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Assessing the load capacity curve hypothesis considering the green energy transition, banking sector expansion, and import price of crude oil in the United States

Xianying Pang[1] | **Sana Fatima**[2] | **Onur Yağiş**[3] | **Mohammad Haseeb**[4,5] | **Md. Emran Hossain**[6,7]

[1]School of Rail Transportation, Southwest Jiaotong University Hope College, Chengdu, China

[2]Symbiosis School for Online and Digital Learning, Symbiosis International (Deemed University), Pune, India

[3]Independent Researcher, Canakkale, Türkiye

[4]Department of Management Studies, Graphic Era Deemed to be University, Dehradun, Uttarakhand, India

[5]MEU Research Unit, Middle East University, Amman, Jordan

[6]Department of Agricultural Finance and Banking, Bangladesh Agricultural University, Mymensingh, Bangladesh

[7]Jadara Research Center, Jadara University, Irbid, Jordan

Correspondence
Md. Emran Hossain, Department of Agricultural Finance and Banking, Bangladesh Agricultural University, Mymensingh, 2202, Bangladesh.
Email: emranaerd@gmail.com

Abstract

The existing literature consists of various studies that have addressed the interrelationship between banking expansion and carbon emissions but failed to consider supply-side ecological issues. Keeping this in view, the research aims to assess the impact of green energy transition, banking sector expansion, and import price of crude oil on the "load capacity factor (LCF)" in the United States from 1990 to 2021. The "LCF" has emerged as a novel ecological proxy to date that includes both "biocapacity and ecological footprint." Using the "bootstrap autoregressive distributed lag" model, the research found that the consumption of renewable energy can enhance the ecological quality of the United States. The results verified the acceptance of the "load capacity curve" hypothesis. Moreover, it demonstrates that banking development promotes environmental quality. Specifically, a 1% improvement in the banking industry leads to a 0.93% increase in the LCF in the short term, as well as a 1.28% increase in the long run. Furthermore, the increase in crude oil import prices has a positive impact on the LCF and eventually promotes environmental sustainability. To be precise, a 1% rise in the price of imported crude oil results in a 0.35% increase in the long-term LCF level. These results were backed by the findings of several robustness tests. The study, lastly, recommends that the banking sector and government policymakers should use banking growth in promoting green energy to attain their target of zero carbon emissions by 2050.

KEYWORDS

banking sector expansion, bootstrap ARDL, green energy, load capacity curve, United States

1 | INTRODUCTION

The major contribution to carbon emissions across many countries can be attributed to energy usage (Adams & Klobodu, 2018). For the past few decades, it has been witnessed that with the increasing energy demand, there has been a rise in social and economic development (Boutabba, 2014; Mukhtarov et al., 2020). Moreover, following the Industrial Revolution, there has been a transition in economic production activities from being reliant on labor to being reliant on capital. This movement has resulted in increased energy usage, as more production activities occur during the Industrial Revolution (Erdogan, Pata, et al., 2024; Pata, Erdogan, et al., 2023). However, energy composition has undergone inevitable transformations since the advent of Industry 1.0, therefore altering the ecological equilibrium of the planet. Furthermore, the shift towards cost-effective and environmentally friendly energy sources is a key priority in the sustainable development goals (SDGs-7). Thus, to achieve sustainable growth in the economy and society, economies have made significant efforts to accelerate the proportion of renewable energy in enhancing energy conservation and efficiency, which can effectively mitigate ecological contamination (Menyah & Wolde-Rufael, 2010; Mukhtarov et al., 2022). In this context, this research aims to discover the impact of renewable energy, economic growth (EG), banking development, and crude oil import prices on ecological neutrality in the case of the United States.

The United States is among the nations exhibiting suboptimal ecological performance. The current environmental conditions and pollution levels in the United States have reached a critical and problematic state (Hossain et al., 2023). The lowest value of load capacity factor (LCF) was recorded to be 0.35 in 2006 which rose to 0.52 in 2020 (Figure 1). Although there has been some progress in achieving environmental sustainability, the United States still falls short of the planned targets and is significantly below the sustainability threshold (Figure 1). In addition, the ecological balance of the system falls short of the anticipated aim, since its biocapacity is 202% lower in 2021 than its ecological footprint (EF) (Global Footprint Network, 2024).

However, most previous studies utilized the EF or biocapacity as metrics to assess ecological performance in the United States. Nevertheless, the EF and biocapacity only consider the

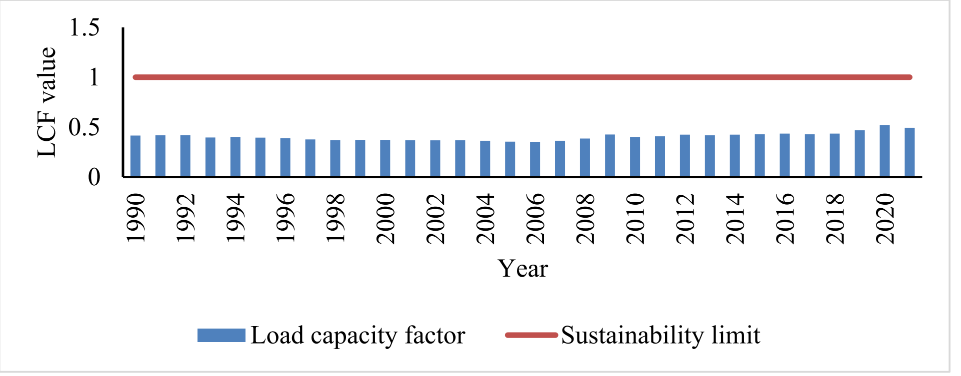

FIGURE 1 Load capacity factor (LCF) of the United States. The calculation of LCF involves the division of biocapacity per person by ecological footprint per person.

demand aspect of the measurement. In this context, the LCF was introduced by Siche et al. (2010) to measure the ecological system's capacity to bear the responsibility for repairing environmental degradation. The LCF facilitates a more comprehensive assessment by considering environmental variables from the perspectives of both demand and supply (Erdogan, 2023; Pata, 2021). The value of LCF may be less, greater, or equal to 1. "LCF = 1" is the equation that denotes the sustainability limit. However, "LCF < 1" signifies an ecological scenario that is not sustainable. On the contrary, "LCF > 1" indicates the presence of a sustainable ecological system (Jahanger et al., 2023). The LCF decreases in the initial phases of the production concerning ecological growth and later it tends to increase as the structure shifts to the service sector. This hypothesis is called the load capacity curve (LCC) hypothesis which is demonstrated with a "U" shaped curve. It was put forth by Dogan and Pata (2022). Given this hypothesis, countries initially seek to support economic development. It uses more fossil fuels, thereby contributing to a rise in pollution. Further, when per capita income reaches its threshold point, people start paying more attention to technological development and renewable energy consumption, thereby enhancing environmental quality (Guloglu et al., 2023).

