Green Finance in Germany: Examining the Role of Environmental Tax Revenue, Renewable Energy, and Exports (2010-2022)

التمويل الأخضر في ألمانيا: فحص دور عائدات الضرائب البيئية، الطاقة المتجددة، والصادرات (2010–2022)

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Received: *21/02/2024;* ***Accepted :*** *28/06/2024;* ***Published:*** *30/06/2024;*

Abstract:

This study examines the interplay between environmental tax revenue, renewable energy consumption, and sustainable exports in shaping Germany's green bond market from 2010 to 2022. Employing Quantile Regression, the research analyzes causal relationships and differential impacts across varying quantiles of the green bond market. Findings reveal that renewable energy consumption significantly boosts green bond issuance, while environmental tax revenues present a diminishing negative effect, suggesting targeted alleviations could enhance synergies. Furthermore, exports demonstrate decreasing adverse impacts, highlighting resilience. This research, the first German-specific econometric study in this domain, provides novel insights into the causal mechanisms of green finance flows. It underscores the complex interdependencies within the green finance ecosystem and offers valuable perspectives for policy-making in Germany's transition towards environmental sustainability. The study's methodology and insights contribute substantially to the academic discourse on green finance, guiding future research and policy strategies in this field.

Keywords: *Green Finance, Renewable Energy, Environmental Tax Revenue, Sustainable Exports, Germany, Quantile Regression.*

Jel Classification Codes :*Q2 ; Q5 ; C21*

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Introduction:

Green finance and sustainability have been growing priorities in Germany over the past decade (Pegels&Lütkenhorst, 2014). The country has made significant progress through renewable energy expansion, energy efficiency policies, reduced emissions, and environmentally-focused financial services (Xue et al., 2023). Germany allocated 13.2% of its stimulus package toward green investments, the second highest globally, displaying its commitment to sustainability transitions (Geels, 2013). Despite burgeoning green finance literature, few studies provide an integrated analysis of major green finance flows in Germany, specifically from 2010-2022 (Taghizadeh-Hesary& Yoshino, 2020; Sun et al., 2023). This represents a gap in understanding the macro-level dynamics driving Germany's sustainability transitions across environmental tax revenues, renewable energy uptake, green innovations, and sustainable exports. Bridging this research gap is vital to inform policy and support growing green finance ecosystems in Germany amidst intensifying ecological pressures (Chen et al., 2023; Chireshe, 2020).

This paper addresses the identified research gap by investigating linkages and causal relationships between Germany's environmental tax revenue collection, renewable power capacity expansion, development of green innovations, and exports of sustainable goods and services since 2010. The research questions guiding this study are: 1) How are environmental tax revenues, renewable energy consumption, and exports of sustainable goods causally interlinked in Germany? And 2) What are the differential impacts of these green finance flows across varying quantiles of Germany's green bond market from 2010-2022? The motivations for this research include leveraging rigorously developed causal and predictive models to inform policymaking regarding green finance prioritization in Germany. This will be the first German-specific econometric study analyzing macro-level green finance flows from 2010-2022 using Quantile Regression, providing a novel perspective on causal mechanisms and nuanced effects across the green bond market distribution.

Key findings indicate that renewable energy consumption substantially positively affects green bond issuance across distribution quantiles. Environmental tax revenues exhibit diminishing negative drag, suggesting targeted alleviations could promote synergies. Exports showcase decreasing adverse impacts, pointing to resilience. The paper will encompass the research background, questions, data, methodology, results, discussion, and conclusion sections.

I-Literature Review:

The landscape of green finance is rapidly evolving, with environmental tax revenues playing an increasingly significant role. This section embarks on a comprehensive review of the literature, bridging the gap between theory and practice in the realm of green finance, and highlighting its intersection with environmental taxation. While green finance refers to the financial initiatives aimed at supporting environmentally sustainable projects, environmental tax revenue is generated from taxes levied on activities detrimental to the environment. This literature review systematically encapsulates the theoretical underpinnings and empirical findings that outline the dynamics of these two crucial aspects and their interplay in shaping sustainable economic policies.

