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Article

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Borsa İstanbul Review

Provided in Cooperation with:

Borsa İstanbul Anonim Şirketi, İstanbul

Suggested Citation: Sun, Xiaohua; Rasool, Zeeshan (2024) : Unlocking the green vault: A comparative analysis on the impact of green financing initiatives in mitigating ecological footprint in Europe, Borsa İstanbul Review, ISSN 2214-8469, Elsevier, Amsterdam, Vol. 24, Iss. 1, pp. 95-105, <https://doi.org/10.1016/j.bir.2023.10.014>

This Version is available at:

<https://hdl.handle.net/10419/340451>

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Unlocking the green vault: A comparative analysis on the impact of green financing initiatives in mitigating ecological footprint in Europe

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ARTICLE INFO

Keywords:

Green finance
Ecological footprint
Quantile estimation

ABSTRACT

The recent global concerns over environmental degradation spark interest in sustainable financial mechanisms, with momentum behind environmentally-friendly financing initiatives growing as a potential solution to ecological sustainability. This study analyzes asymmetric green finance-ecological footprint nexus in ten leading European nations with substantial investments in green finance. Previous investigations explored this relationship using panel data analysis, although few economies could not show such a relation separately. In contrast, this investigation employs the “Quantile-on-Quantile” technique, which dissects the interaction of time series data within every nation. The findings demonstrate a negative impact of green finance on ecological footprint, particularly within specific segments of the data distribution. The findings highlight the imperative for policy-makers to exercise careful consideration while implementing policies related to green finance and ecological sustainability. Targeted regulatory frameworks, incentivization strategies for sustainable investments, and promoting eco-conscious financial products could be critical aspects to consider within the policy framework.

1. Introduction

GF relates to financial products and services to assist environmentally sustainable plans and proposals. The primary goal of GF is to channel financial resources toward endeavors that contribute positively to the environment by reducing emissions and environmental degradation (Chi & Yang, 2023; Jahanger et al., 2023). Integrating GF into mainstream financial systems can significantly change how businesses and individuals manage their finances and, consequently, affect environmental quality (ENQ) (Muganyi, Yan, & Sun, 2021). One of the most prominent impacts of GF on ENQ is the promotion of renewable energy projects. Through GF, funds are channeled into renewable energy sources, including wind, solar, and hydropower, enabling the shift from fossil fuels to cleaner alternatives. By financing such projects, GF helps reduce carbon emissions and dependence on non-renewable resources, thus contributing to lower pollution and combating climate change (Meo & Abd Karim, 2022). GF also encourages companies to adopt more environmentally friendly practices by providing incentives for sustainable investments. Companies seeking financing are increasingly evaluated based on their environmental performance and commitment to

sustainability (Al Mamun, Boubaker, & Nguyen, 2022; Sharif, Saqib, Dong, & Khan, 2022; Wu et al., 2023). Resultantly, businesses are incentivized to execute eco-friendly technologies, reduce waste, and adopt sustainable supply chain practices, ultimately leading to a reduction in their ECF. Furthermore, GF has a considerable impact on urban development and infrastructure. Cities significantly contribute to the ECF due to their high energy consumption, greenhouse gas emissions, and waste generation. Through GF, investments are directed toward building eco-friendly infrastructure, promoting public transport, and implementing energy-efficient buildings. Consequently, this helps cities become more sustainable and lowers their ECF (Khan, Riaz, Ahmed, & Saeed, 2022; Usman, Balsalobre-Lorente, Jahanger, & Ahmad, 2023).

However, despite the positive impact, GF also faces challenges that can hinder its effectiveness in reducing the ECF (Adeel-Farooq, Abu Bakar, & Olajide Raji, 2018). One of the main challenges is the lack of standardized criteria for defining green investments. The absence of a universally accepted definition may lead to greenwashing, where investments that have little or no real environmental benefit are labeled as green. This can mislead investors and result in ineffective allocation of

Peer review under responsibility of Borsa İstanbul Anonim Şirketi.

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<https://doi.org/10.1016/j.bir.2023.10.014>

Received 12 August 2023; Received in revised form 30 October 2023; Accepted 31 October 2023

Available online 13 November 2023

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funds. Moreover, the rapid growth of GF may result in a distortion of market dynamics, diverting resources from critical sectors and delaying the transition to truly sustainable practices (Sinha, Mishra, Sharif, & Yarovaya, 2021). Additionally, an exclusive focus on green projects might lead to neglect of other pressing environmental issues, undermining comprehensive efforts to address the ECF. Furthermore, certain green investments may have unintended consequences, such as land-use changes or increased resource consumption, counteracting their positive intentions. Striking a balance between immediate environmental gains and long-term sustainable development is essential to avoid negative trade-offs (Chen & Feng, 2019). Therefore, clear criteria and robust regulations are necessary to ensure that GF effectively contributes to reducing the ECF without generating unintended adverse effects.

Exploring the association between GF and ECF shows difficulties due to the varied and inconsistent patterns ascertained in various economies. Additionally, the specific influence of GF on ECF remains doubtful, and preceding empirical studies have presented merely small insights into the complex features of this correlation. Therefore, the supreme ambition of our work is to perform a comprehensive investigation of these difficulties. Whereas preceding works have evaluated the bond between GF and ENQ, no one has mainly focused on examining the asymmetric kinship between these variables within European economies (Muganyi et al., 2021; Shen et al., 2021; Khan, Riaz, et al., 2022; Al Mamun et al., 2022; Sharif et al., 2022; Meo & Abd Karim, 2022). Previous research has primarily adopted panel data methodologies to investigate the relationship between GF and ECF. Nevertheless, these outcomes have not shown consistent applicability across different countries. To address these limitations, this research adopts the Quantile-on-Quantile (QQ) technique, permitting a thorough evaluation customized to the distinct features of every economy. Through the application of the QQ model, a much more accurate comprehension of the alliance between GF and ECF can be attained. The utilization of this approach presents notable benefits as it autonomously investigates the time-series relationship within every nation (Sharif et al., 2020). The intricate framework of the GF-ECF connection creates difficulties for customary econometric techniques, for instance, Ordinary Least Squares (OLS) and standard quantile regression (QR).

Unlike prior works that usually concentrate on analyzing the whole dataset employing numerous elements encompassing positive, inverse, or neutral estimates, this research gives a distinctive possibility to examine the effects in both positive and inverse signs among various quantiles. The interplay between GF and ECF could produce varied findings contingent upon economic circumstances, like phases of growth or recession. Moreover, the influence of higher GF ranks on ECF is supposed to diverge from that of low grades. The influence of GF on ECF is to demonstrate instability, especially concerning the dimension of GF. This underscores an intricate and vigorous correlation that becomes more distinct with increased GF ranks. Based on the hypothesis of this study, we present that the asymmetric distribution of characteristics would give rise to variations between GF and ECF, resulting in nonlinear disparities in economic elements. The all-encompassing approach we employ, involving the analysis of different nations and considering fluctuations in associations among variables, furnishes productive perceptions for governments and policymakers. These visions could prove instrumental in attaining their social, political, and economic targets among various components.

