SIN-CHN
SCIENTIFIC PRESS PTE.LTD.

Sustainable Economies 2025, 3(1), 1424.
https://doi.org/10.62617/se1424

Article

The determinants of load capacity factor: Evidence from GCC countries

Oluwatoyin Abidemi Somoye[1,*], Toluwalope Seyi Akinwande[1], Muhammad Mar'I[2], Huseyin Ozdeser[1]

[1] Department of Economics, Near East University, 99138 Nicosia, Cyprus
[2] Department of Banking and Finance, Near East University, 99138 Nicosia, Cyprus
*** Corresponding author:** Oluwatoyin Abidemi Somoye, abidemi.somoye@neu.edu.tr

CITATION

Somoye OA, Akinwande TS, Mar'I M, Ozdeser H. The determinants of load capacity factor: Evidence from GCC countries. Sustainable Economies. 2025; 3(1): 1424. https://doi.org/10.62617/se1424

ARTICLE INFO

Received: 21 January 2025
Accepted: 11 February 2025
Available online: 19 February 2025

Abstract: In light of the global aim of reaching net-zero emissions, numerous studies have examined the leading causes of ecological decline, including carbon dioxide emissions, ecological footprints, and other greenhouse gases. These measures only consider the ecosystem's demand side, ignoring its supply side. To fill this gap, this research investigates the Load Capacity Factor (LCF) determinants in four GCC economies from 1992 to 2021 using the Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL), Panel Vector Autoregression (PVAR)-Granger Causality test, and JKS test. The determinants considered in this study include Total Natural Resources Rents (RENT), Gross Domestic Product Per Capita (GDP), and Financial Globalization (FGLO). The PMG–ARDL's result demonstrates that, in the short term, GDP, and RENT spur LCF, while FGLO is marginally beneficial. The JKS and PVAR-Granger Causality tests reveal a strong causal movement from RENT, GDP and FGLO to LCF, validating the PMG-ARDL findings. The study recommends that the GCC economies develop strategic ways to expand their economies while ensuring ecological quality. These strategies could entail the adoption of new technology, which will provide better ways of using fossils and adopting renewables, which can contribute to environmental progress.

Keywords: load capacity factor; natural resource rent; GDP; financial globalization; GCC countries

1. Introduction

The United Nations SDGs 7 and 13 have emphasized the importance of ecological soundness. As a result, diverse studies have explored the determinants of environmental pollutants like carbon dioxide emissions (CO_2) [1–5] and ecological footprint (ECF) [6–11]. These metrics neglect the supply side of the ecosystem. Thus, this study uses the load capacity factor (LCF).

To derive the LCF, biocapacity (BIOCAP) is divided by ECF [12]. In a case where LCF is greater than 1 (LCF > 1), the population's energy needs can be supplied. On the contrary, if LCF < 1, the ecosystem will experience limitations in its sustainability [12–14]. The LCF shows the degree to which a country can support its population in light of the way people now live [15]. The ECF introduced by Wackernagel and Rees [16] determines how much natural resources, water, and arable land must be available to maintain human production and consumption [17]. This encompasses the land required for cultivating food and fiber, using wood, and absorbing waste [18]. ECF also captures the pollution from soil, air, and water [19]. The ECF is the sole metric that measures the quantity of natural resources we have and use. This allows local leaders to maximize their public project expenditure, countries to improve sustainability and well-being, and citizens to understand their impact on the environment with the help of ECF [20]. BIOCAP, on the other hand, describes nature's capacity to meet human needs [21]. It is concerned with making the most of the available resources [22]. Hoekstra [23] refers to it as the world's carrying capacity. Comparing BIOCAP and ECF—which share the same unit of measurement—can provide valuable insights into the sustainability of the ecosystem [18]. Thus, the Load Capacity Curve (LCC) hypothesis, as discussed by Yang et al. [24] and Guloglu et al. [21], is shown in **Figure 1**.

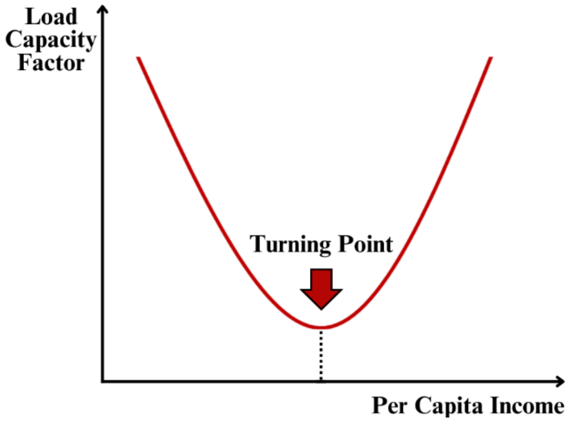

Figure 1. LCF.

According to Guloglu et al. [21], the LCC demonstrates that before the turning point, ECF rises and biocapacity falls, indicating that countries first contribute to environmental deterioration by increasing their demand for fossils to sustain national income. Following the per capita income tipping point, LCF improves due to environmental consciousness, using renewable energy sources, and developing technology to decrease ECF and boost biocapacity. In the end, this U-shaped connection indicates that LCF can gradually improve with income.

Different factors can affect LCF, including natural resource rents (RENT), gross domestic product (GDP), and financial globalization (FGLO). These three factors are the focus of this study. According to the World Bank [25], RENT comes from minerals, forests, hard and soft coal, natural gas, and oil. Pata and Isik [26] stated that due to the generation of RENT through the extraction of coal, oil, and minerals, the capital stock of a country declines. In addition, pollution soars, and the nation borrows against its future when such RENT supports present consumption rather than investing it in its capital and infrastructure [27]. Due to industrialization, frequent extraction dampens BIOCAP and spurs ECF [28]. Degradation of the environment follows because of negative demand and supply pressure on the LCF. It is essential to state that natural resource extraction is fueled by a nation's responsibility to improve the living standards of its people. Globalization has increased the goods and services produced and the financial flows between countries, making room for a stable financial system [29]. Globalization has also made it easy for countries to trade with one another and attract foreign direct investment (FDI) [30]. This trade liberalization has fostered two environmental effects known as the scale and composite effect. The influence of global trade on the level of output is known as the scale effect [31]. This increases the international market's demand for goods and services, stimulating economic activities [32]. The association between a nation's production and trade compositions is called the composition effect. It clarifies why industrialized nations focus on clean industries while developing nations specialize in unclean industries [33,34]. A well-developed financial system increases the incentive for economic growth. It expands the possibility of obtaining capital but also increases the utilization of energy and environmental pollutants [35]. A developed financial system also encourages the adoption of innovative production techniques and the acquisition of cutting-edge, ecologically friendly, and energy-saving technology, which reduces environmental deterioration [36]. Globalization further reduces ecological quality due to rapid production and financial progress.

We focused on the Gulf Cooperation Council (GCC) nations because of their significant influence on the world energy market and the urgent need to comprehend how their economic development is consistent with ecological sustainability. Second, the GCC economies are endowed with energy reserves. Thus, they are continually taking giant strides toward industrialization and the modernization of their economies. Interestingly, energy usage in these bold projects is the primary source of environmental harm [37]. The graph of the GCC economies is reported in **Figure 2**.