The banking sector plays an important role in improving the sustainability of the ecological environment by implementing environmental policies both in the public sector and the private sector at optimal rates (Tamazian & Bhaskara Rao, 2010). The banking sector can be directly associated with the financial development of the country, which can further help in improving environmental quality. As the banking sector expands, the economies can pay attention to adopting new technologies to protect the environment from CO_2 emissions. The energy-efficient options along with innovative technologies available at cheaper rates can be encouraged through banking industry expansion (Solarin et al., 2018). Bank assets with a rise in technological advancements have the potential to decrease environmental degradation in the United States (Ahmed et al., 2023).

Despite its domestic production of crude oil, the United States still depends on imported crude oil to revive its economy. It is reported that heavy crude oil for the United States has been imported from countries such as "Canada, South and Central America, and Mexico" in 2021, accounting for 187.1, 29.2, and 29.0 million tons, respectively (BP, 2022). Further, the importing of light crude oil in 2021 from "Saudi Arabia, Europe, Canada, South and Central America" accounted for a total of 17.7 million tons. This data shows the need for global trade to meet the demands of energy usage in the United States, with various countries supplying crude oil to the country (BP, 2022). Since the United States is the second-largest importer of crude oil in the world, it becomes necessary to understand how oil import price fluctuations impact the environmental sustainability of the United States (Mohamued et al., 2021). Thus, based on the above background, the succeeding research questions (RQ) have been formulated:

RQ1: *How does the green energy transition affect the environmental quality of the United States?*

RQ2: *Is the LCC hypothesis valid for the United States?*

RQ3: *How does banking sector expansion affect the LCF?*

RQ4: *How does crude oil import price affect the LCF of the United States?*

The present work contributes to the empirical papers in the following ways: First, this paper seeks to explain the effect of the banking sector on the LCF in the United States. It undertakes LCF, a novel indicator, to capture both supply and demand elements of environmental quality. This study is one of the initial investigations that examine the growth of the banking sector and the concept of LCF within the United States. The United States is currently undergoing an economic boom, leading to an increased demand for capital by firms and individuals for purposes such as investment, consumption, and wealth management. As a result, the banking sector is expanding to cater to these demands. Recently, technological advancements, namely in digital banking, mobile payments, and financial services automation, have significantly changed the banking industry in the United States. The growth of the banking industry may be influenced by the demands of customers, which may put substantial strain on the energy sector and therefore impact the environmental sustainability of the United States; hence, this study is crucial for the United States. Furthermore, it is necessary to investigate the influence of crude oil import prices on environmental sustainability in the United States, given its status as one of the leading importers of crude oil. This analysis will determine if fluctuations in crude oil prices are beneficial for the environment in the United States. Third, this study enhances the existing body of research on the LCC hypothesis by looking at the impact of green energy in the United States. Most of the United States's energy supply is dependent on fossil fuels, with only 9% coming from renewable sources. This study offers policies designed to investigate if increasing the proportion of renewable energy sources can improve long-term environmental quality. Finally, the bootstrap ARDL approach is used in this investigation to enhance the contributions and findings of this work.

2 | REVIEW OF PAST LITERATURE

2.1 | Theoretical support of the study

Sustainable development under green transition has been taken seriously by economies across the globe. During the implementation of the green transition, different shifts in socioeconomic parameters have been observed. The nexus of these parameters is interdependent and impacts each other directly and indirectly. Grossman and Krueger (1991) gave the concept of environmental indicators (EI) that includes deforestation, carbon dioxide, nitrogen dioxide, and other GHG emissions. The relation of EI with EG showed an "inverted U-shaped" curve (see the left side of Figure 2). The emergence of the EI concept brought about a debate among researchers and academicians on the close association between income and the environment. This concept was backed by the "Environmental Kuznets Curve (EKC)" theory which discusses the various shifts that occur in an environment as the EG starts increasing beyond a threshold.

The EF, as termed by Rees (1992), measures the air pollution, water, and soil pollution in units of global hectares which accounts for the human demand on the environment (Rees & Wackernagel, 2023). Against the human demand of EF, a supply term called biocapacity was introduced which is part of a new hypothesis highlighting environmental sustainability and its corresponding changes. If the biocapacity is greater than the EF, environmental sustainability is ensured, otherwise, it indicates that environmental degradation is occurring (Pata & Samour, 2023; Pata & Yurtkuran, 2023).

Recently, the connection between economic expansion and environmental sustainability has been efficiently demonstrated in the LCC hypothesis. It includes various socioeconomic variables interacting in the short and long run to impact environmental quality. Various past studies have used the importance of LCF to address the interconnection between EG and other factors affecting environmental quality (Caglar et al., 2023; Jin et al., 2023).

The LCF shows how environmental performance is impacted due to the changes in heterogeneous social and economic parameters. As the GDP and income rise, the value of LCF tends to decline, indicating a deterioration in the environment. However, the value of LCF reduces in the initial phases of income but after a threshold value of output level, it gradually increases (see right side of Figure 2). Consequently, the LCC curve takes on a U-shaped pattern (Dogan & Pata, 2022; Huang et al., 2023). This states that when countries achieve a certain income level, their biocapacity level starts to increase (Li et al., 2023). This curve suggests an inflection point in per capita income from where the economies transition to green alternatives. Hence, lowering the EF is suggested by the LCC hypothesis to improve the biocapacity in the long and short run (Pata & Tanriover, 2023). In this study, the crude oil price is the production stage parameter, and banking sector expansion is considered as the socioeconomic variable that

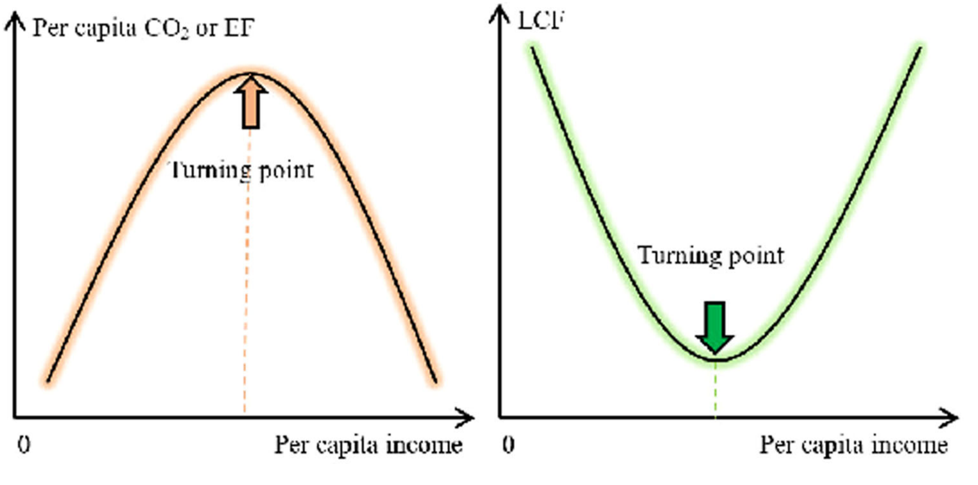

FIGURE 2 Graphical representation of Environmental Kuznets curve and load capacity curve hypothesis. EF, ecological footprint; LCF, load capacity factor.

indicates the structural shift undertaken towards the green energy transition in the United States.

