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Probing environmental sustainability aspects of resource efficiency, renewable energy usage and globalization

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ABSTRACT

Given the pace of economic expansion arising from energy usage among other social and economic factors, emerging economies such as Turkey are increasingly becoming the focus for a net zero future. Therefore, the current attempt considers the drivers of environmental sustainability via load capacity factor (LCF) in the context of resource efficiency, renewable energy utilization, and globalization for Turkey over the period 1982 to 2019. By employing series of empirical tools that include cross-quantilogram method, quantile-on-quantile regression, quantile regression approaches, and the nonparametric quantile Granger causality approach, the result shows there is statistically significant evidence of quantile-to-quantile dependence among the trio of (resource efficiency, renewable energy utilization, and globalization) and LCF such that the dependence it reflects some levels of positive directional predictability, thus showing that these indicators are important drivers of environmental sustainability in Turkey. Furthermore, for the quantile-on-quantile regression results, there are statistically significant and positive effects of (i) resource efficiency on LCF across its conditional quantiles of distribution, (ii) renewable energy utilization on LCF and is mostly visible at the lower quantile up to the upper middle quantiles of renewable energy utilization (0.05–0.65), and (iii) globalization on LCF across the lower to upper middle quantiles. With the other empirical approaches providing similar results, the outcome of this investigation offers specific policy insight into resource circularity and energy efficiency.

1. Introduction

"Environmental sustainability" has become a resounding phrase across the globe given the growing threats of climate change in the 21st century. The usage and overall significance of this phrase were also re-echoed amongst stakeholders in Dubai (the United Arab Emirates) during the recently conducted COP28 United Nations Climate Change Conference. The supporting arguments for the need to combat greenhouse gas (GHG) emissions are gaining more attention globally. This development is not only peculiar to the advanced economies but also common among all the leading emerging economies of the world where a sizable amount of the global GHG emissions come from. Hawksworth & Cookson (2006) identified a list of seven rapidly emerging economies using the short-term "E7" including China, India, Russia, Brazil, Indonesia, Mexico, and Turkey. Just like every other E7 economy, Turkey has pursued an aggressive export-oriented economic growth policy over the last couple of decades which has culminated unprecedented rise in manufacturing and industrialization in the country (World Bank, 2010; Pamuk, 2008). Consequently, there has been a phenomenal growth in energy demand and the need to ensure the security of supply to sustain economic activities has triggered the increased reliance on fossil energy resource utilization. As of 2023, oil, natural gas, and coal consumption accounted for approximately 32.85 %, 24.85 %, and 23.57 % of energy consumption respectively, thus making fossil energy

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utilization account for about 81.2 % of the total primary energy consumption in Turkey (BP, 2023). Therefore, considering that Turkey's economic growth path has mainly remained more energy-dependent and pollution-intensive over the past decades (Aşıcı, 2015), the country must take steps to enhance its environmental quality as one of the major developing markets that is facing the 21st-century environmental challenge.

Given that Turkey's economic growth is primarily dependent on fossil fuel-based solutions, its current trajectory of economic expansion is not environmentally sustainable. Consequently, Turkey is facing challenges in reorganizing its current policies to fulfill the SDG-13 objective of climate action (Adebayo et al., 2022). Although Turkey's sustainable development policies are still in their infancy, they have already begun to take effect on a micro level. However, in order for the policies to see the limelight, adequate attention must be paid to the roles of resource efficiency and the matters of renewables in the growing era of globalization.

Resource efficiency is the process of optimizing and maximizing the use of resources sustainably and responsibly. There is a growing concern about how to reverse the trend in environmental degradation that is associated with increased manufacturing and equally sustain consumption to keep societal welfare balanced (Lei et al., 2022; Raza et al., 2022). Also, the Organization for Economic Co-operation and Development (OECD) has emphasized the significance of minimizing environmental consequences from material consumption by increasing resource efficiency and speeding the development of a circular economy (OECD, 2012). Doing this is noted to be a major step in the bloc's commitment to combating climate change. However, the levels of resource availability have eroded and deteriorated due to human activities, population expansion, industrialization, and the enormous demand for natural resources. Consequently, severe environmental pollution often characterizes this poor natural resource utilization and their attendant negative influence on economic growth has also been pointed out (Sonnenschein & Mundaca, 2016; Miao, 2017). Therefore, in recent times, most nations are giving more consideration to resource efficiency and energy utilization behavior, to prevent, eliminate, or at least lessen environmental pollution and ecological catastrophe.

The current state of the international economy, which has become increasingly globalized, depends significantly on energy input for both economic and non-economic activity. The significance of globalization may be seen in how it promotes international cooperation and technology transfer in the fight against climate change. Globalization generates a significant portion of greenhouse gas emissions simultaneously as it creates the challenge of energy security (Ansari et al., 2020). More focus has been placed on the environmental reactions to population dynamics, energy usage, economic growth, and several other notable factors as a result of increasing human activities (Shah et al., 2022; Destek et al. 2023; Wang & Dong, 2019; Alola, 2019; Shahbaz & Sinha, 2019; Emir & Bekun, 2018). Moreover, global economies have recently experienced fast growth, enabling them to reduce poverty, construct essential infrastructure, and raise people's living standards. However, environmental quality has been dramatically reduced due to globalization (Baz et al., 2020). The manufacturing sector often expands as the population and global economy grow, necessitating more raw materials to meet demand. As a result, environmental deterioration results from this growth's impact on the depletion of biodiversity and natural resources.

On the other hand, it is well acknowledged that renewable energy consumption (REC) can help solve the issue of energy security while also stemming greenhouse gas emissions. It can offer a new and non-exhaustive source of energy that should be supported for more sustainable future development (Bhat, 2018). The detrimental effects of economic growth initiatives on the established ecosystem have received increased attention from policymakers in recent years. In this way, the widespread use of renewable energy sources has aided in improving the environment (Sharma et al., 2021). Even though REC has lifecycle emissions, they are far less than those produced by fossil-fuel-based energy utilization. As a result, it should lessen the demand for bio-productive resources and their environmental impact (Ansari et al., 2020). Sharma (2021) provides evidence that non-renewable energy sources have worsened environmental conditions in many countries because residents of those nations are reliant on these energy sources for their daily tasks. According to the literature, renewable energy sources are preferable to fossil fuels since they have a less negative impact on the environment while maintaining economic growth (Destek & Sinha, 2020; Ben Jebli et al., 2019; Balsalobre-Lorente et al. 2023). Bulut (2017) emphasized that there is no denying that using renewable energy sources may also lead to some degrees of environmental contamination. However, the influence of renewable energy on climate change is less detrimental and more cost-effective when compared to non-renewable energy (Sinha et al., 2018; Chen et al., 2019).

Given this background, countries must develop less carbon-intensive energy portfolios by leveraging renewable energy resources for climate solutions. In this regard, the current study aims to: (i). Unravel the potential of the trio of resource efficiency, globalization, and renewable energy consumption, in stabilizing the environmental quality of the rapidly emerging Turkish economy; (ii). Concentrate on the load capacity factor (LCF) as a gauge of environmental quality since this indicator encompasses several aspects of environmental stress and resource utilization which are the central focus point of this study; (iii). To develop effective energy and environmental policy based on a robust second-generation analysis where the empirical evidence from the novel LCF metrics is contrasted against results from traditional environmental indicators like carbon emissions that currently dominate the empirical literature for Turkey. Zhao et al. (2023) assert that LCF precisely pinpoints the cutoff points beyond which ecosystems become overstressed and incapable of regenerating and supporting ecological and human well-being, resulting in LCF being associated as an environmental quality indicator (Pata & Balsalobre-Lorente, 2022; Ali et al., 2023). Adopting these metrics therefore provides additional merits given the increased climate challenges faced by most rapidly emerging economies like Turkey. A summary of relevant research alongside theoretical and analytical underpinnings is provided in the next section while section 3 contains the data and methodology. Section 4 presents the findings and discussions, and Section 5 concludes the study with relevant policy insights.

2. Literature review

Researchers have been exploring the potential drivers of environmental sustainability over the past decades. The current study focuses on three major potential factors that are likely to impact ecological sustainability in Turkey. These include resource efficiency, consumption of renewable energy, and globalization. Therefore, the review of literature covers existing studies within this framework of these three indicators, and the review has been summarized in three subsections.

2.1. Resource efficiency and environmental sustainability

Using panel data from 2008 to 2021, Yi et al. (2023) investigated the relationship between green finance and resource utilization efficiency. The study was conducted from a financial structure perspective. The findings from the regression indicate that the size of green finance could increase resource utilization efficiency through green technology advancements. In another study, Hatfield-Dodds et al. (2017) generated resource efficiency projections for the year 2050 using a multi-regional methodology. According to the study's forecast, efficient resource utilization may result in economic and environmental advantages of around $2.4 trillion by 2050, while worldwide extraction of resources would have slowed down by a further 28 % by that time. In the study by Li et al. (2020), the specific instance of energy efficiency as a component of resource efficiency was related to CO_2 emission for the sampled cases

Table 1
Variable description in terms of measurement and source.

Abbreviation	Name	Measurement	Source
LCF*	Load Capacity Factor	BC/EF (gha)	GFN (2023)
RE	Resource Efficiency	US$ per kilogram	OECD (2023)
REC	Renewable Energy Consumption	% of total	OWD (2023)
GLO	Globalization	Index	KOF (2023)

Note: * symbol indicates the dependent variable

of China and Nigeria from 1991 to 2014. The study used Fisher's ideal index decomposition, panel-corrected standard error, autoregressive distributed lag, practicable generalized least squares, and Bayesian variance autoregressive approaches to derive energy efficiency from the energy intensity of the mining and extractive industries. The study attempted to prove that energy efficiency in the two analyzed sectors and for the countries is sufficient to give policy tools for both circular economy and CO_2 emission reduction. However, it was unable to do so using the above-mentioned econometric approaches.