The main concentration of this investigation cores around European economies, a choice supported by several justifications. Firstly, these economies are expected to exert a significant impact on ECF as they heavily rely on conventional energy sources, potentially hindering the adoption of environmentally friendly energy practices (Saqib, Ozturk, Usman, Sharif, & Razzaq, 2023). For that reason, investigating the effect of GF on these economies may significantly contribute to global activities intended to lower greenhouse gas emissions and foster the acceptance of sustainable energy solutions (Balsalobre-Lorente, Shahbaz, Murshed, & Nuta, 2023). Moreover, previous evidence has

demonstrated the speedy circulation of technical expansions from one economy to its nearby economies, stressing the importance of studying these high-GF European countries as capable of regional progress. Additionally, a nation's energy sector is susceptible to the impact of neighboring energy sectors, as well as internal and external disruptions, emphasizing the interconnectedness of energy systems and the possibility of ripple effects (Zhen, Ullah, Shaowen, & Irfan, 2022). To handle the different models and interconnections among different nations, we use the QQ approach, which estimates each separate nation within the study. Disregarding these elements could guide notable flaws in the outcomes and establish biases. The correlation between GF and ECF may show asymmetrical behavior affected by elements including economic growth, industrialization, and accelerated switches in energy-related policies. To efficiently account for these considerations, this research conducts distinct observations for each nation. It is crucial to recognize that regardless of their nearby geographical vicinity, these countries demonstrate significant changes from one another. Every nation has its distinctive rank of productiveness in employing GF to push the development and adoption of ECF estimates. In order to address the differences throughout these units, it is vital to utilize an econometric method, for example, QQ, to fabricate empirical patterns. This tool is necessary for achieving all-inclusive comprehension of the relationships between the studied variables, exceeding the constraints of typical econometric methods (Chang, Moldir, Zhang, & Nazar, 2023). The findings obtained by this investigation will put the valued groundwork for forthcoming investigations within the association between GF and ECF, alongside its possible ramifications in other nations.

The work is formed into distinct sections: Section 2 comprises a complete investigation of related literature from preceding empirical research. Section 3 shows the data used in this study, and Section 4 discusses the employed econometric tool. In Section 5, the outcomes are completely discussed. Lastly, Section 6 finishes the investigation by outlining the conclusions and offering authorizations for future works.

2. Literature review

In recent years, there has been an expanding fascination with examining how GF affects ECF. Many investigations have been conducted to review the connection between these two variables and gain insights into their relationship. For example, Muganyi et al. (2021) conducted an examination of the influence of GF policies within China by employing text analysis and panel data sourced through 290 cities over the period from 2011 to 2018. The study showed that these policies guided a considerable mitigation of industrial gas emissions. Furthermore, Fintech development was found to contribute to a decrease in sulfur dioxide emissions and had a positive effect on environmental protection investment proposals. Sartzetakis (2021) established the need for central banks to respond to climate change challenges and presented various ways in which they can get involved. The use of green bonds as a tool for financing the low-carbon transition was explained, primarily based on the theoretical argument of intergenerational burden sharing and the practical necessity for significant, long-term infrastructure investments. Shen et al. (2021) investigated the role of financial development, green investment, and energy consumption in diminishing carbon emissions for achieving a clean environment and sustainable development in China. Panel data from 30 states between 1995 and 2017 were analyzed using the cross-sectionally augmented autoregressive distributed lags (CS-ARDL) tool. The outcomes indicated that CO₂ emissions were positively affected by energy consumption and financial development. On the

Khan, Khan, Ahmed, and Khan (2022) calculated the effect of GF on the ECF in 26 Asian economies. A baseline model employing ordinary least squares was initially utilized, followed by a fixed-effects analysis. The empirical results displayed that GF had an inverse influence on ECF. Al Mamun et al. (2022) found that GF significantly reduced carbon emissions in the panel of 46 countries. Meo and Abd Karim (2022)

scrutinized the linkage between GF and CO₂ emissions in the top ten GF-supporting nations. Using QQ regression, it confirmed an inverse effect on CO₂ emissions. Similarly, Rafique, Fareed, Ferraz, Ikram, and Huang (2022) observed the part of economic growth and environmental taxes on the ECF in 29 OECD nations. The autoregressive distributed lag (ARDL) technique and relevant transitional predictors were applied for analysis. Results showed that foreign direct investment, economic growth, environmental taxes, energy usage, urbanization, industrialization, and renewable energy significantly influenced the long-run dynamics of ECF in OECD countries. Sharif et al. (2022) examined the influence of green technology innovation and GF on carbon emissions in the G7 economies from 1995 to 2019. Both green technology innovation and GF had a significant negative effect on CO₂ emissions.

GF has been shown to sometimes have an opposing effect and, in certain instances, no impact on ENQ. The presence of GF may not consistently lead to a more environmentally friendly setting (Adeel-Farooq, Abu Bakar, & Olajide Raji, 2018). Under specific circumstances, GF can impede green innovation and solely improve energy efficiency through technological implementation. Additionally, as per Adeel-Farooq et al. (2018), expanding GF may inversely affect ENQ depending on the area and place. In a separate study, Sinha et al. (2021) empirically scrutinized the influence of GB financing on social and environmental sustainability. S&P 500 Global GB Index and S&P 500 Environmental and Social Responsibility Index were taken from October 1, 2010, to July 31, 2020. An amalgamation of QQ Regression and Wavelet Multi-scale Decomposition techniques was used. The outcomes revealed that green financing mechanisms had progressive inverse transformational influences on ENQ and social responsibility during the specified period. Moreover, Chen and Feng (2019) and Li, Yuan, and Wang (2019) argued that GF has no impact on emissions.

Following broad studies of the past literature, it is evident that preceding research has principally centered on the whole influence of GF on ECF, unless exploring the analysis of variables' quantiles. These works have established a symmetric interrelation between these elements. Nonetheless, by neglecting the possibility regarding nonlinear influence, essential distinctions might be overlooked, possibly leading to ambiguous conclusions. Additionally, previous study has exhibited a trend to prefer panel data exploration over time-series data, nevertheless the essential problems interrelated with panel data, including the selection of model, measurement inaccuracies, and issues concerning the generalizability of results to comprehensive frameworks. When investigating the interrelation between GF and ECF, the correlation can appear uncertain in panel data, posing difficulties in determining the average impact of GF on ECF for every nation. Hence, it is suggested to use the QQ approach, which permits the individual analysis of every nation. This technique makes a complete understanding of the association under the subject matter.

3. Data and description

The essential ambition of our investigation is to probe the correlation between GF and ECF in the top ten GF supporter European nations (France, Germany, UK, Sweden, Switzerland, Netherlands, Denmark, Norway, Finland, and Spain). In this study, GF is considered the independent variable. Based on the study by Meo and Abd Karim (2022) and Hacıomeroglu, Danişoglu, and Güner (2022), the S&P green bond (GB) index is adopted as a gauge for the GF market, where GB represents GF. GB is chosen as a proxy for GF due to its focus on environmentally friendly projects, alignment with investor demand, transparency in reporting, and quantifiable metrics for ecological impact assessment. The S&P GB index serves as a recognized benchmark for tracking the performance of GB in the market (Meo & Abd Karim, 2022). This study treats ECF as the dependent variable to represent ENQ. The ECF is a widely accepted measure of environmental impact that quantifies the demand humans place on Earth's resources (Balsalobre-Lorente, Topaloglu, Nur, & Evcimen, 2023; Khan, Khan, et al., 2022). Its use as a proxy

Table 1

The ordering of abbreviations and symbols.