2.2 | Empirical backing of this study

2.2.1 | Energy and environmental quality

This first section of the literature highlights the connection between energy use and ecological quality. Numerous researchers have explored the relationship between energy utilization and ecological quality in different countries with varying income levels such as the "United States, France, China, and Pakistan." With the help of Granger causality, VECM, and ARDL-VECM model, "a unidirectional association between energy use to CO_2 emissions" was found in these countries, respectively (Ang, 2007; Hao & Huang, 2018; Mirza & Kanwal, 2017; Sarwar et al., 2019; Soytas et al., 2007). Moreover, Javid and Sharif (2016), and Ahmad et al. (2016) used the ARDL-VECM model and revealed bidirectional causation from energy utilization to CO_2 emissions for "China, and India," respectively.

Further, Dogan and Seker (2016) stated that the increase in renewable energy consumption (REC) can help in mitigating pollution levels in the United States. Following the same Ma et al. (2021) revealed that REC can significantly reduce CO_2 emissions. In the same context, various studies have shown a decisive association between LCF and REC (Hossain et al., 2023). Contrarily, a recent study by Wang et al. (2024) stated that REC does not have a significant effect on the EF. It should be emphasized that the United States, despite having the seventh largest economy in terms of natural resources, nevertheless relied on 20% of inorganic commodities (Zafar et al., 2019).

Agbede et al. (2021) conducted a study on MINT countries with the Granger causality test for 71 years from 1971 to 2017 using the PMG modeling technique that showed that energy usage, EG, and bio-capacity are positively related to environmental degradation. With every 1% increase in primary energy usage, it has been noted that it increases 0.41% of environmental damage in the long run, even though in the short run it is imperceptible. Energy usage is directly proportional to economic impacts which suggests that the EF increases by 23.06% faster to adjust itself every year in these countries. Considering energy use as a determining factor for environmental degradation, it has been found that nuclear and renewable energy can be of benefit (Pata & Kartal, 2023). Further, bioenergy or biomass energy can help mitigate CO_2 emissions (Wang et al., 2023). Mukhtarov (2024) stated that in Turkey, the utilization of green energy, total factor productivity, and exports have a detrimental impact on CO_2 emissions. Hasanov et al. (2023) obtained comparable findings by employing a machine-learning algorithm in the context of Azerbaijan. In their study, Pata, Kartal, Dam, et al. (2023) found that renewable energy had a positive effect on the LCF in both the short and long term in the Latin American and Caribbean (LAC) countries.

2.2.2 | Economic expansion and environmental quality

Saboori et al. (2012) stated that an inverse U-shaped causation exists between CO_2 emissions and GDP in Malaysia and supported the EKC hypothesis. Similar results were found by Gao and Zhang (2014), Al-Mulali et al. (2015), and Cerdeira Bento and Moutinho (2016) for

Sub-Saharan Africa, Vietnam, and Italy, respectively. Zhang et al. (2021) found a causality between GDP growth to CO_2 emissions in China. The authors suggested an increase in the real output in the county led to increased fossil fuel utilization and ecological pollution. Akadiri and Adebayo (2022) unveiled the positive association between GDP and CO2 emission using the NARDL approach. Recently, Wang et al. (2023) suggested the validation of the EKC framework in the case of G7 countries. Similarly, Xing et al. (2023) used the "STIRPAT model" to understand the EKC curve in Asian countries. Ali et al. (2023) assessed the environmental influence of EG and globalization and it was found that with increasing EG, environmental pollution also increases. In their study, Mukhtarov et al. (2024) discovered a direct correlation between income levels and CO_2 emissions in Kazakhstan, indicating that higher income is associated with increased CO_2 emissions.

Various research investigated the effect of EG on LCF. Awosusi et al. (2022) studied the influence of real output on the LCF in South Africa using ARDL and found an inverse economic expansion-LCF nexus. Similar findings were suggested by Xu et al. (2022), Pata (2021), and Fareed et al. (2021) for Brazil, Japan, the United States, Indonesia, and ASEAN countries, respectively. Another study by Pata, Kartal, Adebayo, et al. (2023) uses the LCF to understand the effects of clean energy technologies from 1974 to 2018 in the United States. It found that economic expansion along with urbanization are instrumental in environmental quality degradation, even though clean energy technologies do not contribute to LCF. Pata, Kartal, Erdogan, et al. (2023) examined the impact of energy R&D on environmental quality while considering the influence of EG and assessed the credibility of the EKC and the LCC hypothesis. The researchers discovered that the EKC hypothesis holds true for Germany, whereas the LCC hypothesis is not supported. Erdogan (2024) examined the influence of combined and separated natural resource revenues and EG on ecological health in African countries. Empirical data supports the validity of the EKC theory, while the LCC hypothesis is not valid.

2.2.3 | Expansion of the banking sector and environment

Several papers have been carried out to study the interlink between "financial expansion and economic expansion." For instance, Erdoğan et al. (2020), Cheng et al. (2021), and Guru and Yadav (2019) suggested a decisive role between finance sectors and EG rate. Further, Shahbaz et al. (2013) and Zaidi et al. (2019) found a positive link between financial expansion and CO_2 emissions for Malaysia and selected countries of Asia, respectively. In BRICS countries, Rafique et al. (2020) found positive financial sector- CO_2emissions nexus. On the other hand, some recent empirical papers showed that with a significant rise in financial development, the level of ecological neutrality decreases in BRICS economies (Zoaka et al., 2022).

However, limited empirical papers mainly assessed the banking expansion-environment link. Radulescu et al. (2022) stated that expansion in the banking industry can have a great impact on environmental quality among OECD countries. Aigbovo and Isibor (2024) found that credit to the private sector, a factor influencing banking sector development, has a significantly positive influence on CO_2 emission.