2.2. Globalization and environmental sustainability

Unquestionably, globalization is a positive aspect of modern civilization since it fosters economic growth and development, but studies have shown that it can also have unfavorable externalities, such as the deterioration of the environment (Akadiri et al., 2020; Ulucak & Danish, 2020). According to a study by Shahbaz et al. (2018), globalization raises CO_2 emissions. This conclusion was reached when they looked at the relationship between wealth, energy, globalization, and the environment. They contend that greater energy is required for fast economic expansion, which hurts the environment because of excessive greenhouse gas emissions. Likewise, using the Vector Error Correction Model, Khurshid et al. (2023) investigated the effects of globalization, knowledge spillover, and energy efficiency on environmental sustainability in Pakistan from 1980 to 2021. Their findings demonstrated that while globalization has a favorable influence on environmental sustainability, knowledge spillover and energy efficiency have a negative impact by increasing the ecological footprint. In addition to this, Lee and Min (2014), Shahbaz et al. (2018) and Haseeb et al. (2018) all contend that governments need to support globalization for environmental sustainability.

In contrast, Khan and Ullah (2019) investigated how globalization influences Pakistan's efforts to create a sustainable environment. According to their long-term estimates using the ARDL bound and Johansen cointegration tests, globalization increases carbon emissions. Shahbaz et al. (2015) investigated the relationship between globalization and emissions by integrating energy use, financial development, and economic expansion in the CO_2 emission function for India. They focused on yearly data for the 1970–2012 period. The evidence they obtained revealed that India's emissions are rising due to globalization.

2.3. Renewable energy consumption and environmental sustainability

The study by Omri et al. (2015) shows that trade and CO_2 emissions are the two main factors influencing renewable energy consumption per person using a Generalized Method of Moments (GMM) estimator on a panel of 64 nations. Sharma et al. (2021) used a sample of eight developing countries in South and Southeast Asia to examine the effects of adopting renewable energy on the ecological footprint between 1990 and 2015. By adopting a cross-sectional augmented autoregressive distributed lag model, they empirically analyzed the data for this time frame and found that, in the short and long periods, adopting renewable energy significantly boosted environmental sustainability. The ecological footprint decreased by 0.216 % over the long term and by 0.318 % over the short term for every 1 % increase in REC. In a similar vein, studies by Usman et al. (2020), Ike et al. (2020), Balsalobre-Lorente et al. (2018), Bhattacharya et al. (2017), and Dogan & Seker (2016) showed that using renewable energy is comparatively more biologically friendly and reduces environmental degradation over time. On the contrary, Ansari et al. (2020) analyzed the effects of renewable energy consumption and ecological footprint among the top energy-utilizing

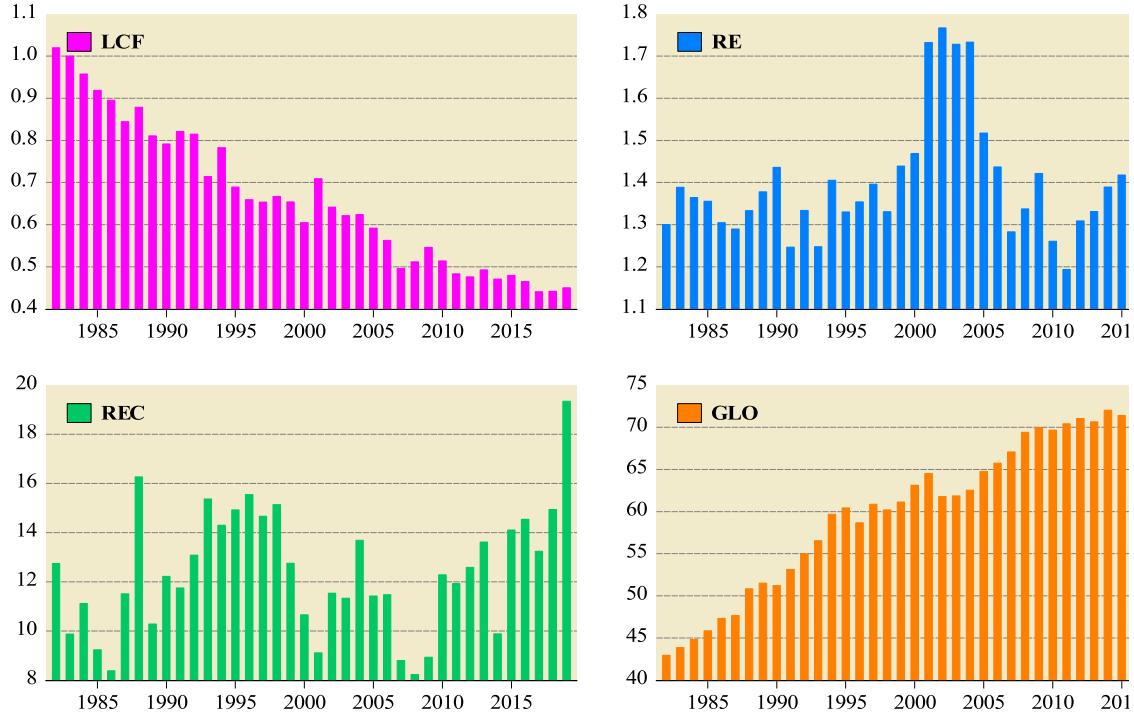


Fig. 1. Annual Values of Load Capacity Factor, Resource Efficiency, Renewable Energy Consumption, and Globalization of Turkey from 1982 to 2019. .
Source: LCF was computed from the data of the Global Footprint Network, RE from the OECD database, REC from Our World in Data, and GLO from KOF database

Table 2
Estimates of the Unit Root Tests.

ADF (Dickey & Fuller, 1979)					
At Level					
		LCF	RE	REC	GLO
I	t-Statistic	−1.239	−2.307	−1.801	−2.687*
	p − value	0.656	0.171	0.379	0.079
I&T	t-Statistic	−2.616	−2.621	−1.827	−1.494
	p − value	0.274	0.272	0.686	0.827
N	t-Statistic	1.446	−0.221	0.879	1.874
	p − value	0.963	0.605	0.898	0.985
At First Difference					
		d(LCF)	d(RE)	d(REC)	d(GLO)
I	t-Statistic	−3.639***	−3.346**	−3.280**	−2.953**
	p − value	0.006	0.015	0.018	0.042
I&T	t-Statistic	−3.756**	−3.361*	−3.313*	−3.789**
	p − value	0.022	0.061	0.069	0.020
N	t-Statistic	−2.348**	−3.340***	−3.188***	−2.169**
	p − value	0.019	0.001	0.002	0.029
PP (Phillips & Perron, 1988)					
At Level					
		LCF	RE	REC	GLO
I	t-Statistic	−1.322	−1.804	−2.296	−3.052**
	p − value	0.619	0.378	0.175	0.033
I&T	t-Statistic	−2.778	−1.921	−2.505	−0.723
	p − value	0.208	0.638	0.326	0.969
N	t-Statistic	1.843	0.018	0.101	3.670
	p − value	0.984	0.687	0.713	1.000
At First Difference					
		d(LCF)	d(RE)	d(REC)	d(GLO)
I	t-Statistic	−7.773***	−6.258***	−6.213***	−6.204***
	p − value	0.000	0.000	0.000	0.000
I&T	t-Statistic	−9.217***	−6.216***	−6.232***	−5.892***
	p − value	0.000	0.000	0.000	0.000
N	t-Statistic	−7.143***	−6.307***	−6.226***	−6.032***
	p − value	0.000	0.000	0.000	0.000

Notes: (1) I: Intercept; I&T: Intercept & Trend; N: None. (2) ***,**, and * symbols indicate the rejection of the null hypothesis that the variable has a unit root at the 1 %, 5 %, and 10 % confidence levels, respectively.

countries from 1991 to 2016 using the dynamic ordinary least squares and the fully modified ordinary least squares methods. They discovered that using renewable energy can also hurt the environment. This conclusion has earlier been affirmed by the studies of Apergis & Payne (2014) and Sebri & BenSalha (2014). Overall, previously evaluated studies were mainly based on the carbon emission indicator and the observed environmental stability drivers have largely produced conflicting results. Therefore, the current work sets itself apart by concentrating on the load capacity factor (LCF) as a gauge of environmental quality since this indicator encompasses several aspects of environmental stress and resource utilization. By doing so, a thorough examination of how resource efficiency, globalization, and the use of renewable energy influence environmental quality in the case of the rapidly emerging Turkish economy was carried out with cutting-edge econometric methods.

3. Data and methods

3.1. Data

In this paper, we provide empirical evidence of the heterogenous impact of resource efficiency, renewable energy consumption, and globalization on environmental sustainability for Turkey based on the time-series data spanning from 1982 to 2019.1 In order to analyze environmental sustainability level, we employ the load capacity factor (LCF) following recent studies such as Caglar & Askin (2023), and Kartal et al. (2023). We calculate Turkey's LCF for the sample period as biocapacity (BC)/ecological footprint (EF) with the obtained series from the Global Footprint Network (GFN, 2023). The per capita metric tons of CO_2 emissions data obtained from OWD (2023) is employed as an alternative environmental indicator. Furthermore, we use the ratio of gross domestic product to material footprint as a measure of resource efficiency (RE) in line with Wang et al. (2022). The RE series is obtained from OECD (2023) as US$ per kilogram. Renewable energy consumption (REC) data as a percentage of total energy consumption is downloaded from OWD (2023). Finally, we utilize the KOF globalization index as revisited by Gygli et al. (2019) to measure globalization (GLO). The data of GLO is obtained from KOF (2023). We summarize the information about the study variables in Table 1.

The annual values of Turkey's LCF, RE, REC, and GLO are plotted in Fig. 1. It is evident from the figure that the LCF of Turkey has a decreasing trend throughout the sample period, whereas GLO has an increasing trend. On the other hand, although there was no overall stabilization, RE displayed an upward trend between 1987–1990, 1991–2001, 2007–2009, and 2011–2017. Similarly, Turkey has also not achieved stability in REC. However, we observe that Turkey's REC reached its highest level for the sample period in 2019.

3.2. Preliminary estimations

Given the relatively small sample size (39 observations) of the dataset, there is a valid possibility of experiencing small sample bias. In order to eliminate the problem of small sample size and also possible heteroscedasticity, the transformation of the annual series to quarterly series was considered via quadratic match sum. This transformation preceded the subsequent logarithm transformation of the series following the studies of Balcilar et al. (2023), Lee et al. (2023), Olasehinde-Williams et al. (2023), and Özkan et al. (2023).