Symbol/ Abbreviation	Explanation	Symbol/ Abbreviation	Explanation
ECF	Ecological footprint	ENQ	Environmental quality
GF	Green finance	ρ_φ	quantile loss function
QQ	Quantile-on-Quantile	$\text{Sup}_\tau V_n(\tau) $	Value of supremum norm for the coefficients (α and γ)
QR	Quantile regression	μ_t^0	Quantile error term
τ	τ^{th} quantile of ecological footprint	h	Bandwidth parameter
ADF	Augmented Dickey-Fuller	s	Number of quantiles
J-B	Jarque-Bera	QC	Quantile cointegration

for ENQ in the study is justified by its capability to capture the holistic impact of human actions on ecosystems, making it a suitable indicator for assessing the effectiveness of GF initiatives in mitigating ecological stressors (Ashraf, 2022; Balsalobre-Lorente, Gokmenoglu, Taspinar, & Cantos-Cantos, 2019).

Monthly GB progression data is sourced from DataStream, while the annual dataset for ECF is achieved from the Global Footprint Network website (<https://www.footprintnetwork.org/>). To convert the annual ECF data into monthly sequence, the quadratic match-sum method introduced by Chang et al. (2023) is employed. This method effectively addresses data discrepancies and balances occasional cycles when transitioning from lower to higher frequencies, as supported by Chang et al. (2023) and Sharif et al. (2020). The data is taken from January 2005 to December 2020, comprising 180 monthly observations for each GF and ECF. To ensure consistency and standardization in our research, Table 1 provides a comprehensive compilation of symbols and abbreviations used throughout the study.

4. Econometric approach

The key goal of this section is to scrutinize the methods utilized for examining the connection between GF and ECF. To fulfill this objective, we apply a quantile-based cointegration test to investigate the long-run linkages between these variables. In addition, in the econometric analysis used in this study, we assimilate the QQ instrument to achieve a complete knowledge of the association between GF and ECF.

4.1. Quantile cointegration (QC) test

In this investigation, we use the QC test introduced by Xiao (2009) to surmount the restrictions of typical cointegration tests that rely on fixed cointegration vectors. By applying the QC model, we could better obtain long-run associations between variables. Contrary to traditional procedures, the QC technique identifies that the level of cointegration within variables might fluctuate throughout various quantile arrays of the data distribution. The pattern of QC presented by Xiao (2009) discusses these restrictions by consolidating the time series dynamics and linkage throughout the independent and dependent variables' quantiles. By examining the provisionally data distribution, this technique productively deals with capable evaluation biases that may arise when investigating long-run correlations. In 2009, Xiao introduced a groundbreaking tool that amalgamates disconnected cointegration errors with lead-lag factors, surmounting the constraints of traditional approaches. In addition, Saikkonen (1991) suggested including a persistent vector $\alpha(\tau)$ within the QC pattern to oblige the essential heterogeneity present in the dataset.

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

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 per [Xiao \(2009\)](#), including the persistent parameter $F_v^{-1}(\tau)$ effectively considers the drift element, and the quantile error in the conditional distribution of data is designated as $\beta(\tau)$. The mathematical expression for the quadratic components of the cointegrated pattern should be fabricated as below.

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

To evaluate the cointegration coefficients, one could utilize a test of QC, where $H_0: \alpha(\pi) = \alpha$, the null hypothesis is examined as submitted in equation (3). The test findings are obtained employing the supremum rule, represented by $\widehat{V}_n(\tau) = [\widehat{\alpha}(\tau) - \widehat{\alpha}]$, along with the analogous test stat values. The critical thresholds to verify the null hypothesis are achieved through 1000 Monte Carlo simulations.

4.2. Quantile-on-quantile (QQ) technique

As a result of the skewed nature of the dataset, it is decided to use the QQ tool for scrutinizing the relationship between the quantiles of variables. The QQ technique, initiated by [Sim and Zhou \(2015\)](#), presents a more sophisticated alternative, impressively overcoming the restrictions of the methodology of QR, that mainly concentrates on calculating the average impacts of the independent variable on the dependent variable quantiles. By employing the QQ model, we may obtain significant benefits in investigating the union between the independent and dependent variables' quantiles ([Meo & Abd Karim, 2022](#)). The QQ tool combines non-parametric analyses with the customary QR approach to investigate the interconnections between the GF and ECF quantiles. By adopting this procedure, the research aims to reveal possible difficulties in the connection between GF and ECF that might not be smoothly detectable utilizing ordinary econometric instruments, for example, QR and OLS. The elementary framework of the non-parametric QQ procedure, followed by the study of [Meo and Abd Karim \(2022\)](#), might be written down as follows:

$$ECF_t = \alpha^\theta(GF_t) + \mu_t^\theta \quad (4)$$

In this context, ECF denotes ecological footprint, and GF stands for green finance for a period specified as 't'. The sign θ symbolizes the θ^{th} quantile of GF, and the factor load $\alpha^\theta(\cdot)$ is left unidentified because of confined information about the connection between GF and ECF. The residual term for the θ^{th} quantile is symbolized as μ^θ .

Equation 4 is derived by applying the local linear regression tool submitted by [Cleveland \(1979\)](#). This tool consists of a regression analysis that gives peculiar stress to the GF value, as clarified in further debate.

$$\alpha^\theta(GF_t) \approx \alpha^\theta(GF^\tau) + \alpha^\theta(GF^\tau)(GF_t - GF^\tau) \quad (5)$$

The emblem $\alpha^\theta(GF_t)$ exhibits the partial effect of GF_t on GF^τ , with $\alpha^\theta(GF^\tau)$ and $\alpha^\theta(GF^\tau)$ being affiliated with θ and τ , separately. We adopt $\alpha_0(\theta, \tau)$ to represent $\alpha^\theta(GF^\tau)$ and $\alpha_1(\theta, \tau)$ to denote $\alpha^\theta(GF^\tau)$. Subsequently, equation (5) could be interpreted as follows.

$$\alpha^\theta(GF_t) \approx \alpha_0(\theta, \tau) + \alpha_1(\theta, \tau)(GF_t - GF^\tau) \quad (6)$$

To perform the regression of QQ, followed by [Sim and Zhou \(2015\)](#),

we put Equation (6) into Equation 4.

$$ECF_t = \frac{\alpha_0(\theta, \tau) + \alpha_1(\theta, \tau)(GF_t - GF^\tau)}{(*)} + \mu_t^\theta \quad (7)$$

In the QQ procedure, Equation (7) outlines the affiliation between the θ^{th} GF quantile and the τ^{th} ECF quantile. The sign $(*)$ constitutes the conventional GF quantile, whereas α_0 and α_1 are the parameters connected with θ and τ , separately. The quantile correlation between GF and ECF is described through parameters α_0 and α_1 that are indexed for both τ and θ . The particular values of parameters might alter centered on the chosen quantiles of GF and ECF. Equation (7) presents the essential modelling of the correlation between GF and ECF by aligning different distributions.

The QQ model, a bivariate regression technique, restricts the addition of further explanatory variables besides one independent and one dependent variable. Nonetheless, it exceeds traditional time series tools by offering exact anticipations of the asymmetric association between GF and ECF, mainly at the utmost conclusions of data distribution. Numerous previous works performed by investigators regularly underscore the model's supreme effectiveness and reliability compared to traditional methods. However, cautious choice of a suitable bandwidth during the optimization process is essential to capture the interdependence between GF and ECF effectively.

