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Article

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Borsa İstanbul Review

Provided in Cooperation with:

Borsa İstanbul Anonim Şirketi, İstanbul

Suggested Citation: Gong, Zheng; Gong, Liuji; Rasool, Zeeshan (2024) : From brown to green: Exploring asymmetric nexus between green finance and carbon footprint in BRICS+6 alliance, Borsa İstanbul Review, ISSN 2214-8469, Elsevier, Amsterdam, Vol. 24, Iss. 2, pp. 363-375, <https://doi.org/10.1016/j.bir.2024.01.010>

This Version is available at:

<https://hdl.handle.net/10419/340471>

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From Brown to green: Exploring asymmetric nexus between green finance and carbon footprint in BRICS+6 alliance

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ARTICLE INFO

Keywords:

Green finance
Carbon footprint
Quantile estimation

ABSTRACT

Green finance is the beacon of hope in a world striving for sustainability, where financial growth and environmental responsibility go hand in hand. The BRICS, containing five emerging economies (Brazil, Russia, India, China, and South Africa), recently announced Iran, Egypt, Argentina, Ethiopia, Saudi Arabia, and the UAE as six potential new members. This expansion offers promising prospects for advancing environmental sustainability through green finance, which can be an excellent tool. In this respect, this research examines how green finance affects the carbon footprint in BRICS+6 economies. Earlier studies used panel data techniques to probe the association between these variables but overlooked that certain countries still needed to possess such a link separately. Hence, this research adopts the Quantile-on-Quantile approach, which provides a holistic universal view and customized findings for each country. The outcomes display that green finance improves environmental quality by diminishing carbon footprint at distinct quantiles of data distribution.

1. Introduction

The perception of green finance (GNF) has recently received significant traction, primarily because of issues raised about climate change and environmental sustainability. GNF refers to financial instruments and investments specifically aimed at projects and activities that positively influence the environment (Adebayo & Kartal, 2023; Teng, Wang, Ali, & Nazar, 2023). One of the most profound impacts of GNF is its potential to reduce carbon footprint (CF) globally. GNF channels capital into projects and initiatives that promote sustainability, renewable energy, energy efficiency, and other eco-friendly endeavors and accelerates the transfer to a low-carbon nation (Sampene et al., 2023; Saqib, Mahmood, Murshed, Duran, & Douissa, 2023). For instance, green bonds allow organizations to raise funds for environmentally friendly ventures containing renewable energy infrastructure or green building construction. This targeted investment reduces the dependency on fossil fuels, diminishing the carbon emissions associated with traditional energy sources. Furthermore, GNF encourages innovation in historically carbon-intensive industries (Nawaz et al., 2021). As financial incentives and regulatory pressures mount to reduce carbon emissions, companies increasingly invest in research and development to create cleaner

technologies and processes. This innovation reduces CF within these industries and provides a competitive advantage in a rapidly changing global marketplace (Khan, Riaz, Ahmed, & Saeed, 2022; Saqib & Dincă, 2023).

In addition to its impact on industries, GNF directly influences consumer behavior. As individuals become more environmentally conscious, they are inclined to invest their money in sustainable funds or support companies with firm environmental commitments (Chi & Yang, 2023; Saqib, Usman, Ozturk, & Sharif, 2024). This shift in consumer preferences drives investments toward environmentally responsible businesses and pressures companies to adopt sustainable practices and reduce their CF to attract investors and customers (Lee & Lee, 2022). Another notable impact of GNF on CF is the enhanced ability to measure and report environmental performance. As companies and projects seeking GNF must meet stringent environmental criteria, they are often required to track, report, and reduce their carbon emissions. This increased transparency and accountability contribute to a greater awareness of the environmental effect of many investments, leading to more informed decision-making and a reduction in carbon-intensive activities (Zhang, 2022). GNF, while aiming to improve environmental quality (EQL), can also have adverse effects. One notable concern is

Peer review under responsibility of Borsa İstanbul Anonim Şirketi.

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<https://doi.org/10.1016/j.bir.2024.01.010>

Received 19 September 2023; Received in revised form 19 January 2024; Accepted 19 January 2024

Available online 23 January 2024

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greenwashing, where entities falsely portray themselves as environmentally friendly to attract investments, potentially leading to misallocated funds (Adeel-Farooq, Abu Bakar, & Olajide Raji, 2018). Additionally, the intense focus on GNF may divert resources from other critical environmental issues, such as biodiversity conservation or pollution control. Some green projects, particularly in renewable energy, can also have unintended environmental trade-offs, like habitat destruction or ecosystem changes (Sinha, Mishra, Sharif, & Yarovaya, 2021). Therefore, while GNF holds promise in promoting sustainability, it must be carefully managed to minimize these adverse impacts and ensure a comprehensive approach to EQL improvement (Chen, Zhang, & Wang, 2023).

Examining the correlation between GNF and CF presents difficulties due to the assorted and unforeseeable trends discovered among several economies. Moreover, the unclear effect of GNF on CF contributes to the intricacy, and previous empirical research has delivered merely a restricted perception of the intricacies intrinsic to this association. Thereby, the fundamental target of this study is to probe the complexities related to asymmetric GNF-CF association. Although preceding investigations have touched upon the GNF-EQL relationship, none has distinctly concentrated on investigating the asymmetric correlation between GNF and CF (Gholipour, Arjomandi, & Yam, 2022; Nawaz et al., 2021; Sampene et al., 2023; Shen et al., 2021; Sinha et al., 2021). Past works have majorly stressed on panel data tools to probe the GNF-CF relationship. In addition, the outcomes of these studies have yet to exhibit broad applicability consistently across various economies. Recognizing these constraints, the current investigation chooses the Quantile-on-Quantile (QQ) instrument, facilitating an absolute review personalized to the unique traits of every individual nation. Consolidating the QQ methodology endorses a much more intricate conception of the GNF-CF association. This approach confers distinct benefits by separately scrutinizing the temporal correlation within each nation (Sinha et al., 2021). Given the complex nature of the GNF-CF association, typical econometric methods such as Ordinary Least Squares (OLS) and standard Quantile Regression (QR) meet problems (Hung, 2023a).

In contrast to conventional studies that often evaluate the complete dataset by applying elements pointing to neutral, positive, or inverse values, the current investigation introduces a unique method for exploring effects that cover negative and positive paths across multiple quantiles. The GNF-CF connection may get various results contingent upon economic circumstances, encompassing expansion and economic downturn periods. Moreover, there is an anticipation that the influence of increased GNF levels on CF will contrast with that of lower levels. The projected results stemming from the impact of GNF on CF are anticipated to expose notable differences, precisely concerning the extent of GNF consolidation. This highlights a complex, ever-changing connection that becomes more conspicuous as GNF levels rise. Consistent with our hypothesis, the nonlinear dispersion of characteristics is predicted to initiate disparities between GNF and CF, resulting in asymmetric discrepancies across economic indicators. Our comprehensive approach entails examining a range of nations and evaluating association changes across variables across several economies. This technique imparts worthwhile perceptions that facilitate governments and policymakers in pursuing multiple political, social, and economic aims with diverse indicators.

Current research directs its primary attention towards BRICS+6 countries, a choice driven by many convincing reasons. The BRICS, containing Russia, Brazil, China, India, and South Africa, are well-known emerging economies with significant environmental and economic implications. The recent announcement of their intention to incorporate Egypt, Argentina, Saudi Arabia, Ethiopia, Iran, and the UAE as potential new members expands the group's geopolitical and economic significance. These new additions represent a diverse range of countries with varying levels of economic development, environmental challenges, and potential for GNF initiatives. Therefore, studying the impact of GNF on CF in this expanded BRICS+6 group makes sense as it

addresses the pressing need for environmental sustainability across a broad spectrum of emerging and developing economies. The nexus between GNF and CF within the BRICS+6 alliance holds profound implications for global sustainability efforts. Each member nation presents a unique economic landscape and environmental profile, influencing the dynamics of this relationship. In the context of China, as a major economic powerhouse, understanding how its GNF initiatives impact its carbon footprint is crucial for global climate efforts. Similarly, India's commitment to GNF is pivotal for addressing its growing carbon emissions. Brazil's emphasis on sustainable development offers insights into balancing economic growth with environmental conservation. As a significant energy player, Russia showcases the challenges of aligning GNF with carbon reduction in resource-dependent economies. South Africa's efforts indicate the probable trade-offs between economic betterment and environmental preservation. The additional six nations further diversify this analysis, highlighting the collective and individual roles in the global push for sustainable finance and reduced carbon footprints within the BRICS+6 alliances. This research has the potential to provide valuable insights into how GNF can be leveraged effectively in a geopolitically significant and diverse set of countries to mitigate carbon emissions and promote sustainable development. Furthermore, historical data underscores the rapid dissemination of technological advancements among neighboring nations, highlighting the significance of probing these nations with heightened GNF as capacity catalysts for geographical progress. In addition, a nation's energy sector is intricately connected to its neighboring nations' energy industries, exposing it to external and internal interruptions (Saqib, 2022). It stresses the intricate systems of interrelated GNF networks and the ability for ripple influences. To exhaustively understand the assorted models and interrelationships across diverse countries, we apply the QQ technique, facilitating an all-inclusive estimation of every definite nation included in our evaluation. Neglecting these factors may significantly distort findings and display biases. The GNF-CF correlation reveals variations affected by industrialization, economic growth, and abrupt shifts in energy approaches. Our research performs separate analyses for each country to consider these variables adequately. Every nation possesses its distinct ability to employ GNF to advance and implement CF-related tactics. To accommodate these differences among entities, using an econometric method containing QQ in formulating empirical models becomes critical. This strategy plays a central role in achieving an all-encompassing awareness of the alliance between the investigated variables, going beyond the limitations of old econometric tools. The findings of the ongoing investigation should build a fundamental basis for forthcoming research endeavors exploring the GNF-CF nexus, along with its probable repercussions for other nations.