3.2.1. Stationarity test of the series

Given the need to find out the levels at which the quarterly logarithmic series are stationary, we apply the ADF and PP unit root tests. The estimates in Table 2 imply that, at level, the null hypothesis can be rejected only for the model with intercept and for GLO. However, it can be rejected for all models and variables at the first difference, revealing that the quarterly logarithmic series becomes stationary after getting the first difference.

3.3. Empirical method

After obtaining the stationary data, several analytical procedures were carried out in the process of examining the heterogeneous impact of resource efficiency (RE), renewable energy consumption (REC), and globalization (GLO) on environmental sustainability in Turkey. The synopsis of these procedures is illustrated in Fig. 2. Specifically, the statistical properties of the stationary data series are examined via descriptive statistics, quantile–quantile (Q-Q) plots, and the Brock, Dechert, and Scheinkman (BDS) test as developed by Broock et al. (1996). This was done in addition to the correlation matrix reporting the unconditional Pearson correlations among LCF, RE, REC, and GLO over the entire sample period. Since the correlation between variables may vary over periods, the wavelet correlation method for examining the correlations between LCF and RE, REC, and GLO at various time frequencies was also employed.

Consequently, the relationship and levels of dependencies among the conditional quantile distribution of LCF, RE, REC, and GLO were analyzed via the Cross-Quantilogram (C-Q) methodology developed by Han et al. (2016). Moreover, the impact of the conditional quantiles of RE, REC, and GLO on the conditional quantiles of LCF is assessed by applying the Quantile-on-Quantile Regression (QQR) constructed by Sim and Zhou (2015). Furthermore, to test the validity of the QQR

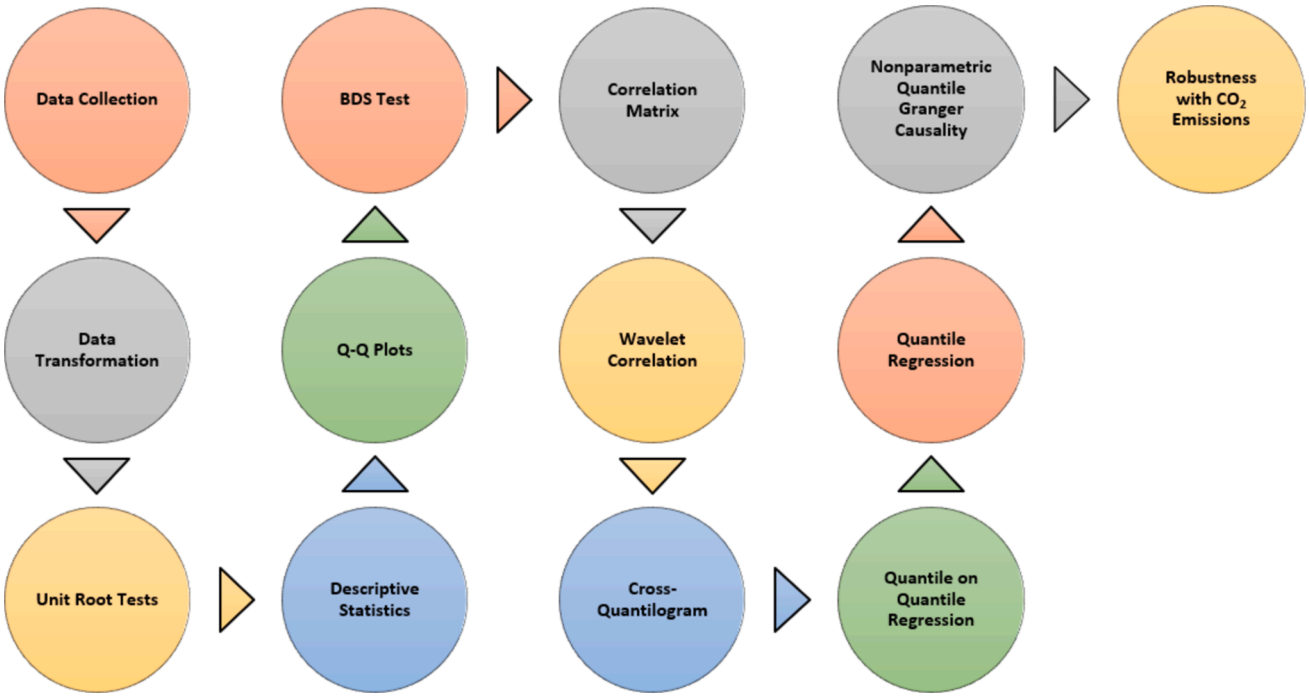


Fig. 2. Analysis flowchart indicating the path of the investigation. .
Soucre: Authors' computation

Table 3
Descriptive Statistics.

	LCF	RE	REC	GLO
Mean	−0.001	0.000	0.001	0.001
Median	−0.001	0.001	0.001	0.001
Maximum	0.029	0.022	0.061	0.008
Minimum	−0.022	−0.024	−0.085	−0.007
Std. Dev.	0.006	0.006	0.018	0.002
Skewness	0.745	−0.170	−0.419	−0.223
Kurtosis	12.532	6.502	8.004	8.361
Jarque-Bera	585.565***	77.875***	161.955***	182.109***
p − value	0.000	0.000	0.000	0.000
Observations	151	151	151	151

Note: *** symbol indicates the rejection of the null hypothesis that the variable has a normal distribution at the 1 % confidence level.

results, a comparison of the estimates of the Quantile Regression (QR) of Koenker and Bassett (1978) and Koenker (1981) and that of the averaged QQR estimates are conducted.

In terms of robustness, the Nonparametric Quantile Granger Causality (NQGC) developed by Balcilar et al. (2016) is employed to examine the causality running from the dependent variables to LCF. Meanwhile, to further consolidate the results of the analyses from the above-mentioned techniques, another environmental sustainability indicator, namely CO_2 emissions was employed in lieu of the LCF indicator.

4. Empirical results

4.1. Preliminary analysis

Before delving into the main analyses, we aim to unveil the statistical properties of the quarterly first difference logarithmic series. For this purpose, we first analyze the descriptive statistics presented in Table 3. From the table, we observe that LCF has a negative quarter average in the sample period, while the other variables have a positive. The values of the standard deviation exhibit that REC has higher volatility relative to other variables. Moreover, RE, REC, and GLO have a negative skewness, whereas LCF is positively skewed. Furthermore, the kurtosis values greater than 3 indicate that the distributions of all variables are leptokurtic. Finally, the estimations of the Jargue-Bera normality test (Jarque & Bera, 1980) imply that the null hypothesis is rejected at the 1 % confidence level for all variables, indicating the presence of non-normality.

To check the results of the Jarque-Bera test, we utilize the Q-Q plots provided in Fig. 3. In the Q-Q plots, the black dashed lines represent a normal distribution, and the red dots show how our data is distributed. The greater the difference between the red dots and the black lines, the more our data differs from the normal distribution. This difference tells us how far our data deviate away from the normality assumption as explained by Liu et al. (2023). It can be seen from the Q-Q plots that there is no variable following the normal distribution line, thereby strengthening the non-normality conclusion. The non-normality of the series reveals the appropriateness of the quantile methods preferred in this study.

Following the non-normal distribution evidence, we employ the BDS test to understand whether or not our quarterly first difference logarithmic series are linear or nonlinear, as in Khan et al. (2023) and Pata et al. (2023). The BDS estimates given in Table 4 demonstrate that the null hypothesis is rejected for LCF at the 2nd and 6th dimensions, for RE and REC at the 2nd, 3rd, 5th, and 6th dimensions, and for GLO at all dimensions. These findings indicate the presence of nonlinear structures in all study data, which also justifies the use of quantile methods.

4.2. Discussion of findings

We begin with the correlation box in Fig. 4 which reflects how the levels of resource efficiency (RE), globalization (GLO), and renewable energy (REC) relate to the load capacity factor (LCF) of Turkey. From Fig. 4, all the variables are positively associated with LCF in Turkey. We have evidence of a very strong positive association between RE and Turkey's LCF. Additionally, the association appears to be stronger in the case of globalization and LCF as compared to the strength of the positive link between REC and LCF. We reassess these levels of association by

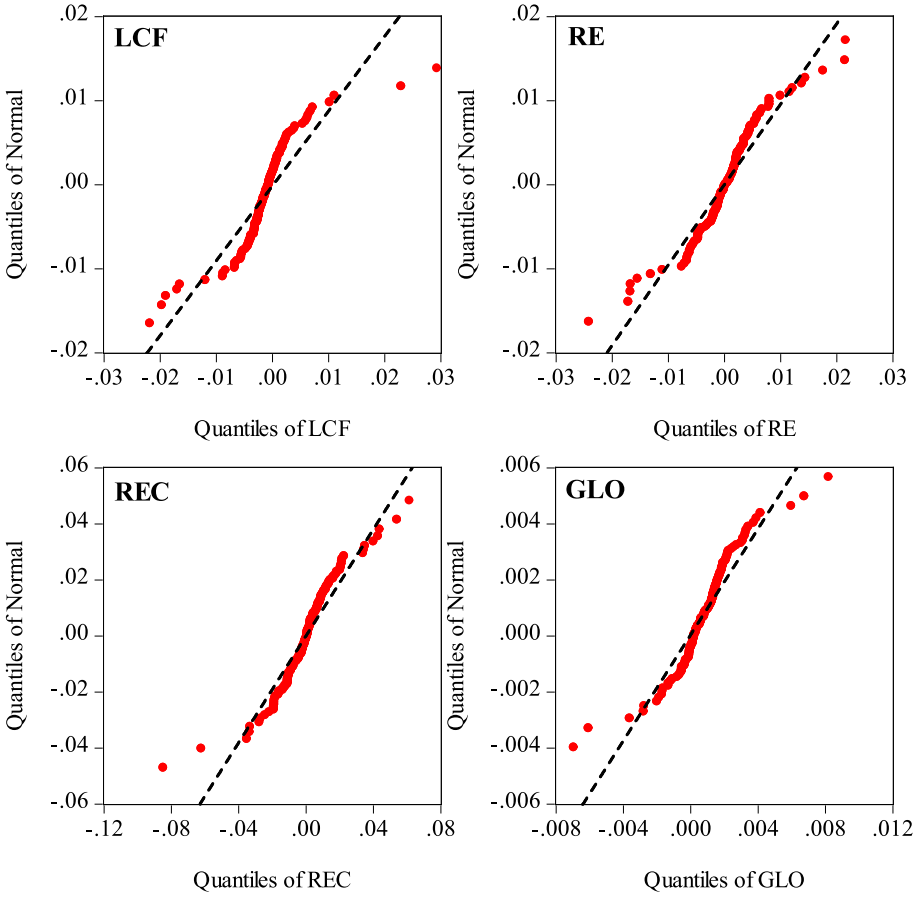


Fig. 3. Q-Q Plots .
Soucre: Authors' computation

Table 4
Estimates of the BDS Test.