To resolve this matter, we utilize the minimization issue put forth by [Chu and Marron \(1991\)](#).

$$\text{Min}_{\delta_0, \delta_1} \sum_{t=1}^n \rho_\varphi[ECF_t - \delta_0 - \delta_1(GF_t - GF^\tau)] L\left[\frac{M_n(GF_t) - \tau}{h}\right] \quad (8)$$

Quantile regression employs a loss function embodied as ρ_φ . To appraise the effectiveness of the minimization function, a Gaussian kernel function designated as $L(\cdot)$ is practiced. This kernel function allocates weights to the points of data according to their distance from the renewable ECF. These weights are defined by dividing the empirical function of ECF distribution by its associated quantile function.

The bandwidth parameter 'h' holds a noteworthy position in kernel regression as it affects the trade-off between variance and bias. A confined bandwidth may raise variation, though an excessively wide bandwidth could result in a skewed distribution. Therefore, it is crucial to strike a stability between variation and bias. Drawing from the research of [Sharif et al. \(2020\)](#), we have selected a precise bandwidth limit of $h = 0.05$ in our study. In this scenario, the standard indicator function is represented as 'I'.

4.3. Robustness of the QQ technique

The QQ approach outstrips the QR method by furnishing precise calculations for the independent variable, GF, and the dependent variable, ECF. While the technique of QR is primarily centered on studying the θ^{th} GF quantile, the QQ procedure delves into the effect of the θ^{th} GF quantile on the τ^{th} quantile of ECF. This approach, which incorporates θ and τ as quantile parameters, enables a much-nuanced evaluation. The parameters of QR may be achieved by averaging the coefficients of QQ concerning τ . The slope coefficients, symbolized as $\gamma_1(\theta)$ in the QR approach, are applied to probe the kinship between GF and numerous ECF quantiles, as summarized in the work of [Sim and Zhou \(2015\)](#).

$$\gamma_1(\theta) \equiv \bar{\alpha}_1 = \frac{1}{s} \sum_{\tau} \widehat{\alpha}_1(\theta, \tau) \quad (9)$$

In our research, we established the quantity of quantiles, designated as 's,' at 19. The spectrum of quantiles, indicated as τ , embraces values from 0.05 to 0.95, with lags of 0.05. To evaluate the exactness of the QQ approach, this study establishes a relationship between the mean values of QQ calculated at τ and the assessed parameters resulting from the QR model.

Table 2

Descriptive stat values for GF and ECF.

Nations	Mean	Max.	Min.	Std. Dev.	J-B Stats	ADF Level	ADFA
Panel A: Green Finance (GF)							
France	123.95	149.40	93.10	11.20	324.40*	-2.14*	-4.53**
UK	123.10	156.25	90.50	18.12	262.52*	-0.94	-6.76*
Germany	122.42	142.26	92.65	11.42	200.90*	-1.52	-5.63*
Sweden	121.40	132.43	92.70	7.75	54.27*	-1.48	-4.61*
Netherlands	118.72	149.42	92.76	15.95	326.28*	-1.34	-5.80*
Denmark	112.92	141.12	95.43	11.42	250.30*	-1.70	-5.81*
Finland	110.60	133.23	88.10	11.41	396.72*	-1.68	-4.81**
Norway	95.81	104.55	76.85	3.20	407.11*	-1.44	-4.31*
Switzerland	92.52	113.92	75.55	10.04	243.85*	-1.68	-5.02*
Spain	89.72	108.11	81.70	4.69	237.83*	-1.97	-5.79*
Panel B: Ecological Footprint (ECF) (in thousand global hectares)							
France	518056	606376	435700	49811	4.72*	-1.85	-4.15*
UK	331111	378577	278014	27605	3.17*	-1.67	-5.73*
Germany	437501	502417	386178	30305	4.82*	-1.08	-5.72*
Sweden	59422	62584	49422	3657	9.50*	-1.89	-3.74**
Netherlands	98903	115392	85193	10142	4.72*	-1.86	-5.16*
Denmark	40460	45648	36974	2761	2.87*	-1.57	-5.72*
Finland	290525	340828	255623	34002	2.68*	-4.33*	-6.76*
Norway	289045	308183	267794	11511	4.80*	-1.71	-4.47*
Switzerland	78566	82482	72380	3311	4.40*	-1.71	-5.65*
Spain	300976	343124	257031	26877	1.39	-5.73*	-5.24*

Note: * and ** designate the rank of significance at 1% and 5%, individually.

Table 3

Correlation between GF and ECF.

Economy	Correlation	t-Stats	p.value
France	-0.85	-10.59*	0.00
UK	-0.81	-5.91*	0.00
Germany	-0.71	-7.63*	0.00
Sweden	-0.86	-13.35*	0.00
Netherlands	-0.68	-5.95*	0.00
Denmark	-0.76	-5.35*	0.00
Finland	-0.69	-9.32*	0.00
Norway	-0.77	-7.10*	0.00
Switzerland	-0.74	-9.35*	0.00
Spain	0.66	5.17*	0.00

Note: ** specifies the significance level at 1%.

5. Results and discussion

This section offers a complete assessment of the initial and major findings of the research, attended by an in-depth discussion.

5.1. Initial outcomes

Table 2 shows descriptive stat values that provide a complete outline of the characteristics of GF and ECF. The statistics suggest a prominent increase in GF across the studied economies.

France has the highest GF among the European countries, boasting an average price of GB (123.95), which falls within the range of 93.10 to 149.40. The UK secures the second position with an average GF value of 123.10, and its prices span from 90.50 to 156.25. Germany takes the third spot, closely followed by Sweden and the Netherlands. In terms of ECF, France exhibits the highest pollution levels compared to other European economies. It records an average ECF of 518056 thousand global hectares (tgha), extending from 435700 to 606376 tgha. Germany takes the second position, having an average EF value of 437501 tgha, with values fluctuating between 386178 and 502417 tgha. The UK ranks third, with Spain and Finland following closely behind. The J-B test results reveal that, excluding Spain, where ECF pursues a normal distribution, each GF and ECF vary from a normal distribution in many of the examined nations. This divergence from the normal distribution stresses the worth of adopting the QQ model, which is mainly well-suited for examining datasets that do not adhere to a normal

Table 4

Outcomes of QC test (GF and ECF).