Figure 2. GCC countries.

Thus, this research investigates the impact of RENT, GDP, and FGLO on LCF in GCC economies. The following are the study's gaps and contributions: (i) This study used LCF, a supply-side indicator, as a substitute for ecological soundness. This holistic assessment makes ecological processes more explicit [24]. Other studies have focused on the demand side of the ecosystem. (ii) There is inadequate research on the determinants of LCF, especially in GCC economies. Economies in the OECD, BRICS, and E7 have received more attention in other studies. (iii) This research used the Pooled Mean Group Autoregressive Distributed Lag (PMG-ARDL) method adopted by Dam et al. [38]. However, other novel methods, such as the JKS and the Panel Vector Autoregressive (PVAR)-Granger Causality tests, were employed. Utilizing a combination of econometric techniques prevents impartial results. (iv) The globalization index has been used in other studies as a stand-in for globalization. FGLO, however, is used in this study as a proxy for globalization. (v) Lastly, this study found that RENT, GDP, and FGLO influence LCF positively in the short run but negatively in the long run. This is in contrast to the existing literature.

This is how the study is organized: Section 1 explores the idea of LCF; Section 2 presents the reviewed literature; Section 3 deals with the data and methodology; Section 4 analyzes and discusses the findings; and Section 5 wraps up the study.

2. Reviewed literature

This segment investigates the association between RENT, GDP, FGLO, and LCF.

2.1. RENT and LCF association

Various studies have shown that the link between RENT and LCF is asymmetrical. This means that the connection can be positive or negative. Pata and Isik [26] for China, Ni et al. [39] for 11 high resource—consuming economies, and Adebayo et al. [40] for Thailand established that RENT reduces LCF. In addition, Akadiri et al. [13] revealed that RENT has no association with LCF in the short run, but the long run association is positive. Furthermore, Yang et al. [24] for BRICS and Li et al. [41] for Next-11 economies also established an adverse association. On the contrary, (21) for 26 OECD economies, Sun et al. [42] for 17 APEC countries, Wang et al. [43] for 96 developing economies, and Villanthenkodath and Pal [44] for India established that RENT improves LCF.

2.2. GDP and LCF association

The link between GDP and ecological quality is an important topic debated globally. More studies have confirmed this association to be harmful because of the use of unclean energy. Liu et al. [45] and Awosusi et al. [46] for South Africa, Abdulmagid Basheer Agila et al. [47] for South Korea, and Akadiri et al. [13] for India in the long run, Shang et al. [48] for the ASEAN economies, Pata and Balsalobre-Lorente [49] for Turkey, Ni et al. [39] for 11 high-resource-consuming economies, Xu et al. [50] and Kirikkaleli and Adebayo [51] for Brazil, Awosusi et al. [52] for Japan, Yang et al. [24] for BRICS, Li et al. [41] for Next-11 economies, Khan et al. [53] for G7 and E7 economies, Sun et al. [42] for 17 APEC economies, Dam et al. [38] for 22 OECD countries, Raihan et al. [54] for Mexico, and Pata et al. [55] for 11 LAC ascertained that an increase in GDP reduces LCF. On the contrary, studies have also shown that GDP can improve LCF: Okezie et al. [56] for Nigeria and Caglar et al. [57] for BRICS.

2.3. FGLO and LCF association

According to KOF Swiss Economic Institute [58], globalization has different dimensions, including economic (trade and financial), social, and political. All these components make up the globalization index. Saud et al. [35] for OBOR economies, Awosusi et al. [46] for South Africa, and Villanthenkodath and Pal [44] established that GLO improves the environment, while Li et al. [41] for Next–11 economies, and Pata et al. [55] for 11 LAC countries revealed that GLO diminishes LCF. Specifically, Agila et al. [47] for South Korea found that TGLO decreases LCF, Yang et al. [24] established that SGLO reduces LCF for BRICS, while Kirikkaleli and Adebayo [51] discovered that SGLO improves LCF for Brazil. Ulucak et al. [36] for 15 emerging countries, Akadiri et al. [13] for India, Xu et al. [50] for Brazil, and Raihan et al. [54] for Mexico ascertained a positive FGLO–LCF nexus. Saud et al. [35], however, ascertained that the development of the financial system could hinder ecological quality.

The gaps in the evaluated literature are noted: (i) The relationship between RENT, GDP, FGLO, and LCF yields mixed results. This indicates that no definitive outcome has been reached about the study questions; (ii) this research, along with a few others, employs LCF to examine the supply side of the environment rather than the demand side, which is centered on ECF and CO_2; (iii) globalization metrics employed in other research include the globalization index, social, and trade globalization. This study employs FGLO because cross–border money transfers underpin economic progress. (iv) Finally, this research deviates from the body of literature by employing the JKS panel causality test. A breakdown of the reviewed literature is displayed in **Table 1**.

Table 1. Synopsis of the literature.

Author(s)	**Duration**	**Country(ies)**	**Technique(s)**	**Findings**
Saud et al. [35]	1990–2014	OBOR	PMG	$\mathrm{FGLO}^{-}\vert\mathrm{GLO}^{+}$
Ulucak et al. [36]	1974–2016	15 Emerging	PMG & DOLS	FGLO^{+}
Pata & Isik [26]	1981–2017	China	Dynamic ARDL	$\mathrm{RENT}^{-}\vert\mathrm{GDP}^{-}$
Liu et al. [45]	1990–2018	South Africa	ARDL	GDP^{-}
Abdulmagid Basheer Agila et al. [47]	1970Q1–2018Q4	South Korea	Quantile-on-Quantile	$\mathrm{GDP}^{-}\vert\mathrm{TGLO}^{-}$
Akadiri et al. [13]	1970–2017	India	Dual Adjustment and Frequency Domain Approach	$\mathrm{GDP}^{+}\vert\mathrm{FGLO}^{+}\vert\mathrm{RENT}^{\neq}\vert$In the long–run, $\mathrm{GDP}^{-}\vert\mathrm{FGLO}^{+}\vert\mathrm{RENT}^{+}$
Awosusi et al. [46]	1980–2017	South Africa	ARDL	$\mathrm{GLO}^{+}\vert\mathrm{GDP}^{-}$
Shang et al. [48]	1980–2018	ASEAN	CS–ARDL	GDP^{-}
Pata & Balsalobre-Lorente [49]	1965–2017	Turkey	Dynamic ARDL	GDP^{-}
Ni et al. [39]	1996–2019	11 High-Resource Consuming	CS–ARDL	$\mathrm{RENT}^{-}\vert\mathrm{GDP}^{-}$
Adebayo et al. [40]	1975Q1–2018Q4	Thailand	Quantile Causality	$\mathrm{RENT}^{-}\vert\mathrm{GDP}^{-}$
Xu et al. [50]	1970–2017	Brazil	ARDL & Frequency Domain Causality	$\mathrm{GDP}^{-}\vert\mathrm{FGLO}^{+}$
Xu et al. [51]	2000Q1–2018Q4	Brazil	Dynamic ARDL	$\mathrm{SGLO}^{+}\vert\mathrm{GDP}^{-}$
Awosusi et al. [52]	1980–2017	Japan	Dynamic ARDL	$\mathrm{GDP}^{-}\vert\mathrm{TGLO}^{+}$
Yang et al. [24]	1990–2018	BRICS	MMQR	$\mathrm{RENT}^{-}\vert\mathrm{GDP}^{-}\vert\mathrm{SGLO}^{-}$
Guloglu et al. [21]	1980–2018	26 OECD	Dynamic Quantile Mean Group	RENT^{+}
Li et al. [41]	1990–2018	Next-11	CS–ARDL	$\mathrm{RENT}^{-}\vert\mathrm{GDP}^{-}\vert\mathrm{GLO}^{-}$
Khan et al. [53]	1997–2018	G7 & E7	CS–ARDL	GDP^{-}
Sun et al. [42]	1990–2019	17 APEC	AMG, CCEMG & D–H Non-causality	$\mathrm{RENT}^{+}\vert\mathrm{GDP}^{-}$
Wang et al. [43]	2000–2018	96 Developing	Threshold Regression Model	RENT^{+}
Dam et al. [38]	1999–2018	22 OECD	PMG–ARDL	GDP^{-}
Raihan et al. [54]	1971–2018	Mexico	ARDL, FMOLS, DOLS & CCR	$\mathrm{GDP}^{-}\vert\mathrm{FGLO}^{+}$