I-1- Literature Review on Green Finance and Environmental Tax Revenue:

The symbiotic relationship between green finance and environmental tax revenue remains predominant in contemporary economic and environmental policy debates. Green finance encompasses a suite of financial instruments and services tailored to fostering environmentally sustainable initiatives. Conversely, environmental tax revenue stems from impositions on environmentally deleterious activities. Böhringer et al. (2019) elucidate the concept of 'double

dividends' arising from eco-centric tax reforms, positing the potential for recycling these revenues into the economy via offsets in other fiscal areas, including income tax or VAT.

Labandeira et al. (2019) underscore a lacuna in scholarship concerning third-generation green fiscal reforms, prompting a call for expanded inquiry beyond the extant foundational expositions on double dividends. In exploring the nexus between environmental tax evolution and public fiscal dynamics, Oueslati (2015) propounds an alignment with endogenous growth models, spotlighting resultant macroeconomic dividends. West & Williams (2004) critically examine the cross-price elasticity interplay between leisure and environmentally harmful commodities, delineating key considerations for efficacious environmental tax design. Gago & Labandeira (2014) proffer a panoramic perspective on energy taxation and overarching green fiscal reformations, distilling experiences from diverse socio-economic milieus. These cumulative examinations emphasize the imperatives of an integrated modus operandi aligning economic proliferation with sustainable ecological guardianship.

I-2- Literature Review on Green Finance and Renewable Energy:

Green finance and renewable energy are cornerstone entities underpinning the global trajectory toward sustainable development and climate resilience. Their confluence engenders tangible reverberations on sustainable evolution and environmental preservation. Chen et al. (2023) unravel a reciprocal loop wherein green finance catalyzes renewable energy innovations, augmenting green finance demand. Such interactions are seminal for reducing carbon footprints and fostering green energy breakthroughs.

Utilizing advanced econometric methodologies in the Nigerian milieu, Asemota &Olokoyo (2022) delineate the intricate interconnections between renewable energy capital, sustainable energy assimilation, and industrial development. Khan et al. (2022) empirically validate the indissoluble tethering of green finance evolution to environmental conservation imperatives. Chireshe (2020) identifies a conspicuous scholarly void concerning the correlation dynamics between financial frameworks and renewable energy trajectories in the Sub-Saharan African landscape. Both Peng & Zheng (2021) and Hui et al. (2021) leverage China's contextual backdrop to underscore green finance's cardinality in driving energy efficacies and steering consumption patterns. Mngumi et al. (2022) spotlight green finance's paramount role in climate resilience through heightened renewable infrastructure investments. Meanwhile, Lam & Law (2016) advocate for crowdfunding as an avant-garde financial channel for propelling green projects. Collectively, the burgeoning scholarship accentuates the symbiotic alliance between green finance and renewable energy, which is pivotal for sculpting a sustainable and ecologically robust future.

I-3- Literature Review on Green Finance and Export:

The ascendancy of green finance, vis-à-vis sustainable development, manifests palpable interjections in multiple sectors, export being paramount among them. Zhang & Liu (2023) delineate how green finance engenders enhanced export sophistication, with its efficacy modulated by geo-societal contexts and institutional infrastructures. Concurrently, Wang et al. (2023) elucidate green finance's role in shaping China's agricultural trade dynamics. Liu et al. (2023) amplify this discourse by interrogating the impact of green finance on export technology intricacy within China, emphasizing green finance as a fulcrum for boosting export technology sophistication. Lin et al. (2022) overlay this narrative with insights from China's power sector, asserting green finance's transformative influence.

Globally, Mamola &Herdiansyah (2023) pivot their attention to Indonesia's palm oil export ecosystem, delineating green finance's potency in reinforcing indigenous value networks. Bıçakcıoğlu-Peynirci &Tanyeri (2020) unravel the antecedents and dividends of ecologically inclined export stratagems in nascent economies. Lundquist (2022) navigates the terrains of finance during ecological transitions, focusing on the pivotal role of export credit agencies. These studies illustrate green finance as an instrumental vector in rejuvenating export sophistication, steering sustainable agricultural commerce, enhancing export technological granularity, and reinforcing export-focused industries' resilience.