Furthermore, when green growth is taken into consideration by Ahmed et al. (2023), it was observed, using CS-ARDL and PMG-ARDL techniques, that banking industry improvement has a decisive association with the environmental technology for top polluted economies. Even though the connection is established, Prempeh et al. (2023) tried to dive deeper into this relationship and investigated this relationship for the ECOWAS using a balanced panel data set from 1990 to 2019. The findings stated that banking sector expansion gradually decreases environmental depletion. In a largely populous country like China, a similar ARDL approach was used by Khan and Rehan (2022) to investigate the impact of banking sector development on REC and green growth. It was found that the emissions from 1995 to 2020 have been reduced due to financial inclusion.

2.2.4 | Crude oil import price and environmental sustainability

The dependency on fossil fuels due to the rising demand for energy amid degrading environmental quality has shifted the spotlight to renewable energy sources. The association between crude oil import prices and the sustainability of the environment has received immense attention (Fatima et al., 2021; Li et al., 2020). The price of crude oil is thought to be one of the important factors affecting the economy and energy utilization (Fatima et al., 2021). Since global warming is rising, the authorities are constantly facing oil price shocks (Ullah et al., 2020). The oil prices are likely to impact carbon emissions, environmental depletion, and energy consumption. Ullah et al. (2020) stated that oil pricing is an effective method that can help reduce reliance on fossil fuel, implement energy efficiency, and reduce carbon dioxide emissions, as well as control resource allocation, financing, and risk assessment. Additionally, the increase in oil prices could trigger a shift to cheaper, eco-friendly energy sources, thereby reducing carbon dioxide emissions. In turn, lower oil prices may lead to increased use of fossil fuels, thereby deteriorating the environment (Ebaid et al., 2022).

A study conducted on 26 EU countries by Mohamued et al. (2021) investigated the impact of oil price volatility and GHG emissions. Implementing the Driscoll–Kraay model, they found that there is a positive impact on GHG emissions in oil-producing and importing countries. Regarding achieving the SDGs, a study conducted by Adewuyi and Awodumi (2021) tried to quantify the clean production and the efficiency of energy import in South Africa and Nigeria with data from 1981 to 2015 using the threshold regression analysis on aggregate and sectoral level data. The study identified that when the petroleum import per capita is kept above the threshold, the relationship between oil importation and emissions differs from country to country. Similarly, the South Asian economies were studied by Murshed and Tanha (2021) for their nonlinear association of crude oil prices with renewable energy usage. It was observed that even though the oil price fluctuations do not encourage renewable energy usage in the initial stage. However, once it reaches a threshold level of price, there is evident consumption of renewable energy later.

2.3 | Research gap

Unlike the previous studies, the present study aims to assess the interconnection among the LCF as a novel EI, green energy, crude oil import price, and banking development. As per the literature review conducted, it can be stated that no empirical study has been conducted to understand the linkage between banking development and LCF in the United States. It was noted from the literature review that the banking sector expansion has been only studied for its contribution to environmental degradation, but the LCF has not been studied, although it was reported to have an inconclusive impact when intervened by affluence and populace

(Prempeh et al., 2023). The inconclusiveness should be investigated through a comprehensive analysis of major economies and compared to relatively smaller ones. The LCF in terms of energy usage and the United States dependency on natural resources has been addressed for clean energy technologies only. However, there is no study in the literature that examines the effects of renewable energy usage, banking expansion, per capita GDP and per capita GDP^2, and the increase in crude oil import price on the LCF. Further, the LCC hypothesis has been examined for a nexus of socioeconomic parameters in the United States, but it has yet to include oil price fluctuations.

3 | DATA NARRATION AND METHODOLOGY

3.1 | Data narration and model

The prime aim of the current work is to evaluate the influence of the REC, banking sector expansion, GDP, GDP^2, and the increase in crude oil import price on the LCF in the United States using the data from 1990 to 2021. All variables have been logarithmically transformed to eliminate the issue of numerous units of measurement and to express the calculated coefficients as elasticities. Based on the theoretical background we discussed previously, the theoretical connections among the tested variables are expressed as follows:

$$\text{lnLCF}_{\text{it}} = \beta_0 + \beta_1 \text{InBSD}_{\text{it}} + \beta_2 \text{InGDP}_{\text{it}} + \beta_3 \text{InGDP}^2_{\text{it}} + \beta_4 \text{InREC}_{\text{it}} + \beta_4 \text{OIP} + \varepsilon_t, \quad (1)$$

where InGDP_{it} is the GDP per capita (2015 = 100) in USD and gathered from the World Bank. InGDP^2_{it} is the GDP per capita squared, InREC_{it} is the "consumption share (%) of renewable energy out of total energy utilization" which is accumulated from the BP Statistics website. LCF_{it} is LCF (captured as biocapacity/EF) which is extracted from the "Global Footprint Network" database. lnOIP is the crude oil import price measured in USD per barrel of oil and collected from the OECD database. In the context of InBSD, it refers to the expansion of the banking sector. This is measured by combining three indicators: % of private credit in the loan and savings banking industry relative to GDP, % of banks deposited assets relative to GDP, and the proportion of banks' liquid liabilities relative to GDP. "Principal Component Analysis (PCA)" is used to enhance the representation of these three proxies in BSD measurement. The PCA result is displayed in Appendix A. Only elements with an eigenvalue greater than 1 are chosen for this study. The eigenvalues indicate that the 1st and 2nd primary elements effectively represent the BSD index; thus, considered in our estimated models. Data for these three elements variables were obtained from the "World Bank Global Financial Development Database."

3.2 | Bootstrap ARDL (BARDL) methodology

Before using the BARDL technique, we assessed the stationarity and cointegration features of the time series data. The study employed ADF as suggested by Dickey and Fuller (1979) for unit root testing. However, this assessment does not consider the dates of structural break (DSB); to overcome this issue, the current paper employed the "Perron and Vogelsang (PV) unit root assessment" accounting for DSB as introduced by "Perron and Vogelsang (1992)."