Table 1. (*Continued*).

Author(s)	Duration	Country(ies)	Technique(s)	Findings
Pata et al. [55]	1990–2018	11 LAC	PMG–ARDL & Toda–Yamamoto	GDP^{-}|GLO^{-}
Okezie et al. [56]	1970–2021	Nigeria	ARDL & DOLS	GDP^{+}
Caglar et al. [57]	1990–2018	BRICS	CUP–BC & CUP–FM	GDP^{+}
Villanthenkodath and Pal [44]	1990–2019	India	Dynamic ARDL	GLO^{+}|$RENT^{+}$
Zhang et al. [59]	1985Q1–2022Q4	China	Wavelet Analysis	$FGLO^{-}$

Note: (+): Positive Association; (−): Negative Association; (≠): No Association; ARDL: Autoregressive Distributed Lag; RENT: Natural Resources Rent; GDP: Gross Domestic Product; GLO: Globalization; TGLO: Trade Globalization; FGLO: Financial Globalization; CSARDL: Cross–sectional ARDL; MMQR: Method of Moments Quantile Regression; SGLO: Social Globalization; PMG–ARDL: Pooled Mean Group ARDL; FMOLS: Fully Modified Ordinary Least Square; DOLS: Dynamic Ordinary Least Square; CCR: Canonical Cointegrating Regression; CUP–FM: Continuously Updated Fully Modified; CUP–BC: Continuously Updated Bias–Corrected; OBOR: One-Belt-One-Road.

3. Methodology

3.1. Data

This research focuses on four GCC economies: Saudi Arabia, UAE, Bahrain, and Oman. Kuwait and Qatar were not included because of data unavailability. The period investigated is from 1992 to 2021. The dependent variable used to proxy for ecological soundness is LCF, sourced from the Global Footprint Network [20]. The explanatory variables are RENT, GDP, and FGLO. RENT and GDP were sourced from World Bank [25], while FGLO is sourced from KOF Swiss Economic Institute [58]. **Table 2** presents the variable summary along with its sources.

Table 2. Variables synopsis.

Variables	Abbreviation	Measurement	Source
Load Capacity Factor	LCF	Biocapacity/EF (global hectares)	Global Footprint Network (2024)
Total Natural Resources Rents	RENT	(% of GDP)	World Bank (2024)
GDP Per Capita	GDP	Constant 2015 US$	World Bank (2024)
Financial Globalization	FGLO	Index	KOF Swiss Economic Institute (2024)

3.2. Model

To uncover ecological soundness in GCC economies, this study adopts the model in Equation (1) as utilized by Akadiri et al. [13].

$$LCF_{it} = f\ (RENT_{it}, GDP_{it}\ FGLO_{it}) \quad (1)$$

Using a logarithmic series, Equation (2) is calculated to determine the coefficients of elasticities:

$$LLCF_{it} = \beta_0 + \varpi_1 LRENT_{it} + \varpi_2\ LGDP_{it} + \varpi_3 LFGLO_{it} + \varepsilon_{it} \quad (2)$$

L is symbolized as logarithm; the constant term is denoted by β_0; the long-term coefficients are ϖ_1, ϖ_2, and ϖ_3; cross-sections and time are denoted by it, and the error term is denoted by ε. In Equation (2), in the long run, the a priori expectation for RENT will be negative ($\varpi_1 < 0$). Akadiri et al. [13] opined that greater natural resource output largely results in increased RENT, leading to environmental pressure and adversely affecting the environment. It is crucial to note that aside from using debt measures to finance infrastructural development and meet other economic needs, GCC economies exchange their natural resources for financial gains, which could adversely affect the environment. The impact of GDP on LCF is also expected to be negative ($\varpi_2 < 0$). This is defined by scale, composite, and technique effects suggested by Grossman and Krueger [60]. The scale effect suggests that more production necessitates greater material inputs, increasing economic activity, waste, and pollution. The composition effect is the turning point where economies begin to adopt new technologies, which is evident in different sectors of the economy. The technique effect produces less pollution because commodities made with more advanced clean technologies need fewer materials. In essence, resources drive the scale effect, while adopting new technology drives the composite and technique effects. Lastly, although several studies argued that FGLO positively drives ecological quality, this study proposes a negative sign ($\varpi_3 < 0$) because of the structure of the GCC economies. Ulucak et al. [36] stated that globalization might lead to the three effects, while Copeland [61] suggested that globalization better explains the link between GDP and the environment. Saud et al. [35] argued that financial development could drive the scale effect and promote economic activities. It is also important to state that financial development can foster investment in ecologically friendly projects.

3.3. Techniques

The estimation strategies of this study are presented in five steps and can be seen in **Figure 3**.

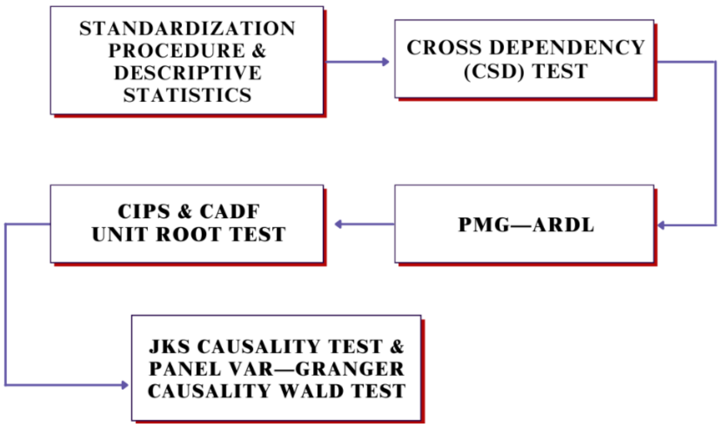

Figure 3. Estimation strategies.