Nations	Coefficients	Sup _r V _n (τ)	C1	C5	C10
France	α	68561.33	58375.33	57353.24	54800.74
GF vs. ECF	γ	2462.64	1483.25	1446.48	1432.10
UK	α	1838.70	1547.79	1046.78	994.80
GF vs. ECF	γ	962.77	688.60	497.75	346.82
Germany	α	8755.52	6713.11	4770.13	1477.82
GF vs. ECF	γ	398.17	203.60	102.08	99.13
Sweden	α	6248.65	5685.96	4687.54	3780.78
GF vs. ECF	γ	3281.96	2691.71	2183.70	1848.40
Netherlands	α	3940.93	3770.27	249.54	205.94
GF vs. ECF	γ	168.72	157.80	48.09	45.70
Denmark	α	8325.20	5284.24	3135.05	2522.37
GF vs. ECF	γ	179.62	112.41	55.85	39.39
Finland	α	7116.34	3497.15	3086.17	2230.29
GF vs. ECF	γ	606.40	301.86	216.16	118.13
Norway	α	538.40	325.36	294.73	237.55
GF vs. ECF	γ	289.90	198.80	124.70	98.30
Switzerland	α	7016.35	3294.13	3185.18	2128.32
GF vs. ECF	γ	612.41	310.87	218.16	116.11
Spain	α	7110.36	3491.14	3082.10	2225.35
GF vs. ECF	γ	609.40	303.80	214.20	119.12

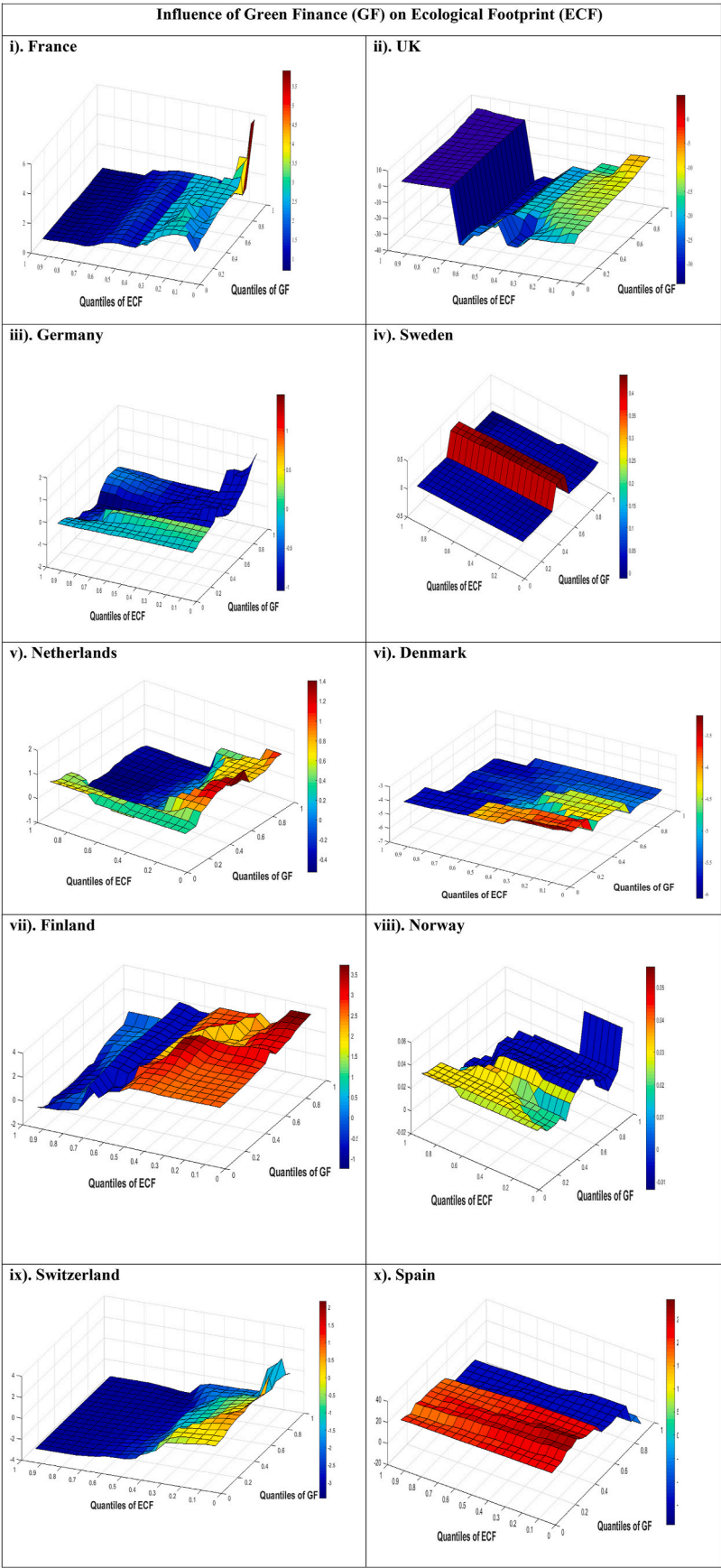
For computing the t-statistic, we employ a series of 19 equally spaced quantiles from 0.05 to 0.95. The assessments of the supremum norm (α and γ) are presented together with their respective critical thresholds at a level of significance of 1% (C1), 5% (C5), and 10% (C10).

distribution (Sharif et al., 2020). In addition, the outcomes achieved by the ADF test proposed that converting the variables within their first differences achieves persistence throughout almost all countries. In line with the methodology presented by Sharif et al. (2020), we obtain differenced data series, yielding stationary observations.

In Table 3, all economies, except for Spain, exhibit a significant, negative interrelation between GF and ECF. Among these economies, Sweden shows the topmost correlation coefficient of (-0.86), pursued by France (-0.85), the UK (-0.81), and Norway (-0.77).

5.2. Main outcomes

Table 4 illustrates the results of the QC test employed to measure the balance of the variables. The review primarily centers on the α and γ coefficients (supremum norm coefficients) achieved through equation



(caption on next page)

Fig. 1. Quantile-on-Quantile (QQ) estimations of the slope coefficient $\alpha_1(\theta, \tau)$

Note: the figures show estimations of slope coefficients $\alpha_1(\theta, \tau)$ along the z-axis. ECF quantiles are presented on the y-axis, and GF quantiles are depicted on the x-axis. Color bars located to the right of the graphs correspond to these gradient coefficients, extending from blue (denoting low values) to red (denoting high values). A deep red color signifies a positive and powerful bond between GF and ECF, while a deep blue shade illustrates a substantial inverse amalgamation between GF and ECF. In the same way, a lighter red shade indicates a weak positive connection, and a lighter blue hue signifies a mild negative association between GF and ECF. This representation streamlines the assessment of the strength and trend of the nexus between GF and ECF in numerous situations. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

(3), with τ representing the quantile under examination for ECF.

The outcomes gained by using the QC test demonstrate disparities in the connection between GF and ECF among several quantiles in each economy. Among all ranks of significance, the supremum norm values of the coefficients α and γ exceed their respective thresholds, signifying a noteworthy nonlinear and enduring correlation between GF and ECF in all economic contexts. These findings signify a substantial relationship between these two variables within entire nations.

Fig. 1 designates the slope coefficients $\alpha_1(\theta, \tau)$, signifying the effect regarding the θ^{th} GF quantile on the τ^{th} ECF quantile. The research investigates numerous composites of values for θ and τ . In France, the UK, and Switzerland, GF ascertains a negative and vigorous effect on ECF. A powerful negative GF-ECF bond is displayed in the segments that include all quantiles of GF together with lower-median to foremost ECF quantiles (0.45-0.95) in all three nations. This notable strong and negative conjunction determined that GF uplifts the ENQ by lessening ECF at low-medium to uppermost grades of ECF in these countries. In contrast, a fragile and negative relation between GF and ECF persists throughout the sectors that affiliate all quantiles of GF with bottommost to lower-middle ECF quantiles (0.05-0.40) in all three nations. In Germany, an inverse and strong amalgamation between GF and ECF is observed through the purviews that unify medium-low to topmost GF quantiles (0.40-0.95) with overall ECF quantiles. This specific inverse and vigorous junction ascertained that GF upgrades the ENQ by diminishing ECF at the lower-mid to the utmost grades of GF. Further, a feeble and negative interrelation between GF and ECF is identified across the districts that meld bottommost to middle-low quantiles of GF (0.05-0.35) alongside all ECF quantiles in Germany. The findings corroborate the work held by Sharif et al. (2022), who displayed that GF decreased CO₂ emissions in G7 countries.

