be specific, using the FMOLS method, the long-run elasticities of globalization, energy consumption, trade openness, and GDP are 0.151%, 0.350%, − 0.001%, and 0.356%, respectively. The results of DOLS correspond with the FMOLS results. The positive and significant coefficients of energy consumption (LEC) imply that energy consumption has a positive impact on ecological footprint. An increase in energy consumption presents a serious menace to the environmental quality due to the increased demand for fossil fuels. The outcomes concur with the findings of Lee and Min (2015)

Table 5 EG and Co-HP trend tests (dual adjustment approach)

	Engle-Granger CI analysis	Co-HP trend analysis			
		λ_{HP}	λ_{RU}	λ_{BK}	λ_{CF}
c	3.193 (6.148)**	3.099 (1.473)	4.248 (3.706)**	2.081 (2.279)**	2.363 (2.254)**
LEC	0.027 (0.108)	0.219 (0.512)	− 0.011 (− 0.049)	0.353 (3.275)**	0.309 (2.017)**
LGLOB	0.137 (2.600)**	0.160 (2.511)**	0.149 (3.739)**	0.164 (9.082)**	0.171 (6.432)**
LGDP	0.555 (4.193)**	0.421 (2.055)**	0.547 (4.860)**	0.339 (5.826)**	0.358 (4.250)**
TO	− 0.001 (− 0.796)	− 0.001 (− 0.663)	− 0.001 (− 1.000)	− 0.001 (− 2.591)**	− 0.001 (− 1.738)*
EG/Co-HP^{w}	− 6.248 <0.000>**	− 6.652 <0.000>**	− 7.089 <0.000>**	− 7.793 <0.000>**	8.036 <0.000>**
LEC	-	0.327 (0.881)	0.458 (1.084)	0.484 (1.050)	0.527 (1.253)
LGLOB	-	− 0.059 (− 0.512)	− 0.041 (− 0.276)	− 0.063 (− 0.379)	− 0.055 (− 0.378)
LGDP	-	0.734 (2.488)**	0.842 (2.684)**	0.880 (2.535)**	0.960 (2.891)**
TO	-	− 0.001 (− 1.868)*	− 0.001 (− 3.602)**	− 0.001 (− 3.750)**	− 0.001 (− 4.538)**
λ	-	100	6.25	-	-

The values within () and <> present test statistics and *p* values, respectively. ** and * indicate the 5% and 10% significance levels

HP Hodrick-Prescott (λ = 100), *RU* Ravn-Uhlig (λ = 6.25), *BK* Baxter-King, *CF* Christiano-Fitzgerald

and Khan et al. (2020). The results of FMOLS and DOLS methods suggest that globalization significantly and positively affects ecological footprint in the long run, meaning that environmental sustainability is negatively affected by globalization in Turkey in the long run. Globalization, by increasing the flow of goods and services, has increased the competition and hence poses a severe threat to the environment. These results align with the findings of Liddle (2018), Khan et al. (2020), and Destek and Sarkodie (2019). The results further suggest that GDP is positively related with ecological footprint in the long run, meaning that environmental sustainability is negatively affected by economic activities in Turkey in the long run. An increase in economic activities leads to an increased demand for fossil fuels, which deteriorates the environmental sustainability. The results support the findings of Apergis and Ozturk (2015).

Table 6 Long-run estimators

Variable	Coefficient	Std. error	*t*-statistic	Prob.
Method: dynamic least squares				
LGLOB	0.151	0.045	3.332	0.001
LEC	0.350	0.186	1.881	0.066
TO	− 0.001	0.001	− 1.100	0.277
LGDP	0.356	0.096	3.692	0.000
c	2.409	0.630	3.819	0.000
R-squared	0.991	S.E. of regression		0.017
Method: fully modified least squares				
LGLOB	0.159	0.044	3.585	0.009
LEC	0.390	0.197	1.979	0.054
TO	− 0.001	0.000	− 0.923	0.361
LGDP	0.315	0.102	3.074	0.003
c	2.730	0.659	4.137	0.000
R-squared	0.990	S.E. of regression		0.018

Conclusion and policy implications

This study examines the role of globalization on ecological footprint in Turkey while controlling economic growth, energy consumption, and trade openness. To achieve this objective, we employ dual adjustment approach (proposed by Ismihan (2019)). The econometric method offers robust results:

(i) The variables are mixed order of integration.
(ii) The null hypothesis of no common HP trend is rejected in all cases, i.e., with the four different smoothing parameters.
(iii) There is a long-run linkage between ecological footprint and globalization, economic growth, energy consumption, and trade openness.
(iv) Ecological footprint is stationary around the common component of globalization and other control variables (Co-HP trend).
(v) Globalization has significant and positive effects on ecological footprint in the long run, meaning that environmental sustainability is negatively affected by globalization in Turkey in the long run.
(vi) We fail to capture any significant effect of globalization on ecological footprint in the short run.
(vii) In the long run, ecological footprint is positively affected by economic growth.

(viii) The effect of economic growth on ecological footprint also remains effective in the short run as well.
(ix) Energy consumption deteriorates environmental sustainability in the long run.
(x) In the short run, ecological footprint is negatively affected by trade openness in Turkey.
(xi) The variables ecological footprint, globalization, energy consumption, and trade openness are cointegrating. In long run, globalization, GDP and energy consumption are important factors in explaining ecological footprint.
(xii) Except trade openness, all variables are important in explaining ecological footprint in case of Turkey.
(xiii) The long-run elasticities of energy consumption, globalization, trade openness, and GDP are 0.350%,0.151%, −0.001% and 0.356%.
(xiv) The results of DOLS method are consistent with the findings of FMOLS.

In terms of policy implications, this study suggests that in order to improve the environmental quality, Turkey should adopt such policies that encourage energy consumers to shift toward renewable energy. Moreover, the government should take necessary steps to diversify the overall energy mix toward renewable energy. Moreover, different eco-innovation strategies should be adopted, which aim to shift the industrial structure from non-renewable energy to sustainable energy. The government should also adopt the carbon pricing approach in order to restrict the increasing trend in CO_2 emissions. Furthermore, since globalization deteriorates environmental quality, policymakers should devise strategies to evaluate the environmental sustainability of foreign investment, and steps should be taken against entities using obsolete dirty technologies. In addition, international investors should be persuaded to use technology that is clean and to engage in cleaner energy projects by providing attractive benefits. The social collaboration with other countries should be strengthened, and domestic media should be used to encourage environmental consciousness.

Authors' contributions Dervis Kirikkaleli and Tomiwa Sunday Adebayo designed the experiment and collected the dataset. The introduction and literature review sections are written by Tomiwa Sunday Adebayo and Zeeshan Khan. Dervis Kirikkaleli and Shahid Ali constructed the methodology section and empirical outcomes in the study. Tomiwa Sunday Adebayo contributed to the interpretation of the outcomes. All the authors read and approved the final manuscript.

Data availability The data that support the findings of this study are available from the World Bank.

Compliance with ethical standards

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

Ethical approval We confirmed that this manuscript has not been published elsewhere and is not under consideration by another journal. Ethical approval and Informed consent do not applicable for this study.

Consent to participate Not applicable

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