The rest of the investigation follows the following structure: Section 2 conducts a broad examination of relevant literature drawn from prior empirical works. Section 3 demonstrates the research data, whereas Section 4 expounds on the chosen econometric methodology. Section 5 introduces and delves into the findings. Section 6 gives the study's conclusion by briefly summing up the insights and recommending guidelines for forthcoming research endeavors.

2. Literature review

Numerous studies have explored different facets of renewable energy, environmental sustainability, and reducing carbon emissions. This empirical review offers a concise glimpse into significant research efforts in this field, emphasizing their primary discoveries and investigative approaches. Shen et al. (2021) evaluated how green investment, financial development, energy consumption, and natural resources influence reducing carbon emissions for a cleaner environment. The study analyzed data from 30 Chinese provinces from 1995 to 2017 using an innovative CS-ARDL approach. The results indicated that financial development and energy consumption led to higher carbon emissions, whereas green investment contributed to their reduction. Moreover,

national natural resources rent was related to increased carbon emissions. Nawaz et al. (2021) utilized the difference-in-difference (DID) methodology to analyze the influence of GNF on EQL in N-11 economies from 2005 to 2019. It was observed that GNF enhanced EQL. Sampene et al. (2023) studied the effect of GNF on the ecological footprint (EF) using the environmental Kuznets curve (EKC) structure using the data from 1990 to 2017 in South Asian economies. The results supported the EKC hypothesis in the region, revealing that GNF decreased EF. Similarly, Khan et al. (2022) executed a study to quantify the impact of GNF on EF in twenty-six Asian nations. Fixed-effects estimation and ordinary least squares models were employed for the data from 2011 to 2019. The outcomes indicated that GNF had a positive and environmentally friendly effect by reducing EF. In another study, Al Mamun, Boubaker, and Nguyen (2022) examined how GNF affected carbon reduction across 46 countries. The study revealed that GNF significantly reduced carbon emissions, especially in countries with robust credit markets, innovation, and vulnerability to climate change. Moreover, the results consistently emphasized the importance of GB in global carbon reduction efforts, especially in technologically advanced and climate-vulnerable nations.

Gholipour et al. (2022) explored the connection between green property finance and CO₂ emissions in 98 high-income and underdeveloped nations from 2012 to 2018. The study revealed a powerful negative connection between the growth of green property finance and CO₂ emissions, especially in developing nations. Yeow and Ng (2021) explored how GB affected corporate performance using data from corporate bond issuances in various countries between 2015 and 2019. After applying propensity score matching (PSM) and difference-in-difference (DiD) methods, it was shown that GB positively influenced EQL, mainly when third-party certification was used, without affecting financial performance. Adebayo and Kartal (2023) probed the impact of GB, prices of oil, and the COVID-19 pandemic on industrial CO₂ emissions in the USA by analyzing the data from March 6, 2020, to September 30, 2022. The wavelet local multiple correlation approach revealed asymmetric correlations among variables. GB, oil price, and COVID-19 reduced industrial CO₂ emissions. Ahmad, Dai, Mehmood, and Abou Houran (2023), using the CS-ARDL tool, found that renewable energy conversion and financial globalization reduced the EF.

GNF has demonstrated that its effect on environmental and social sustainability and its impact on EQL can vary depending on specific circumstances. According to Adeel-Farooq et al. (2018), GNF would not persistently result in a much ecologically friendly context. In certain situations, GNF might hinder green innovation while merely enhancing energy performance with technical execution. Chen et al. (2023) examined the GNF-CO₂ nexus in China. It was found that the bond between GNF and CO₂ emissions was U-shaped, with the negative effect of GNF on pollution being more distinct in zones with comparatively low CO₂ emissions. In another work, Sinha et al. (2021) contemplated the influence of GNF on social and environmental sustainability. The data was collected from the S&P 500 Global GB Index and the S&P 500 Environmental and Social Responsibility Index between October 1, 2010, and July 31, 2020. The analysis employed a combination of QQ Regression and Wavelet Multiscale Decomposition tools. The results indicated that green financing mechanisms had progressively transformative effects, negatively impacting EQL and social responsibility over the determined time frame. Additionally, Chen and Feng (2019) and Li, Yuan, and Wang (2019) found that GNF does not influence emissions.

A thorough literature review reveals a discernible knowledge gap, underscoring the need for a more meticulous exploration of the relationship between GNF and EQL. Previous studies predominantly relied on CO₂ emissions and EF as indicators of EQL, yet a critical aspect remains unexplored the influence of GNF on CF. The ongoing body of research has primarily explored the overall impact of GNF on EQL, neglecting potential nonlinear effects that could introduce essential complexities and lead to misinterpreted conclusions. Moreover, there is

a prevailing tendency in prior studies to favor panel data evaluation over time-series data, although the intrinsic problems posed by panel data. These difficulties include complexities in selecting appropriate models, potential measurement inaccuracies, and limitations in generalizing outcomes to diverse circumstances. The adoption of the Quantile-on-Quantile (QQ) tool is proposed as a robust alternative, enabling the independent analysis of individual countries and giving a much broader awareness of the nuanced relationship under investigation. By addressing these gaps, our study advances the understanding of the intricate interplay between GNF and EQL, thereby enhancing the relevance and reliability of findings within specific economies.

3. Data and description

The key aim of the ongoing paper is to check out the influence of GNF on CF in BRICS+6 economies (Brazil, Russia, India, China, South Africa, Iran, Saudi Arabia, Egypt, Argentina, UAE, and Ethiopia). In the context of this research, GNF is assigned the role of the independent variable. Following Hacımeroğlu, Danişoğlu, and Güner (2022), Adebayo and Kartal (2023), and Wang, Su, Umar, and Peculea (2023), GNF is represented by green bonds (GB) measured through S&P GB index. GB is selected as a proxy for GNF because it prioritizes environmentally friendly initiatives, aligns with investor preferences, maintains limpidity in its reporting, and offers measurable metrics for evaluating ecological effects (Adebayo & Kartal, 2023). Current research treats CF as the dependent variable to represent EQL. The EF quantifies how human actions affect the environment, considering the land and water resources required to support a specific way of life. The CF is a significant component of the EF, as it is one of the leading greenhouse gases contributing to climate change (Shadbahr et al., 2022). When measuring CF in global hectares (gha), it considers the direct carbon emissions and the land and resources needed to absorb or offset them. This approach gives all-inclusive awareness regarding the ecological influence of carbon emissions, considering the planet's finite capacity to absorb carbon dioxide and maintain a balanced ecosystem (Numan, Ma, Sadiq, Bedru, & Jiang, 2023). CF is a globally recognized metric, directly linked to climate change, quantifiable, and offers valuable insights into the effectiveness of GNF in reducing emissions in BRICS+6 nations and ecological stressors (Chukka et al., 2022).

We obtain monthly GB data from DataStream, and annual data for CF is acquired from the Global Footprint Network (<https://www.footprintnetwork.org/>). The conversion of annual CF data into monthly series is accomplished utilizing the quadratic match-sum methodology followed by Yi, Raghuṭla, Chittedi, and Fareed (2023). This methodology successfully handles data inconsistencies and stabilizes intermittent cycles when conversion from lowest to utter frequencies (Hung, 2023b; Yi et al., 2023). The dataset covers January 2007 to December 2020, containing 156 monthly observations for GNF and CF.

4. Econometric technique

The core intent of the ongoing section is to evaluate the approaches elected to study the GNF-CF relationship. To pursue this goal, we implement a cointegration test based on quantiles to assess the long-run association between variables. As a crucial element of existing econometric investigation, we consolidate the QQ procedure to acquire an all-encompassing understanding of the GNF-CF association.