Step 1: Standardization procedures and descriptive statistics are carried out at the preliminary stages. It is important to note that the variables take on a variety of forms. The Z-distribution is used in a standardization process to reduce the possibility of misinterpretation, enhance the comprehensibility of the results, and facilitate comparisons across variables. Using this standardization technique, the data is ensured to follow a regular normal distribution, represented by the symbol N (0, 1). By standardizing the data, the impact of differing scales is lessened among the variables, allowing for more accurate and equitable comparisons and interpretations [62]. Equation (3) is an expression of the standardizing process:

$$z = \frac{x - \mu}{\sigma} \quad (3)$$

where μ stands for the mean, σ for the standard deviation, z for the standardized value, and x for the original value. Furthermore, the descriptive statistics illustrate the characteristics of the utilized data.

Step 2: The Cross Dependency (CSD) tests proposed by Baltagi et al. [63] , Breusch and Pagan [64], and Pesaran [65] were applied in this research. The first-generation unit root test cannot be used in the presence of CSD. Moreover, the likelihood that a social, political, or economic shock in one nation may spread to others is increased when CSD is present [55]. In this situation, traditional panel data techniques that do not take CSD into account might yield biased outcomes.

Step 3: Due to the presence of CSD, the second-generation unit root tests CIPS [66] and CADF [67] are implemented. Unit root analysis is necessary for the PMG–ARDL technique, as it is necessary for the variables not to be I (2).

Step 4: Pesaran et al. [68] introduced the PMG–ARDL methodology, which sets itself apart from the Vector VAR technique. Unlike VAR, the ARDL method enables testing cointegration in a single–equation model across different periods. In addition, the PMG estimator accommodates heterogeneous dynamic panels, while the MG estimator allows for differences in slope and disturbance terms among countries [69]. In addition, the PMG–ARDL can handle variables that are of mixed order, i.e., I (0) and I (1). This characteristic makes this method very flexible. It is also applicable to moderate panel samples. Lastly, the PMG–ARDL provides the error correction term, which other panel methods do not provide. Equation (4) expresses the PMG–ARDL model.

$$\Delta LCF_{i,t} = \alpha_i + ECT_{i,t} + \sum_{j=1}^{m-1} \beta 1_{ij} \Delta LCF_{i,t-j} + \sum_{l=0}^{n-1} \beta 2_{il} \Delta RENT_{i,t-1} + \sum_{r=0}^{n-1} \beta 3_{il} \Delta GDP_{i,t-1} \sum_{v=0}^{p-1} \beta 4_{ir} \Delta FGLO_{i,t-r} + \sigma 1_{ij} LCF_{i,t-1} + \sigma 2_{ij} RENT_{i,t-1} + \sigma 3_{ij} GDP_{i,t-1} + \sigma 4_{ij} FGLO_{i,t-1} + \varepsilon_{i,t} \quad (4)$$

$LCF_{i,t}$ is the regressed term at time *t* for the *i*-th country; α is a constant term specific to each country, and RENT, GDP, and FGLO are the dependent variables. The parameters $\beta 1_{ij}, \beta 2_{ij}, \beta 3_{ij}, and\ \beta 4_{ij}$ represent the long-run parameters, while $\sigma 1_{ij}, \sigma 2_{ij}, \sigma 3_{ij}, and\ \sigma 4_{ij}$ denote short-term parameters. The term $\varepsilon_{\mathrm{i,t}}$ is the identical disturbance term for the model and *ECT* represents the error correction model. For the ECT to infer the existence of a long-term association, it must be significantly negative and less than 1.

Step 5: Juodis et al. [70] introduced a novel technique for examining Granger non-causation in panel data models called the JKS test. The model applies to coefficients that are either heterogeneous or homogenous. The unique feature of the JKS technique is that all Granger–causation parameters are uniformly zero under the null hypothesis, indicating homogeneity. As a result, the method recommends using a pooled least-squares estimator—similar to a fixed-effects model—just for these parameters. The estimator's rate of convergence is guaranteed by the pooling across

cross-sections. To address the well-known Nickell bias, the method incorporates the Split Panel Jack knife technique. Following this, a Wald test is suggested, utilizing the bias-corrected estimator as its foundation. The main formula can be written as follows:

$$y_{i,t} = \phi_{0,i} + \sum_{p=1}^{P} \phi_{p,i} y_{i,t-p} + \sum_{p=1}^{P} \beta_{p,i} x_{i,t-p} + \varepsilon_{i,t} \quad (5)$$

where β represents the diverse feedback parameters, $0, i$ denotes individual-specific effects, p, i signifies heterogeneous autoregressive coefficients, and ε represents the error term. In this context, computational expenses are kept to a minimum as the number of lags linked to $x_{i,t}$ is identical to that of $y_{i,t}$. In the null hypothesis scenario, it is posited that $x_{i,t}$ does not Granger cause $y_{i,t}$.

4. Empirical investigation

4.1. Descriptive statistics

Presented in **Table 3**, the mean (−1.816177) and median (−2.027207) values for LLCF are the lowest, while LGDP has the highest mean and median values at 10.12141 and 9.932021, respectively. LLCF, LGDP, and LFGLO are skewed positively, while LRENT is negatively skewed. In addition, all variables are platykurtic (kurtosis < 3). LRENT is normally distributed, while LLCF, LGDP, and LFGLO are not normally distributed.

Table 3. Descriptive statistics.

	LLCF	**LRENT**	**LGDP**	**LFGLO**
Mean	−1.816177	3.228233	10.12141	4.202848
Median	−2.027207	3.210349	9.932021	4.189692
Maximum	0.116513	4.007777	11.06338	4.464545
Minimum	−2.870080	2.266814	9.652554	3.927708
Std. Dev.	0.817126	0.387441	0.424174	0.173974
Skewness	0.648645	−0.125611	1.215915	0.076239
Kurtosis	2.497455	2.473777	2.938217	1.529273
Jarque–Bera	9.677567	1.700117	29.58805	10.93144
Probability	0.007917	0.427390	0.000000	0.004229
Observations	120	120	120	120

4.2. CSD test

Table 4 presents the CSD test results and corresponding P values. The outcome shows that CSD exists, thereby challenging the assumption of independence among observations. The ramifications of this rejection necessitate a more in-depth investigation into potential interconnectedness or shared factors influencing the variables under examination.

Table 4. CSD test.

Variables	**Breusch–Pagan LM**	**Bias–corrected scaled LM**	**Pesaran's CD**
LLCF	151.7691 (0.0000)	42.01094 (0.0000)	12.30007 (0.0000)
LRENT	142.8523 (0.0000)	39.43690 (0.0000)	11.94431 (0.0000)
LGDP	33.40812 (0.0000)	7.843076 (0.0000)	−3.035417 (0.0024)
LFGLO	103.6990 (0.0000)	28.13431 (0.0000)	9.851482 (0.0000)

4.3. CIPS and CADF unit root test

Overall, the outcome in **Table 5** indicates a mixed order of integration for the CIPS test, while the CADF test shows all variables are integrated at order 1. This allows the ARDL approach to be employed, estimating our model's short- and long-run dynamics.

Table 5. CIPS and CADF unit root test.