Dimension	LCF	RE	REC	GLO
$\varepsilon = 2$	2.585^{***}	3.699^{***}	3.778^{***}	5.338^{***}
p − value	0.009	0.000	0.000	0.000
$\varepsilon = 3$	1.144	2.273^{**}	2.065^{**}	3.926^{***}
p − value	0.252	0.023	0.038	0.000
$\varepsilon = 4$	0.460	1.238	0.821	2.877^{***}
p − value	0.644	0.215	0.411	0.004
$\varepsilon = 5$	1.491	2.375^{**}	1.939^{*}	3.281^{***}
p − value	0.135	0.017	0.052	0.001
$\varepsilon = 6$	1.783^{*}	2.821^{***}	2.355^{**}	3.155^{***}
p − value	0.074	0.004	0.018	0.001

Note: *** symbol indicates the rejection of the null hypothesis that the variable is generated by a linear, independent, and identically distributed stochastic process at the 1 % confidence level.

adopting the wavelet correlation approach as reported in Fig. 5. Based on the wavelet approach, the findings from the correlation box can be seen to have been reinforced by all indications as we observed that Globalization, REC, and RE demonstrate a positive association with LCF in Turkey at all the various scales (D1 – D4) as displayed in Fig. 5. Overall, the observed positive correlation appears to be relatively stronger at middle and lower scales between LCF and both RE and GLO while the strength of the positive correlation is relatively weaker in the case of REC.

We used the Cross-Quantilogram to show if there are some levels of dependence between the quantile distribution of our variables. In this case, this approach works based on the quantile distributions of the trio of RE GLO and RE alongside the quantiles of LCF in order to examine if

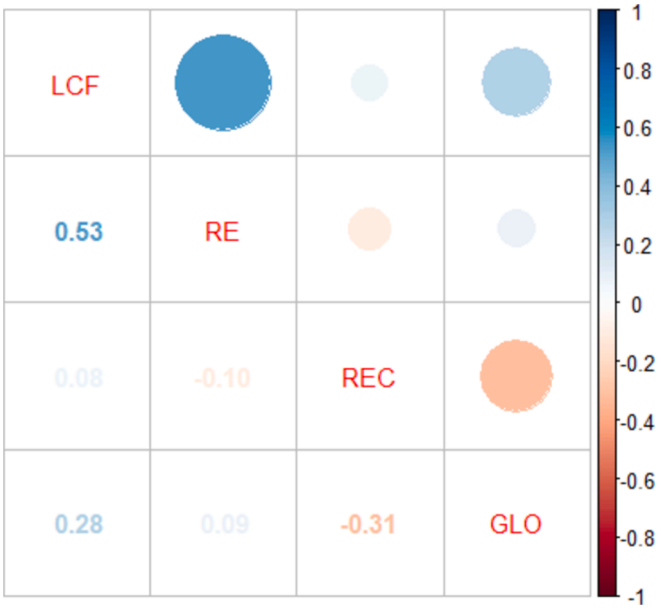


Fig. 4. Correlation Matrix .
Soucre: Authors' computation

there is a quantile-on-quantile serial connection among the variables. When we examine the results of the Cross-Quantilogram heatmaps in Fig. 6, we can visualize how these three factors (RE, REC, and GLO)

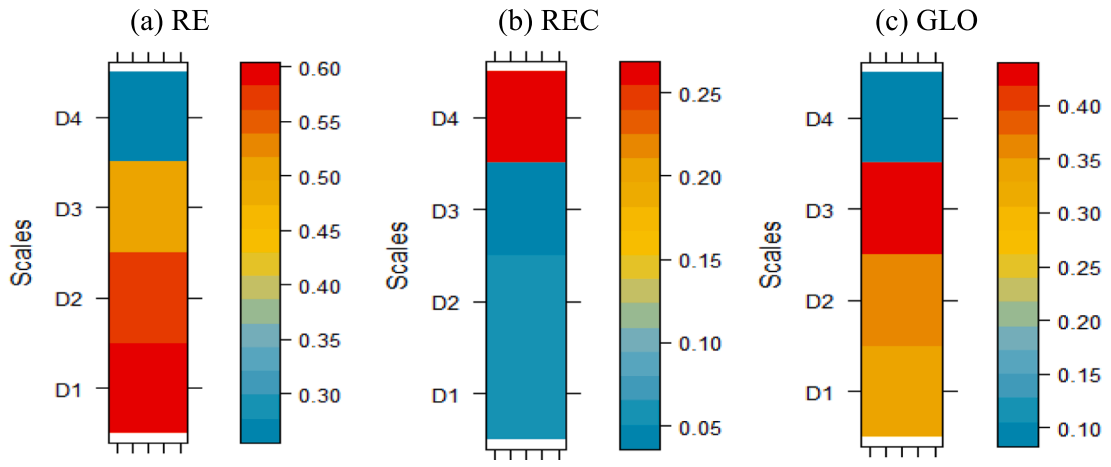
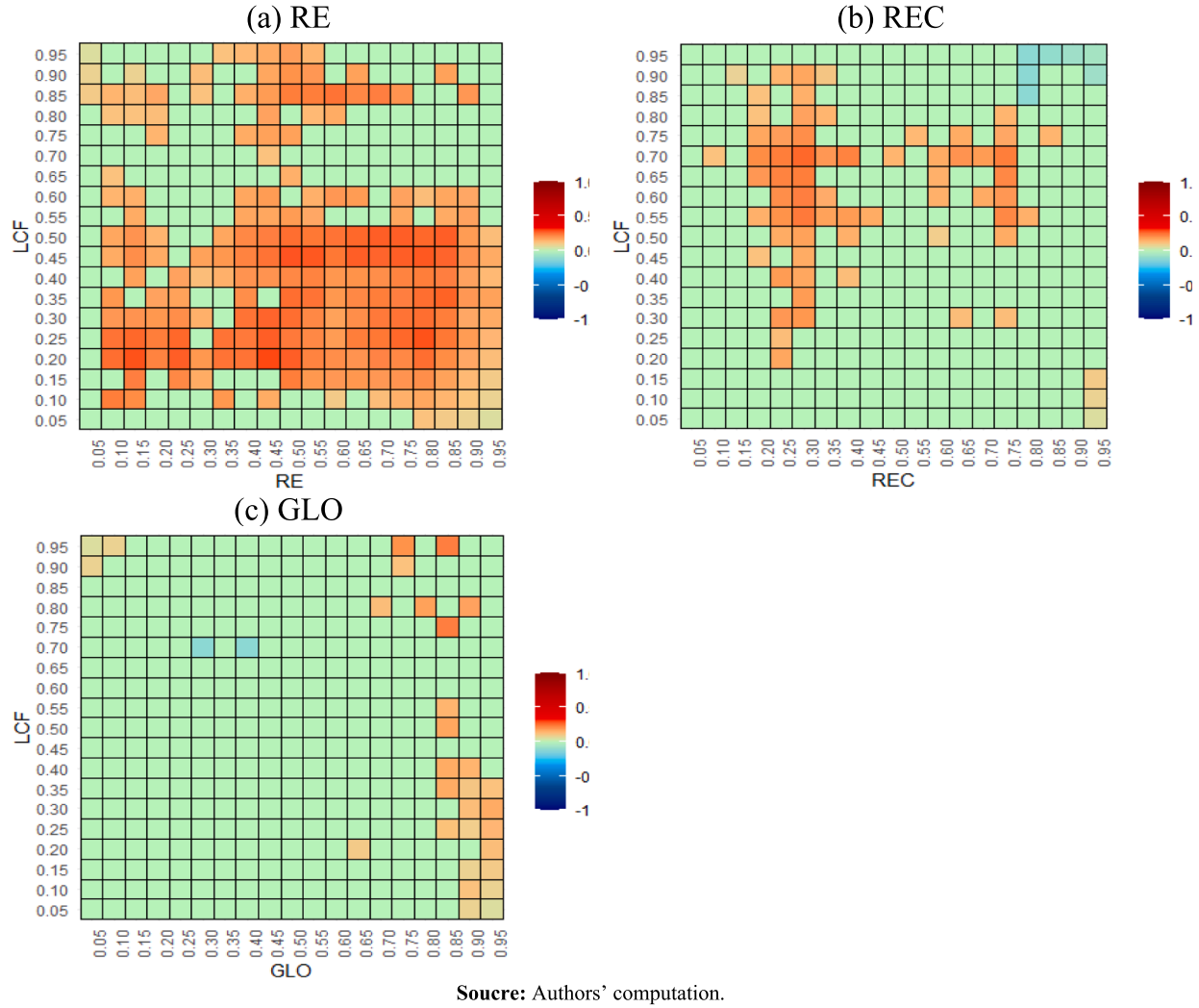


Fig. 5. Wavelet Correlations .
Soucre: Authors' computation



Soucre: Authors' computation.