In Sweden, an inverse and strong link between GF and ECF settles throughout the districts that amalgamate bottommost to medium-low and mid-higher to topmost quantiles of GF (0.05-0.40 & 0.70-0.95) with overall ECF quantiles. This vigorous and inverse junction ascertained that GF upgrades the ENQ by diminishing ECF at the lowest to low-median and middle-high to utmost ranks of GF in Sweden. Moreover, a positive and vigorous amalgamation between GF and ECF persists throughout the chunks that include low-mid to mid-high GF quantiles (0.45-0.65) along with complete ECF quantiles. This certain positive and vigorous conjunction confirmed that GF lowers the ENQ by raising ECF at lower-median to high-mid grades of GF in Sweden. In the Netherlands, an inverse and powerful influence of GF on ECF is illustrious. A strong inverse alliance between GF and ECF is ascertained throughout the precincts that blend whole GF quantiles F alongside mid-low to uppermost ECF quantiles (0.30-0.95). This specific vigorous and inverse junction ascertained that GF upgrades the ENQ by diminishing ECF at the lower-mid to topmost grades of ECF in the Netherlands. Moreover, a powerful positive interrelationship between GF and ECF is detected during the localities that coalesce all quantiles of GF with lowermost to mid-low quantiles of ECF (0.05-0.35). Moreover, a weak positive bond between GF and ECF prevails in the domains that integrate lower quantiles of GF with low to topmost quantiles of ECF (0.05-0.95) in Netherlands. The inverse GF-ECF tie in Sweden and the Netherlands is endorsed by the work done by Rafique et al. (2022).

In Denmark, the inverse and strong effect of GF on ECF is illustrious. An inverse strong kinship between GF and ECF is detected throughout the precincts that coalesce high-mid to topmost quantiles of GF (0.70-0.95) with complete ECF quantiles. This specific powerful and negative

conjunction demonstrated that GF uplifts the ENQ by lowering ECF at mid-high to upmost scales of GF in Denmark. Moreover, a powerful and positive GF-ECF bond ties among the spots that associate bottommost to mid-low (0.05-0.30) GF quantiles with lowermost to high-mid quantiles of ECF (0.05-0.65). This certain positive and vigorous conjunction confirmed that GF lowers the ENQ by enhancing ECF at the bottommost to mid-low grades of GF in Denmark. Likewise, a powerful positive GF and ECF linkage is established in the parts that consolidate mid-low to mid-high quantiles of GF (0.35-0.65) with lowest to middle-higher ECF quantiles (0.05-0.65). In Norway, a powerful and inverse affiliation between GF and ECF is presented throughout the zones that interrelate medium to high GF quantiles (0.50-0.095) with all ECF quantiles. This negative and strong conjunction ascertained that GF improves the ENQ by diminishing ECF at the medium to high levels of GF in Norway. Likewise, a weak positive GF and ECF linkage is established in the parts that consolidate the lower to medium-low quantiles of GF (0.05-0.45) with entire ECF quantiles. The negative GF-ECF association in Norway and Denmark is backed by Meo and Abd Karim (2022), who found that GF improved ENQ.

In Finland, there is a mixed correlation between GF-ECF. A powerful negative GF-ECF junction is displayed in the chunks that include the full GF quantiles together with the median to foremost ECF quantiles (0.55-0.95). This notable strong and negative conjunction determined that GF uplifts the ENQ by lessening ECF at the medium to utmost ranks of ECF. A powerful positive affiliation between GF and ECF is matured throughout the areas that comprise total quantiles of GF with bottommost to moderate ECF quantiles (0.05-0.50). This certain positive and vigorous conjunction confirms that GF lowers the ENQ by increasing ECF at bottommost to mid ranks of ECF in Finland. Like Finland, a mixed affiliation between GF and ECF is observed in Spain. An inverse and powerful linkage between GF and ECF is ascertained across the vicinities that incorporate middle-higher to topmost quantiles of GF (0.55-95) with entire ECF quantiles. This inverse and vigorous conjunction confirmed that GF enhances the ENQ by decreasing ECF at mid-high to upmost ranks of GF within Spain. In addition, a powerful and positive GF-ECF union persists within the areas that merge bottommost to median GF quantiles (0.05-0.50) along with complete ECF quantiles. This specific positive and vigorous conjunction confirmed that GF lowers the ENQ by increasing ECF at the bottom to middle levels of GF within Spain. The negative amalgamation between GF and ECF in Finland and Spain is backed by the research of Meo and Abd Karim (2022) and Rafique et al. (2022). The positive kinship between GF and ECF in these countries is confirmed by the examinations of Sinha et al. (2021) and Adeel-Farooq et al. (2018).

Table 5 displays an outline of the interrelations between various quantiles of GF and ECF in sample nations by utilizing the data from Fig. 1. The outcomes stress a significant inverse junction between GF and ECF in most countries, demonstrating that an increase in GF is generally connected to a reduction in ECF. Moreover, the linkage between GF and ECF in Spain and Finland shows mixed outcomes.

5.3. Verifying the Robustness of the QQ tool

A comparative assessment scrutinizes the resemblance between the QR and QQ analyses. Fig. 2 corroborates the earlier outcomes attained through QQ analysis, validating that the average QQ estimations of gradient coefficients closely correspond to the QR metrics across various economies. This investigation suggests that analyses share common

Table 5
Summary of Findings (Linkages b/w Multiple Quantiles of GF and ECF).

Nations	Quantiles of GF	Quantiles of ECF	Connection b/w quantiles	Dominant correlation
France	Entire quantiles	Low-median to topmost quantiles	Inverse and Strong	Powerful and negative
	Complete quantiles	Bottommost to low-middle quantiles	Negative and feeble	
UK	Entire quantiles	Low-median to topmost quantiles	Inverse and powerful	Negative and strong
	Complete quantiles	Lowest to low-middle quantiles	Fragile and inverse	
Germany	Mid-low to topmost quantiles	Entire quantiles	Strong and inverse	Strong and inverse
	Bottommost to low-mid quantiles	Whole quantiles	Inverse and weak	
Sweden	Bottommost to mid-low and mid-high to topmost quantiles	Entire quantiles	Inverse and strong	Negative and powerful
	Low-mid to mid-higher quantiles	Complete quantiles	Positive and powerful	
Netherlands	Total quantiles	Mid-low to upmost quantiles	Inverse and powerful	Inverse and powerful
	Entire quantiles	Lowest to mid-low quantiles	Feeble and negative	
	Lower quantiles	Low to topmost quantiles	Inverse and weak	
Denmark	High-mid to topmost quantiles	Complete quantiles	Inverse and powerful	Negative and powerful
	Bottommost to mid-low quantiles	Bottommost to mid-high quantiles	Positive and powerful	
	Mid-low to mid-high quantiles	Bottommost to mid-high quantiles	Positive feeble	
Finland	Full quantiles	Median to uppermost quantiles	Powerful and negative	Mixed relationship
	Total quantiles	Bottommost to mid quantiles	Positive and powerful	
Norway	Medium to high quantiles	Complete quantiles	Inverse and strong	Strong and negative
	Lower to medium-low quantiles	All quantiles	Weak positive	
Switzerland	Total quantiles	Low-median to uppermost quantiles	Inverse and powerful	Inverse and powerful
	Total quantiles	Bottommost to low-middle quantiles	Inverse and weak	
Spain	Mid-high to topmost quantiles	Complete quantiles	Inverse and strong	Mixed relationship
	Bottom to median to quantiles	Overall quantiles	Positive and powerful	

principles and offer comparable analytical results.

