Impact of coal rents, transportation, electricity consumption, and economic globalization on ecological footprint in the USA

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Abstract
Over the last three decades, the world has been facing the phenomenon of the ecological deficit as the ecological footprint is continuously rising due to the persistent decline of the per-capita bio-capacity. Moreover, there is a substantial increase in globalization and electricity consumption for the same period, and transportation is contributing to economic prosperity at the cost of environmental sustainability. Understanding the determinants of ecological footprint is thus critical for suggesting appropriate policies for environmental sustainability. As a result, this study analyzes the impacts of economic globalization, transportation, coal rents, and electricity consumption in ecological footprint in the context of the USA over the period 1995 to 2018. The data have been extracted from “Global Footprint Network,” “Swiss Economic Institute,” and “World Development Indicators.” The current study has also applied the flexible Fourier form nonlinear unit root test to examine the stationarity among variables. For the empirical estimation, a novel technique, the “quantile auto-regressive distributive lag model,” is applied in the study to deal with the nonlinear associations of the variables and to evaluate the long-term stability of variables across quantiles. The study’s findings indicate that coal rents, transportation, and globalization significantly and positively contribute to the deterioration of ecological footprints at different quantile ranges in the short and long run. Electricity consumption is found to have a positive and significant impact at lower quantile ranges in the long run but not have a significant impact in the short run. The study suggested that lowering the dependence of the transport sector on fossil fuels, more use of hydroelectricity, and stringent strategies to curb coal consumption would be helpful to reduce the positive influence of these variables on ecological footprints in the USA.

Keywords Ecological footprints · Economic globalization · Transportation · Coal rents · QARDL · USA

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Introduction

One of the greatest issues in today’s world is environmental degradation. Greenhouse gases (GHG), the thinning of the ozone layer, and global warming are all severe risks to human life. The quality of the air and water is frequently deteriorating. In this regard, several scholars have used various measurements to estimate the environmental deterioration depending on the variables chosen, e.g., CO₂ emission and GHG emission. The use of CO₂ emissions as a proxy for environmental degradation has a herding behavior. Carbon dioxide emission selection is partially faulty as it only considers data on comprehensive environmental degradation due to consumption of energy and ignores intermediate consequences and larger environmental considerations (Al-Mulali et al. 2015). Therefore, the ecological footprint (EFP) provides a unique indicator of environmental sustainability as it measures the reliance of human economies on natural assets. To put it another way, it assesses the societal and technical influences on the Earth’s ecosystem (Nawaz et al. 2021a; Zhan et al. 2021).

The concept of ecological footprints (EFP) was first introduced by Wackernagel and Rees (1998) as the usage of land and water to produce all human-consumed resources and the removal of waste produced by the population (Hassan et al. 2019). Global Footprint Network defines the term ecological footprint (EFP) as “a measurement of how much natural resources we are currently having and how much we have consumed” (Sun et al. 2020; Ullah et al. 2021). The EFP serves as a framework for contrasting human demands for ecological assets with natural ecological capacities to supply these demands while also absorbing waste generated in the process (Xue et al. 2021).

The total EFP is divided into three categories: EFP of production, EFP of consumption, and net EFP embodied in international commerce (Xue et al. 2021). All the renewable resources utilized in the production process are included in the EFP. Agriculture footprint, for example, refers to the natural assets used in agriculture (the land required to grow all crops, including livestock/animal feeds, oil, fish foods, crops, and rubber). The annual primary production required to obtain marine species is measured by the fishing grounds’ footprint. The land needed by different industries, transportation, or any other activity associated with the construction of infrastructural facilities is measured by the construction land footprint. The forest area necessary to absorb carbon emissions induced by human actions is measured by carbon footprint and forest land footprint (Ullah et al. 2021; Zhuang et al. 2021).

Various factors affecting EFP have been identified through research, such as economic growth, natural resources, tourism, foreign direct investment, and resource rents (Ahmad et al. 2021; Hassan et al. 2019; Kongbuamai et al. 2020; H. Liu and Kim 2018; Ozturk et al. 2016; Ulucak and Khan 2020; Zeraibi et al. 2021). However, the literature has not extensively researched some important factors that contribute to environmental sustainability in the context of EFP. One of these factors is “globalization,” which refers to the growing economic, social, and political interconnection of economies as a result of trade across the border, mobility of the population, investment, technology, and information flows (Z. A. Baloch et al. 2021; Chien et al. 2021b). It can be defined as a transition from isolated countries characterized by different regulations, restrictions, and cultural differences to interconnected and globally interrelated economies (Chien et al. 2021a). The KOF index developed by Dreher (2006) is commonly used to gauge globalization having three dimensions: economic, political, and social globalization. Out of these three dimensions, since the 1990s, economic globalization has accelerated, resulting in significant shifts in capital flows and foreign trade liberalization. Economic globalization boosts the total productivity of the factors of production, expands investment opportunities, and strengthens financial markets. Various advantages accrue to the countries through economic globalization such as FDI, trade, and portfolio investment choices which are helpful in their economic development (Pata 2021).

Moreover, as a result of increased transportation and industrial output, globalization enhances human activities, which raises pollution levels. On the other hand, it may have positive effects on the environment through different channels. Firstly, foreign investors frequently employ efficient and innovative technologies to reduce the consumption of resources and the cost of production. Even local firms use the same technology to be competitive, which encourages environmental sustainability. Second, through structural change, trade openness can aid in the development of a knowledge-based service economy. Third, the technique effect of trade in industrialized countries can provide green technologies and more environmentally friendly regulations (Ahmed et al. 2021a). Some of the studies have analyzed the impact of globalization on environmental quality in terms of CO₂ emission (Destek 2020; Shabbaz et al. 2017; You and Lv 2018), and there is a need to estimate its effect in terms of ecological footprints, a far comprehensive measure of environmental quality than CO₂ emission.