Fig. 6. Cross-Quantilogram .
Soucre: Authors' computation

individually predict LCF on a quantile-on-quantile level as shown in Panel A to C respectively. Generally, the areas that appear to be plainly colored green in the figure point to an absence of relevant relationships among the variables. On the other hand, the red and blue colors are used to project the directional connection among the variables such that the former connotes a positive relationship while the latter shows the

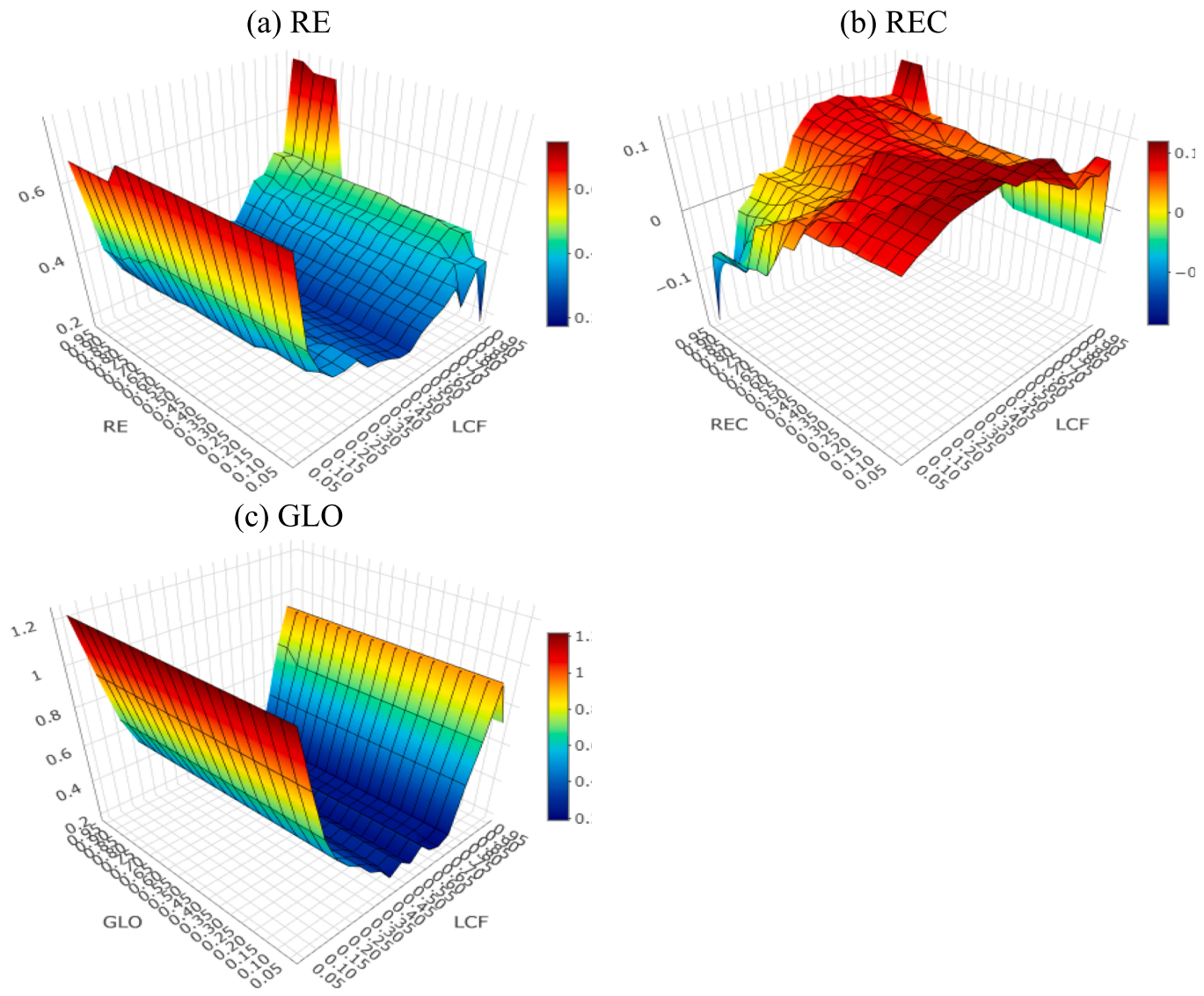


Fig. 7. Quantile-on-Quantile-Regression .
Soucre: Authors' computation

existence of a negative nexus. Of course, as may be expected, the thicker or darker these colors are, the stronger or weaker the degree of relationship.

Panel-a simply reveals that there is a pattern of connection between RE and LCF in Turkey. The observed relationship is very strong such that RE influences LCF in Turkey in a positive direction across most of the quantile distribution. Panel-b also reveals degrees of positive pattern in the dependence structure among REC and LCF. However, the positive connection is relatively weaker at the lower quantiles (0.20–0.40) as compared to the evidence of a strong positive relationship in the middle and lower upper quantile distribution (0.40–0.80). As for globalization, Panel-c reveals that a sizable amount of variations in GLO shows no predictability connections with LCF in Turkey especially in the lower and middle quantile until the upper quantile where we witnessed some degree of strong dependence between GLO and LCF with a positive directional predictability.

Overall, we have evidence of quantile-to-quantile dependence among the trio of (RE, REC, GLO) and LCF and this dependence mostly reflects some levels of positive directional predictability. This essentially indicates that resource efficiency, renewable energy consumption, as well as globalization, are useful tools that drive LCF level in Turkey. As such, considerations based on these factors are recommended to be integrated when drafting policy measures for environmental sustainability in Turkey.

Looking at the QQR results in Fig. 7 from panels a to c, the impacts of resource efficiency, renewable energy consumption, as well as globalization on Turkey's LCF are significantly noticeable. To begin with panel-a, we see the effects of RE on LCF across its conditional distribution from the lower quantiles to the upper ones. It is evident that RE positively impacts LCF in Turkey. These observed positive impacts are strong and flow across all the quantile distributions from the lower quantiles (0.05–0.30) to the mid-quantile (0.40–0.60) as well as the upper ones (0.7–0.95). The implication is that a better level of resource efficiency helps to produce an increased LCF which actually is a welcome and positive development for the environmental sustainability of Turkey. The Republic of Turkey boasts of a rapidly emerging economy with fast growth rates that have propelled the nation into one of the top 20 economies globally (WDI, 2022). This finding thus provides a timely insight into the fact that it is necessary to ensure that a lower material footprint is released even as the nation gradually transforms into a regional production hub. To achieve a higher level of resource efficiency, the right measures must be taken to ensure proper conduct in resource utilization and imbibe internationally acceptable best practices in production activities. Also, Turkey can leverage the global rise in

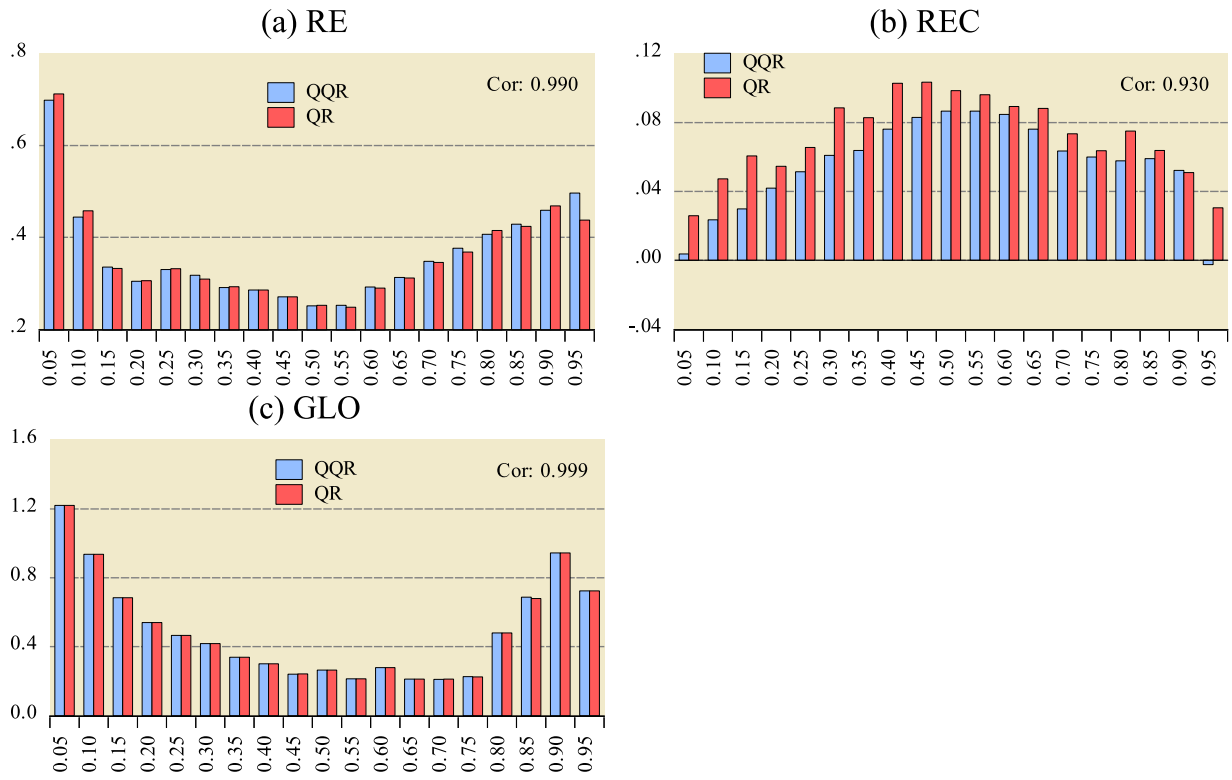


Fig. 8. Comparison of the QR and Averaged QQR Estimates .
Soucre: Authors' computation

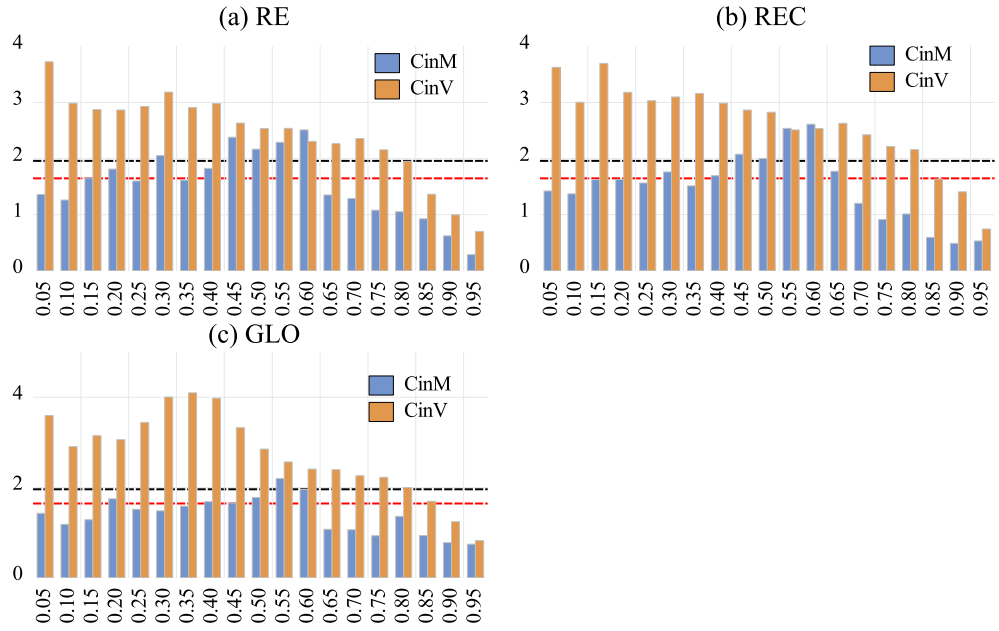


Fig. 9. Nonparametric Quantile Granger Causality .
Soucre: Authors' computation

green innovation to enhance efficiency in its resource utilization considering that such innovations have been identified as a key pollutant-reducing factor within the natural resource utilization context (Aydin et al. 2023; Musah et al. 2024a; Musah et al. 2024b). This would foster a better LCF level and ultimately position the nation on the path to a sustainable future.