Fig. 2 demonstrates a conspicuous inverse bond between GF and ECF in almost all of our chosen European nations. These findings underscore the disparities in the correlation between GF and ECF across distinct nations. Moreover, the coefficients' magnitudes reveal a more

substantial influence of GF on ECF in Spain, Switzerland, and the UK, while a lesser impact is noted in Sweden.

5.4. Discussion of outcomes

Most economies reveal a significant link between GF and ECF, where 8 out of 10 countries demonstrate an inverse connection between GF and ECF. These outcomes are endorsed by past works conducted by Muganyi et al. (2021), Shen et al. (2021), Khan, Khan, et al. (2022), Al Mamun et al. (2022) and other researchers, consistently emphasizing the detrimental impact of GF on ECF. Our findings further corroborate the conclusions drawn from prior studies by Sharif et al. (2022) for G7 nations, Rafique et al. (2022) for OECD economies, and Meo and Abd Karim (2022) for GF supporter countries, all of which underscore the negative effects of GF on ECF. Diverging from conventional research, our findings offer an alternative perspective on the established understanding of GF's effects. Unlike past investigations, which mainly concentrated on the whole influence of GF on ECF, this study displays a much more intricate viewpoint. The linkage between GF and ECF can offer valuable insights across diverse data distributions, potentially yielding noteworthy repercussions for policymakers and governments in various economies. These intuitions provide valuable guidance for shaping policies related to different levels of GF and ECF.

In Finland and Spain, the association between GF and ECF shows a heterogeneous pattern, encompassing both positive and inverse relationships. Optical illustrations demonstrate that the influence of GF on ECF is not persistently inverse but rather fluctuates depending on components like duration, time, and location. The impact of GF on ECF may evolve over time due to changing environmental policies, technological advancements, and shifts in investor preferences. In the early stages of GF implementation, the impact on ECF might be modest as it takes time for investments to yield significant environmental benefits. However, over the long term, the cumulative effect of sustained green investments can lead to more substantial reductions in the ECF. As a result, visual representations might show fluctuations in the relationship between GF and ECF, reflecting the evolving nature of GF initiatives. The duration of GF programs and policies can also influence their impact on ECF. Short-term initiatives may focus on immediate and visible environmental gains, leading to a positive association between GF and ECF during the program's lifespan. Conversely, some green projects might have long gestation periods before showing measurable outcomes, resulting in a lagged effect on the ECF. Therefore, studies that examine different time horizons may display varying relationships between GF and ECF, depending on the duration of the analyzed data. The influence of GF on ECF can vary through diverse areas or countries due to diverse environmental challenges and economic structures. In Finland and Spain, the specific characteristics of their economies, natural resources, and industrial activities may influence how GF initiatives are implemented and their effectiveness in reducing the ECF. Regional disparities can lead to varying outcomes in terms of environmental improvement, thus explaining the heterogeneous pattern observed in visual representations. Additionally, the expansion of GF may lead to unforeseen consequences on ECF, impacted by a series of socioeconomic and geographical variables. The complexity of this correlation could be ascribed to a range of factors, encompassing varied business models, energy consumption trends, economic uncertainties, investment approaches, and technological betterments. The positive affiliation between various quantiles of GF and ECF in Spain and Finland is backed by the investigations of Sinha et al. (2021) and Adeel-Farooq et al. (2018).

The connection between GF and ECF presents notable changes impacted by economic conditions and income levels. Several countries, such as France, the UK, Denmark, Finland, Norway, and Switzerland, show a strong negative relationship between GF and ECF, particularly at topmost quantiles. The outcomes recommend that a significant boosts in GF has a favorable influence on ECF by diminishing its intensity. The logic behind this negative relationship lies in allocating financial