To test the interaction among BSD, GDP, GDP^2, REC, OIP, and LCF in the United States, the existing work utilized the BARDL approach introduced by McNown et al. (2018). In conventional ARDL testing, an F-test (F-statistic$_{ov}$) on the lagged level variables, and t-tests are employed to explore the long interrelation among variables. However, the BARDL cointegration approach suggests an additional F-test on the independent examined variables. Therefore, the upgraded ARDL method considers three statistical assessments: "(i) an F-test (F-statistic$_{ov}$) on the lagged levels of all the employed variables, (ii) a t-test (t-statistic$_{DV}$) on the lagged levels of the dependent variable, and (ii) an F-test (F-statistic$_{IDV}$) on the lagged levels of the explanatory selected variable (McNown et al., 2018). The third test is a supplementary test proposed by McNown et al. (2018). This test circumvents the assumption made by Pesaran et al. (2001) that the dependent variable is integrated of order 1, that is, ($I(1)$), to eliminate the possibility of having degenerate lagged independent variable(s). The F-statistic generated from this test was compared to the critical values (CVs) provided by Sam et al. (2019). In the first test, the lower and upper-bound CVs provided by Narayan (were utilized. In the second test, the CVs provided by Pesaran et al. (2001) were used."

This process ensures the stability of the outcomes in typical co-integration approaches. Furthermore, the enhanced method permits the consideration of endogeneity in numerous variables that are being investigated. Furthermore, the revised ARDL method is an appropriate strategy for the empirical model to incorporate several tested variables. The cointegration amid the BSD, GDP, GDP^2, REC, OIP, and LCF will be determined if the values of F-statistic$_{ov}$, t-statistic$_{DV}$, and F-statistic$_{IDV}$ exceed the CVs. This approach is examined and formulated as below:

$$\Delta \ln \mathrm{LCF}_{it} = \alpha_0 + \sum_{i=1}^{r} \gamma_1 \Delta \ln \mathrm{LCF}_{t-j} + \sum_{i=1}^{r} \gamma_2 \Delta \mathrm{lnBSD}_{t-j} + \sum_{i=1}^{r} \gamma_3 \Delta \mathrm{lnGDP}_{t-j} + \sum_{i=1}^{r} \gamma_4 \Delta \mathrm{InGDP}^2_{t-j} + \sum_{i=1}^{r} \gamma_5 \Delta \mathrm{lnREC}_{t-j} + \sum_{i=1}^{r} \gamma_6 \Delta \mathrm{lnOIP}_{t-j} + \delta_1 \ln \mathrm{LCF}_{t-1} + \delta_2 \mathrm{lnBSD}_{t-1} + \delta_3 \mathrm{lnGDP}_{t-j} + \delta_4 \mathrm{InGDP}^2_{t-j} + \delta_5 \mathrm{lnREC}_{t-j} + \delta_6 \mathrm{lnOIP}_{t-j} + \omega \mathrm{ECT}_{t-1} + \varepsilon_{1t}, \tag{2}$$

where ε_{1t} is the residual term; Δ presents first difference operation; α means the uninterrupted term; γ_1, γ_2, γ_3, $\gamma_4 \gamma_5$, γ_6 and δ_1, δ_2, δ_3, δ_4, δ_5, δ_6 present the estimated coefficients of the LCF, BSD, GDP, GDP^2, REC, and OIP in the short and long run, respectively. r means the lags selections using the AIC value; and ωECT_{t-1} represent the is the "error correction term" that displays the rate of change of the variable being investigated.

To check the robustness of the prevailing empirical model, the current study uses a number of statistical diagnostic tests, including the "Ramsey RESET test (R^{-X})" to assess the stability in the examined model. The "ARCH test (A^{-X}), the Breush-heteroscedasticity test (B^{-X}) and the normality test (N^{-X})" to confirm that the model is correct and avoid any autocorrelation. The current study also utilized the "CUSUM" and "CUSUM-square" tests to affirm that the examined model is correct. On the other hand, the study used the "fully modified ordinary least square (FMOLS)" and "dynamic ordinary least square (DOLS)" regression to check the validity of the BARDL results.

4 | EMPIRICAL FINDINGS

Table 1 displays the descriptive data of the specific series of investigations. The findings show the values of mean, median, maximum, minimum, and standard deviation, which enables enhanced comprehension of the examined data and how it is dispersed across the structure.

TABLE 1 Statistical description of data.

Variable	Average	Median	Max.	Min.	Std. Dev.
$\ln \text{LCF}_t$	−1.16651	−1.14026	−1.03996	−1.42169	0.093895
$\ln \text{BSD}_t$	4.558917	4.574761	4.811894	4.345675	0.139131
$\ln \text{GDP}_t$	10.48233	10.46408	11.03214	10.56462	0.111886
$\ln \text{REC}_t$	1.017078	0.704087	2.366752	−0.06233	0.853893
$\ln \text{OIP}_t$	2.87341	1.98241	3.32411	1.08612	0.345231

The LCF exhibits the least amount of oscillation in the data series, as it has the lowest value in terms of standard deviation. On the other hand, REC has the largest level of volatility throughout the invested period of time. The GDP has the greatest average value, with the BSD following closely after. The variable REC has the greatest range since it exhibits a higher disparity between its maximum and minimum values compared to other variables. Figure 3 displays the time series plot of the variables being examined.

Table 2 displays the findings of the unit-roots analysis. The findings of these tests affirm the chosen variables (LCF, BSD, GDP, GDP^2, REC, and OIP) are stationary at the first process (Δ). Hence, the focused variables of this research are integrated at $I(1)$. Both the ADF and PV tests yield comparable results as all the variables are integrated at the first difference operator. Nevertheless, the PV test also indicates the presence of a structural break in the data series. The LCF data series indicates a break date in 2009, while the BSD data series indicates a break date in 2000. This is because the American banking sector has transitioned from traditional banking to extensive automation during the 2000s. Furthermore, since 2009, the LCF value has shown a tendency to rise due to the American government's adherence to stringent environmental rules aimed at promoting sustainability. However, the break dummy variable was excluded from the main model due to its lack of significance. Furthermore, the model without the break dummy variable exhibited greater stability compared to the model that included it.

The outcomes of the BARDL method of cointegration are displayed in Table 3. The outcomes affirm that the "F-statistic$_{-OV}$, t-statistic$_{-DV}$, and F-statistic$_{-IDV}$" values outpace the CVs of the BARDL approach. These results reinforce that the cointegration amid the LCF, GDP, GDP^2, REC, BSD, and OIP is confirmed.

Table 4 shows the empirical findings of the empirical model in short and long-run analysis. The results demonstrate a strong and positive correlation between the BSD and the LCF. A 1% enhancement in the banking industry in the United States is correlated with a noteworthy gain of 0.93% in the near term and 1.28% in the long term in the LCF. These findings align with the conclusions of Radulescu et al. (2022), who affirmed that the progress of banking has a substantial impact on achieving ecological neutrality in OECD nations.