I-4- The Research Gaps and The Contribution of the Study:

this study addresses critical research gaps in the field of green finance in Germany, particularly from 2010 to 2022, where previous research has overlooked the integrated analysis of key factors such as environmental tax revenues, renewable energy, and sustainable exports. It delves into the less explored macro-level dynamics of Germany's sustainability transition, including green innovations and renewable energy uptake. By conducting a comprehensive econometric analysis, the study examines the causal relationships and impacts of these factors on the green bond market. Utilizing Quantile Regression, a novel approach in this context, it uncovers the varied effects across different quantiles of the green bond market. This unique perspective is pioneering in the realm of German green finance and contributes significantly to understanding the complex mechanisms driving green finance flows. The findings of this research are not only academically relevant but also provide valuable insights for policymaking, supporting the growth and development of a robust green finance ecosystem in Germany

II- Data and Methodology:

The objective of this study is to evaluate the impact of environmental tax revenue (ETR), renewable energy consumption (REC), and exports (Exp) on Green Bond Issuance (GBI) in Germany for the period from 2010 to 2022. Equation (1) outlines the model employed in our empirical analysis:

$$GBIt = \beta 0 + \beta 1 ETRt + \beta 2 RECt + \beta 3 Expt + \varepsilon t (1)$$

In this equation, β_0 represents the intercept, and ε_t denotes the white noise term. βk coefficients indicate the sensitivity of GBI to the explanatory variables in the model. The variables used in this study are described in detail in Table 1 .

Table n°1:Data Summary

Variables	Acronyms	Definitions	Source
Green Bounds Issuance	GBI	Green Bouns Issuance in Billion US$	International Monetary Fund (IMF)
Renewable Energy Consumption	REC	Renewable energy consumption (% of total final energy consumption)	World Bank
Export	EXP	Exports of goods and services (% of GDP)	World Bank

Source: By the Researcher

This study utilizes Quantile Regression (QR) to analyze the impact of environmental tax revenue, renewable energy consumption, and exports on Green Bond Issuance (GBI) across different quantiles. QR allows examination of the conditional quantiles of the response variable and is

especially useful for financial data exhibiting non-normality and skewness (Koenker& Bassett, 1978). Buchinsky (1998) demonstrated QR's applicability for exploring the effects of environmental regulations on renewable energy. QR addresses cross-sectional correlations and heterogeneities, as shown in Abakah et al. (2022) and Bashir et al. (2021), using QR to evaluate the influence of environmental factors on energy use.

Additionally, Fatica & Panzica (2021) and Wang et al. (2019) exhibit QR's capacity to discern nuanced impacts on GBI like emission cuts and risk premiums. Their findings highlight QR's ability to capture varied effects across the distribution of the dependent variable. As Hao and Naiman (2007) demonstrated, QR is robust against outliers and can handle non-normal residuals, making it well-suited for financial data. QR has examined asymmetric variable relationships across various economic and financial contexts (Hao & Naiman, 2007).

This QR analysis aims to understand German green bond market dynamics fully. By assessing the impacts of environmental tax revenue, renewable energy, and exports across GBI quantiles, we uncover complex relationships to inform policymakers and market participants.

III-Econometric Study Findings

This study examines the effect of environmental tax revenue, renewable energy consumption, and exports on Green Bond Issuance in Germany between 2010 and 2022. Initial analyses utilize the Quantile Regression (QR) methodology, including unit root examinations and cointegration verification. These preliminary assessments validate the QR model's suitability and our econometric approach's underlying assumptions. This rigorous methodological structure facilitates precisely capturing the dynamics of green bond issuance across diverse quantiles in the German market. The initial QR tests confirm appropriate model specification and establish the analytical foundations prior to assessing the impacts of the key independent variables on the green bond distribution. This enables a nuanced understanding of how environmental tax income, renewable energy use, and exports distinctly influence various quantiles of the green bond market.