Similarly, the heavy reliance on coal by coal-consuming countries, as well as the high amounts of carbon emission, needs a comprehension of the link between coal rents and long-term sustainable development. Coal rents or resource

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1 Six categories of EFP are estimated based on the nature of human ecological demand: grazing land EFP, cropland EFP, forestland EFP, fishing grounds EFP, built-up land EFP, and carbon EFP. The aggregate of these six types yields the overall EFP figures (Xue et al. 2021).
rent from the production of coal incentivize coal exploring companies to use coal as an energy source. It is a fact that coal production is mostly used for energy consumption that is a source of CO₂ emission. Literature reveals that coal rents, like oil rents and other natural resource rents, have an important role in the economies of both industrialized and underdeveloped countries, and it is necessary to demonstrate how natural assets can affect long-term growth and environmental sustainability (Adedoyin et al. 2020). The same is the case with the transportation sector. The provision of good transportation services is an essential element in any economy’s growth and development (Godil et al. 2020a). But growth in transportation services has some environmental disadvantages as well (Adams et al. 2020). The transport sector consumes a significant proportion of petroleum and other liquid fuels and causes an increase in (GHG) and other environmental pollutant emissions. Previous research has largely shown that transportation services have had a negative impact on environmental standards in terms of carbon dioxide emissions (Aggarwal and Jain 2016; Baloch and Suad 2018; Cai et al. 2012). The impact of the services provided by the transport sector has traditionally been quantified in terms of carbon dioxide emissions. So, the primary goal of the study is to determine the effect of transportation in the USA, specifically on EFP.

The present study examines the impacts of electricity consumption, coal rents, transportation, and globalization on EFP in the USA. The work is particularly important in the context of the USA, having the second-largest EFP in the world (Zafar et al. 2019). There are numerous reasons to study the country. In terms of economic statistics, the USA has the largest economy in the world, having an income level of 20.544 trillion current US dollars (17.856 trillion constant US dollars) in 2018 (FocusEconomics 2019). Furthermore, with 1.4 trillion dollars in exports in the year 2017, the USA is the second-largest exporter after China. The exports share 12% of US GDP approx. (FocusEconomics 2019). Furthermore, the USA is ranked 7th in terms of ECI. Looking at the globalization history in the USA, after World War II, business in the united areas was keen to increase their profits soon by relocating their manufacturing services to regions with the lowest salaries and weaker labor unions. This laid the foundation for the process of globalization that accelerated at a fast pace in the following years. The USA played a key role in efforts to establish a global economic system based on universally agreed principles (Wu et al. 2018). As per the globalization index (2016), the USA had a globalization of 82 out of 100, which is higher than Japan and China. The levels of political and social globalization in the USA were greater than economic globalization levels at the disaggregated level (93% and 85%, respectively). The largest percentage increase in the submetrics resulted from the levels of economic globalization, which increased by a whopping seventy-three per cent between 1970 and 2016 (WilsonCenter 2018).

In ecological terms, the USA has the world’s 2nd largest total EFP (2.611 billion global hectares) and CO₂ emission (5144 million tons) (EnvironmentalProtectionAgency 2019). The USA has an ecological deficit both in overall and per capita EFP data. As a result, the factors impacting environmental pollution in the USA should be recognized, and more actions to improve environmental quality should be taken (EnvironmentalProtectionAgency 2019). Regarding the usage of energy, the USA is among the world’s most renewable and fossil fuel-consuming countries. In 2018, the USA accounted for 18% of global CO₂ emissions but managed to reduce it by 2% in 2016 (UnitedStatesGeologicalSurvey 2019). Simultaneously, in recent years, the USA has been successful in lowering per capita EFP. As the high pollution level begins to subside, it is worthwhile to study environmental sustainability in the USA (UnitedStatesGeologicalSurvey 2019).

In the USA, transportation consists of road, rail, waterways (via boats), and air transport. For short distances, mostly the passenger travelling is done by automobiles, while for the longer distances, rail road or airplanes are used. Most cargo travelling is done by truck, railroad, pipeline, and boating. For perishables and premium shipments, air shipping is usually used. In the USA, transportation is the major source of greenhouse gas (GHG) emissions. GHG emissions from USA transportation cover about 29% of the country’s total GHG emissions. GHG emissions in the transportation industry exceed any other sector in absolute terms from 1990 to 2019. The use of electricity and other energy sources like coal is increasing rapidly both at the economic and home levels. US consumption of electricity is 3.8 trillion kilowatthours (kWh) according to 2020 statistics. Total fossil fuel use in the USA, which includes petroleum, natural gas, and coal, decreased to 72.9 quadrillion British thermal units (Btu) according to 2020 statistics. It shows a decrease of 9% from 2019 and the lowest level since 1990. The use of energy in all the economic sectors and social activities contribute to the country’s GHG emission with more or less volume.

The use of energy resources for different purposes is increasing at a consistent rate in all the economic and social sectors in the USA, and the pollution emissions from the USA are also increasing. As the environment is a crucial factor in some countries’ overall development, the present article is going to pay attention to this aspect. The main objective of the study is to examine the influences of electricity consumption, coal rents, transportation, and globalization on EFP. The present study is a great contribution to the literature. First, in previously presented articles, there is an estimation of the influences of electricity consumption, coal rents, transportation, and globalization on EFP.
but not through single comprehensive research. The present 
study contributes to the literature as it estimates the impacts 
of these variables on EFP collectively through the same 
research survey. Second, it is also a great theoretical con-
tribution of the present study that distributes the energy into 
electricity and coal. Moreover, it talks both about energy 
consumption and production characteristics like coal rents. 
Third, the present study contributes to the body of knowl-
edge by offering an empirical analysis of a developed coun-
try like the USA because the role of electricity consumption, 
coal rents, and transportation in EFP in the USA has largely 
been ignored in the literature.

The remaining four sections of the study are organized 
as follows: in the second section, the review of the existing 
literature is presented. Model specification, data sources, 
and methodologies used in the study are provided in the 
third section. The fourth section provides and discusses the 
findings. And the final section summarizes conclusions and 
policy recommendations.

**Literature review**

The energy economics literature is empirically estimating 
the different nexuses between environment and economic 
actors from the twentieth century’s last quarter. Some recent 
studies have estimated the impact of a variety of variables, 
e.g., globalization, energy consumption, and transportation, 
on environmental pollution (Mohsin et al. 2021; Nawaz et al. 
2021b; Shair et al. 2021). Following the work of Al-Mulali 
and Ozturk (2015), who believe that EFP is an adequately 
broad metric to comprehend the ecological impacts of 
human activities, EFP is now being used as an environmen-
tial indicator.