As for the results of the REC, we can observe a strong positive impact of this variable on LCF in Turkey and this is mostly visible at the lower quantile up to the upper middle quantiles of renewable energy utilization (0.05–0.65). This outcome actually indicates that the LCF level in Turkey significantly rises as REC increases. However, the magnitude of these positive impacts weakens towards the tail end of the upper quantile of the REC distribution. This is an affirmation of the well-established arguments in favor of renewable energy consumption in

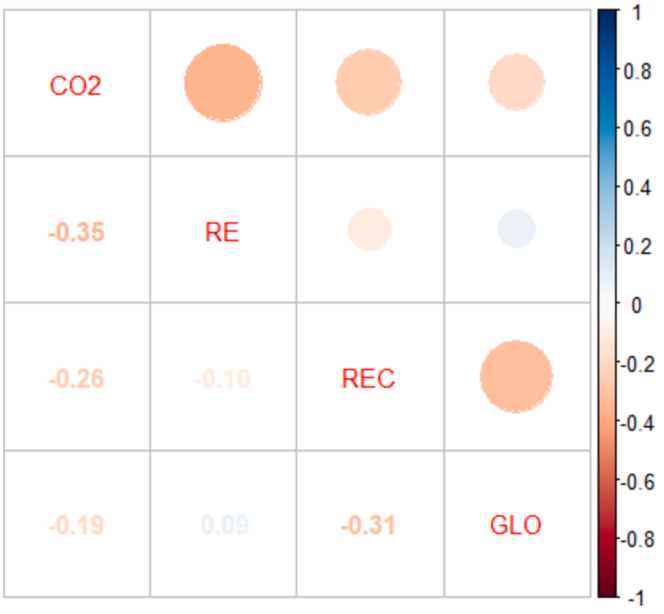


Fig. 10. Correlation Matrix .
Soucre: Authors' computation

the environmental literature for Turkey as well as many other parts of the world (Sharma et al. 2021; Onifade & Alola, 2022; Dogan & Seker, 2016; Pata & Destek, 2023; Appiah et al. 2023; Destek et al. 2024). Hence, the rapidly emerging Turkish economy stands to achieve important environmental gains if authorities can make more effort to boost strategic investments in major potential drivers of renewable energy and environmental sustainability. Such factors include financial development (Horky & Fidrmuc, 2024), technological innovations (Onifade et al. 2024), and human capital development (Dai et al. 2024) among others. This will also help Turkey to decouple its economic growth from its fossil energy propeller (Destek & Aslan, 2017), thereby assisting the country in maintaining sustainable economic growth for the future.

When we proceed to look at the impact of GLO on LCF, the outcomes are quite similar to what was obtainable in the case of RE. Globalization is confirmed to be boosting Turkey's LCF level. There is a strong positive influence of GLO on LCF across all the observed quantile distributions from the lower quantiles to the mid and upper ones. This result indicates that globalization has been a potent tool in driving environmental quality levels in Turkey. The results can be attributed to the possible increase in access to green innovations from the rest of the world as Turkey's economy continues to integrate with the rest of the world. Contrary to studies that sided with the negative side of the globalization-environmental nexus debate such as (Ulucak & Danish, 2020) and Akadiri et al., (2020), the outcome in the present study confirms some other studies that have alluded to the positive side of the globalization-environmental nexus in the vast empirical literature (Khurshid et al, 2023; Gyamfi et al. 2023). In a nutshell, globalization can be concluded to be a double-edged sword that can yield either environmental benefits or woes, but in the present study, we observed the former as far as the LCF of Turkey is concerned. Hence, Turkey needs to further leverage globalization for more sustainable environmental quality gains.

By following Alola et al. (2023), Olanipekun et al. (2023), and Ozkan et al. (2023), we compare the QR and averaged QQR estimates to check the findings of the QQR. From Fig. 8, we confirm that both approaches were similar in their revelations of the patterns through which the trio of globalization, resource efficiency, and renewable energy consumption influence LCF in Turkey. The levels of similarity in outcomes from both methods are quite high especially in the cases of the impacts of GLO and RE.

While we have duly established the impacts of the trio factors on Turkey's LCF, it is important to note that the existence or confirmation of relationships does not necessarily reflect causation directions among variables. Hence, the underlying causal directions in both mean and variance of the quantile distribution were further reported in Fig. 9 under Panel a to c for RE, REC, and GLO respectively. The null hypothesis to be examined in this direction negates the existence of any causal links in mean or variance from a variable (say RE) to the LCF. In Fig. 9, the brown bars are used for causality in variance while the bars in blue denote causality in mean. The decision on the null is to be taken by comparing the position of the bars to the 95 % confidence level as reflected by the dotted black line and 90 % by the dotted red line in case of any causality in variance or causality in mean. Hence, in all cases, the 2 corresponds to a critical value of significance at a 5 % level such that the standard normal distribution of 95 % quantile is utilized for the test's critical values. The bars have to rise above the line of 2 and the lower dotted red line for any possibility of rejecting the null hypothesis which invariably would imply the existence of a valid causal nexus from the explanatory factor to the explained variable in this case the LCF. In addition, the fatter the bars are above the threshold red and black lines, the stronger the causality. As can be seen from Panel-a, we reject the null hypothesis for no causality in variance in most of the quantiles from the least quantile (0.05) up to (0.80) meaning that RE has a strong causal