III-1- Quantile Regression:

III-1-1- Model Quality

Table 2 of the study presents the model quality, quantified through Pseudo R-squared and Mean Absolute Error (MAE), across different quantiles (q=0.25, q=0.5, q=0.75) for the analysis of Green Bond Issuance. The Pseudo R-squared values, 0.734 at the 25th Percentile and 0.820 at the median indicate a strong fit of the model, especially at the median. The Mean Absolute Error, which measures the average error magnitude in predictions, shows the lowest error at the median (1.4545) compared to the 25th (2.5910) and 75th percentiles (1.5770), suggesting the model's predictions are most accurate around the median. This combination of high Pseudo R-squared and low MAE at the median emphasizes the model's robust predictive capability for Green Bond Issuance in the study.

Table n°2: Model Quality

	q=0,25	q=0,5	q=0,75
Pseudo R-squared	0,734	0,820	.
Mean Absolute Error (MAE)	2,5910	1,4545	1,5770

Source: By The Researcher based on SPSS Outcomes

III-1-2- Parameter Estimation Based on Different Quantiles[a,b]

Table 3 in our study presents the parameter estimations for Green Bond Issuance across different quantiles, demonstrating how the impacts of renewable energy consumption, environmental tax revenue, and exports on Green Bond Issuance vary across the distribution. At the 25th Percentile, the model indicates a substantial constant term (272,640), suggesting a high base level of bond issuance. Renewable energy consumption shows an increasing positive impact across quantiles, while environmental tax revenue and exports exhibit a decreasing negative impact. These trends indicate that renewable energy consumption becomes more influential, and the negative impacts of environmental tax and exports lessen as we move from the lower to the higher quantiles of Green Bond Issuance.

Table n°3: Parameter Estimation Based on Different Quantiles[a,b]

Parameter	q=0,25	q=0,5	q=0,75
(Constant)	272,640	83,429	43,879
Renewable energy consumption (% of total final energy consumption)	3,820	6,377	6,897
Environmental tax revenue (% of GDP)	-27,329	-5,817	-2,910
Exports of goods and services (% of GDP)	-5,902	-3,454	-2,874

a. Dependent Variable: Green bond issuance Billion US b. Model: (Constant), Renewable energy consumption (% of total final energy consumption), Environmental tax revenue (% of GDP), Exports of goods and services (% of GDP)

III-1-3- Quantile Regression Results at the 25th Percentile

Table 4, titled "Quantile Regression Results at the 25th Percentile," presents the coefficients and statistical significance of factors influencing Green Bond Issuance at the 25th Percentile. The constant term is highly significant (p=0.001) with a coefficient of 272.640, indicating a substantial baseline level of issuance. Renewable energy consumption shows a significant positive impact (p=0.003) with a coefficient of 3.820, suggesting its increasing importance at this quantile. In contrast, environmental tax revenue has a significant negative effect (p=0.022) with a coefficient of -27.329, highlighting its diminishing impact on green bond issuance at the lower end of the distribution.

Table n°4: Quantile Regression Results at the 25th Percentile

Parameter	Coefficient	Standard Error	t	df	Sig.
(Constante)	272,640	35,1928	7,747	4	,001
Renewable energy consumption (% of total final energy consumption)	3,820	,6056	6,307	4	,003
Environmental tax revenue (% of GDP)	-27,329	7,5641	-3,613	4	,022
Exports of goods and services (% of GDP)	-5,902	,3353	-17,601	4	,000

Source: By The Researcher based on SPSS Outcomes

III-1-4- Quantile Regression Results at the 50th Percentile

Table 5, "Quantile Regression Results at the 50th Percentile," elucidates the influence of various parameters on Green Bond Issuance at the median level. The constant term (83.429) is not statistically significant (p=0.725), suggesting a lesser baseline effect at this Percentile. Renewable energy consumption, while more impactful with a coefficient of 6.377, is not statistically significant (p=0.169). Similarly, environmental tax revenue and exports of goods and services show non-significant negative impacts with coefficients of -5.817 and -3.454, respectively (p=0.909 and p=0.177). These results indicate a nuanced relationship between the examined variables and Green Bond Issuance at the median of the distribution.