4.1. Quantile cointegration (QC) test

In the present study, we implement the quantile cointegration (QC) test developed by Xiao (2009) to overwhelm the impediments of conventional cointegration tests that depend on fixed cointegrating vectors. Integrating the QC tool upgrades our capability to grasp persistent connections across variables. Contrarily typical methodologies, the QC methodology acknowledges the probable variation in the volume of

cointegration within variables among several quantile ranges throughout the data distribution. Xiao (2009) suggested that the QC technique tackles these issues by accounting for the time-related oscillations of sequels and the linkages with asymmetries for both the dependent and independent variables. For provisional data distribution, this approach efficiently reduces possible evaluation biases that might emerge when examining persistent relationships. Xiao (2009) established an innovative technique that outstrips the hindrances of typical methodologies by integrating disjointed cointegrating errors with lead-lag indicators. Furthermore, to address the data intrinsic heterogeneity, Saikkonen (1991) submitted the addition of a constant vector $\alpha(\tau)$ inside the QC regression.

$$X_i = \alpha + \alpha' Y_i + \sum_{k=-s}^k \Delta Y'_{i-k} \Pi_k + v_i \quad (1)$$

and

$$Q_\tau^X(X_i M_i^X, M_i^Y) = \beta(\tau) + \alpha(\tau)' Y_i + \sum_{k=-s}^s \Delta Y'_{i-k} \Pi_k + F_v^{-1}(\tau) \quad (2)$$

As clarified in Xiao's 2009 investigation, enclosing the consistent parameter $F_v^{-1}(\tau)$ efficaciously manages the appearance of the drift factor. The sign $\beta(\tau)$ serve as the quantile error in the conditional distribution of data. The mathematical depiction of the quadratic components of the cointegrated regression may be formulated below.

$$Q_\tau^X(X_i M_i^X, M_i^Y) = \beta(\tau) + \alpha(\tau)' Y_i + \delta(\tau)' Y_i^2 + \sum_{k=-s}^s \Delta Y'_{i-k} \Pi_k + \sum_{k=-s}^s \Delta Y_{i-k}^2 \Pi_k + F_v^{-1}(\tau) \quad (3)$$

When analyzing cointegration coefficients, selecting a QC test is a pragmatic choice, where the null hypothesis $H_0: \alpha(\pi) = \alpha$, as defined in Equation (3), is examined. The outcomes of this analysis are acquired through applying the supremum rule denoted by $\hat{V}_n(\tau) = [\hat{\alpha}(\tau) - \hat{\alpha}]$, along with the related test statistics. Critical thresholds are determined by adopting 1000 Monte Carlo simulations to affirm the validity of the null hypothesis.

4.2. Quantile-on-quantile (QQ) method

Considering the asymmetrical nature of data, we opt to implement the QQ technique in place of the traditional QR tool for variable evaluation. The QQ methodology, assured by Sim and Zhou (2015), offers a much-sophisticated replacement that overcomes the limits of the QR method, which primarily stresses assessing the mean effect of the independent variable on the quantile of the dependent variable. Choosing the QQ method significantly improves the association between the dependent and independent variables' quantiles (Alola, Adebayo, & Onifade, 2022; Yu, Nazar, & Ali, 2023).

Our study employs the QQ technique that melds non-parametric computations throughout the usual QR method to estimate the GNF-CF quantiles relationships. By selecting this methodology, the study intends to expose probable problems within the GNF-CF connection, which might merely be comparatively patent when applying standard econometric methodologies, including OLS and QR. The essential context of the non-parametric QQ regression of this research, forming upon the contributions of Nawaz et al. (2021) and Khan et al. (2022), can be briefly outlined as follows:

$$CF_t = \alpha^\theta(GNF_t) + \mu_t^\theta \quad (4)$$

In this context, 'CF_t' corresponds to carbon footprint, and 'GNF_t' represents green finance within a specific time period denoted as 't'. The symbol θ stands for the θ^{th} GNF quantile, whereas the coefficient $\alpha^\theta(\cdot)$ stays unspecified for the reason of a small awareness of the GNF-CF

linkage. The residual term for the θ^{th} quantile is designated as μ_t^θ . Equation (4) is fabricated utilizing the local linear regression methodology developed primarily by Cleveland (1979). As detailed in the continuing discussion, this technique comprises managing model estimation with specific attention to the GNF value.

$$\alpha^\theta(GNF_t) \approx \alpha^\theta(GNF^\tau) + \alpha^{\theta'}(GNF^\tau)(GNF_t - GNF^\tau) \quad (5)$$

The notation $\alpha^{\theta'}$ designates the derivative of $\alpha^\theta(GNF_t)$ with respect to GNF_t, referred to as a partial derivative.

To implement the QQ model as Sim and Zhou (2015) outlined, we substitute Equation (5) into Equation (4).

$$CF_t = \frac{\alpha_0(\theta, \tau) + \alpha_1(\theta, \tau)(GNF_t - GNF^\tau)}{(*)} + \mu_t^\theta \quad (6)$$

In the QQ anatomy, Equation (6) interprets the interplay between the θ^{th} GNF quantile and the τ^{th} CF quantile. The emblem (*) represents the conditioned GNF quantile, while α_0 and α_1 correspond to the parameters interrelated with θ and τ , respectively. Equation (6) exposes the fundamental underlying trend in the GNF and CF bond by harmonizing various distributions. Practicing as a bivariate regression framework, the QQ regression is structured to incorporate just one independent variable and one dependent variable that restricts adding control variables. Despite this limitation, it outclasses typical time series approaches by giving robust predictions of the nonlinear GNF-CF relationship, majorly at the extremes of the data distribution.

4.3. Robustness of the QQ methodology

The QQ methodology surpasses the QR tool by showcasing improved exactness in regress the GNF and CF. While the QR approach concentrates merely on evaluating the θ^{th} GNF quantile, the QQ model goes beyond to comprehensively explore the influence of the θ^{th} GNF quantile on the τ^{th} CF quantile. By including both θ and τ as quantile parameters, this technique permits a more advanced and exact regression methodology. The parameters of QR are determined by averaging QQ coefficients interrelated with τ . The slope coefficients, indicated as $\gamma_1(\theta)$ in the QR methodology, are employed to explore the GNF-multiple CF quantiles correlation, as expressed in the work carried out by Sim and Zhou (2015).

$$\gamma_1(\theta) \equiv \bar{\alpha}_1 = \frac{1}{s} \sum_{\tau} \hat{\alpha}_1(\theta, \tau) \quad (7)$$

In this investigation, 's' shows the quantity of quantiles equal to 19. The range of quantiles, represented as τ , encompasses values from 0.05 to 0.95. To check the robustness of the QQ model, a connection is developed between the mean QQ values derived at τ and the analyzed coefficients of the QR model.

5. Findings and discussion

The continuing section introduces the preliminary and core findings of the article, accompanied by a thorough discussion.

5.1. Preliminary findings

Table 1 provides descriptive stat values, delivering a broad understanding of the attributes of both GNF and CF.

China has emerged as the frontrunner in the realm of GNF, with an average GB price standing at 124.92. This figure spans from 95.07 to 147.44. India solidified its position in second place, showcasing an average GNF rating of 123.15, with fluctuations ranging from 91.55 to 156.27. South Africa secures the third position, followed by Brazil, Russia, and Iran. Regarding CF, China leads the way with an average CF value of 36.69.07 million global hectares (mgha), from 3296.09 to 3875.93 mgha. India secures the second position, continued by Russia

Table 1

Descriptive statistics values for GNF and CF.

Countries	Mean	Max.	Min.	Std. Dev.	J-B Stats	ADF Level	ADFA
Panel A: Green Finance (GNF)							
China	124.92	147.44	95.07	11.20	53.28*	−1.52	−5.63*
India	123.15	156.27	91.55	17.19	62.60*	−1.34	−5.80*
South Africa	122.47	140.25	92.66	11.45	47.15*	−1.70	−5.81*
Brazil	121.45	132.40	91.74	7.78	20.96*	−1.68	−5.02*
Russia	118.73	149.42	92.76	15.98	26.29*	−1.44	−4.31*
Iran	113.98	142.12	96.40	11.42	50.30*	−1.48	−4.61*
Saudi Arabia	112.62	134.24	89.03	11.43	44.85*	−0.94	−6.76*
Egypt	98.65	135.23	86.05	10.42	24.45*	−1.97	−5.79*
Argentina	96.85	104.57	76.80	4.24	96.70*	−2.14	−4.53**
UAE	92.50	112.90	75.57	10.06	37.83*	−2.54*	−4.53**
Ethiopia	89.73	108.15	81.70	5.60	34.40*	−1.68	−4.81**
Panel B: Carbon Footprint (CF)							
China	3669.07	3875.93	3296.09	194.22	3.98*	−1.69	−5.63*
India	727.56	873.80	515.67	112.65	5.34*	−1.84	−4.13*
South Africa	142.31	152.14	127.97	6.51	4.76*	−4.30*	−6.73*
Brazil	166.34	198.52	134.65	18.75	5.65*	−1.89	−3.73**
Russia	514.98	550.85	468.45	26.73	6.89*	−1.09	−5.70*
Iran	139.45	175.45	90.45	26.99	4.34*	−1.55	−5.70*
Saudi Arabia	145.67	150.87	125.78	7.87	5.39*	−5.70*	−5.23*
Egypt	139.45	147.98	122.32	6.40	4.90*	−1.80	−5.45*
Argentina	62.05	66.82	52.93	4.12	2.93*	−1.69	−4.45*
UAE	61.62	68.86	53.78	4.50	3.78*	−1.34	−5.35*
Ethiopia	7.11	9.78	4.67	1.93	1.67	−1.78	−5.10

Note: * and ** indicate the level of significance at 1% and 5%, correspondingly.

and Brazil. The Jerque-Berra (J-B) test findings uncover that, with the exclusion of Ethiopia, where CF asserts a normal distribution, both GNF and CF diverge from normality in nearly entire chosen countries. This withdrawal from normality stresses the valuation of choosing the QQ method that is uncommonly competent to scrutinize data that do not cohere with normality (Sharif, Saqib, Dong, & Khan, 2022; Wan, Nazar, Ali, & Anser, 2024; Yu et al., 2022). Moreover, the results of the ADF test submit that the conversion of variables inside their initial differences convinces stationarity in most nations. Consistent with Hung (2023a), Liu et al. (2024), and Sharif et al. (2022), we chose the data series in differenced forms to ensure stationarity.