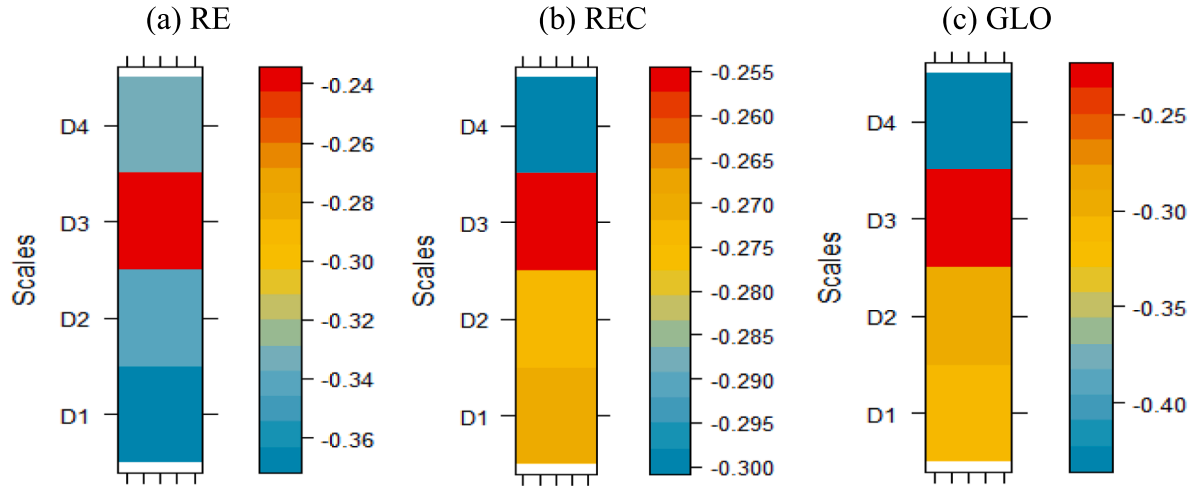


Fig. 11. Wavelet Correlations .
Soucre: Authors' computation

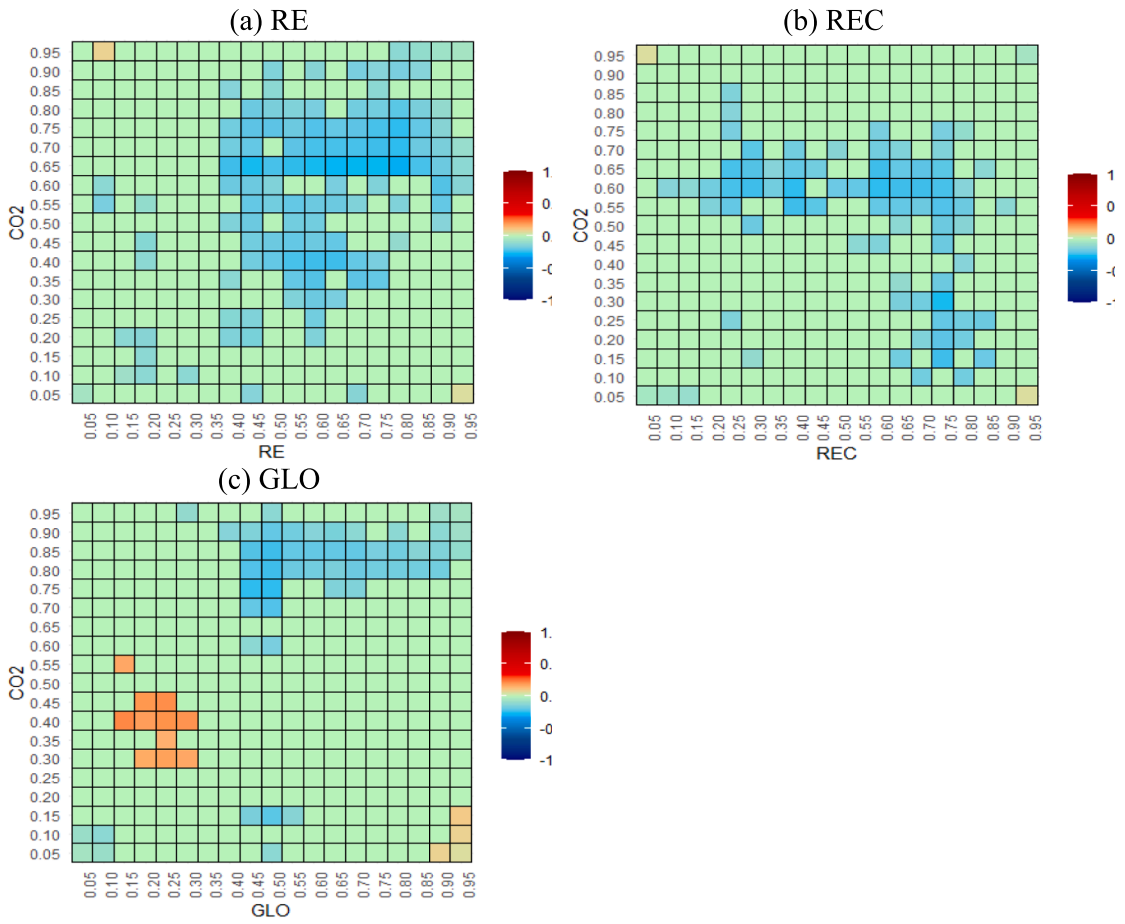


Fig. 12. Cross-Quantilogram .
Soucre: Authors' computation

impact on LCF but this causality in variance slowly diminishes at the higher quantile distribution.

On the other hand, evidence of weak causality in the mean is only upheld at the mid-quantile levels while there is no sufficient basis to reject the null hypothesis at either the lower or upper quantile distributions. This reaffirms the important role of resource efficiency level as an influencer factor for Turkeys LCF. As for REC, strong causality in variance was validated across quantile distributions from the lower quantiles to 0.80 quantiles while the causality in mean only holds true at the mid-quantile distribution. A slightly similar causality nexus was obtained for the case of GLO. Overall, we noticed that the variance causality significantly shows that the trio of resource efficiency, renewables, and globalization demonstrate a causal effect on Turkey's LCF level and can thus help provide a solid basis for useful policy direction to drive the desired environmental sustainability of the nation.

4.3. Robustness with CO_2 emissions

We utilized CO_2 emission as an alternative measure for the environment instead of LCF for a robustness check. This helps us to see if there would be any significant difference in our overall findings. The outcomes boost our overall confidence in the performance of the model that utilizes the LCF for the environment. The only difference is that the figures reflect in an opposite direction. This is actually expected since the LCF provides an interesting diametrical directional measure when compared to using metrics like carbon emissions levels. For instance, we would expect a lower emissions level which invariably could be tantamount to a higher LCF to have a better environmental quality. Fig. 10 shows that the trio of RE, GLO, and REC all have a negative correlation with Turkey's emissions level, and this is quite desirable since this negative correlation with emissions supports a stance of improvement in environmental quality level. The findings from the correlation box are also reinforced by all indications in the outcomes from the wavelet correlation approach in Fig. 11. We observed that Globalization, REC, and RE demonstrate a negative association with carbon emissions at all the various scale levels (D1 – D4). The outcome from the carbon emission proxy here thus further supports the findings from the LCF indicator.

The robustness check conducted with a Cross-Quantilogram using carbon emissions levels as seen in Fig. 12 also provides some evidence of quantile-to-quantile dependence among the trio of (RE, REC, GLO) and CO_2 emission Interestingly, the observed dependence mostly reflects some levels of negative directional predictability from these factors for Turkey's CO_2 emission which is actually a reinforcement to the results from the LCF analysis. For example, the strength of the negative directional predictability among RE and CO_2 emission is more pronounced from the mid-quantile distribution and gradually continues up to the upper quantile. This further supports the conclusion that resource efficiency, renewable energy consumption, as well as globalization, are useful tools that can be leveraged for the environmental sustainability of the Turkish economy.

The outputs of the Quantile-on-Quantile-Regression in Fig. 13 also reveal the evidence of mostly negative impacts of RE, REC and GLO on emissions levels across most of the quantile distribution. These emission reduction impacts are more potent in the cases of REC and GLO from the lower quantiles to the upper quantile levels compared to that of RE. The results however generally connote a good signal for improving environmental quality level in Turkey by the instrumentality of these

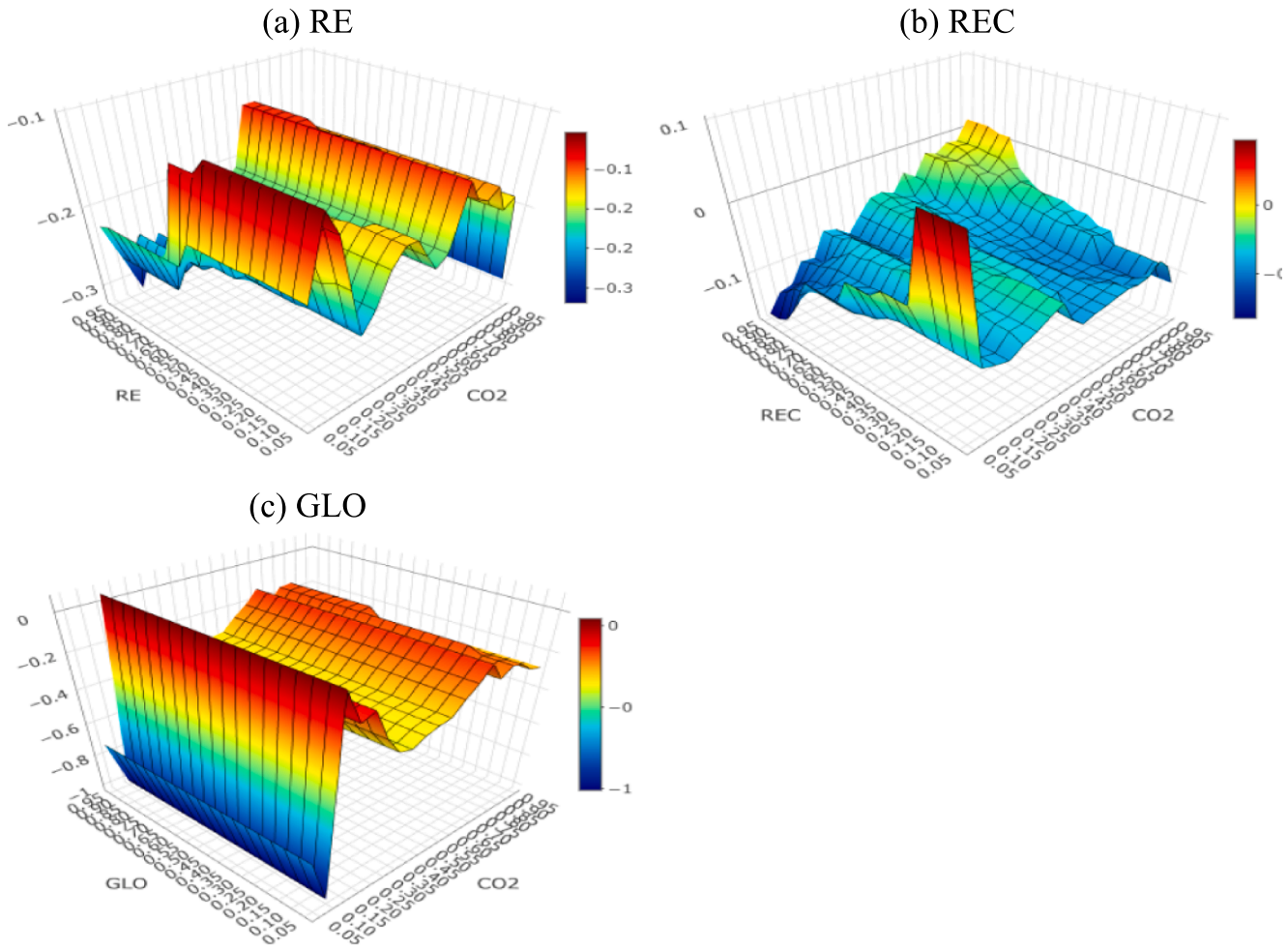


Fig. 13. Quantile-on-Quantile-Regression .
Soucre: Authors' computation

understudied indicators.

Moving to the comparison of the QR and averaged QQR estimates as seen in Fig. 14. We also observed here that both approaches were close in the ways they demonstrate the patterns that GLO, RE, and REC have on CO_2 emission in Turkey. The levels of similarity in outcomes are higher in the analyses for GLO and RE compared to that of REC in the CO_2 emissions model. This provides more credence for the robustness of the analysis conducted using the LCF. Furthermore, more evidence of causality in variance dominates the CO_2 emissions models as compared to the available evidence on causality in mean going by the results of the Nonparametric Quantile Granger causality that is provided in Fig. 15. Similar to the LCF results we further notice a sizable amount of causality in variance from lower to the upper-mid quantiles distributions of CO_2 emission from all three variables with some minimal level of causality in mean towards the mid quantiles (0.30–0.60) especially for the RE. All this evidence buttresses the performance of the LCF model and as such supports the basis for result-based policy initiatives for the sustainability of the Turkish economy.

5. Conclusion and policy recommendations

The drivers of environmental sustainability have been widely examined for different cases without leaving out the developing countries. Specifically, emerging economies such as Turkey have not only been broadly studied, but the countries are also increasingly becoming the focus of carbon neutrality literature. In the current attempt, the drivers of environmental sustainability are examined in the context of resource efficiency, renewable energy utilization, and globalization. By employing the dataset that covers the period 1982 to 2019, load capacity factor was implemented as the environmental indicator such that the combination of empirical tools that include cross-quantilogram method, quantile-on-quantile regression, quantile regression approaches, and the nonparametric quantile Granger causality approach yields useful observation.