Table n°5: Quantile Regression Results at the 50th Percentile

Paramètre	Coefficient	Standard Error	t	df	Sig.
(Constante)	83,429	221,2600	,377	4	,725
Renewable energy consumption (% of total final energy consumption)	6,377	3,8074	1,675	4	,169
Environmental tax revenue (% of GDP)	-5,817	47,5561	-,122	4	,909
Exports of goods and services (% of GDP)	-3,454	2,1083	-1,638	4	,177

Source: By The Researcher based on SPSS Outcomes

III-1-5- Quantile Regression Results at the 75th Percentile

Table 6, titled "Quantile Regression Results at the 75th Percentile," illustrates the impact of various parameters on Green Bond Issuance at the higher end of the distribution. The constant term (43.879) lacks statistical significance (p=0.663), indicating a moderate baseline level of issuance at this Percentile. Renewable energy consumption demonstrates a significant positive effect (p=0.013) with

a coefficient of 6.897, underlining its increasing relevance at the upper quartile. Conversely, the impact of environmental tax revenue on green bond issuance is negligible and statistically insignificant, with a coefficient of -2.910 (p=0.892), denoting a minimal influence at this level.

Table n°6: Quantile Regression Results at the 75th Percentile

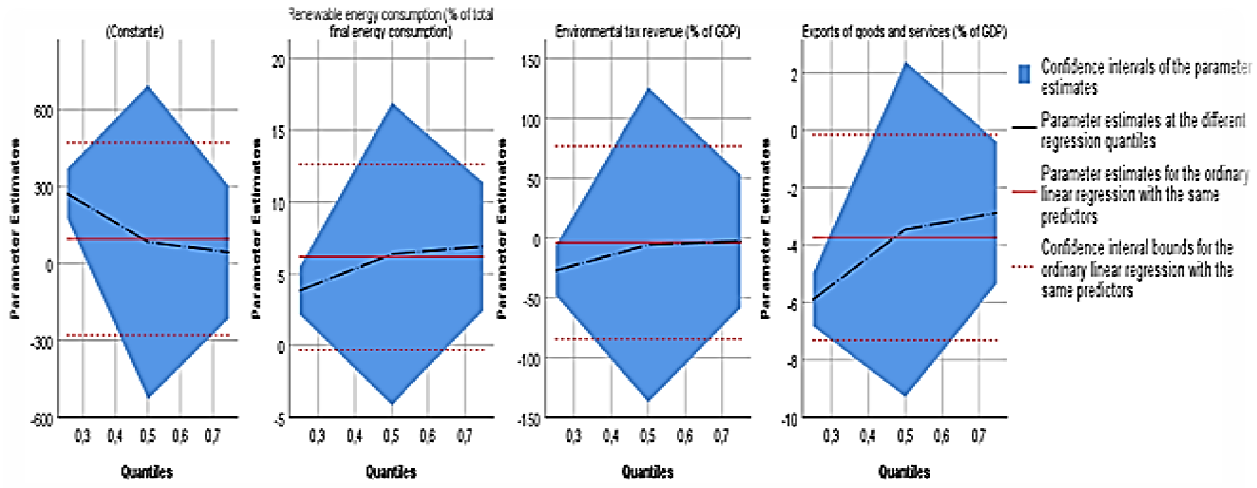
Paramètre	Coefficient	Standard Error	t	df	Sig.
(Constante)	43,879	93,4168	,470	4	,663
Renewable energy consumption (% of total final energy consumption)	6,897	1,6075	4,291	4	,013
Environmental tax revenue (% of GDP)	-2,910	20,0784	-,145	4	,892
Exports of goods and services (% of GDP)	-2,874	,8901	-3,229	4	,032