The findings of the unit root test are depicted in Table 2, employing the technique outlined by Kim and Perron (2009) and accounting for structural breaks into the dataset.

The Kim and Perron (2009) test outcomes uncover structural breaks in the data. Additionally, the results signify that the variables carry out stationarity primarily through first-order differencing. Notably, for China and Iran, the CF variable is stationary at its initial level. Therefore, aligning with the methodologies submitted by Sharif et al. (2022) and Hung (2023a), we have decided to convert the data series into their first differences to ensure stationarity.

We apply the BDS test to probe the asymmetric or nonlinear associations within our data. This test is designed to discern whether the time series in our study exhibit patterns of similarity, independence, or linear interdependence, following the framework established by Brock and De Lima (1996). Under the null hypothesis, we assume a linear interconnection within the data points. However, the alternate hypothesis insinuates the failure of such interconnection. Our findings lead

Table 2

Unit root test for structural breaks.

Nations	Variables	Level			First Difference		
		t-stat	Break	Decision	t-stat	Break	Decision
China	GNF	−2.98	2008M4	Non-Stationary	−9.18*	2008M3	Stationary
	CF	−4.08**	2008M6	Stationary	−	−	−
India	GNF	−2.31	2017M3	Non-Stationary	−8.09*	2019M4	Stationary
	CF	−1.95	2010M4	Non-Stationary	−5.42*	2012M3	Stationary
South Africa	GNF	−2.05	2018M7	Non-Stationary	−9.99*	2018M8	Stationary
	CF	−2.00	2017M4	Non-Stationary	−5.45*	2016M9	Stationary
Brazil	GNF	0.16	2013M6	Non-Stationary	−9.65*	2013M7	Stationary
	CF	−2.14	2008M9	Non-Stationary	−11.85*	2008M8	Stationary
Russia	GNF	−2.79	2018M11	Non-Stationary	−10.29*	2017M10	Stationary
	CF	−2.49	2007M6	Non-Stationary	−8.39*	2007M5	Stationary
Iran	GNF	−2.20	2014M3	Non-Stationary	−7.14*	2014M3	Stationary
	CF	−4.97*	2017M6	Stationary	−	−	−
Saudi Arabia	GNF	−2.56	2016M7	Non-Stationary	−9.50*	2013M9	Stationary
	CF	−2.18	2017M6	Non-Stationary	−8.60*	2016M4	Stationary
Egypt	GNF	−1.39	2016M9	Non-Stationary	−7.55*	2016M6	Stationary
	CF	−2.10	2009M6	Non-Stationary	−10.08*	2009M7	Stationary
Argentina	GNF	0.18	2013M7	Non-Stationary	−9.66*	2013M6	Stationary
	CF	−2.99	2014M10	Non-Stationary	−14.56*	2013M8	Stationary
UAE	GNF	0.19	2013M5	Non-Stationary	−9.66*	2013M7	Stationary
	CF	−2.46	2019M4	Non-Stationary	−9.37*	2018M10	Stationary
Ethiopia	GNF	0.17	2013M6	Non-Stationary	−9.65*	2013M5	Stationary
	CF	−2.15	2018M11	Not-stationary	−11.85*	2017M12	Stationary

Note: * and ** manifest the significance level at 1% and 5%, correspondingly.

us to reject the null hypothesis, pointing to nonlinear characteristics in the data. Therefore, as shown in Table 3, the outcomes of the BDS test affirm the existence of nonlinear or asymmetric GNF-CF relationships in the countries under examination.

Table 4 indicates a significant and negative bond between GNF and CF is observable in all economies, excluding Ethiopia. Within this group of economies, South Africa exhibits the highest correlation coefficient of -0.84 , chased by India (-0.83), China (-0.82), and Iran (-0.78).

5.2. Major findings

The outcomes acquired throughout the QC test appear in Table 5, assessing the variables' stability. In this analysis, we apply the α and γ (supremum norm coefficients) collected from Equation (3), with τ representing the τ^{th} CF quantile.

The findings captured from the QC test manifest modifications in the GNF-CF connection through diverse quantiles in each economy. The supremum norm values (γ and α) exceed their critical thresholds, emphasizing a significant, long-run, and nonlinear GNF-CF connection across nations.

In Fig. 1, the depicted slope coefficients $\alpha(1(\theta, \tau))$ signifies the effect of the θ^{th} GNF quantile on the τ^{th} CF quantile. The evaluation embraces an assorted range of value alliances for both θ and τ . In **China** and **India**, an

Table 3
BDS test of Nonlinearity.

Countries	Dimension	GNF		CF	
		BDS stats.	p.value	BDS stats.	p.value
China	2	3.93	0.00	2.97	0.00
	3	2.15	0.00	2.35	0.00
	4	2.93	0.00	2.91	0.00
	5	3.17	0.00	3.67	0.00
India	2	1.20	0.15	3.46	0.00
	3	2.71	0.00	2.78	0.00
	4	2.94	0.00	2.36	0.00
	5	3.04	0.00	2.83	0.00
South Africa	2	2.48	0.00	1.50	0.13
	3	2.94	0.00	2.57	0.00
	4	2.88	0.00	2.14	0.00
	5	3.06	0.00	3.00	0.00
Brazil	2	2.06	0.00	2.80	0.00
	3	2.51	0.00	3.01	0.00
	4	2.90	0.00	2.47	0.00
	5	3.07	0.00	2.46	0.00
Russia	2	3.48	0.00	2.92	0.00
	3	2.49	0.00	3.26	0.00
	4	2.52	0.00	2.16	0.00
	5	2.57	0.00	2.48	0.00
Iran	2	2.05	0.00	3.01	0.00
	3	2.81	0.00	4.79	0.00
	4	2.82	0.00	2.58	0.00
	5	3.00	0.00	2.76	0.00
Saudi Arabia	2	2.59	0.00	3.49	0.00
	3	2.77	0.00	3.33	0.00
	4	2.92	0.00	3.68	0.00
	5	3.27	0.00	3.15	0.00
Egypt	2	2.15	0.00	2.56	0.00
	3	2.99	0.00	3.98	0.00
	4	3.02	0.00	2.68	0.00
	5	4.80	0.00	2.94	0.00
Argentina	2	1.05	0.00	3.76	0.00
	3	2.08	0.00	2.24	0.00
	4	2.54	0.00	2.46	0.00
	5	2.94	0.00	2.64	0.00
UAE	2	2.15	0.00	3.49	0.00
	3	2.49	0.00	3.13	0.00
	4	2.57	0.00	3.08	0.00
	5	3.99	0.00	2.64	0.00
Ethiopia	2	2.58	0.00	3.49	0.00
	3	2.76	0.00	3.34	0.00
	4	2.93	0.00	3.67	0.00
	5	3.28	0.00	3.14	0.00

Table 4

Correlation between GNF and CF.

Nation	Correlation	t-Stats	p.value
China	-0.82	-4.93^*	0.00
India	-0.83	-10.62^*	0.00
South Africa	-0.84	-12.32^*	0.00
Brazil	-0.67	-9.33^*	0.00
Russia	-0.76	-9.38^*	0.00
Iran	-0.78	-4.12^*	0.00
Saudi Arabia	-0.76	-4.12^*	0.00
Egypt	-0.76	-5.38^*	0.00
Argentina	-0.69	-7.95^*	0.00
UAE	-0.71	-7.64^*	0.00
Ethiopia	0.70	7.57*	0.00

Note: '*' expresses the level of significance at 1%.

Table 5

Findings of QC test (GNF and CF).