Similarly, a negative correlation between GDP per capita and LCF is reported. A rise of 1% in the per capita GDP of the United States is associated with a decline of 1.87% and 1.60% in the LCF in both the short and long term, respectively. These findings align with the research done by Fareed et al. (2021), which confirmed the favorable correlation between GDP and LCF in Indonesia. On the other hand, the findings indicate that the square of per capita GDP has a positive influence on LCF in both the short and long term. An increase of 1% in the United States per capita GDP^2 is associated with a significant decrease of 0.32% and 0.68% in LCF in

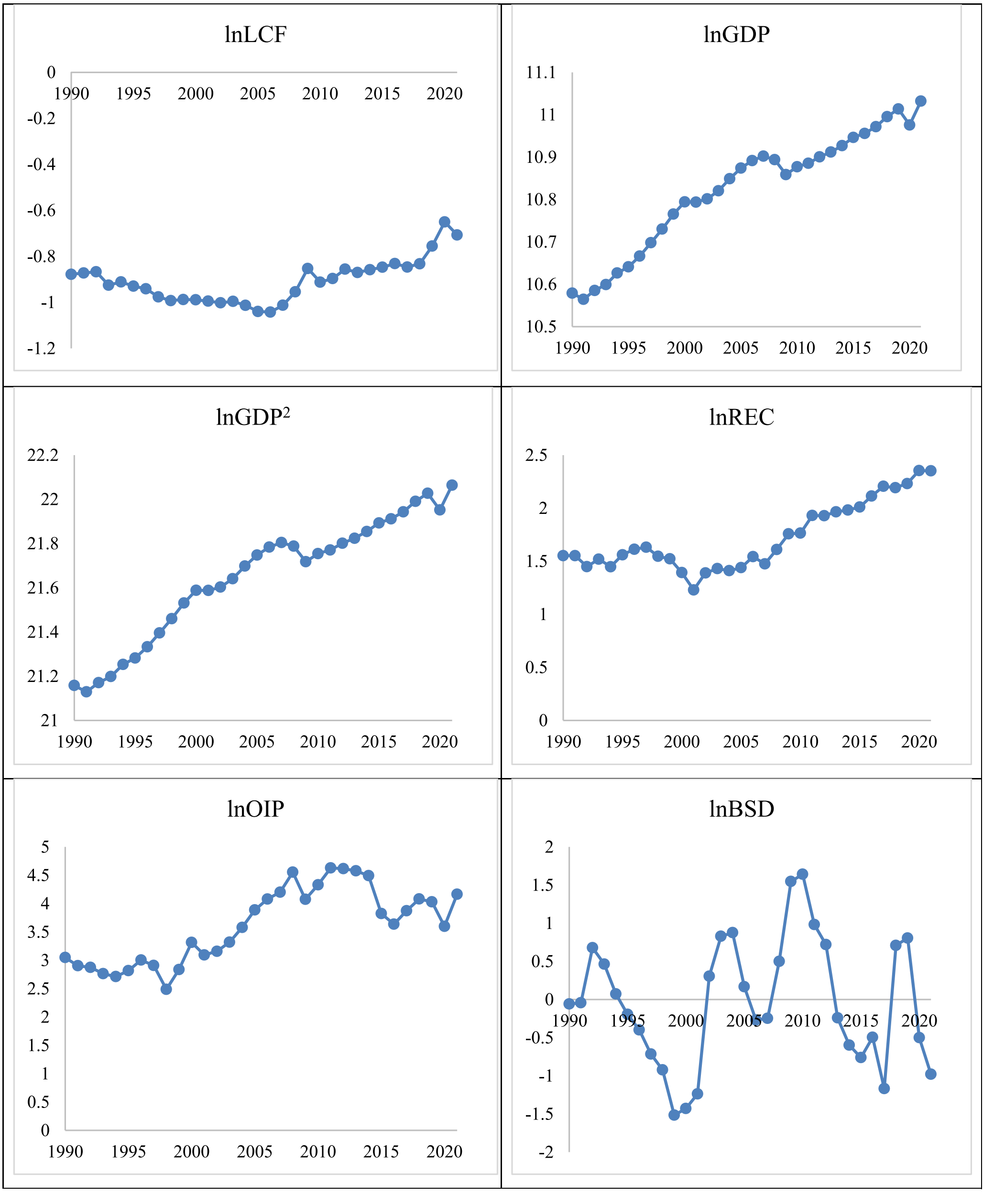

FIGURE 3 Time series plot of the selected variables.

both the short and long term, respectively. The LCC hypothesis is derived from the coefficient of per capita GDP and per capita GDP^2.

The results of this study indicate that a 1% rise in REC leads to a 0.38% increase in LCF level in the short run and a 0.31% increase in the long run. The findings are corroborated by significant statistical data presented by Adebayo (2022), indicating that REC exerts a potent influence on strengthening the LCF. The rise in import prices of crude oil had a growing impact on the LCF. Specifically, a 1% rise in the price of imported crude oil will lead to a 1.54% increase

TABLE 2 The stationarity testing.

Variables	ADF test Level	ADF test 1st difference	PV test Level	DSB	1st difference	DSB
$\ln LCF_t$	−1.107	−6.157***	−4.012	1997	−6.765***	2009
$\ln BSD_t$	−0.124	−4.116***	−2.900	2010	−7.453***	2000
$\ln GDP_t$	−1.098	−5.983***	−0.897	1991	−6.616***	2009
$\ln GDP_t^2$	−0.974	−3.872***	−1.086	1993	−5.903***	2010
$\ln REC_t$	−1.991	−3.886***	−1.199	2004	−5.078***	1995
$\ln OIP_t$	−0.8973	−4.8732***	−1.783	2006	−6.784***	2008

***Significance level at 1%. DSB symbolizes dates of structural break.

TABLE 3 The BARDL cointegration approach.

	BARDL findings			Diagnostic tests			
	$F.stat_{-OV}$	$t.stat_{-DV}$	$F.stat_{-IDV}$	R^{-X}	A^{-X}	N^{-X}	B^{-X}
Estimate value	7.982**	−4.863**	7.532**	0.61^{FS}	0.32^{FS}	0.07^{FS}	0.72^{FS}
CV at 5%	6.294	−3.810	5.306	0.56^{PV}	0.71^{PV}	0.96^{PV}	0.70^{PV}

Note: "*F*-statistic$_{ov}$ means an *F*-test on the lagged levels of all the employed variables, *t*-statistic$_{DV}$ means a *t*-test on the lagged levels of the dependent variable, and *F*-statistic$_{IDV}$ means an *F*-test on the lagged levels of the explanatory selected variable.

Abbreviations: FS, *F*-statistics; PV, *p*-value.