Numerous researches have studied the globalisation-
environment nexus (Chien et al. 2021c; Li et al. 2021). Glo-
balization affects economic development by increasing fac-
tor productivity, foreign direct investment, and commerce, 
but it also has an indirect impact on the consumption of 
energy and environmental deterioration. Various measures 
of globalization have been employed in the literature to ana-
lyze its environmental impact (Sabir and Gorus 2019). Of 
these studies, Figge et al. (2017) analyzed the relationship 
between several kinds of EFP and types of globalization in 
one hundred and seventy-one nations. According to the find-
ings of correlation analysis and multivariate regression, the 
study concluded that increased economic globalization led 
to increased consumption and imports of EFP (Figge et al. 
2017). Rudolph and Figge (2017) also examined the asso-
ciation between EFP and forms of globalization in a group 
of 146 countries from 1981 to 2009. The empirical find-
ings showed that the more globalization an economy had, 
the higher were the levels of footprints in terms of output, 
consumption, exports and imports. Furthermore, it was also 
observed that within the period studied, economic globaliza-
tion Granger caused ecological footprints, but no causality 
was found from environmental deterioration towards eco-
nomic globalization (Rudolph and Figge 2017).

In the context of Malaysia, Ahmed et al. (2019) attempted 
to estimate the association between globalization and the 
EFPS from 1971 to 2014 but Bayer and Hanck test for 
cointegration and the ARDL bound estimations indicated 
that globalization had an insignificant impact on EFPS in 
Malaysia but had a significant impact on carbon footprints 
(Ahmed et al. 2019). In the same vein, the findings of Sabir 
and Gorus (2019) indicated that the per capita eco-footprint 
was increased due to an increase in the KOF index in South 
Asian economies during the period 1975 to 2017. Moreo-
ver, a unidirectional causality was found from globalization 
toward environmental deterioration (Sabir and Gorus 2019). 
The study of Yilanci and Gorus (2020) highlighted the fact 
that eco-footprint granger caused financial trade and eco-
nomic globalization for a group of MENA countries and 
found that financial globalization had the ability to anticipate 
future levels of environmental deterioration in the Middle 
East and North Africa (MENA) (Yilanci and Gorus 2020).

Most recently, in the context of Turkey, Kirikkaleli et al. 
(2021) tried to investigate the impact of globalization on 
EFP, controlling for economic growth, consumption of 
energy, and trade liberalization. The findings revealed that 
globalization had a positive impact on EFP in the long run, 
while trade openness had a negative impact on EFP in the 
short run. However, GDP growth had a negative impact on 
EFP in short as well as in the long run (Kirikkaleli et al. 
2021). Ahmed et al. (2021a) analyzed the long-run asym-
metric effect of overall globalization and political, social, 
and economic globalization on ecological footprints in the 
USA. It was found that negative changes in economics and 
overall globalization increased EFP, but positive changes in 
social globalization mitigated the EFPS in the USA (Ahmed 
et al. 2021b). The same attempt was made by Ahmed et al. 
(2021a) in the context of Japan, who found that there was 
a reduction in ecological footprint by positive and negative 
changes in economic globalization (Ahmed et al. 2021b).

Likewise, there is a set of studies that focus on electricity 
consumption and its environmental impacts in terms of 
CO2 emission or ecological footprints. For instance, 
Asongu et al. (2020) analyzed the causal link between eco-
nomic growth, consumption of electricity, and CO2 emission 
in African economies for the period 1980–2014, and the 
results through ARDL PMG evidenced that consumption 
of electricity Granger caused carbon dioxide emissions in 
most of the African countries and deteriorates the environ-
mental condition. Zhang (2018) explored the link between 
consumption of electricity, industrialization, trade openness, 
carbon dioxide emissions, and environmental quality in
South Korea over the 1971–2013 period. Findings of ARDL bound testing evidenced that consumption of electricity significantly contributed to the emission of CO\textsubscript{2} in South Korea, and Granger causality analysis indicated that consumption of electricity granger caused pollutant emission, financial development, and growth of the industrial sector.

A similar study was conducted by Aqlah et al. (2021) in the context of Kuala Lumpur, Malaysia, and it was found that bi-directional causality was present between consumption of electricity and CO\textsubscript{2} emission in the short run. In contrast, Lin and Li (2020) concluded that by incorporating clean electricity-based energy, the electricity consumption reduced CO\textsubscript{2} emissions (Lin and Li 2020). Similarly, in EU economies, it is suggested that the use of renewable energy-based electricity improved environmental sustainability (Balsalobre-Lorente et al. 2018).

Ikram et al. (2020) examined electricity consumption, financial development, agriculture, and CO\textsubscript{2} emission. According to study findings, electricity consumption is one of the reasons for environmental degradation through the ecological footprint of SAARC economies. The objective of the study of Bello et al. (2018) was to estimate the impact of consumption of hydroelectricity on ecological footprint, water footprint, carbon footprint, and CO\textsubscript{2} emission in Malaysia over the 1971 to 2016 period. It was found that hydroelectricity reduced environmental deterioration. The results of VECM Granger causality evidenced that a unidirectional causal relationship existed between the consumption of fossil fuels and hydroelectricity towards all forms of environmental deterioration (Bello et al. 2018). Likewise, the study of Figge et al. (2017) found that globalization and electricity consumption Granger caused ecological footprints, and both significantly increased the ecological footprints.

Like electricity consumption, transportation services also affect environmental sustainability in a significant way. Different indicators for environmental quality have been adopted by previous researchers, and CO\textsubscript{2} emission is widely used. For instance, the study of Rothman et al. (2021) examines transportation and environmental quality in Canadian cities. The study concluded that subsidizing fuel prices was inefficient as demand for transport services was found to be non-responsive to the prices. The authors further concluded that the investment in infrastructure could cause a reduction in carbon dioxide emissions by the transport sector. Rizkallah et al. (2018) also explored the bi-directional linkage between energy usage, carbon dioxide emission, and economic growth in OECD economies, and their findings established that the level of carbon emissions could be reduced by effective consumption of energy in OECD economies. Prior studies investigate the relationship between the consumption of energy by the transport sector and economic growth with the level of carbon dioxide emission. The findings indicated that CO\textsubscript{2} emission was greatly affected by the amount of energy consumed by the transport sector (Baloch and Suad 2018).

In the context of Sweden, Hu et al. (2019) attempted to test the effect of the consumption of products and services on the level of carbon emission by transportation services, and it was found that the carbon emission of transportation services accounted for fourteen per cent of EFP (Hu et al. 2019). Godil et al. (2020b) analyzed the nexus between carbon emission and passenger automobiles and logistics providers. The findings were sufficient to prove the presence of the negative link. However, in the context of freight transportation, it mostly appeared in the lower quantiles when it came to passenger vehicles (Godil et al. 2020a).