	CIPS		**CADF**	
Variable	I (O)	I (1)	I (O)	I (1)
LLCF	−2.851*	−5.772*	−2.157	−3.515*
LRENT	−1.871	−4.801*	−1.577	−3.371*
LGDP	−1.249	−3.441*	−0.808	−2.625*
LFGLO	−1.271	−4.216*	−1.160	−3.161*

* denotes $P < 0.01$.

4.4. PMG–ARDL

Table 6 presents the results of the PMG–ARDL analysis. In the context of long-run dynamics, the investigation reveals compelling evidence of a negative association between the dependent variable and the predictors LRENT, LGDP, and LFGLO. The low *p*-values of 0.007, 0.038, and 0.000 further bolster the argument for the statistical significance of these long-run relationships. Additionally, the constant term (C) proves non-significant, with a coefficient of −0.059, a standard error of 0.041, a static value of −1.450, and a *p*-value of 0.146. Shifting our focus to the short–run dynamics, the ECT emerges as a significant negative contributor, evidenced by a coefficient of −0.119, a remarkably low standard error of 0.014, a striking static value of −8.560, and a *p*–value of 0.000. Thus, the short-run deviations balance out in the long run. Meanwhile, LRENT and LGDP display noteworthy positive relationships in the short run, with coefficients of 0.035 and 0.325, complemented by standard errors of 0.007 and 0.098. The static values of 5.280 and 3.320, combined with *p* values of 0.000 and 0.001, solidify the significance of these short-run associations. However, LFGLO fails to achieve statistical significance, as evidenced by a coefficient of 0.087, a standard error of 0.135, a static value of 0.650, and a *p*-value of 0.519.

Table 6. PMG–ARDL.

Variables	Coefficient	Standard error	Static	***P*-value**
Long-run				
C	−0.059	0.041	−1.450	0.146
LRENT	−0.549	0.205	−2.680	0.007
LGDP	−1.001	0.483	−2.070	0.038
LFGLO	−0.580	0.152	−3.810	0.000
Short-run				
ECT	−0.119	0.014	−8.560	0.000
LRENT	0.035	0.007	5.280	0.000
LGDP	0.325	0.098	3.320	0.001
LFGLO	0.087	0.135	0.650	0.519

4.5. Causality tests

Table 7 presents the outcomes of the JKS test, wherein an evaluation is initiated to ascertain whether LRENT, LGDP, and LFGLO exert Granger causality on LLCF. As indicated by **Table 7**, LRENT, LGDP, and LFGLO encompass information conducive to forecasting LLCF. To fortify the robustness of these findings, a supplementary univariate test was conducted independently for each variable to examine Granger non-causality, utilizing the PVAR-Granger causality Wald test. The outcome of this univariate analysis is explained in **Table 8**, which shows that LRENT, LGDP, and LFGLO's outcome aligns with the results obtained from the JKS test. Consequently, we infer that the research variables possess predictive capacity for LLCF.

Table 7. JKS test.

Variables	Coefficient	Standard error	Static	***P*-value**
LRENT	0.044	0.014	3.270	0.001
LGDP	−0.442	0.111	−4.000	0.000
LFGLO	0.207	0.057	3.620	0.000

Table 8. PVAR-Granger causality Wald test.

Variables	Chi2	Df	***P*-value**
LRENT	5.69	1	0.017
LGDP	21.976	1	0.000
LFGLO	10.488	1	0.001
ALL	35.35	3	0.000

4.6. Discussion

Upon closer examination, it becomes evident that there is an adverse relationship between GDP and LCF over the long term. In simpler terms, as the economy expands, the ability to handle and sustain loads diminishes. This has significant implications for the environment, especially in GCC countries, where the economy heavily relies on manufacturing industries. This corresponds with the investigations carried out by

Akinsola et al. [71] and Xu et al. [50], despite using different environmental degradation measures and timeframes in their analyses. Both studies suggest that GDP contributes to environmental harm. Overall, this suggests that the GCC nations are presently undergoing a phase marked by an agenda that is pro–growth. The implications of GCC nations' economic development may be seen in environmental concerns like pollution. This stems from their dependence on oil as a primary economic driver, leading to carbon–intensive energy production to fuel economic progression. Essentially, the data supports the notion that a sustainable environment does not always follow from a rise in per capita income [50]. Other studies that affirm this position include [26,38,48,49]. On the contrary, some studies also established a positive GDP–LCF nexus [13,44,56,57].

The long-term analyses reveal a negative link between RENT and LCF. This result is explained by the GCC nations' transportation and industrial sectors' excessive reliance on energy sources that produce emissions, such as fossil fuels. Specifically, increased fuel consumption through RENT contributes to economic expansion in GCC economies, leading to adverse environmental consequences. In agreement, the research of Majeed et al. [72] underscores that elevated income levels drive economic activities, industrialization, and natural resource utilization, resulting in heightened CO_2 levels and ecological decline. The interconnectedness of growth and the environment is evident, as all economic endeavors have environmental foundations. Metals, minerals, soil, forest resources, and energy are critical inputs for many activities, and business entities create a lot of waste, which harms the environment. As the manufacturing sector expands, the environment in GCC nations degrades rapidly. Other studies that align with this negative long run assertion include Adebayo et al. [26], Li et al. and Pata and Isik [40,41]. On the contrary, these studies found a positive link between RENT and LCF [13,21,42].

The analysis also revealed that, in the long run, FGLO is negatively related to the level of LCF. Although previous literature indicated a positive relationship [13,36,54], this negative correlation can be attributed to the concentration of industries in GCC countries being primarily based on the oil industry. Therefore, FGLO caters to activities related to these industries. In addition, FGLO can drive the scale effect through trade globalization. This allows for FDI in the GCC economies, which have more relaxed environmental policies than developed economies. This, in turn, adversely affects the environment. This is greatly supported by the studies of Saud et al. [35] and Zhang et al. [59].

In summary, the positive short-term link between RENT, GDP, FGLO, and LCF, as opposed to the negative long-term interaction, clearly reflects GCC nations' efforts to implement an environmental agenda and policies that preserve the environment. However, a shortcoming of these policies is their short-term nature, as their effects soon diminish, and the dominant negative effect persists in the long-term. **Figure 4** shows the graphical highlights of the results.

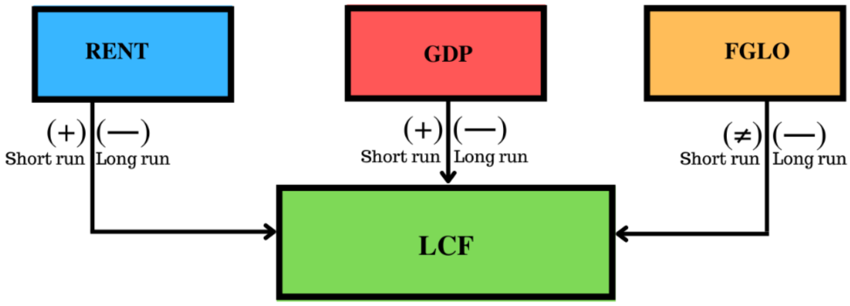

Figure 4. Synopsis of results.