Foremost, there is statistically significant evidence of quantile-to-quantile dependence among the trio of (RE, REC, GLO) and LCF such that the dependence mostly reflects some levels of positive directional predictability. This essentially indicates that resource efficiency, renewable energy consumption, as well as globalization, are important drivers of the LCF level in Turkey. Furthermore, the QQR results show the effects of RE on LCF across its conditional distribution from the lower quantiles to the upper ones. It clearly indicated that RE positively impacts LCF in Turkey. Similarly, for the REC, there is a statistically significant and positive impact of this variable on LCF in Turkey which is mostly visible at the lower quantile up to the upper middle quantiles of renewable energy utilization (0.05–0.65). Although the magnitude of this positive impact weakens towards the tail end of the upper quantile of the REC distribution, the outcome indicates that the LCF level in Turkey significantly rises with an increase in REC. For the impact of GLO on LCF, the outcomes are quite similar to that of RE and LCF nexus, thus further suggesting that globalization spurs LCF levels in Turkey. The results of other empirical tools are not generally different from the above-indicated observations. However, this study can be improved in future implementation by applying a similar combination of empirical

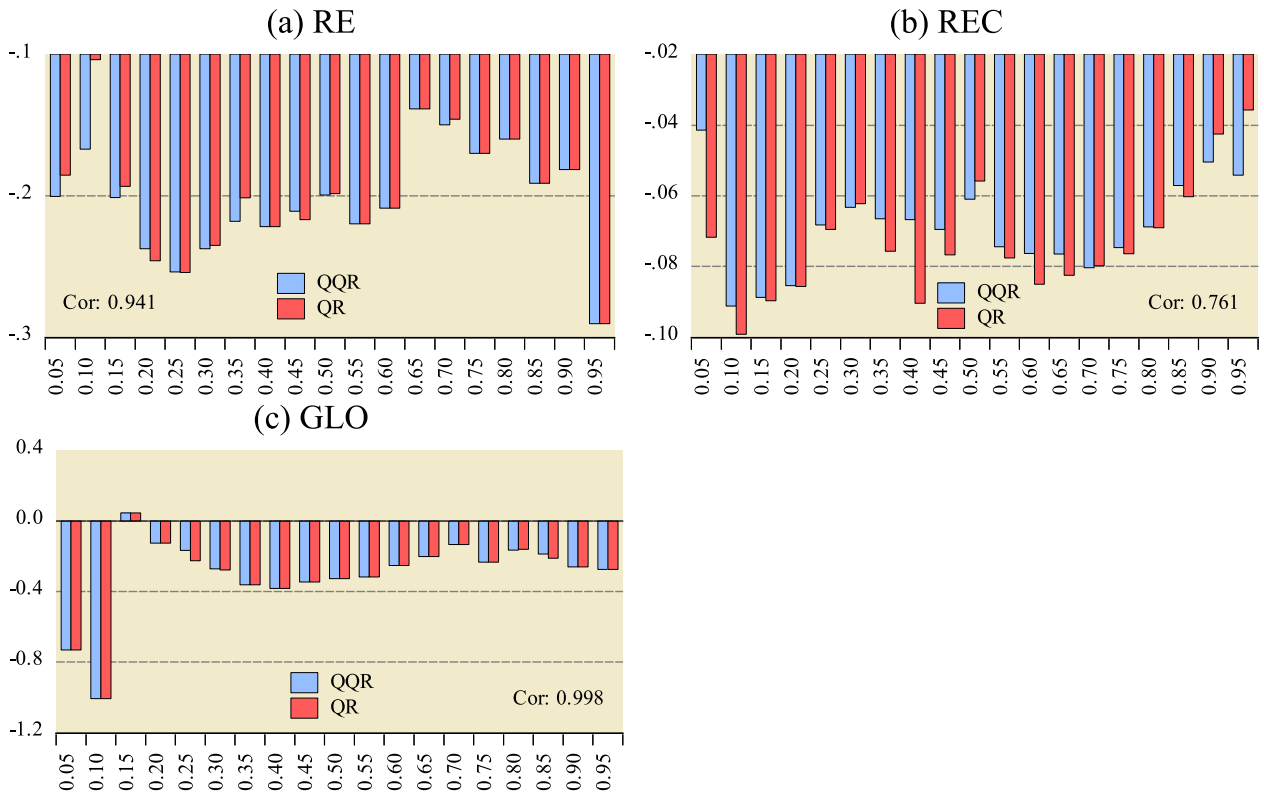


Fig. 14. Comparison of the QR and Averaged QQR Estimates .
Soucre: Authors' computation

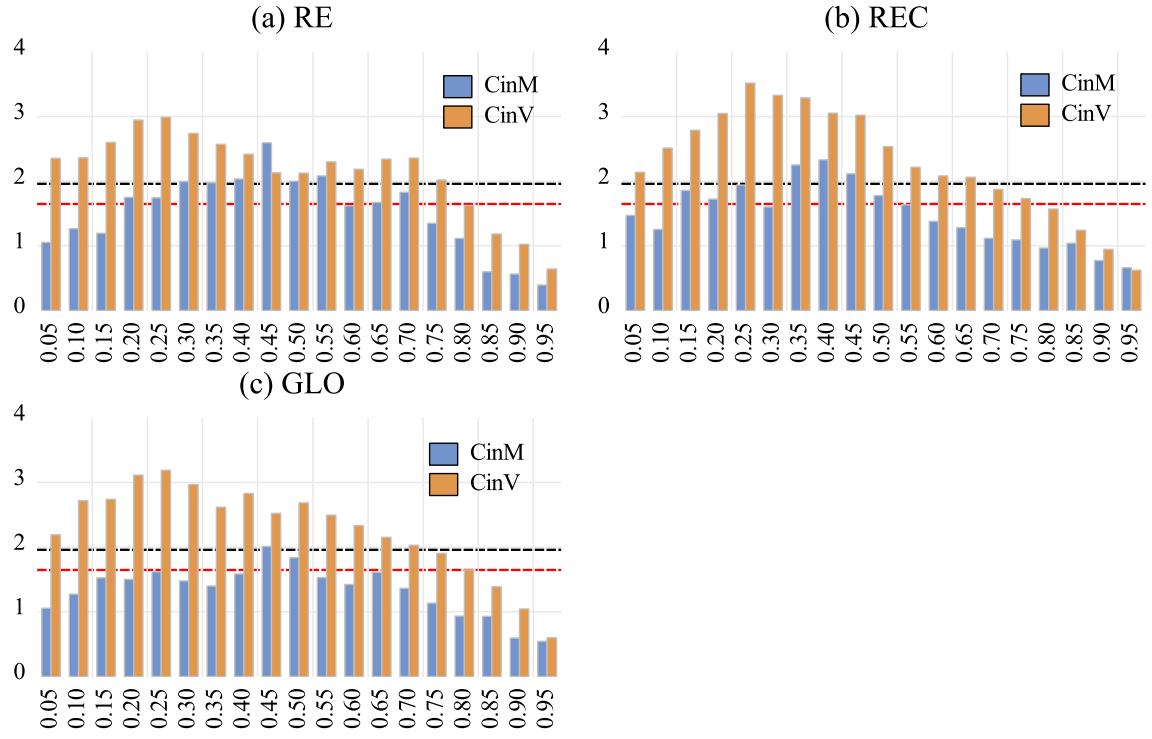


Fig. 15. Nonparametric Quantile Granger Causality. .
Soucre: Authors' computation

approaches to examine the role of the efficiency of disaggregated renewable energy sources in environmental sustainability and alongside other variables of interest.

5.1. Policy recommendations

From a policy perspective, while there is a global effort toward

improving energy efficiency, enhancing the efficient use of renewable energy sources in particular is no doubt a faster pathway to a net zero future. Therefore, the development and utilization of renewable energy sources in Turkey should be improved through adaptive energy technologies that are efficient. Specifically, scaling up clean technology investment in research and development through improved public and private partnerships is essential to navigate the clean technology financing hurdle. Moreover, beyond energy efficiency insight, a more inclusive approach to resource efficiency can be accomplished through a stricter measure that encourages the adoption of social and economic circularity practices.

Additionally, going by the obtained environmental benefits of renewable as it boosts LCF, authorities of the rapidly emerging Turkish economy can leverage the opportunities from renewable energy for more environmental gains. This can be achieved by making more efforts to boost strategic investments in major potential drivers of renewable energy as a crucial environmental sustainability indicator. The authorities and stakeholders can work out more public–private partnership arrangements to foster the nation's R&D spending and financial inclusivity to boost renewable energy production and consumption. This will also help Turkey decouple its economic growth from its fossil energy propeller, thereby assisting the country to maintain sustainable economic growth for the future.

Lastly, the overall results essentially indicate that apart from resource efficiency and renewable energy consumption, globalization also acts as a useful tool that drives the LCF level in Turkey. Hence, the regulatory authorities and stakeholders in the energy, environment, and resource sectors should ensure that the Turkish globalization experience is fully harnessed for the nation's environmental substantiality gains. This can be achieved by prioritizing policy initiatives that foster green technology transfers into Turkey as well as programs that enhance human capital development on the ambient of the numerous opportunities offered by globalization in our modern world.

5.2. Limitations and direction for future studies

In the current study, the drivers of environmental sustainability in Turkey were examined in the context of resource efficiency, renewable energy utilization, and globalization. We believe this scope is not exhaustive. Hence, subsequent studies can leverage the developed framework to develop and expand a larger scenario. Additionally, the generalization of the current findings to all other rapidly emerging economies can be limited by country-specific heterogeneous factors. As such, subsequent investigations within this framework can consider a direct investigation of other emerging economies across the globe.

CRediT authorship contribution statement

Oktay Özkan: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft. **Hephzibah Onyeje Obekpa:** Writing – original draft. **Stephen Taiwo Onifade:** Writing – original draft, Writing – review & editing. **Andrew Adewale Alola:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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