There has been just a small number of studies on the influence of the transportation sector on the environment that have used EFP as an environmental indicator. Das and Roy (2019) researched in Michigan’s Houghton County, and the findings predicted that, despite planned improvements in vehicle fuel efficiency, in coming years, a rise in EFP in the transportation sector will be seen because of an increase in travel volume. According to Asher et al. (2020), rural road development had a minor influence on areas covered by forests. However, highway expansion had a significant detrimental impact on areas covered by forests in terms of EFP (Asher et al. 2020). Georgatzi et al. (2020) found in 12 EU countries from 1994 to 2014 that the footprint of transportation-related activities included fuel usage by transportation and built-up regions for transportation setups. Furthermore, they claimed transportation as a component of the overall EFP and supported the idea that cities imposed ancillary environmental issues on the city’s localities.

The empirical studies also provide evidence for the impact of coal rents on CO\textsubscript{2} emissions. For example, by introducing coal rents as a proxy for the coal sector, Bhattacharya et al. (2017) found that a long-run relationship was present between carbon dioxide emission and economic growth in India and coal rents had a feedback impact on carbon dioxide emission (Bhattacharya et al. 2017). Adeleyin et al. (2020) studied the nexus between economic growth, coal rents, and carbon emission for a panel of BRICS nations over the period 1990–2014. The findings of pooled mean group (PMG) and dynamic autoregressive distributed lag model (ARDL) revealed that for BRICS nations, coal rents had a negative and significant effect on CO\textsubscript{2} emissions. Regulating coal rents in the form of carbon damage prices were also found to have a positive and significant impact on CO\textsubscript{2} emissions, contrary to expectations (Adeleyin et al. 2020). Gyarfi et al. (2021) explored the nexus between coal rent, energy, and the environment in E7 countries. For this purpose, the study adopted POLS (panel ordinary least squares) and panel quantile regression analysis. It was found that GDP and coal rents had a significant and positive impact on
CO₂ emissions. Furthermore, the results showed that regulating coal consumption by rent, in addition to the cost of carbon damage, will raise CO₂ emissions in E7 countries even more (Gyamfi et al. 2021). In the same way, Adedoyin et al. (2021) considered ECI (economic complexities index), international travelling, and coal rents to see their impact on the environment for a panel of 119 countries (from different income groups) for the period 1995–2016 and from the empirical estimation of system GMM, the researchers concluded that increased coal rents and energy consumption led to more carbon content emission in all the income groups (Adedoyin et al. 2021).

The literature reviewed above reveals many literary gaps that the present study fulfils. In previous literature, conflicting outcomes regarding the relationship between coal rents, transportation, globalization, and electricity consumption on EFP have been found. The present study, after reviewing the literature and making an empirical analysis, gives the notion that coal rents, transportation, globalization, and electricity consumption are bound with ecological footprints in a positive relationship. In previous literature, a single study has examined one or two of the variables like coal rents, transportation, globalization, and electricity consumption for analysis of EFP. The current research removes this literary gap by analyzing the role of all variables like coal rents, transportation, globalization, and electricity consumption in EFP. Long empirical research has been done in order to explore the globalization impacts on EFP. That research has dealt with globalization as a whole, including social, economic, and political globalization. But the present study makes a distinction as it examines only economic globalization, which is a major cause of EFP. The present article also carries a great contribution to literature as it initiates to examine the impacts of coal rents, transportation, globalization, and electricity consumption on EFP in the USA for an extended period of 1995–2018 using the QARDL estimator.

**Methodology**

**Model construction**

The study aims to analyze the impact of coal rents, transportation, globalization, and electricity consumption on ecological footprints in the USA for the period 1995–2018. The current study examined the time span from 1995 to 2018 because during this time span major changes have been watched in transportation, globalization, electricity consumption, and coal rents that may significant factors for ecological footprints. In addition, USA economy has considered major country where the changes in abovementioned factors have taken place and selected for the analysis. The selection of the variables is made based on the empirical studies and data availability. The ecological footprint (EFP) is taken as the dependent variable, which is defined as “a metric for measuring the arable land and ocean required to support human consumption and to assimilate/ingest its waste, given current technology and management strategies.” Independent variables include coal rents, transportation, globalization, and electricity consumption. The role of coal rents on EFP is introduced for the first time in this study, especially in the context of the USA. Coal rents are the difference between the value of both hard and soft coal production at world prices and their total costs of production. Globalization has three dimensions: economic, social, and political. Out of these three, only economic globalization is taken into consideration because the major aim of the study is to explore the economic aspect impact on the EFP. In addition, the availability of data issues related to the social and political dimension of globalization is also the reason to adopt only economic globalization in the study. This study is an expectation that economic globalization may help the environment by structurally transforming the economy and introducing more resourceful cleaning technology, particularly in high-income countries with rigorous environmental regulations (Zhang et al. 2017). Transportation and consumption of electricity are also included in the model as the previous literature indicates them to be the significant contributors to ecological deterioration (Bello et al. 2018; Charfeddine and Khediri 2016; Godil et al. 2021).

The empirical literature (Ahmed et al. 2019; Sabir and Gorus 2019; Bello et al. 2018; Godil et al. 2021, 2020b; Lin and Li 2020) supported the construction of the following model to estimate the impacts of coal rent, transportation, globalization, and electricity consumption on the ecological footprints.

\[
\text{EFP}_t = \alpha_0 + \alpha_1\text{COAL}_t + \alpha_2\text{TRA}_t + \alpha_3\text{EGLO}_t + \alpha_4\text{EPC}_t
\]  

(1)

where EFP = ecological foot print; COAL = coal rents; TRA = transportation; EGLO = economic globalization; and EPC = electricity consumption. The data of the study spans 1995 to 2018. Following Table 1 provides the detailed measurements and the data sources of the variables of the study.