5. Conclusion

This research investigates the LCF determinants in four GCC economies from 1992 to 2021 using the PMG–ARDL, PVAR–Granger Causality test, and JKS test. The determinants considered in this study include RENT, GDP, and FGLO. The PMG–ARDL's result demonstrates that, in the short term, GDP and RENT spur LCF, while FGLO is marginally beneficial. However, RENT, GDP, and FGLO all diminish the LCF with time. The JKS and PVAR–Granger Causality tests reveal a strong causal movement from RENT, GDP, and FGLO to LCF, validating the PMG–ARDL findings.

The study recommends that GCC economies develop strategic ways to expand their economies while ensuring ecological quality. These strategies could entail the adoption of new technology, which will provide better ways of using fossils (solar and wind integration with fossil fuel power plants) and adopting renewables, which can contribute to environmental progress. In addition, for GCC economies, Majeed et al. [72] opined that to minimize environmental damage and lessen the dominance of unclean energy use, GCC economies should invest in clean energy innovation and raise the percentage of green energy they utilize. Gyamfi et al. [73] suggested that abundant natural resources facilitate the absorption of excess GHGs, fostering an ecologically sustainable milieu. Therefore, GCC economies need strict policies to protect their citizens and natural resources and identify who has the right to use a piece of land for social infrastructure. In addition, stringent policies on how unclean energy is used are also important. Stringent policies such as the use of carbon pricing mechanisms and strict fuel efficiency and emission standards for the industrial and transportation sectors. SDGs 7, 8, and 13 may be achieved using these regulations. In summary, the GCC economies can decouple economic progress from ecological decline by investing more in non–oil sectors such as tourism, green finance, and manufacturing. These sectors can help generate the revenue that GCC countries need to meet their macroeconomic objectives. The development of green industries is also crucial because it will provide jobs for people and, at the same time, improve the environment due to the development of carbon capture technologies. Furthermore, the GCC economies should design FGLO policies supporting capital inflows for innovative and environmentally friendly projects. These capital inflows can be green bonds, climate investment funds, carbon credits, and green crowdfunding.

To sum up, this study exclusively focuses on the GCC economies. However, the model can be applied to other countries for robust policy formulations. Additionally, variables like cultural and information globalization should be included in future research, while other methods, such as the Wavelet and Quantile-on-Quantile approaches, can also be used. Furthermore, Kuwait and Qatar are excluded from this study because of data unavailability. The inclusion of these countries in our analysis could have influenced our findings since both countries are high–income and resource–rich countries. However, the extent of their impact remains unknown due to data inadequacy.

Author contributions: Conceptualization, OAS and TSA; methodology, OAS and MM; software, OAS and MM; validation, OAS, TSA, MM and HO; formal analysis, OAS and MM; investigation, OAS and MM; resources, OAS, TSA, MM and HO; data curation, OAS; writing—draft preparation, OAS, TSA and MM; writing—review and editing, OAS; visualization, OAS and MM; supervision, OAS and HO; project administration, OAS and HO. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare no conflict of interest.

References

1. Borozan D. Do geopolitical and energy security risks influence carbon dioxide emissions? Empirical evidence from European Union countries. Journal of Cleaner Production. 2024; 140834. doi: 10.1016/j.jclepro.2024.140834
2. Neves SA, Marques AC, Patrício M. Determinants of CO2 emissions in European Union countries: Does environmental regulation reduce environmental pollution? Economic Analysis and Policy. 2020; 68: 114–25. doi: 10.1016/j.eap.2020.09.005
3. Shah SAA, Shah SQA, Tahir M. Determinants of CO2 emissions: exploring the unexplored in low-income countries. Environ Sci Pollut Res. 2022; 29(32): 48276–84. doi: 10.1007/s11356-022-19319-3
4. Somoye O, Akinwande TS. Can Urbanization Influence Carbon Dioxide Emissions? Evidence from BRICS–T Countries. JCUA. 2023; 7(1): 164–74. doi: 10.25034/ijcua.2023.v7n1-11
5. Zambrano-Monserrate MA. Clean energy production index and CO2 emissions in OECD countries. Science of The Total Environment. 2024; 907: 167852. doi 10.1016/j.scitotenv.2023.167852
6. Abba Yadou B, Ntang PB, Baida LA. Remittances-ecological footprint nexus in Africa: Do ICTs matter? Journal of Cleaner Production. 2024; 434: 139866. doi: 10.1016/j.jclepro.2023.139866
7. Alqaralleh H. On the factors influencing the ecological footprint: using an asymmetric quantile regression approach. MEQ. 2024; 35(1): 220–47. doi: 10.1108/meq-04-2023-0128
8. Espoir DK, Sunge R, Nchofoung T, et al. Analysing the drivers of ecological footprint in Africa with machine learning algorithm. Environmental Impact Assessment Review. 2024; 104: 107332. doi: 10.1016/j.eiar.2023.107332
9. Guliyev H. Determinants of ecological footprint in European countries: Fresh insight from Bayesian model averaging for panel data analysis. Science of The Total Environment. 2024; 912: 169455. doi: 10.1016/j.scitotenv.2023.169455
10. Metin Dam M, Kaya F, Bekun FV. How does technological innovation affect the ecological footprint? Evidence from E-7 countries in the background of the SDGs. Journal of Cleaner Production. 2024;141020. doi: 10.1016/j.jclepro.2024.141020
11. Xia A, Liu Q. Modelling the asymmetric impact of fintech, natural resources, and environmental regulations on ecological footprint in G7 countries. Resources Policy. 2024; 89: 104552. doi: 10.1016/j.resourpol.2023.104552
12. Siche R, Pereira L, Agostinho F, et al. Convergence of ecological footprint and emergy analysis as a sustainability indicator of countries: Peru as case study. Communications in Nonlinear Science and Numerical Simulation. 2010; 15(10): 3182–92. doi: 10.1016/j.cnsns.2009.10.027
13. Akadiri SS, Adebayo TS, Riti JS, Awosusi AA, et al. The effect of financial globalization and natural resource rent on load capacity factor in India: an analysis using the dual adjustment approach. Environmental Science and Pollution Research. 2022; 29(59): 89045–62. doi: 10.1007/s11356-022-22012-0