**Significance at 5%.

TABLE 4 BARDL testing results.

Variable	Coeff.	t_{stat}	*p* Value
Short run results			
$\Delta \ln BSD_t$	0.93389***	2.87312	0.002
$\Delta \ln GDP_t$	−1.87451**	−2.45431	0.023
$\Delta \ln GDP_t^2$	0.32871	1.71781	0.112
$\Delta \ln REC_t$	0.38211**	2.20892	0.041
$\Delta \ln OIP_t$	1.54312***	3.76311	0.002
Long run result			
$\ln BSD_t$	1.27812***	7.98712	0.000
$\ln GDP_t$	−1.60081***	−4.25876	0.001
$\ln GDP_t^2$	0.67549**	2.43289	0.024
$\ln REC_t$	0.30987***	3.09651	0.001
$\ln OIP_t$	0.34870***	4.98430	0.000
ECT_{t-1}	−0.67542***	−5.09642	0.000

*, ** and *** symbolizes significances at 10%, 5%, and 1%.

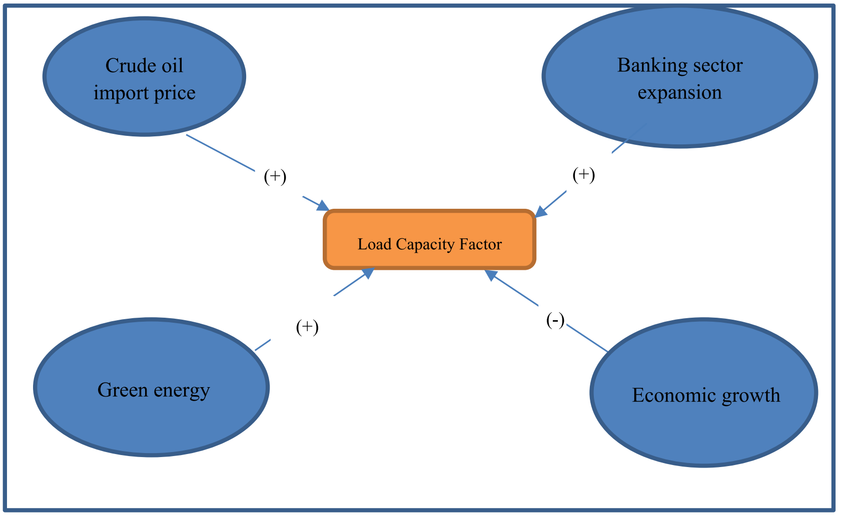

FIGURE 4 Graphical presentation of long-run results. (+) Positive effect, and (−) negative effect.

in the short-term LCF and a 0.35% increase in the long-term. In this scenario, it leads to an improvement in environmental quality. In this scenario, policymakers should enact regulations that give priority to the environment and simultaneously impose restrictions on the import of crude oil, as crude oil contributes to the degradation of environmental quality. Figure 4 displays the visual depiction of the long-term outcomes of the estimated model.

ECT_{t-1} represents the transition of production functions to a state of long-term equilibrium, with a speed adjustment of 67.54% from the short to long-term in the calculated model. To ensure the stability of the existing work paradigm, some diagnostic tests are conducted. Table 3 presents the outcomes of the diagnostic assessment. The results of the "heteroscedasticity test (B^{-X})" depicted that data are homoscedastic and autocorrelation test (A^{-X})" reinforced that no serial autocorrelation exists in the studied model. Likewise, the "normality test (N^{-X})" reinforced that the studied model is normally distributed and the "Ramsey RESET test (R^{-X})" reinforced that the model is statistically stable. The "CUSUM" and "CUSUM square" assessments are illustrated in Figure 5. The figures showed that the "blue line" falls between the red presented lines. Thus, the figure affirmed that the model of the current work is formulated correctly. Table 5 presents the results of the FMOLS and DOLS models. Both models indicate that the coefficients have the same sign as the BARDL results. This suggests that the coefficients generated from the BARDL results are reliable and consistent and can be used for policy implications.

5 | FINDINGS DISCUSSION

The BARDL investigation revealed that there is a negative correlation between GDP per capita and LCF in the United States for the specified time period. The study also confirms that an increase in square GDP per capita has a positive effect on LCF. Consequently, the LCC framework holds valid in the United States means that a higher income level will lead to a rise in ecological pollution during the initial phase of economic development. Subsequently, this

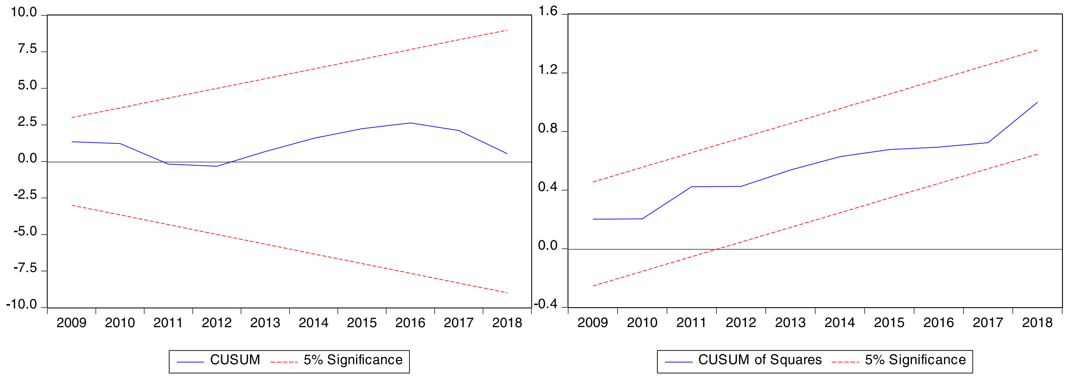

FIGURE 5 CUSUM and CUSUM square tests.

TABLE 5 Robustness check using the FMOLS and DOLS approach.

Variables	FMOLS coeff.	DOLS coeff.
$\ln GDP_t$	−0.7653**	−0.9984***
$\ln GDP_t^2$	0.3718*	0.6542**
$\ln BSD_t$	0.2543**	0.4532**
$\ln OIP_t$	0.4409***	0.6541***
$\ln REC_t$	0.1982***	0.2981***

*, ** and *** symbolizes significances at 10%, 5%, and 1%.

advancement will have a substantial impact on advancing ecological sustainability. The literature by Pata (2021) and Ni et al. (2022) also documents similar findings.