**Econometric methodology (QARDL approach)**

To evaluate the relationship between transportation, coal rents, economic globalization, electricity consumption, and EFP, we have applied the QARDL model proposed by Cho et al. (2015). The quantile long-run equilibrium effect of transportation, coal rents, economic globalization, and electricity consumption on EFP is tested through this model. The
QARDL is a sophisticated and latest form of ARDL estimation that enables testing non-linearities and asymmetries between transportation, coal rents, economic globalization, electricity consumption, and EFP. It has several other advantages over other conventional time series techniques. First, an unbiased estimator in various orders of integration under various quantiles of the explained variable is provided by the ARDL approach. Second, the problem of asymmetric distribution of the variables can easily be overcome by QARDL. Third, the traditional ARDL quantile regressions can easily be synthesized through this approach. Hence, ARDL provides short-run and long-run estimates along with the rate convergence under multiple quantiles. Finally, to overwhelm a monotonic conditional mean over the time horizon, multiple integrating associations are considered by QARDL. The following Eq. (1) indicates the basic form of the ARDL model.

$$\begin{align*}
EFP_t &= \mu + \sum_{i=1}^p \sigma EFP_{t-i} + \sum_{i=0}^q \sigma COAL_{t-i} + \sum_{i=0}^p \sigma TRA_{t-i} + \sum_{i=0}^q \sigma EGLO_{t-i} + \sum_{i=0}^u \sigma EPC_{t-i} + \varepsilon_t \tag{2}
\end{align*}$$

In the above equation, $\sigma$ shows that the coefficient $\varepsilon_t$ is the error disturbance term which is specified as $EFP_t - E\left[\frac{EFP_{t-1}}{w_{t-1}}\right]$, where $w_{t-1}$ is taken as the smallest $v$ field formed by $EFP_t$, $COAL_t$, $TRA_t$, $EGLO_t$, $EPC_t$, $EFP_{t-1}$, $COAL_{t-1}$, $TRA_{t-1}$, $EGLO_{t-1}$, and $EPC_{t-1}$, and $p$, $q$, $r$, $s$, and $u$ are the orders of lags given by the Schwarz Information Criterion (SIC) due to the time series data.

The QARDL form of Eq. (1) developed by Cho et al. (2015) is specified in Eq. (2) below. QARDL $(p, q, r, s, u)$ model:

$$
Q_{\Delta EFP_t} = \mu(\tau) + \sum_{i=0}^p \sigma EFP_{t-i} + \sum_{i=0}^q \sigma COAL_{t-i} + \sum_{i=0}^p \sigma TRA_{t-i} + \sum_{i=0}^q \sigma EGLO_{t-i} + \sum_{i=0}^u \sigma EPC_{t-i} + \varepsilon_t(\tau) \tag{3}
$$

where $\sigma$ shows the coefficient $\varepsilon_t(\tau) = EFP_t - Q_{\Delta EFP_t}(\frac{\tau}{\delta_{t-1}})$ (Kim & White, 2003) and $0 > \tau < 1$ refers quantile and $\delta_{t-1}$ shows unit impulse function. In addition, because of the issue of serial correlation in the error term, the QARDL in Eq. (2) is generalized as follows:

$$
Q_{\Delta EFP_t} = \mu(\tau) + \mu(\tau) + \rho(\tau) + \sum_{i=0}^p \sigma EFP_{t-i} + \sum_{i=0}^q \sigma COAL_{t-i} + \sum_{i=0}^p \sigma TRA_{t-i} + \sum_{i=0}^q \sigma EGLO_{t-i} + \sum_{i=0}^u \sigma EPC_{t-i} + \varepsilon_t(\tau) \tag{4}
$$

Equation (3) can regenerate and extended for error correction term of QARDL as follows:

$$
Q_{\Delta EFP_t} = \mu(\tau) + \mu(\tau) + \rho(\tau) + (EFP_{t-1} - \beta COAL_{t-1}) COAL_{t-1} - \beta TRA_{t-1} TRA_{t-1} - \beta EGLO_{t-1} EGLO_{t-1} - \beta EPC_{t-1} EPC_{t-1} + \sum_{i=0}^p \sigma EFP_{t-i} + \sum_{i=0}^q \sigma COAL_{t-i} + \sum_{i=0}^p \sigma TRA_{t-i} + \sum_{i=0}^q \sigma EGLO_{t-i} + \sum_{i=0}^u \sigma EPC_{t-i} + \varepsilon_t(\tau) \tag{5}
$$

Table 1 Operational description of the variables

| Variable name | Abbreviation | Measurement | Data sources |
|---------------|--------------|-------------|--------------|
| Ecological footprints | EFP | Global hectares per capita | GFN |
| Economic globalization | EGLO | Index based on actual flows of FDI, trade, portfolio investments and restrictions, e.g., tariffs, import barriers, and taxes | SEI |
| Coal rents | COAL | Coal rents (% of GDP) | WDI |
| Transportation | TRA | Transport services (% of commercial services export) | WDI |
| Electricity consumption | EPC | Electric power consumption (kWh per capita) | WDI |

GNF Global Footprint Network, SEI KOF Swiss Economic Institute, WDI The World Development Indicators
The Wald test

Wald test is applied to identify short-run and long-run asymmetric effects of COAL, TRA, EGLO, and EPC on EFP. For ρ (speed of adjustment parameters), the null hypothesis ρ*(0.05)=ρ*(0.10)………….. ρ*(0.95). A similar hypothesis is tested on β_COAL, β_TRA, β_EGLO, and β_EPC (the long-run parameters) and σ_COAL, σ_TRA, σ_EGLO, and σ_EPC (the short-run parameters) (Al-Ghwayeen and Abdallah 2018).

Results and interpretations

Descriptive statistics

Now we proceed to the estimation and the results. We estimate the impact of coal rent, transportation, economic globalization, and electricity consumption on ecological footprints in the USA using quarterly data for each variable from 1995 to 2018. The time period starts from 1995 because the data availability related to the coal rent is not available, and the time period ends in 2018 before Covid-19. Table 2 gives the descriptive statistics of the variables of the study, i.e., EFP, COAL, TRA, EGLO, and EPC. The mean values of all the variables are found to be positive. On average, EFP is 0.752, with a variability of about a mean of 0.052. The maximum and minimum values of EFP are 1.001 and 0.072, respectively. Similarly, the average values of the COAL and TRA are 1.426 and 0.657, respectively, with a standard deviation of 1.039 and 0.027, respectively. The maximum value of COAL is 2.010, and the minimum value is 0.046, whereas the maximum value of TRA is 1.011 and the minimum value is 0.067, respectively. The mean value of EGLO is 2.042, and its maximum and minimum values are 3.001 and 1.020, respectively. And last, the average EPC is 0.841 with maximum and minimum values of 1.101 and 0.061, respectively.

We performed a “Jarque–Bera normality test”. The null hypothesis of the test states the normality of data, and the alternative hypothesis states the reverse. The results of the test vindicate that each series is highly significant (i.e., at 1% significance level), indicating that data is not normally distributed. Owing to the non-linearity in data, Zivot-Andrews (ZA) test was used, and further statistical estimations were applied through a sophisticated quantile approach (QARDL) following Godil et al. (2021); Godil et al. (2020b); Chang et al. (2020); and Suki et al. (2020).