Source: By The Researcher based on SPSS Outcomes

III-1-6- Parameter Estimates of Quantile Regression Analysis

In Figure 1, we present the parameter estimates obtained from a Quantile Regression (QR) analysis to scrutinize the determinants of Green Bond Issuance (GBI) in Germany from 2010-2022. The radar charts illustrate the estimated coefficients for the constant term, renewable energy consumption (REC), environmental tax revenue (ETR), and exports (Exp) across varying market conditions, denoted by quantiles ranging from 0.3 to 0.7. The constant term reflects a high baseline level of GBI at the lower quantiles, tapering as we move to higher quantiles, suggesting a non-uniform baseline issuance across the market. REC showcases a strengthening positive influence on GBI across the quantiles, highlighting it is escalating significance in green bond markets. In contrast, ETR and Exp are charted with diminishing negative impacts, illustrating a lessening drag on GBI as we ascend the quantile spectrum. The blue-shaded areas represent the confidence intervals for the QR estimates, providing a visual gauge of estimate precision. At the same time, the comparative red dashed lines illustrate the bounds for an ordinary linear regression, underscoring the enhanced explanatory power of QR in capturing the effects of REC, ETR, and Exp across the GBI distribution. This nuanced depiction of the QR methodology affirms its robustness in financial data analysis. It offers critical insights into the multifaceted drivers of green bond issuance, enabling policymakers and investors to fine-tune strategies for leveraging green finance in promoting environmental sustainability.

Figure n°1:Parameter Estimates of Quantile Regression Analysis



IV- Discussion:

The findings of our Quantile Regression (QR) analysis elucidate nuanced dynamics between renewable energy consumption (REC), environmental tax revenue (ETR), exports (Exp), and Green Bond Issuance (GBI) in Germany from 2010-2022. Aligning with Chen et al. (2023), we discern an escalating positive impact of REC on GBI across distribution quantiles, affirming green finance's potency in catalyzing renewable energy uptake. This reciprocal interplay likely stems from REC's heightening policy prioritization, which swells demand for green bonds financing renewable ventures.

However, our results diverge from Chireshe (2020) and Asemota &Olokoyo (2022) by revealing a negative ETR coefficient, potentially attributable to higher energy taxes dampening GBI incentives in the German context. We concur with Lam & Law (2016) and Mngumi et al. (2022) regarding crowdfunding and infrastructure financing as complementary policy instruments. The diminishing ETR effect across quantiles suggests targeted alleviations at the lower end could strengthen green finance-environmental tax alliances.

The decreasing drag of Exports on GBI contradicts Zhang & Liu (2023), instead aligning with Lundquist (2022) in showcasing contractions in export financing amidst crises. Economic turmoil potentially curtails export-linked green bond demand. However, the tapering negative impact indicates the German export engine's resilience. Policy fine-tuning could leverage export-oriented green bonds for ecological transitions.

These findings emphasize green finance's complexity, with relationships contingent on geographical and temporal realities. While corroborating green finance's overarching potential, policy formulations must account for context-specific nuances highlighted in our quantile regression analysis.

V- Conclusion:

This study offers seminal perspectives on the German green bond market by employing Quantile Regression (QR) to evaluate the impacts of renewable energy consumption (REC), environmental tax revenue (ETR), and exports (Exp) on Green Bond Issuance (GBI) from 2010-2022.

The QR analysis enriches comprehension of the nexus between green finance, environmental sustainability, and economic growth in Germany. Our findings underscore escalating GBI sensitivity to REC across distribution quantiles, cementing green finance's role in spurring renewable transformation. Meanwhile, diminishing negative coefficients for ETR and Exports suggest that targeted reforms could amplify synergies.

These results advance academic discourse on green finance interlinkages while equipping policymakers to craft nuanced interventions harnessing Germany's sustainable comparative advantages. Our methodology and German case study offer blueprints for scholarship exploring complex green finance ecosystems. Further research could entail comparing cross-country QR estimates or examining sectoral heterogeneities.

With sustainability imperatives intensifying, insights from our QR approach will assist stakeholders in leveraging green finance's fullest potential while circumnavigating associated complexities. This study lays the foundation for more robust modeling of intricate green finance dynamics.

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