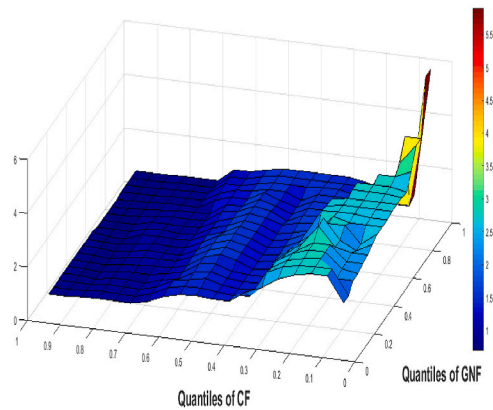
Country	Coefficients	Sup $_{\tau}$ V $_{\alpha}(\tau)$	C1	C5	C10
China	α	3943.91	3775.26	248.53	200.90
GNF vs. CF	γ	167.73	157.81	49.07	45.78
India	α	7114.36	3492.10	3082.11	2225.39
GNF vs. CF	γ	609.45	303.88	213.20	118.13
South Africa	α	8325.20	5284.23	3135.05	2522.37
GNF vs. CF	γ	179.62	112.41	55.88	39.33
Brazil	α	8754.53	6712.11	4771.12	1476.80
GNF vs. CF	γ	398.17	204.61	103.09	99.11
Russia	α	1838.70	1547.79	1046.78	994.89
GNF vs. CF	γ	962.77	688.61	497.73	346.80
Iran	α	538.43	325.36	292.74	237.58
GNF vs. CF	γ	289.98	197.91	129.73	98.38
Saudi Arabia	α	1245.71	935.79	550.08	208.70
GNF vs. CF	γ	787.82	587.96	497.93	375.70
Egypt	α	68581.33	58366.33	57303.24	54880.74
GNF vs. CF	γ	2462.64	1483.21	1446.48	1432.10
Argentina	α	6247.67	5684.96	4687.50	3780.78
GNF vs. CF	γ	3281.96	2691.71	2182.70	1848.40
UAE	α	7117.36	3496.14	3086.19	2229.30
GNF vs. CF	γ	606.41	301.86	217.15	118.12
Ethiopia	α	1145.70	937.72	650.45	210.75
GNF vs. CF	γ	785.82	585.90	495.95	370.75

Note: The computation of the t-statistic covers 19 equidistant quantiles from 0.05 to 0.95. The estimations for the supremum norm (α and γ) are furnished, together with the respective critical thresholds for significance levels of 1% (C1), 5% (C5), and 10% (C10).

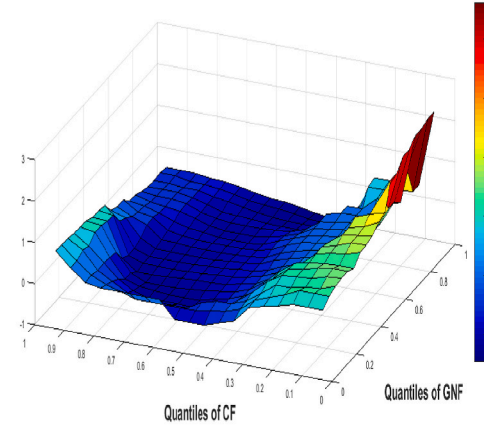
inverse powerful GNF-CF association is demonstrated throughout the points, which blend complete GNF quantiles throughout medium-low to higher CF quantiles (0.35–0.95). This negative powerful interdependence revealed that GNF uplifts EQL by diminishing CF across various levels of CF, ranging from medium-low to the highest ranks, in both economies. In addition, a weak and negative conjunction between GNF and CF is matured through the points, which merge full GNF quantiles throughout the lowest to moderate-low CF quantiles (0.05–0.30) in both nations. Furthermore, the powerful positive GNF-CF conjunction is also identified in the precincts that unify upper GNF quantiles with the bottommost CF quantiles in China and India. This definite positive and powerful linkage revealed that GNF decreases EQL by rising CF across the lowest levels of CF in both economies. In **South Africa** and **Brazil**,

Influence of Green Finance (GNF) on Carbon Footprint (CF)

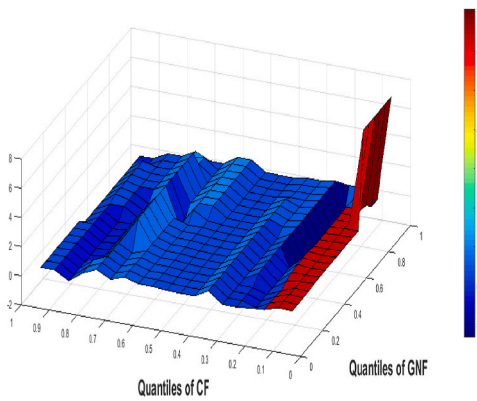
i). China



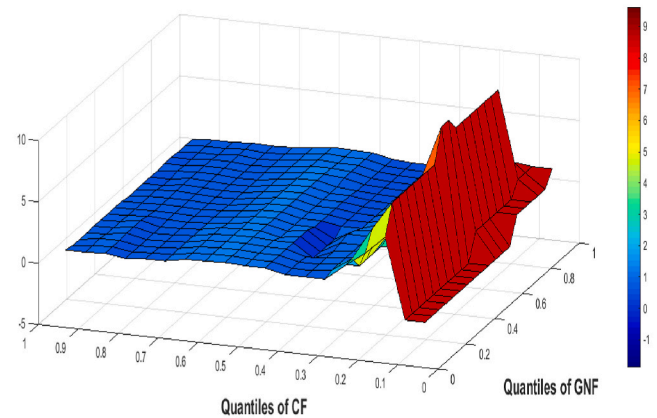
ii). India



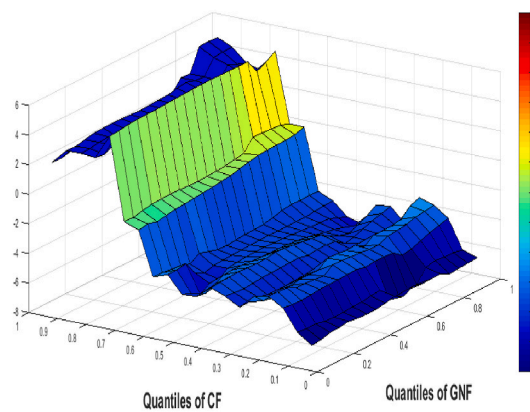
iii). South Africa



iv). Brazil



v). Russia



vi). Iran

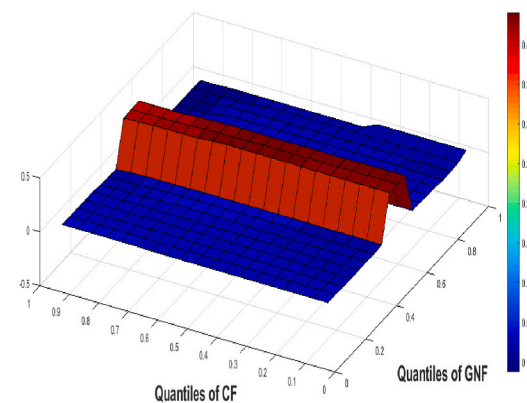


Fig. 1. Quantile-on-Quantile (QQ) estimations of the slope coefficient α_1 (θ , τ).

the powerful negative GNF-CF conjunction is conceived throughout the localities, which relate complete GNF quantiles with moderate-lower to highest CF quantiles (0.25–0.95). This negative powerful association revealed that GNF enhances EQL by diminishing CF across various levels

of CF, ranging from medium-low to the highest ranks, in both economies. Furthermore, a powerful positive GNF-CF conjunction is identified in the divisions, which tie overall GNF quantiles with the bottommost CF quantiles in South Africa and Brazil. This certain strong and positive