Unit root test

We applied flexible Fourier (FF) form nonlinear unit root test and ZA tests to check the stationarity of data. The tests are used to find out the structural breaks and stationarity of the time series data.

The results in Table 3 indicate that all the variables are non-stationary at the level and become stationary by taking the first difference, i.e., I(1).

Main findings (QARDL approach)

After knowing the integration order, we apply the QARDL approach. We divide the ecological footprint series into eleven quantiles (0.05–0.95). Table 4 depicts the results of the model measuring the impact of COAL, TRA, EGLO, and EPC on EFP. The coefficient of error correction (ECM) is significant and negative under all quantiles, indicating the convergence of the model to the long-run equilibrium after any exogenous shock. The symbol β’s in the table indicate the long-run relationships of independent variables (COAL, TRA, EGLO, and EPC) with the dependent variable (EFP).

Long-run results

It is indicated from the results that economic globalization affects EFP significantly and positively, showing that globalization deteriorates environmental quality in the USA in the long run. Economic globalization worsens the quality
of EFP significantly over the range of quantiles (0.05 – 0.4); however, for higher quantiles (0.5 – 0.95), its impact is insignificant. It shows that at a lower intensity level of EFP, more economic globalization is going to further deteriorate the environment, but at higher intensity levels of EFP, there is an insignificant effect of economic globalization. This result implies that as the pace of global interconnectivity of a country accelerates, its ecological footprint increases, thereby lowering the environmental quality in the long run. The result is credible because, as a result of increased human activity such as transportation, industrial production, and deforestation, globalization has the potential to exacerbate environmental deterioration. FDI (a component of economic globalization) has a significant contribution in this context because it may result in the establishment of pollution havens, as developed country investors opt to transfer pollution-intensive technologies to countries with laxer environmental regulations (Destek and Okumus 2019). Foreign investors frequently use dirty technologies and low-cost production strategies that exploit natural resources. Moreover, an increase in the intensity of energy that follows an increase in the rate of globalization fuels the positive relationship between globalization and ecological footprint. Our finding is second to the findings of Kirikkaleli et al. (2021); Usman

Table 3. Unit root test results

| Quantiles | Constant | ECM | FF [level] | FF (Δ) | ZA [level] | Break year | ZA (Δ) | Break year |
|-----------|----------|-----|------------|--------|------------|------------|--------|------------|
| 0.05      | 0.012    | (−0.114*** | 0.361*** | 0.061 | 0.148* | 0.242** | 0.046*** | 0.024 | 0.041** | 0.456 | 0.035 |
| 0.1       | 0.009    | −0.105*** | 0.350*** | 0.072 | 0.121* | 0.251** | 0.037*** | 0.042 | 0.038*** | 0.447 | 0.027 |
| 0.2       | 0.016    | −0.110*** | 0.341** | 0.078* | 0.137* | 0.263** | 0.040*** | 0.040* | 0.047 | 0.450 | 0.032 |
| 0.3       | 0.010    | −0.115*** | 0.336** | 0.067* | 0.114* | 0.272 | 0.050*** | 0.060** | 0.058 | 0.420* | 0.010 |
| 0.5       | 0.018    | −0.102*** | 0.324** | 0.059** | 0.125 | 0.240 | 0.047*** | 0.030** | 0.049 | 0.432* | 0.028 |
| 0.6       | 0.008    | −0.129*** | 0.340** | 0.090** | 0.135 | 0.264 | 0.051*** | 0.061** | 0.063 | 0.421* | 0.031 |
| 0.7       | 0.011    | −0.106*** | 0.3623*** | 0.162*** | 0.123 | 0.288 | 0.030*** | 0.053** | 0.048 | 0.451** | 0.026 |
| 0.8       | 0.019    | −0.109*** | 0.338* | 0.176*** | 0.141 | 0.252 | 0.031*** | 0.046** | 0.079 | 0.440** | 0.009 |
| 0.9       | 0.022    | −0.123    | 0.344* | 0.168*** | 0.134 | 0.270 | 0.055*** | 0.037** | 0.057 | 0.410*** | 0.025 |
| 0.95      | 0.013    | −0.116    | 0.330* | 0.189*** | 0.167 | 0.255 | 0.045** | 0.041** | 0.078 | 0.430*** | 0.007 |
|           | 0.005    | −1.009    | (1.939) | (−3.010) | (0.943) | (0.659) | (4.033) | (1.989) | (0.334) | (3.001) | (0.007) |

The table provides the unit root estimation results. The t-statistics are between brackets. ***, **, and * show 1%, 5%, and 10% levels of significance, respectively. Source: EFP test results should be specified by the values in the table. The asterisks ***, **, and * show 1%, 5%, and 10% levels of significance, respectively.

Table 4. Results of QARDL approach for ecological footprint

| Quantiles | Constant | ECM | Long-run estimation | Short-run estimation |
|-----------|----------|-----|---------------------|---------------------|
|           | α(t)     | ρ(t) | β_COAL(t) | β_TRA(t) | β_EGLO(t) | β_EPC(t) | φ_q(t) | ω_q(t) | λ_q(t) | θ_q(t) |
| 0.05      | 0.012    | (−0.114*** | 0.361*** | 0.061 | 0.148* | 0.242** | 0.046*** | 0.024 | 0.041** | 0.456 | 0.035 |
| 0.1       | 0.009    | −0.105*** | 0.350*** | 0.072 | 0.121* | 0.251** | 0.037*** | 0.042 | 0.038*** | 0.447 | 0.027 |
| 0.2       | 0.016    | −0.110*** | 0.341** | 0.078* | 0.137* | 0.263** | 0.040*** | 0.040* | 0.047 | 0.450 | 0.032 |
| 0.3       | 0.010    | −0.115*** | 0.336** | 0.067* | 0.114* | 0.272 | 0.050*** | 0.060** | 0.058 | 0.420* | 0.010 |
| 0.4       | 0.015    | −0.134    | (2.671) | (1.717) | (1.576) | (3.179) | (1.961) | (1.022) | (1.657) | (0.506) |
| 0.5       | 0.018    | −0.102*** | 0.324** | 0.059** | 0.125 | 0.240 | 0.047*** | 0.030** | 0.049 | 0.432* | 0.028 |
| 0.6       | 0.008    | −0.129*** | 0.340** | 0.090** | 0.135 | 0.264 | 0.051*** | 0.061** | 0.063 | 0.421* | 0.031 |
| 0.7       | 0.011    | −0.106*** | 0.3623*** | 0.162*** | 0.123 | 0.288 | 0.030*** | 0.053** | 0.048 | 0.451** | 0.026 |
| 0.8       | 0.019    | −0.109*** | 0.338* | 0.176*** | 0.141 | 0.252 | 0.031*** | 0.046** | 0.079 | 0.440** | 0.009 |
| 0.9       | 0.022    | −0.123    | 0.344* | 0.168*** | 0.134 | 0.270 | 0.055*** | 0.037** | 0.057 | 0.410*** | 0.025 |
| 0.95      | 0.013    | −0.116    | 0.330* | 0.189*** | 0.167 | 0.255 | 0.045** | 0.041** | 0.078 | 0.430*** | 0.007 |