14. Pata UK. Do renewable energy and health expenditures improve load capacity factor in the USA and Japan? A new approach to environmental issues. Eur J Health Econ. 2021; 22(9): 1427–39. doi: 10.1007/s10198-021-01321-0
15. Pata UK, Samour A. Do renewable and nuclear energy enhance environmental quality in France? A new EKC approach with the load capacity factor. Progress in Nuclear Energy. 2022; 149: 104249. doi: 10.1016/j.pnucene.2022.104249
16. Wackernagel M, Rees W. Our ecological footprint: reducing human impact on the earth. Vol. 9. New society publishers; 1998.
17. Rafique MZ, Fareed Z, Ferraz D, et al. Exploring the heterogenous impacts of environmental taxes on environmental footprints: an empirical assessment from developed economies. Energy. 2022; 238: 121753. doi: 10.1016/j.energy.2021.121753
18. Moran DD, Wackernagel M, Kitzes JA, et al. Measuring sustainable development—Nation by nation. Ecological economics. 2008; 64(3): 470–4. doi: 10.1016/j.ecolecon.2007.08.017
19. Adebayo TS. Towards unlocking the chain of sustainable development in the BRICS economies: analysing the role of economic complexity and financial risk. Geological Journal. 2023; 58(5): 1810-1821 doi: 10.1002/gj.4694
20. Global Footprint Network. Ecological Footprint [Internet]. 2024. Available online: https://www.footprintnetwork.org/our-work/ecological-footprint/ (accessed on 25 December 2024).
21. Guloglu B, Caglar AE, Pata UK. Analyzing the determinants of the load capacity factor in OECD countries: Evidence from advanced quantile panel data methods. Gondwana Research. 2023; 118: 92–104. doi: 10.1016/j.gr.2023.02.013
22. Wackernagel M, Monfreda C, Moran D, et al. National footprint and biocapacity accounts 2005: the underlying calculation method. 2005: The underlying calculation method. Available online: https://elearning.humnet.unipi.it/pluginfile.php/101792/mod_resource/content/0/Footprint%20Method%202005.pdf (accessed on 10 December 2024).
23. Hoekstra AY. Human appropriation of natural capital: A comparison of ecological footprint and water footprint analysis. Ecological economics. 2009; 68(7): 1963–74. doi: 10.1016/j.ecolecon.2008.06.021
24. Yang M, Magazzino C, Awosusi AA, et al. Determinants of Load capacity factor in BRICS countries: A panel data analysis. In Wiley Online Library; 2023. doi: 10.1111/1477-8947.12331
25. World Bank. World Bank Open Data [Internet]. 2024. Available online: https://data.worldbank.org/ (accessed on 25 December 2024).
26. Pata UK, Isik C. Determinants of the load capacity factor in China: a novel dynamic ARDL approach for ecological footprint accounting. Resources Policy. 2021; 74: 102313. doi: 10.1016/j.resourpol.2021.102313
27. World Bank. The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium [Internet]. The World Bank; 2010 [cited 2024 Jan 20]. Available online: http://elibrary.worldbank.org/doi/book/10.1596/978-0-8213-8488-6 (accessed on 25 December 2024).
28. Nathaniel SP, Yalçiner K, Bekun FV. Assessing the environmental sustainability corridor: Linking natural resources, renewable energy, human capital, and ecological footprint in BRICS. Resources Policy. 2021; 70: 101924. doi: 10.1016/j.resourpol.2020.101924
29. Erdoğan S, Yıldırım DÇ, Gedikli A. Natural resource abundance, financial development and economic growth: An investigation on Next-11 countries. Resources Policy. 2020; 65: 101559. doi: 10.1016/j.resourpol.2019.101559
30. Dauvergne, P. Globalization and the environment. Global political economy. 2005;2(2), 448-478. Available online: https://d1wqtxts1xzle7.cloudfront.net/44051950/15_Cha14-libre.pdf?1458790742=&response-content-disposition=inline%3B+filename%3DGlobalization_and_the_environment.pdf&Expires=1710505211&Signature=ey54OFOpyoqQnvC6eZAE5BJLSz~xyi3CTUVQDfHFycHZjmssEt2JYQDqs4-GDauWJkXWk5xz4Y1kK87JELZOdErcdJKU6brNQ0X-vuENmf2YPzmJb54WRiknVgWjxfhGrXpJshuWyfGQCazj1S9m2PuY04XTIvF1D-97WfdmjaS-nSNabC6oU1Ib387YGd3nGYbahfW-ulSzSPrR49TQtTXPJR7mRzCp6YxidQgLoz3E2a7-XGPukzxUsUK4aSZT-LwRqOoN3EVq-MKDNu32KaN-b3luUfjLRBNmQdupqj0vIEoim0~wfLFr1S0nk0QIvM3kZIy3FzS7VfgRNKW2w__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA (accessed on 25 December 2024).
31. Bilgili F, Ulucak R, Koçak E, et al. Does globalization matter for environmental sustainability? Empirical investigation for Turkey by Markov regime switching models. Environ Sci Pollut Res. 2020; 27(1): 1087–100.doi: 10.1007/s11356-019-06996-w

32. Le TH, Chang Y, Park D. Trade openness and environmental quality: International evidence. Energy Policy. 2016; 92: 45–55. doi: 10.1016/j.enpol.2016.01.030
33. Copeland BR, Taylor MS. Trade and the environment: Theory and evidence. Princeton university press; 2005.
34. Frankel J. The Environment and Globalization [Internet]. Cambridge, MA: National Bureau of Economic Research; 2003 Nov [cited 2024 Mar 15] p. w10090. Report No.: w10090. Available online: http://www.nber.org/papers/w10090.pdf (accessed on 25 December 2024).
35. Saud S, Chen S, Haseeb A, et al. The role of financial development and globalization in the environment: Accounting ecological footprint indicators for selected one-belt-one-road initiative countries. Journal of Cleaner Production. 2020; 250: 119518. doi: 10.1016/j.jclepro.2019.119518
36. Ulucak ZŞ, İlkay SÇ, Özcan B, et al. Financial globalization and environmental degradation nexus: Evidence from emerging economies. Resources Policy. 2020; 67: 101698. doi: 10.1016/j.resourpol.2020.101698
37. Hazmi A, Kort HM, Khallouli W, et al. A Dynamic Interrelationships among Clean Energy, Environmental Pollution, and Economic Growth in GCC Economies: A Panel ARDL Approach. Aydin M, editor. International Journal of Energy Research. 2024; 2024: 1–16. doi: 10.1155/2024/5571175
38. Dam MM, Işık C, Ongan S. The impacts of renewable energy and institutional quality in environmental sustainability in the context of the sustainable development goals: A novel approach with the inverted load capacity factor. Environmental Science and Pollution Research. 2023; 30(42): 95394–409. doi: 10.1007/s11356-023-29020-8
39. Ni Z, Yang J, Razzaq A. How do natural resources, digitalization, and institutional governance contribute to ecological sustainability through load capacity factors in highly resource-consuming economies? Resources Policy. 2022; 79: 103068. doi: 10.1016/j.resourpol.2022.103068
40. Adebayo TS, Pata UK, Akadiri SS. A comparison of CO2 emissions, load capacity factor, and ecological footprint for Thailand's environmental sustainability. Environment, Development and Sustainability. 2022; 1–21. doi: 10.1007/s10668-022-02810-9
41. Li X, Sun Y, Dai J, et al. How do natural resources and economic growth impact load capacity factor in selected Next-11 countries? Assessing the role of digitalization and government stability. Environ Sci Pollut Res. 2023;30(36): 85670–84. doi: 10.1007/s11356-023-28414-y
42. Sun Y, Usman M, Radulescu M, et al. New insights from the STIPART model on how environmental-related technologies, natural resources and the use of the renewable energy influence load capacity factor. Gondwana Research. 2023; doi: 10.1016/j.gr.2023.05.018
43. Wang Q, Sun J, Li R, et al. Linking Trade Openness to Load Capacity Factor: The Threshold Effects of Natural Resource Rent and Corruption Control. Gondwana Research. 2023; doi: 10.1016/j.gr.2023.05.016
44. Villanthenkodath MA, Pal S. Environmental degradation in geopolitical risk and uncertainty contexts for India: A comparison of ecological footprint, CO2 emissions, and load capacity factor. Energy and Climate Change. 2024; 100122. doi: 10.1016/j.egycc.2023.100122
45. Liu X, Olanrewaju VO, Agyekum EB, et al. Determinants of load capacity factor in an emerging economy: The role of green energy consumption and technological innovation. Frontiers in Environmental Science. 2022; 10: 2071. doi: 10.3389/fenvs.2022.1028161
46. Awosusi AA, Kutlay K, Altuntaş M, et al. A roadmap toward achieving sustainable environment: evaluating the impact of technological innovation and globalization on load capacity factor. International Journal of Environmental Research and Public Health. 2022; 19(6): 3288. doi: 10.3390/ijerph19063288
47. Abdulmagid Basheer Agila T, Khalifa WMS, Saint Akadiri S, et al. Determinants of load capacity factor in South Korea: does structural change matter? Environ Sci Pollut Res. 2022; 29(46): 69932–48. doi: 10.1007/s11356-022-20676-2
48. Shang Y, Razzaq A, Chupradit S, et al. The role of renewable energy consumption and health expenditures in improving load capacity factor in ASEAN countries: Exploring new paradigm using advance panel models. Renewable Energy. 2022; 191: 715–22. doi: 10.1016/j.renene.2022.04.013
49. Pata UK, Balsalobre-Lorente D. Exploring the impact of tourism and energy consumption on the load capacity factor in Turkey: a novel dynamic ARDL approach. Environmental Science and Pollution Research. 2022; 29(9): 13491–503. doi: 10.1007/s11356-021-16675-4
50. Xu D, Salem S, Awosusi AA, et al. Load capacity factor and financial globalization in Brazil: the role of renewable energy and urbanization. Frontiers in Environmental Science. 2022; 9: 823185. doi: 10.3389/fenvs.2021.823185