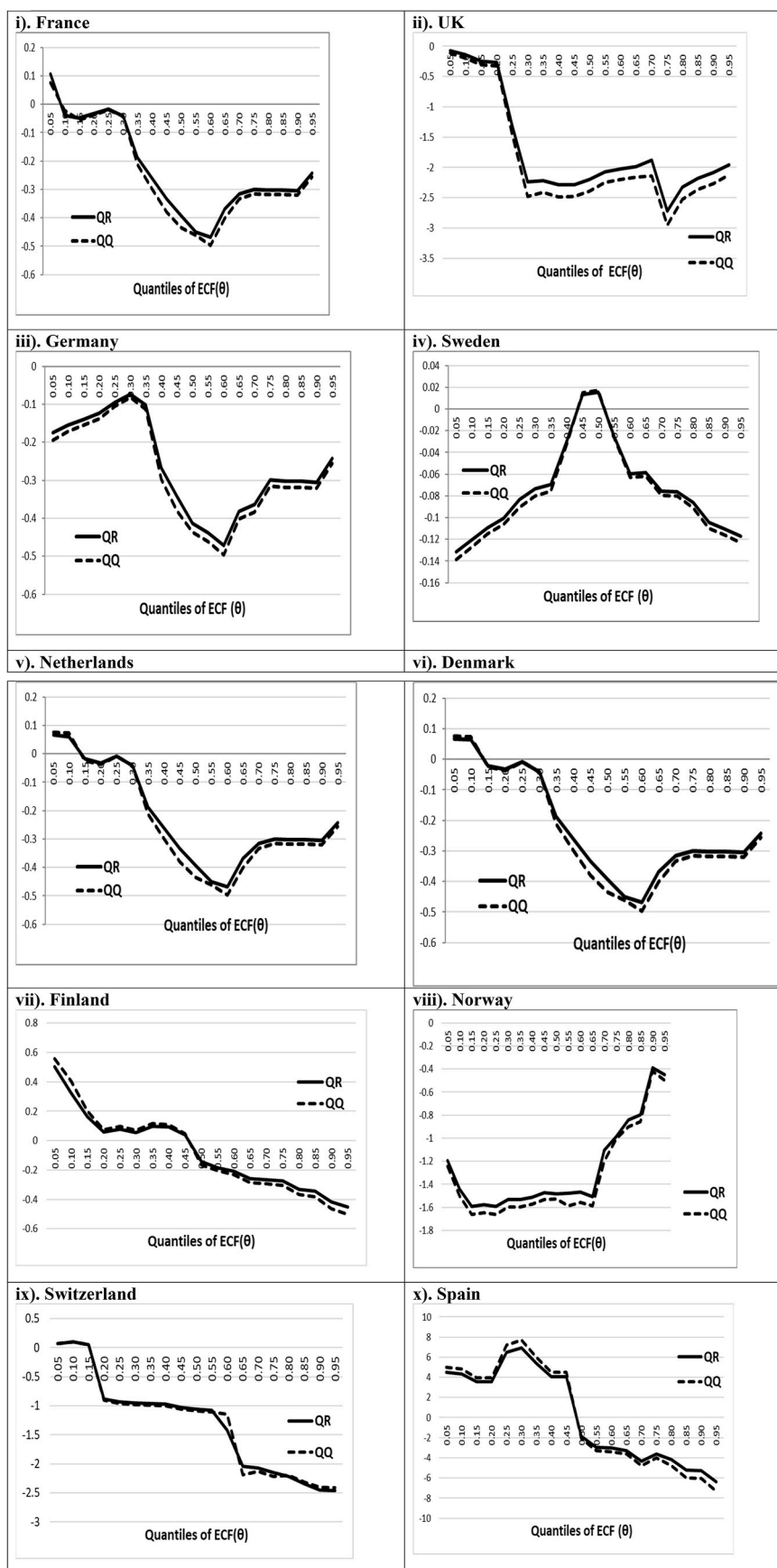


Fig. 2. Verifying the Robustness of the QQ Technique by Comparing QQ and QR Method
 Note: The analysis includes customary QR and averaged QQ estimates for various ECF quantiles.

resources towards eco-friendly projects and initiatives. When GF is channeled towards renewable energy, sustainable infrastructure, and environmentally responsible businesses, it fosters a shift away from traditional, resource-intensive practices. Consequently, this leads to a decline in the overall ECF of these countries. The positive influence of GF on ECF reduction may be attributed to the reality that these investments promote a transition to more sustainable and efficient economic activities (Khan, Riaz, et al., 2022). Countries like Spain and Finland, however, exhibit a different pattern in their correlation between GF and ECF. In these cases, the positive relationship between GF and ECF is evident up to a certain threshold. Beyond this point, further increases in GF show a negative impact on ECF reduction. This phenomenon can be explained by diminishing returns on green investments. Initially, when GF is relatively low, every additional unit of investment has a significant impact on reducing the ECF. However, as the level of GF increases, the low-hanging fruits of eco-friendly projects are already targeted, and it becomes more challenging to find equally impactful investment opportunities. At this point, some green projects may become less economically viable or result in unintended environmental consequences due to potential trade-offs or rebound effects.

The slope coefficients of GF and ECF exhibit differences through economies, suggesting that the direction and dimension of economic shocks, especially the situation of the economy (whether experiencing a boom or recession), influence ECF through economic activities. Economic prosperity encourages higher investment in environmentally sustainable projects and technologies. During booms, there is greater access to capital, and investors are more willing to fund green initiatives that might have a longer-term payoff. This leads to expanding green sectors, including sustainable infrastructure, renewable energy, and eco-friendly technologies, ultimately reducing the ECF (Meo & Abd Karim, 2022). On the other hand, economic downturns often lead to reduced capital availability, limiting the funding available for green projects. Investors may become risk-averse and prefer safer, short-term investments, diverting funds from environmentally sustainable initiatives. The uncertainties and cautious sentiment during recessions can result in delayed or canceled green projects. Companies may prioritize immediate cost-cutting measures over long-term sustainability investments, potentially leading to an increase in the ECF during this period. The economic conditions of a nation significantly affect diverse economic activities, including the adoption of renewable energy. Furthermore, every economy faces unique difficulties that cannot be fully discoursed individually through panel data techniques. Therefore, to gain complete information on the specific characteristics of every nation, we have utilized the QQ model.

6. Conclusion and policy recommendations

This research has studied the nonlinear correlation between GF and ECF in the top ten GF supporter European nations (France, UK, Germany, Netherlands, Sweden, Denmark, Finland, Switzerland, Spain, and Norway). The QQ estimation has shown that GF has a predominantly negative influence on ECF, especially within specific segments of the data distribution across diverse economies. However, Spain and Finland have mixed results.

Governments should implement policies encouraging private and institutional investors to allocate a significant portion of their portfolios toward environmentally sustainable ventures. This could be achieved through tax incentives, subsidies, and grants for green investments. Additionally, establishing of green bond markets and other financial instruments can attract more capital toward projects with positive environmental impacts, ultimately reducing the ECF of the financial sector. Regulators should mandate financial institutions to disclose the environmental impact of their investments and operations. Implementing standardized and transparent reporting frameworks can help investors and the public better understand the ECF of their financial decisions. This transparency will not only foster accountability but also

enable consumers to make more informed choices about where to invest their money. Central banks and financial regulators should actively promote green banking initiatives that encourage environmentally sustainable lending practices. Implementing guidelines for banks to assess the ecological impact of their lending portfolios will ensure that credit is channelled toward low-carbon and eco-friendly projects. This approach will not only mitigate ecological risks but also promote a more resilient and sustainable financial system.

Governments and financial institutions should invest in public awareness campaigns and educational programs to promote GF literacy. Improved financial knowledge can empower individuals to align their investment decisions with environmentally responsible options. Financial literacy initiatives can be tailored to educate citizens about the environmental consequences of their financial choices, enabling them to actively contribute to reducing the ECF. Policymakers should engage in international collaborations to develop unified frameworks for GF regulations and standards. Harmonizing GF policies across borders can facilitate cross-border investments in eco-friendly projects and create a more robust global green financial market. Joint efforts can also address challenges related to greenwashing and ensure the credibility and effectiveness of GF initiatives. Governments should allocate funds and create financial incentives to support research and development in green technologies and practices. By promoting innovation in sectors including agriculture, renewable energy, sustainable and circular economy initiatives, countries can boost the shift toward a low-carbon and more ecologically sustainable economy (Balsalobre-Lorente, Bekun, Etokakpan, & Driha, 2019). Governments may explore instituting carbon pricing mechanisms, like carbon taxation or cap-and-trade systems, to adopt the expenses associated with carbon emissions. Carbon pricing generates economic incentives in favor of companies to lessen their carbon footprint and invest in greener alternatives, driving the flow of finance toward environmentally sustainable ventures. Encouraging partnerships between governments, private investors, and businesses can amplify the impact of GF initiatives. Public-private collaborations can facilitate large-scale green projects, increase financial resources, and share expertise in tackling ecological challenges effectively.

This research determines particular constraints that could provide as supervision for upcoming studies in this area. Firstly, this study concentrated entirely on ECF and did not examine greenhouse gas emissions, for example, CH₄, CO₂, N₂O, and SO₂. In forthcoming investigations, it should be profitable to include these environmental components to examine feasible alterations in results when utilizing the above-mentioned environmental representatives. Additionally, reviewing the interrelation between GF and ECF in various other economic blocs, including G20, G7, MENA, and BRICS, would provide significant value. Moreover, it is essential to understand a restriction in this research, mainly centered on using the QQ model. This technique constrains the interpolation of extra variables that might capably impact the bond between GF and ECF. To overcome this limitation, forthcoming studies should adopt numerous procedures, for example, Quantile ARDL modeling. By consolidating these approaches, we can introduce additional explanatory variables and learn about the connection between GF and ECF. Addressing these limitations in future research will allow us to contribute to a deeper comprehension of the intricate dynamics between GF and ECF.

Funding

The provincial-level project of the Henan Provincial Department of Education, titled "Management Science" for the construction of first-class undergraduate courses in Henan Province (No.: 2020(523).

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