The table provides the unit root test results. The t-statistics are between brackets. ***, **, and * show 1%, 5%, and 10% levels of significance, respectively. Source: EFP test results should be specified by the values in the table. The asterisks ***, **, and * show 1%, 5%, and 10% levels of significance, respectively.
but is consistent with Asher et al. (2020), Chi and Stone the ecological footprints and environmental sustainability Godil et al. (2021), who found that transportation improves the quality of EFP is opposite to C. Liu et al. (2016) and tor from 1990 to 2019 (the USA Environmental Protection mental deterioration increased faster than in any other sec - York State Archives 2020). Pollutant emissions and environ-

the EF is 7.3 and 12.2 hectares per person, respectively (New

cities. In the New York and Los Angeles metropolitan areas,
have travelled 8317 km, the least of any of the 13 American
effect on EFP. However, as the intensity level of EFP
deteriorates the quality of EFP. But at higher intensity lev-
levels of EFP, an increase in electricity consumption has no effect on EFP. The results can be attributed to the USA’s dependency on fossil fuels for the production of electricity, as these are the largest contributors to energy production in the USA. Coal and natural gas power plants account for 19 and 40% of the country’s installed total energy production capacity, respectively (US Energy Information Administration, 2020). Carbon dioxide is produced during the production of power from natural gas and coal, which is then dis-

Shifting the analysis towards the short-run scenario, column $\delta_1(\tau)$ indicates that former levels of EFP positively and significantly affect the present EFP changes for all quantiles (0.05–0.95) in the USA. Column $\omega_0(\tau)$ shows that the current and former changes in coal rents (COAL) have a significantly positive impact over the present and preceding variations in EFP at low to higher intensity levels, i.e., (0.2–0.95). Column $\lambda_0(\tau)$ highlights the fact that prevailing and earlier changes in transportation (TRA) influence the prevailing and earlier changes in EFP significantly and positively in the low-intensity range (0.05–0.2). Furthermore, the current and previous changes in globalization have a significant and positive impact on current and prior variations in EFP from the middle to high-intensity range (0.4–0.95), as depicted in column $\theta_0(\tau)$. However, as per column $\epsilon_0(\tau)$, electricity consumption EPC is insignificant and has no short-run effect on EFP, and these findings are matched with the outcomes of Baz et al. (2020).

Thus, the overall QARDL model concludes that coal rents, transportation, and economic globalization have a significantly positive impact in the short run and in the long run, while the impact of electricity consumption is significant (positive) only in the long run.

The Wald test

We applied the Wald test to check the constancy of the parameters across the 11 quantiles. Moreover, as stated in the methodology part, the Wald test also checks the
non-linearity in parameters of the short run and long run to estimate locational asymmetries.

Table 5 reports Wald test results. The acceptance of the null hypothesis indicates the existence of the asymmetries and non-linearities in the variables under consideration. On the basis of the test findings, we are able to reject the null hypothesis of symmetric and linear relationships for all the independent variables (COAL, TRA, EGLO, and EPC) in the long run. The null hypothesis is again not accepted in the short run except for TRA and EPC. It is established from the outcomes that all the independent variables, i.e., COAL, TRA, EGLO, and EPC, embody nonlinear and asymmetric relationships in the long run, but TRA and EPC exhibit linear and symmetric association in short-run dynamics.

**Quantile Granger causality test**

Lastly, we apply quantile Granger causality test to estimate the bi-directional relationship between independent variables and EFP.

### Granger causality in quantile test results

| Quantiles | \( \Delta \text{EFP}_t \) | \( \Delta \text{COAL}_t \) | \( \Delta \text{EFP}_t \) | \( \Delta \text{TRA}_t \) | \( \Delta \text{EFP}_t \) | \( \Delta \text{EGLO}_t \) | \( \Delta \text{EFP}_t \) | \( \Delta \text{EPC}_t \) |
|-----------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| [0.05–0.95] | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.05 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 0.10 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 |
| 0.20 | 0.000 | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 | 0.000 | 0.000 |
| 0.30 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| 0.40 | 0.000 | 0.000 | 0.000 | 0.000 | 0.009 | 0.000 | 0.000 | 0.000 |
| 0.50 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.000 | 0.000 | 0.000 |
| 0.60 | 0.000 | 0.000 | 0.000 | 0.000 | 0.018 | 0.000 | 0.000 | 0.000 |
| 0.70 | 0.000 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 0.000 | 0.000 |
| 0.80 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 |
| 0.90 | 0.000 | 0.000 | 0.000 | 0.000 | 0.016 | 0.000 | 0.000 | 0.000 |
| 0.95 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 |

Source: authors’ estimation

As per the test results provided in table in the “Granger causality in quantile test results” section, it is revealed that the causal relationship exists between two variables at various quantiles. It is found that COAL, TRA, EGLO, and EPC Granger cause EFP and vice versa. It suggests that each of the aforementioned variables has a causal effect on EFP as well as EFP has the same effect on each of the aforementioned variables.

### Discussions

The results indicated that coal rents have a positive impact on EFP. These results agree with Ahmad et al. (2020), which throws light on the role of coal rents in EFP. The study posits that when the difference between the coal production costs and coal market price increase, the profits on the sale of coal commodities encourage the production, extraction, and consumption of coal within the country. In this situation, the environmental quality degrades and natural resources are affected. These results are also in line with the past study of Ahmed et al. (2020), which highlights that in the countries where the coal rents get high, the production and extraction of coals also increase. This increases coal production and the consumption of coal as a major source of adverse impacts on naturally found resources.