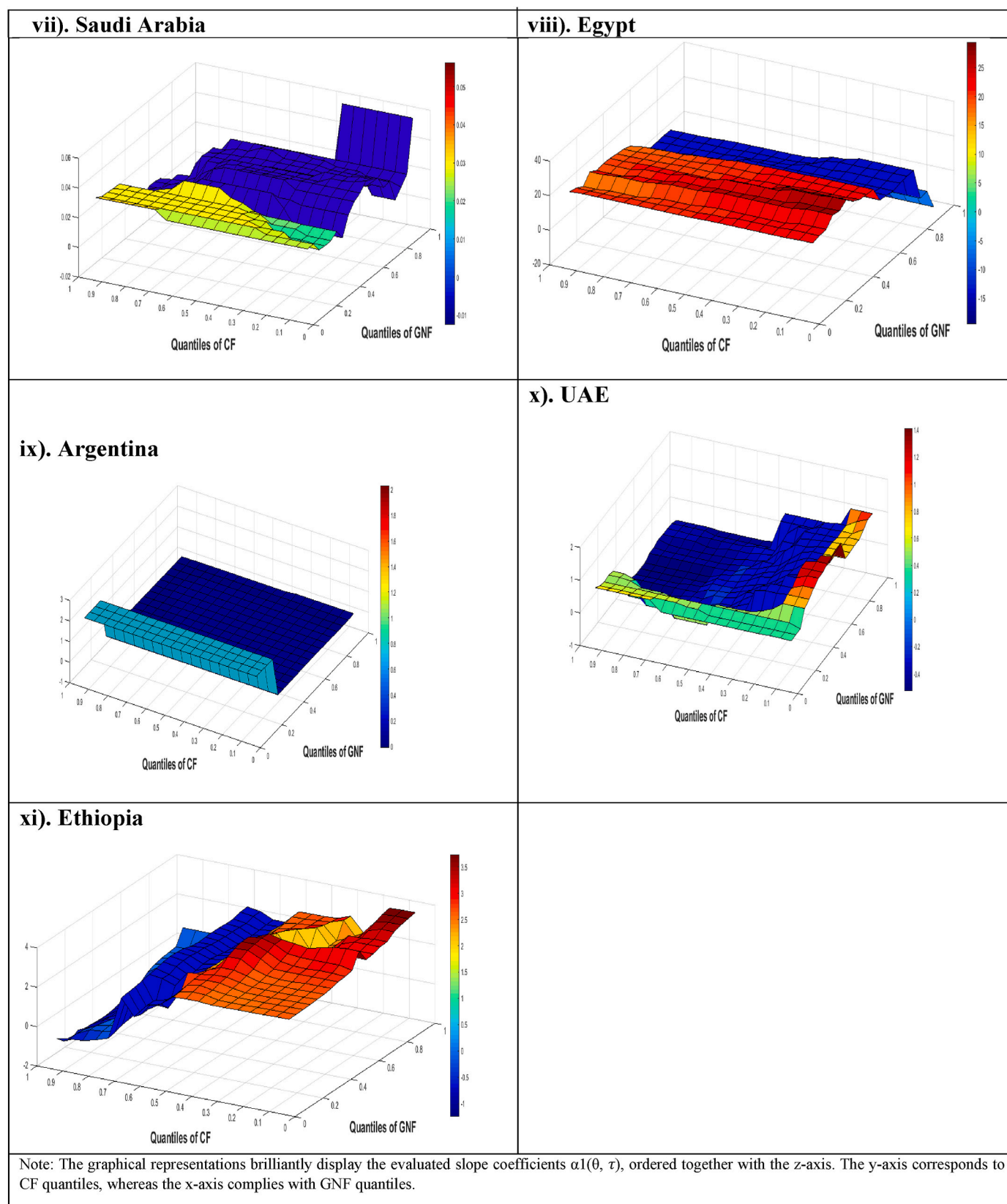


Fig. 1. (continued).

linkage discovered that GNF declines EQL by rising CF across the lowest levels of CF in both economies. The negative GNF-CF bond is asserted by the investigation of [Nawaz et al. \(2021\)](#) and [Sampene et al. \(2023\)](#); both

investigations observed that GNF reduces CF, which enhances EQL.

In **Russia**, a negative and powerful GNF-CF connection is illustrated throughout the regions, which mingle complete GNF quantiles with

lowest to high-middle and topmost CF quantiles (0.05–0.60 & 0.85–0.95). This negative powerful tie identified that GNF boosts EQL by lowering CF among various grades of CF, ranging from bottommost to median-high and highest ranks, in Russia. In addition, a weak and negative GNF-CF alliance is demonstrated with the portions that associate entire GNF quantiles throughout medium-high CF quantiles (0.65–0.80). In **Iran**, a negative and powerful GNF-CF kinship is demonstrated in the precincts that blend lowermost to moderate and moderately upper to high GNF quantiles (0.05–0.50 & 0.75–0.95) throughout entire CF quantiles. This definite negative powerful GNF-CF tie suggested that GNF upgrades EQL by decreasing CF with several grades of GNF, ranging from lowest to mid-high and moderate-higher to topmost levels, in Iran. Conversely, a positive powerful GNF-CF union is illustrated through the vicinities, including median to upper-middle GNF quantiles (0.55–0.70) throughout full CF quantiles. This powerful positive conjunction disclosed that GNF declines EQL by enhancing CF between the median to mid-upper GNF grades in Iran. The negative impact of GNF on CF in Russia and Iran is confirmed by the works of [Yeow and Ng \(2021\)](#) and [Al Mamun et al. \(2022\)](#). These studies discovered that GNF notably cut carbon emissions in credit-strong, innovative, and climate-vulnerable countries. Green bonds positively impacted EQL, especially with third-party certification, without affecting financial performance.

In **Saudi Arabia** and **Argentina**, the powerful and negative GNF-CF nexus is perceived in the sections, which combine moderately low to highest GNF quantiles (0.40–0.95) throughout the entire quantiles of CF. This precise, powerful negative relationship defines that GNF significantly declines CF at lower-medium to uppermost GNF grades in each economy. Additionally, a weak negative GNF-CF interrelation prevails within the vicinities, which include bottommost to low-mid GNF quantiles (0.05–0.35) throughout overall CF quantiles in Saudi Arabia and Argentina. In **UAE**, a negative and powerful GNF-CF tie is ascertained among the areas that amalgamate total GNF quantiles throughout moderate-low to upper CF quantiles (0.30–0.95). This explicit negative powerful GNF-CF kinship indicated that GNF uplifts EQL by diminishing CF with several grades of CF, ranging from median-lower to upmost ranks, in the UAE. Moreover, a mixture of weak and powerful positive connections between GNF and CF originates through the portions that consolidate complete GNF quantiles throughout lower to moderately low CF quantiles (0.05–0.25). Furthermore, a weak negative GNF-CF alliance is ascertained through the divisions, which integrate the bottom GNF quantiles with complete CF quantiles in UAE. The dominance of negative association between GNF and CF in Saudi Arabia, Argentina, and UAE is persistent with the research of [Adebayo and Kartal \(2023\)](#), who observed that asymmetric correlations among variables, indicating GB, prices of oil, and COVID-19 as reducers of industrial CO₂ emissions.

A mixed GNF-CF interaction is perceived in **Egypt**. A strong negative GNF-CF bond is matured alongside the portions, which assimilate middle-upper to the highest GNF quantiles (0.55–0.95) throughout complete CF quantiles. This explicit, powerful, negative interconnection defines GNF as significantly lessening CF at medium-high to utmost levels of GNF in Egypt. In contrast, the powerful positive GNF-CF kinship is presented in the places that conjoin lowermost to moderate GNF quantiles (0.05–0.50) throughout the entire CF quantiles. This powerful positive bond disclosed that GNF declines EQL by increasing CF among the lower to moderate GNF grades in Egypt. Like Egypt, **Ethiopia** also showcases a mixed interconnection between GNF and CF. The negative strong GNF-CF interdependence is ascertained alongside the precincts, which unify overall GNF quantiles throughout high-mid to upper CF quantiles (0.55–0.95). This explicit strong, negative union defines that GNF significantly lessens CF at medium-upper to utmost CF grades in Ethiopia. In addition, the powerful positive GNF-CF interconnection is observed throughout the points, which attach total GNF quantiles throughout low to moderate CF quantiles (0.05–0.50). This definite, positive, and powerful interconnection disclosed that GNF declines EQL by boosting CF among the bottommost to moderate CF grades in

Ethiopia. The mixed association between GNF and CF in Egypt and Ethiopia is verified by the investigation of [Chen et al. \(2023\)](#), who discovered that the GNF-CO₂ bond exhibited a U-shape, with GNF's negative impact on pollution more pronounced in areas with lower CO₂ emissions.

5.3. Confirming the robustness of the QQ method

We can verify the robustness of the QQ method by matching the QR-QQ similarities estimations. [Fig. 2](#) reinforces the preceding conclusions drawn from the QQ analysis, revealing a significant concurrence between the average QQ approximations and the slope coefficient measures of the QQ among diverse economies. This observation insinuates that both calculations share similar principles and yield homologous analytical findings.

In [Fig. 2](#), a prominent negative correlation between GNF and CF is evident in the majority of BRICS+6 economies. However, the results for Ethiopia and Egypt contrast with this prevailing pattern. These observations stress the variations in the GNF and CF associations across diverse economies. Additionally, the magnitudes of the coefficients suggest a powerful effect of GNF on CF in South Africa and Egypt, whereas a less marked impact is ascertained in India and Iran.

5.4. Discussion of findings

Across many nations, a significant GNF-CF association becomes evident, with 9 out of 11 BRICS+6 economies exhibiting a negative relationship. This indicates that GNF has an adverse influence on CF. These findings are validated by former works performed by [Shen et al. \(2021\)](#), [Al Mamun et al. \(2022\)](#), [Ahmad et al. \(2023\)](#), and other researchers persistently stressing the negative influence of GNF on CF. In addition, our outcomes somewhat link with the findings outlined from earlier investigations by [Nawaz et al. \(2021\)](#) for N-11 nations, [Sampene et al. \(2023\)](#) for South Asian nations, [Khan et al. \(2022\)](#) for Asian nations, [Adebayo and Kartal \(2023\)](#) for the USA, all of them stress the beneficial effects of GNF on EQL. Our research findings bring forth an innovative perspective that challenges the conventional understanding of the ramifications of GNF. Departing from prior investigations, which majorly stressed the complete effect of GNF on EQL, the current investigation unveils a properly tailored viewpoint. We present that the interrelationship between GNF and its effects on CF might get diverse results across various portions of the distribution of data. These perceptions keep significant ramifications for governmental entities and policymakers in several economies, granting essential directions for formulating plans to change GNF-CF levels.