Moreover, the results confirmed that REC had a positive impact on ecological quality in the United States. These findings can be attributed to the United States ongoing efforts to enhance its environmental quality through a substantial shift towards renewable energy sources, as opposed to fossil fuels. Additionally, the United States has significantly increased its reliance on renewable energy sources, which now account for around 9% of its total energy utilization. Another crucial issue is attaining environmental quality while pursuing economic development. The United States has pledged to transition its energy strategy to a renewable form to develop a sustainable energy source, which is of utmost importance in the modern world for generating electricity and COP26 pledge. The results align with the research conducted by Awosusi et al. (2022), Shang et al. (2022), and Wang et al. (2024).

The results confirmed that the growth of the banking industry had a favorable impact on the level of environmental sustainability in the United States. The positive improvement in the banking industry in the United States can be linked to these results. In this particular scenario, the aggregate amount of credit extended by banks in the United States to the entire market expressed as a percentage of the GDP, was approximately three times greater in 2022 compared to the GDP value recorded in 1990. The aforementioned findings are also documented by Zoaka et al. (2022), Radulescu et al. (2022), and Aigbovo and Isibor (2024). Nevertheless, the banking industry in the United States is widely recognized for its significant role in facilitating the transition from fossilized to green energy. The banking industry in this country is actively involved in supporting low-carbon initiatives by offering financial resources to green energy initiatives. The findings of this paper provide important insights into establishing a stable banking industry by rectifying its energy sources and adopting environmentally friendly investment policies.

This study found that the rise in the price of imported crude oil had a positive impact on the environmental sustainability of the United States. Increased crude oil import prices can encourage investments in green energy sources like solar, wind, and geothermal power. With the increasing expense of fossil fuels, the competitiveness of green energy is growing, resulting in a greater implementation of clean energy infrastructure and a decrease in reliance on carbon-intensive fuels. In addition, the increase in pricing for imported crude oil can stimulate initiatives to enhance energy efficiency in various sectors, including transportation, industrial, and residential structures in the United States. Furthermore, higher oil prices could bolster public and political backing for carbon pricing schemes, emissions controls, and climate policies. Ultimately, in the United States, increasing oil prices could speed up initiatives to diversify energy sources and decrease reliance on imported fossil fuels, thus enhancing the environment. This finding is supported by research conducted by Ullah et al. (2020).

6 | CONCLUDING REMARKS AND POLICY SUGGESTIONS

6.1 | Conclusions

Energy and environmental literature have extensively examined the connection between "energy, economic expansion, financial growth, and the environment." Most empirical research has utilized CO_2 and EF to quantify environmental quality. Recently, certain celestial research has utilized the LCF as a measure to assess comprehensive ecological quality. This study is the first to examine the influence of banking expansion and crude oil import prices on the LCF in the United States between 1990 and 2021. Furthermore, this study also examines the LCC framework within the context of the United States, specifically concerning the transition towards green energy. The study utilized the bootstrap ARDL technique.

The outcomes of the used model demonstrate that REC has a favorable impact on the LCF, hence enhancing environmental sustainability. Conversely, the empirical findings indicate that GDP has a negative impact on LCF, but the square of GDP has a favorable impact on LCF. Therefore, the LCC framework has been accepted in the context of the United States. Nevertheless, the primary result of this study indicates a favorable correlation between banking expansion and LCF. Ultimately, the import price of crude oil has a positive effect on the LCF, indicating that it enhances environmental sustainability in the United States.

6.2 | Policy implications

The study proposes several consequences for policymakers in the United States, based on the reported results. These recommendations are as follows:

- The officials in the United States should actively encourage investment in environmentally friendly initiatives while imposing restrictions on the use of finance channels for antiecofriendly technology and projects. Within this particular environment, the banking sector has the potential to assume a more substantial role in enhancing the ecological integrity of the US economy. The authorities in this sector need to modify their financial systems and enhance new funding channels to facilitate the advancement of green initiatives. For instance, the banking industry must assess the degree of environmental risk associated with every financial procedure. Furthermore, lower the interest rate on environmentally friendly investments.

- Policymakers should formulate measures aimed at enhancing the adoption of green energy sources to reduce carbon emissions in the United States. This can be achieved by executing strategic measures, such as enacting carbon price legislation by the government and enhancing the capacity of households and investors to adopt and support the use of green energy in their activities and investments. To facilitate these endeavors, governments must create a conducive atmosphere by granting investors and consumers access to green energy sources. Moreover, this boost could also be encouraged by removing hurdles in green-energy sources investments and trade and lowering contradictions among investors and local bodies.
- The influence of rising crude oil import prices on environmental sustainability in the United States is contingent upon a multifaceted interaction of market dynamics, legislative actions, technology breakthroughs, and societal decisions. To optimize the environmental advantages of shifting from fossil fuels to cleaner and more sustainable energy sources, it is essential to adopt a comprehensive strategy that integrates market-driven incentives, regulatory interventions, and collaborations between the public and private sectors.

6.3 | Future research directions

Initially, our attention was only directed towards the United States. Therefore, the next empirical research can concentrate on panel data, specifically on G7 and BRICS economies. Furthermore, we utilized bootstrap ARDL to establish the connection between the chosen variables. In future empirical studies, researchers can utilize other methodologies, such as quantile ARDL, to get results that are particular to different quantiles. Ultimately, we utilized data sets spanning from 1990 to 2021, considering the constraints imposed by the availability of data, specifically regarding LCF. Thus, fresh empirical works can utilize more current data if it is accessible.

AUTHOR CONTRIBUTIONS

Xianying Pang: Conceptualization; investigation; writing—original draft; data curation; funding acquisition. **Sana Fatima**: Writing—original draft; resources; Formal analysis. **Onur Yağiş**: Writing—original draft; visualization; software. **Mohammad Haseeb**: Writing—original draft; project administration; visualization. **Md. Emran Hossain**: Writing—original draft; writing—review and editing; validation; supervision; methodology.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data used in this study is publicly available and can be found by browsing the website mentioned in the data source of the manuscript.

ORCID

Onur Yağiş http://orcid.org/0000-0003-3457-657X
Md. Emran Hossain http://orcid.org/0000-0001-6882-0177

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APPENDIX A

See Table A1.

TABLE A1 PCA for estimating BSD index.

Primary element	Eigen-value	Proportion	Cumulative
Element 1	1.78321	0.574	0.574
Element 2	1.19324	0.398	0.972
Element 3	0.21365	0.028	1
BSD index elements	Element 1	Element 2	Element 3
Private credit in the loan and savings banking (% of GDP)	0.6152	0.1543	−0.6991
Banks' assets deposited (% of GDP)	0.6753	−0.0631	0.7068
Liquid liabilities (% of GDP)	−0.0982	0.9763	0.1081