The results also revealed that transportation has a positive relation to EFP. These results are in line with Nathaniel et al. (2021), a study that explores the environmental impacts of transportation activities. This study states that in the areas where transportation activities are greater in number, the emissions of harmful gases increase. So, progress...
in transportation enhances environmental issues and deteriorates the green natural resources, animals on the land, and water creatures. These results are also in line with Peri et al. (2018) which show that when the number of cars and bikes in personal ownership increases, the smoke, noise, gathering, and CO2 emissions increase. These all reduce the quality of natural resources like crops, greenery, and livestock which rely on the environment and its elements. So, the increased transportation adversely affects the quality of natural resources quality and, thus, causes ecological footprints.

The results also indicated that economic globalization has a positive relation to EFP. These results also agree with Ansari et al. (2021), which states that economic globalization encourages many economic progressive activities within the country like FDI, exports, imports, and industrialization. The utilization of machines, transportation, production technologies, plants, and construction work within the country enhances dust, smoke, toxic gases, and wastes. So, economic globalization leaves impacts on environmental conditions. These results are supported by Kirikkaleli et al. (2021), which posits that when government provides support to the domestic people to benefit from globalization, they get involved in international trade, which stimulates the economic activities within the country.

The results indicated that electricity consumption has a positive relation to the EFP. The results are supported by Bello et al. (2018), which show that the increase in electricity consumption increases the use of fossil fuels or nuclear power, which are essential factors in the production of electricity. The combustion of fossil fuels and working of nuclear power plants causes pollution emissions. The results reveal that the excessive production and use of electricity within the country increases pollution and destroys the natural resources like earth and its yielding, ocean, and sea creatures.

Policy implications

On the basis of the results, some worthy recommendations for the policy makers are provided to diminish the adverse impact of the variables on environmental sustainability. For many years, over-reliance on fossil fuels for transport systems has been the norm. Initiatives have been made in recent years to convert the transport sector from traditional to renewable sources of energy; however, due to the ever-increasing quantity of automobiles, these efforts are unsuccessful. To address these concerns, first and foremost, the reliance on fossil fuels, such as gasoline and diesel, must be reduced, and automobiles should be improved in terms of functionality. Both strategies would assist in the implementation of environmentally friendly technologies. When it comes to globalization, there are a few things to consider. It is the outcome of actions and rules taken in a variety of areas (international finance, communication, trade, and transportation) and at various political levels (globally and locally). Even if globalization has a negative impact on the environment, it is recommended that while accelerating the speed of globalization in the US economy, strict environmental rules be implemented to alleviate the negative environmental impacts of globalization. To ensure the long-term sustainability of the globalization process as a means of stimulating growth, the USA must increase its participation in regional and global market integration with trading partners by removing trade barriers. Because environmental sustainability is a prerequisite for globalization, strategic efforts to increase environmental sustainability should be adopted.

Concluding remarks and recommendations

In the present study, the ecological footprint EFP is chosen as the indicator for environmental standards owing to the fact that it is a unique metric for environmental situation in a way that it reflects the human country’s economic

| Variables | Wald statistics (P-Value) |
|-----------|--------------------------|
| $P$       | 18.241*** [0.000]        |
| $\beta_{COAL}$ | 11.007*** [0.000]       |
| $\beta_{TRA}$  | 8.991*** [0.000]        |
| $\beta_{EGLO}$ | 5.021*** [0.000]        |
| $\beta_{EPC}$  | 3.710*** [0.000]        |
| $\phi_1$    | 12.999*** [0.000]       |
| $\omega_0$  | 2.585** [0.041]         |
| $\lambda_0$ | 1.004 [0.467]          |
| $\theta_0$  | 8.351*** [0.000]        |
| $\bar{\phi}_0$ | 1.716 [0.159] |

The P-values are between square brackets. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Source: Author estimations.
dependence on natural resources or assesses technological and social effects on the ecosystem. There are a number of existing studies about the determining factors of EFP, but the group of variables used in this study is unique, especially in the context of the USA. The impact of coal rents, transportation, globalization, and electricity consumption on ecological footprints has been estimated by applying the QARDL methodology. The quarterly time-series data used for empirical estimation spans 24 years (1995–2018). At various quantile ranges, the relationship of COAL, TRA, EGLO, and EPC with EFP is estimated in short as well as in the long run by applying QARDL and quantile Granger causality approaches, and several fascinating findings are obtained. Last, we applied the Wald test to test whether the variables are parameter dependent or not. Economic globalization is a significant reason for fast consuming resources and produces a high level of wastage that exposed its positive impact on the ecological footprint.

The results of the QARDL analysis suggested that all the variables COAL, EGLO, TRA, and EPC have a significant and positive impact on the EFP in the USA. The results stated that when there is a disparity between coal production costs and market prices, profits on coal commodities are increased, and coal production, extraction, and consumption are encouraged inside the country. Consequently, the environment’s quality deteriorates, and natural resources are harmed. The emissions of hazardous gases rise in places where transportation activities are more numerous. As a result, advancements in transportation exacerbate environmental concerns like climate change, soil destruction, ocean rise, etc.; thus, it increases EFP. Many economic progressive activities within the country, such as FDI, exports, imports, and industrialization, are encouraged by economic globalization. Thus, there is the use of equipment, transportation, production technologies, plants, and construction work that causes CO₂ emissions and harms natural resources. As the electricity demand rises, the use of fossil fuels and nuclear power, which are crucial variables in the creation of electricity, increases and pollution is produced by the combustion of fossil fuels and the operation of nuclear power plants. So, electricity consumption positively contributes to EFP.

Furthermore, the findings from this study have shown that there is a need for the introduction of more strict environmental policies and regulations that may push industries to switch from the use of energy sources that are carbon emitting to cleaner sources of energy as it will improve environmental quality and promote long-term development. Moreover, there is a need to add more hydroelectricity to the energy mix because greater use of hydroelectricity will reduce the utilization of fossil fuels which are greatly responsible for environmental degradation. The study further suggests that the government in the USA, with the 2nd largest EFP, should encourage businesses and individuals to extract and use coal resources in a safe and sustainable manner. It is strongly advised that the economy should invest more in innovative and environmentally favorable industrial processes in order to reduce carbon emissions and achieve long-term development. To address climate change and achieve sustainable growth, there is a need to change the behavior and lifestyles and introduce a particular energy consumption strategy to reduce carbon consumption.

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Data availability The data that support the findings of this study are attached.

Declarations

Ethics approval and consent to participate We declare that we have no human participants, human data, or human tissues.

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