The interplay between GNF and CF in Ethiopia and Egypt showcases a complex arrangement encompassing negative-positive linkages. Visible representations illustrate that the effect of GNF on CF does not consistently lean towards negativism and oscillates based on duration, timing, and regional setting. The effects of GNF on CF in Ethiopia and Egypt can vary depending on the timing of investments and initiatives. Early-stage investments in green technologies, renewable energy, and sustainable practices may initially have a limited impact on CF reduction. It takes time for these investments to yield results, as new infrastructure needs to be developed and integrated into the existing energy and industrial systems. Over time, the CF is likely to decrease as these initiatives mature. The time period of GNF initiatives and policies might significantly affect their effect on CF. Short-term projects would yield limited reductions in CF, mainly if they focus on quick fixes or incremental improvements. In contrast, long-term commitments to GNF, such as multi-year renewable energy projects, reforestation efforts, and sustainable agriculture practices, will likely lead to substantial CF reductions. These long-term investments can reshape entire industries and contribute to lasting environmental benefits. The geographical context in which GNF is implemented plays a crucial role. Ethiopia and Egypt have different environmental and economic landscapes. Ethiopia is

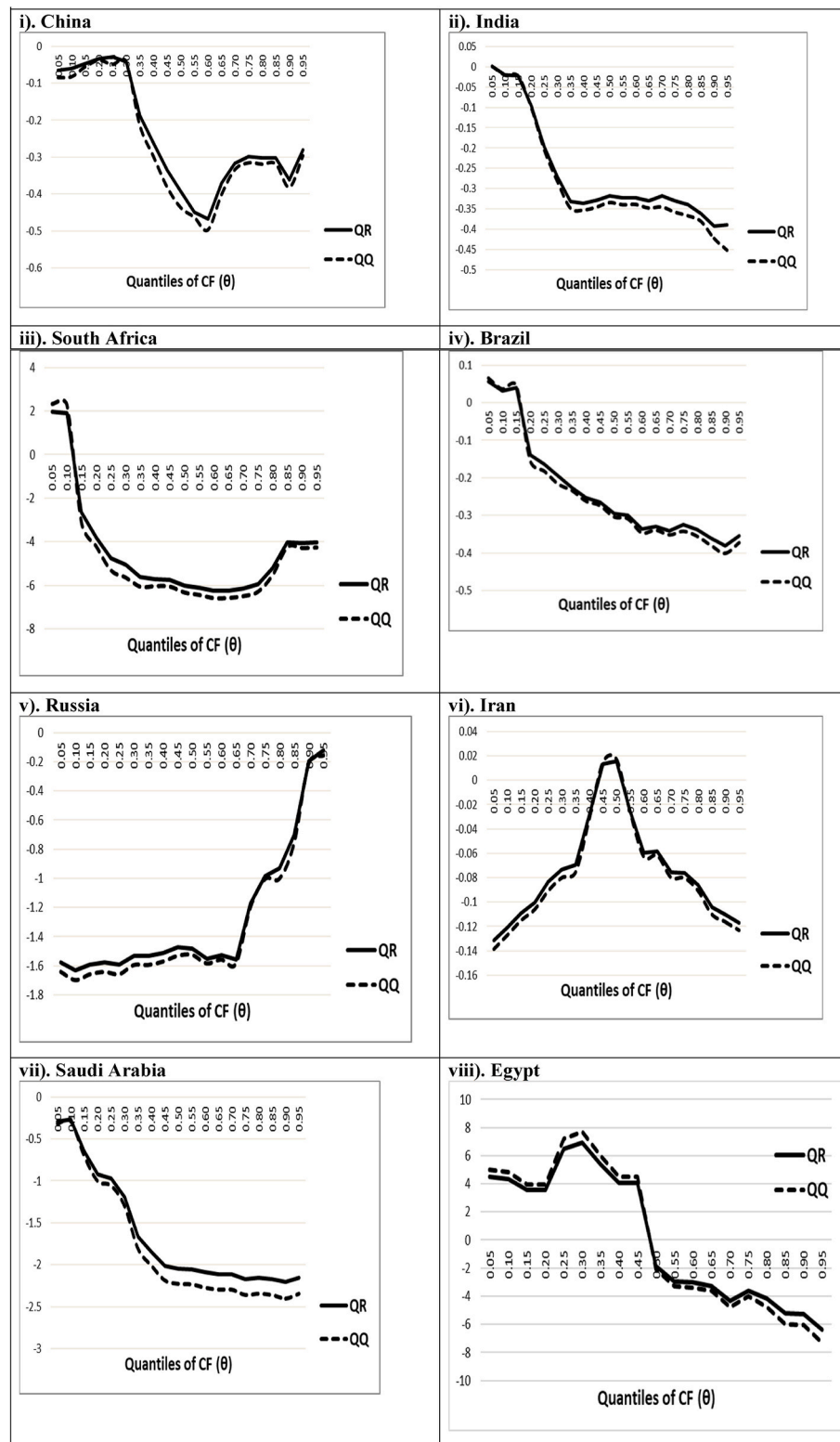


Fig. 2. Verifying the robustness of the QQ approach by Relating QQ and QR method.

known for its efforts in reforestation and renewable energy, while Egypt significantly focuses on sustainable agriculture and water management due to its unique challenges. The effectiveness of GNF in reducing CF may depend on how well-suited the initiatives are to each country's specific environmental conditions and needs. The GNF-CF nexus can be ascribed to several elements, such as dynamic investment strategies,

diverse business models, economic uncertainties, changes in energy consumption trends, and technological advancements. This mixed GNF-CF tie in Ethiopia and Egypt links with the conclusions drawn from earlier investigations by [Chen et al. \(2023\)](#), who perceived a mixed GNF-CO₂ emissions bond.

The relationship between GNF and CF highlights significant

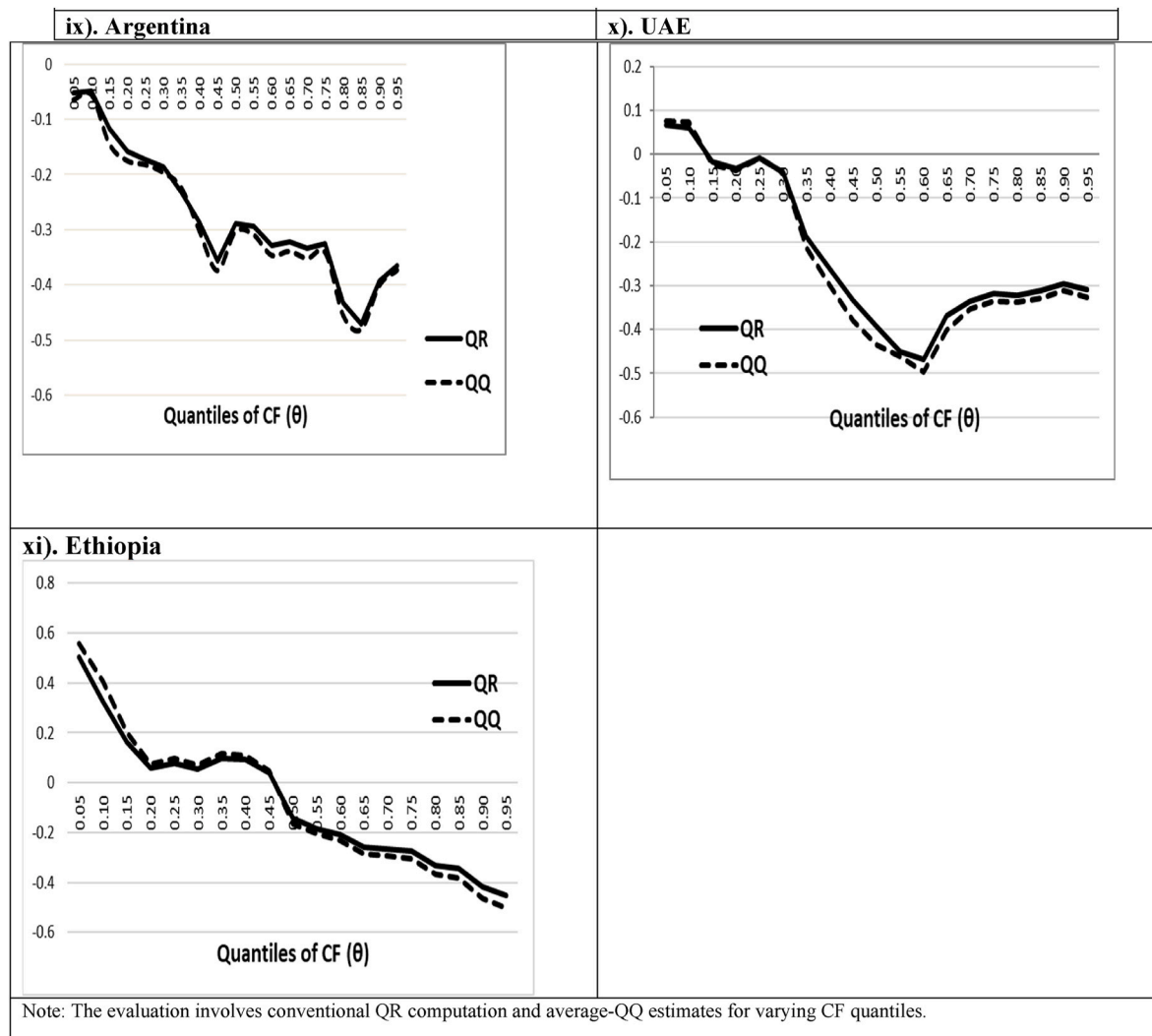


Fig. 2. (continued).

variations shaped by economic circumstances and income levels. Across several economies, together with India, China, Brazil, Russia, South Africa, and Ethiopia, a strong negative GNF-CF connection is evident, exceptionally at the highest CF quantiles. The findings recommend that a significant rise in GNF positively influences EQL by decreasing CF at higher levels of CF. The negative impact of GNF on CF is stronger at higher levels of CF in these economies due to the principle of diminishing returns in environmental mitigation efforts. At higher levels of CF, the environmental damage and emissions are typically more severe and entrenched, making it increasingly challenging and costly to reduce carbon emissions. GNF, when injected at such critical levels, can have a more pronounced effect because it targets emissions reduction more aggressively, investing in cleaner technologies and incentivizing sustainable implementations, which can yield significant reductions in CF. However, the situation diverges in Ethiopia and Egypt, whereas the positive GNF-CF linkage is evident merely up to a specific threshold; beyond that threshold, it shifts within a negative association.