51. Kirikkaleli D, Adebayo TS. Political risk and environmental quality in Brazil: Role of green finance and green innovation. International Journal of Finance & Economics. 2022; doi: 10.1002/ijfe.2732
52. Awosusi AA, Adebayo TS, Kirikkaleli D, et al. Evaluating the determinants of load capacity factor in Japan: The impact of economic complexity and trade globalization. In Wiley Online Library; 2023. doi: 10.1111/1477-8947.12334
53. Khan U, Khan AM, Khan MS, et al. Are the impacts of renewable energy use on load capacity factors homogeneous for developed and developing nations? Evidence from the G7 and E7 nations. Environmental Science and Pollution Research. 2023; 30(9): 24629–40. doi: 10.1007/s11356-022-24002-8
54. Raihan A, Rashid M, Voumik LC, et al. The dynamic impacts of economic growth, financial globalization, fossil fuel, renewable energy, and urbanization on load capacity factor in Mexico. Sustainability. 2023; 15(18): 13462. doi: 10.3390/su151813462
55. Pata UK, Kartal MT, Dam MM, et al. Navigating the Impact of Renewable Energy, Trade Openness, Income, and Globalization on Load Capacity Factor: The Case of Latin American and Caribbean (LAC) Countries. International Journal of Energy Research. 2023; 1-14. doi: 10.1155/2023/6828781
56. Okezie BN, Nwani C, Nnam HI, et al. Testing the income-finance-trade-environment nexus based on the ecological load capacity factor: Frequency-domain causality evidence from Nigeria. Heliyon. 2023; 9(9). doi: 10.1016/j.heliyon.2023.e19584
57. Caglar AE, Daştan M, Mehmood U, et al. Assessing the connection between competitive industrial performance on load capacity factor within the LCC framework: Implications for sustainable policy in BRICS economies. Environmental Science and Pollution Research. 2023;1–18. doi: 10.1007/s11356-023-29178-1
58. KOF Swiss Economic Institute. KOF Globalization Index [Internet]. 2024. Available online: https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html (accessed on 25 December 2024).
59. Zhang H, Khan KA, Eweade BS, et al. Role of eco-innovation and financial globalization on ecological quality in China: A wavelet analysis. Energy & Environment. 2024. doi: 10.1177/0958305x241228518
60. Grossman G, Krueger A. Environmental Impacts of a North American Free Trade Agreement [Internet]. Cambridge, MA: National Bureau of Economic Research; 1991 Nov [cited 2022 Dec 25] p. w3914. Report No.: w3914. Available online: http://www.nber.org/papers/w3914.pdf (accessed on 25 December 2024).
61. Copeland BR. Trade and the Environment. In: Palgrave handbook of international trade. Springer; 2013. p. 423–96.
62. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. Journal of experimental psychology: General. 2012; 141(1): 2. doi: 10.1037/a0024338
63. Baltagi BH, Feng Q, Kao C. A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. Journal of Econometrics. 2012; 170(1): 164–77. doi: 10.1016/j.jeconom.2012.04.004
64. Breusch TS, Pagan AR. The Lagrange multiplier test and its applications to model specification in econometrics. The review of economic studies. 1980; 47(1): 239–53. doi: 10.2307/2297111
65. Pesaran MH. General diagnostic tests for cross section dependence in panels. Available at SSRN 572504. 2004. doi: 10.2139/ssrn.572504
66. Pesaran MH. A simple panel unit root test in the presence of cross-section dependence. J Appl Econ. 2007; 22(2): 265–312. doi: 10.1002/jae.951
67. Im KS, Pesaran MH, Shin Y. Testing for unit roots in heterogeneous panels. Journal of Econometrics. 2003;115(1): 53–74. doi: 10.1016/S0304-4076(03)00092-7
68. Pesaran MH, Shin Y, Smith RP. Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. Journal of the American Statistical Association. 1999; 94(446): 621–34. doi: 10.1080/01621459.1999.10474156
69. Blackburne EF, Frank MW. Estimation of Nonstationary Heterogeneous Panels. The Stata Journal. 2007;7(2): 197–208. doi: 10.1177/1536867x0700700204
70. Juodis A, Karavias Y, Sarafidis V. A homogeneous approach to testing for Granger non-causality in heterogeneous panels. Empir Econ. 2021; 60(1): 93–112. doi: 10.1007/s00181-020-01970-9
71. Akinsola GD, Awosusi AA, Kirikkaleli D, et al. Ecological footprint, public-private partnership investment in energy, and financial development in Brazil: a gradual shift causality approach. Environ Sci Pollut Res. 2022; 29(7): 10077–90. doi: 10.1007/s11356-021-15791-5

72. Majeed A, Wang L, Zhang X, et al. Modeling the dynamic links among natural resources, economic globalization, disaggregated energy consumption, and environmental quality: Fresh evidence from GCC economies. Resources Policy. 2021; 73: 102204. doi: 10.1016/j.resourpol.2021.102204
73. Gyamfi BA, Adebayo TS, Bekun FV, et al. Sterling insights into natural resources intensification, ageing population and globalization on environmental status in Mediterranean countries. Energy & Environment. 2023; 34(5): 1471–91. doi: 10.1177/0958305x221083240