Including new members (Ethiopia, Saudi Arabia, the UAE, Egypt, Iran, and Argentina) in the BRICS alliance presents a dynamic landscape regarding the nexus between GNF and CF. The findings reveal distinctive patterns in these diverse economies. For instance, in Iran, the powerful negative kinship between GNF and CF suggests that GNF enhances EQL by reducing GNF's carbon footprint across various quantiles. Conversely, similar negative impacts are observed in Russia, validating previous studies. Saudi Arabia and Argentina exhibit a strong and

negative nexus, signifying that GNF significantly reduces CF across different quantiles. The UAE displays a robust negative relationship, indicating that GNF uplifts EQL by diminishing CF at various quantiles. Meanwhile, Egypt and Ethiopia showcase a mixed association, with powerful negative bonds at higher GNF quantiles and positive connections at lower quantiles. The diverse effects observed underscore the need for nuanced strategies to leverage GNF for sustainable development within the expanded BRICS alliance, considering each member's unique economic and environmental contexts.

The fluctuations in the effect of GNF on CF among several nations might be a feature of several key factors, including the economic conditions and levels of CF in those economies. Firstly, differences in economic circumstances may explain the noticed fluctuations in the GNF-CF slope coefficients. Economies vary in development, industrialization, and resource availability, influencing their capacity to adopt and implement GNF initiatives effectively. Developed economies may have more mature and accessible green technologies, making it easier to reduce CF through GNF. On the other hand, emerging economies may face greater challenges in transitioning to greener practices due to infrastructure constraints and financial limitations. Furthermore, the role of economic conditions, specifically whether a nation is in a recession or expansion, is crucial in the GNF-CF bond. During economic recessions, businesses and governments would prefer short-term economic stability over long-term environmental goals, possibly reducing investments in green initiatives (Sharif et al., 2022). Contrarily, there is

often more financial capacity and willingness to allocate resources to environmental sustainability in economic expansion periods, leading to stronger negative correlations between GNF and CF. In the context of a recession, GNF may face hurdles in terms of limited funding, reduced investor confidence, and decreased consumer demand for green products and services. These factors can hinder the effectiveness of GNF in reducing CF during economic downturns. However, GNF is more likely to thrive during economic expansion as more resources are available, increased investor interest in sustainable projects, and a greater incentive for firms to utilize environmentally friendly practices to meet consumer demands and regulatory requirements. Moreover, each country faces unique challenges that can only be tackled using panel data approaches. Therefore, to collect an absolute grasp of the distinctive properties of all nations, we have chosen to apply the QQ methodology.

5.5. Conclusion

GNF offers an opportunity to invest in a brighter, cleaner future where financial growth aligns seamlessly with a reduced CF. This research has examined the impact of GNF on CF in BRICS+6 economies using QQ estimation. The findings reveal that GNF improves EQL by diminishing CF at distinct quantiles of data distribution. However, Ethiopia and Egypt show mixed results. Furthermore, the intriguing asymmetry of country-specific variables underscores the necessity for strategic policies addressing GNF and CF mitigation at various levels.

5.6. Policy recommendations

The research findings on the impact of GNF on CF in BRICS+6 economies offer valuable insights for shaping effective environmental policies. One significant policy recommendation is to tailor GNF allocation based on the specific circumstances of each country. This approach recognizes that not all economies in the BRICS+6 group exhibit the exact relationship between GNF and CF. For instance, China, India, South Africa, Brazil, Russia, and Ethiopia display a strong negative correlation, indicating that GNF can substantially reduce CF. Therefore, governments and financial institutions should prioritize these countries when allocating GNF resources. Policymakers can achieve more significant environmental improvements by concentrating efforts where the potential for emission reduction is highest. Another essential policy recommendation revolves around the need for customized GNF programs. These programs should consider the unique economic conditions and income levels within each BRICS+6 nation. While China and India may benefit from large-scale GNF initiatives to accelerate the adoption of cleaner technologies and sustainable practices, countries like Ethiopia and Egypt, where the research indicates mixed results, may require more targeted interventions. Such tailored approaches can address barriers and challenges to GNF adoption, ensuring that resources are utilized effectively to reduce carbon emissions. Policymakers should explore ways to incentivize private sector participation in GNF initiatives. This can be achieved through tax breaks, subsidies, or favorable lending terms for environmentally responsible investments. Governments can mobilize additional financial resources and expertise to drive sustainability efforts by encouraging private-sector engagement. This approach can also stimulate innovation in green technologies and sustainable practices, reducing carbon emissions. Collaboration between the public and private sectors is vital to achieving long-term environmental sustainability goals in the BRICS+6 economies.

In light of the research findings revealing a strong negative correlation between GNF and CF in countries like China, India, South Africa, Brazil, Russia, and Ethiopia, it is recommended that policymakers prioritize substantial increases in GNF at higher quantiles of CF to enhance EQL. Given the principle of diminishing returns in environmental mitigation efforts, GNF's negative impact on CF is more pronounced at elevated CF levels, where environmental damage and emissions are more severe and entrenched. Therefore, directing GNF toward these

critical levels can yield significant reductions in CF by aggressively targeting emissions reduction through investments in cleaner technologies and promoting sustainable practices. This approach is particularly crucial as it addresses the escalating challenges and costs associated with carbon emission reduction in high-CF scenarios, ultimately contributing to improved environmental sustainability. In the unique context of Ethiopia and Egypt, where a positive GNF-CF association exists up to a specific threshold, transitioning into a negative association beyond that point, policymakers should implement a dynamic GNF framework. This framework should involve careful monitoring and assessment of the threshold levels at which GNF ceases to impact CF reduction positively and instead becomes counterproductive. Once these thresholds are identified, policies can be designed to optimize GNF allocation up to those points, focusing on sectors and initiatives that yield the most significant environmental gains. Beyond these thresholds, it may be necessary to shift investment priorities toward complementary strategies, such as enhancing energy efficiency, strengthening regulatory frameworks, or promoting sustainable practices, to diminish the negative influences of excessive GNF and maintain a proper approach to environmental sustainability in these two countries.

In light of the GNF-CF linkages across BRICS+6 economies, policymakers and governments should adopt tailored strategies to optimize environmental sustainability. For countries exhibiting negative GNF-CF correlations, such as China, India, South Africa, and Brazil, prioritizing GNF allocation at higher CF quantiles is imperative to enhance EQL. Encouraging private sector engagement through incentives for sustainable practices can further amplify the impact. Conversely, in Saudi Arabia, Argentina, and the UAE, the focus should be on reducing CF at lower to utmost GNF quantiles to curtail environmental footprint. For countries like Egypt and Ethiopia with mixed GNF-CF relationships, targeted interventions emphasizing CF reductions at specific GNF quantiles will be instrumental. These policy recommendations aim to guide governments in optimizing GNF allocation for sustainable environmental outcomes, acknowledging the nuanced dynamics revealed by the study.

It is imperative to emphasize the specific roles that regulatory bodies and financial institutions can play in operationalizing the research findings into practical policies. Regulatory bodies within the BRICS+6 economies should consider implementing dynamic frameworks that adapt to the varying GNF-CF relationships observed in different countries. These frameworks should incorporate continuous monitoring and assessment mechanisms to identify threshold levels beyond which GNF becomes counterproductive. Regulatory bodies can establish clear guidelines and benchmarks for GNF allocation, providing flexibility for adjustments based on evolving environmental and economic conditions. Moreover, financial institutions can contribute by designing innovative financial instruments tailored to support GNF initiatives. They can create investment products that incentivize environmentally responsible practices and technologies, facilitating the flow of funds toward sustainable projects. Additionally, financial institutions can collaborate with regulatory bodies to develop standardized reporting frameworks that assess the environmental impact of GNF investments. Enhancing transparency and accountability can ensure that GNF resources are channeled effectively to achieve meaningful carbon emission reductions, thus fostering long-term environmental sustainability.

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