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Exploring the Role of Green Energy, Non-Energy Equities, and Green Bond in Mitigating Environmental Pollution

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This study examines the relationship between global CO₂ emissions and green finance assets across various conditional distributions. The empirical results show that eco-friendly assets reduce carbon dioxide emissions across different market conditions. An increase in global CO₂ emissions leads to higher demand for green financial assets. Our findings present several environmental implications for green investors.

I. Introduction

The transition to green investments has gained increasing attention in recent years from environmentally conscious investors. This shift is driven by the urgent need to address environmental issues exacerbated by economic growth, which increases CO₂ emissions and aggravates climate change (Yousfi et al., 2023). Environmental or sustainable finance aims to facilitate the smooth transition to a decarbonized economy. Financing green projects and investing in green assets help mitigate environmental degradation and promote sustainability. Green bonds, clean energy markets, and green equity markets are widely recognized as environmental assets that reduce environmental pollution (Cao, 2023; Wan et al., 2022; F. Wang et al., 2021; M. X. Wang et al., 2018). Tiwari et al. (2023) indicate that green equities are shares of companies that improve the environment. Glomsrod & Wei (2018) indicate that green bonds reduce the consumption of dirty energies and therefore reduce global CO₂ emissions.

As the world grapples with the escalating impacts of climate change, the quest for sustainable solutions has never been more critical. Green finance emerges as a beacon of hope, promising to channel resources towards sustainable projects that can curb pollution and foster a sustainable future. Therefore, this study delves into the potential environmental benefits of green investments, exploring how green bonds, clean energy markets, and green equities can act as powerful tools in reducing carbon footprints. To achieve this objective, our study uses quantile-on-quantile regression to identify the heterogeneous and asymmetric linkage between various green finance assets and global CO₂ emissions across different quantiles. By investigating

the dependence structure between green finance and CO₂ emissions, we aim to uncover insights that will empower investors, policymakers, and corporations to mitigate environmental issues and promote sustainability.

In Sections II, III, and IV, we discuss the methodology and data, empirical results, and the conclusion, respectively.

II. Methodology and Data

This study employs the quantile-on-quantile (QQ) model of Sim & Zhou (2015) to investigate the asymmetric and heterogeneous relationships between CO₂ emissions and green finance assets across various conditional distributions. The nonparametric quantile regression (QR) model is defined as follows:

$$CO2_t = \beta^\theta(GF_t) + \mu_t^\theta \quad (1)$$

where $CO2_t$ is the CO₂ fluctuation in period t and GF_t denotes green finance indices in period t ; θ is the θ^{th} quantile of the conditional distribution of CO₂, and μ_t^θ is a quantile error whose conditional θ^{th} quantile is equal to 0. The $\beta^\theta(\cdot)$ is an unknown function, and at this level, we do not have a prior idea about the nexus between assets.

However, the dependence between the θ^{th} quantile of CO₂ and the ϑ^{th} quantile of green finance indices (GF^ϑ), with $\beta^\theta(\cdot)$ being an unknown function in QR with first-order Taylor expansion around the quantile GF^ϑ , is given as:

$$\beta^\theta(GF_t) \approx \beta^\theta(GF^\vartheta) + \beta^{\theta'}(GF^\vartheta)(GF_t - GF^\vartheta) \quad (2)$$

where $\beta^{\theta'}$ represents the partial derivative of $\beta^\theta(GF_t)$. $\beta^\theta(GF^\vartheta)$ and $\beta^{\theta'}(GF^\vartheta)$ can be defined as $\beta_0(\theta, \vartheta)$ and $\beta_1(\theta, \vartheta)$, respectively, as indicated by Sim & Zhou (2015). We can rewrite Equation (2) as follows:

$$\beta^\theta(GF_t) \approx \beta_0(\theta, \vartheta) + \beta_1(\theta, \vartheta)(GF_t - GF^\vartheta) \quad (3)$$

If we substitute Equation (3) into a standard QR, as shown in Equation (1), we obtain the following equation:

$$CO2_t = \beta_0(\theta, \vartheta) + \beta_1(\theta, \vartheta)(GF_t - GF^\vartheta) + \mu_t^\vartheta \quad (4)$$

Nevertheless, we need to weight the observations in the neighborhood of GF^ϑ . As we know, the quantile-on-quantile model is nonparametric and requires bandwidth selection.

This paper considers global CO₂ emissions as a proxy measure for environmental degradation. For green finance assets, we utilize the S&P Global Green Bond Index and eight energy and non-energy green equity market indices, namely energy efficiency, fuel cells, green buildings, green transportation, pollution mitigation, green solar energy, green water energy, and green wind energy equity markets. Global CO₂ emissions data are obtained from <https://www.co2.earth>, while the green bond data are sourced from <https://www.spglobal.com>. The green stock market data are collected from <https://www.investing.com>. The sample period consists of weekly data sets from January 2014 to December 2023. We transform all variables into logarithmic first differences. Table 1 presents the descriptive statistics of the variables. The descriptive statistics show that the means of carbon dioxide emissions and green equity are positive, while the mean is negative for the green bond. However, the Jarque-Bera test of normality indicates that all variables under study do not follow a normal distribution.

III. Empirical Results

This study employs a quantile-on-quantile model to investigate the relationship between green investments and CO₂ emissions, revealing complex connections across different levels of CO₂ emissions and market conditions. The QQ dependence results, illustrated in Figure 1a-i, highlight both positive and negative linkages that vary depending on the quantiles of the variables under investigation. When examining the relationship between energy efficiency stocks and CO₂ emissions, a strong negative linkage is observed at lower quantiles (0.2–0.4). However, this relationship weakens across middle to higher quantiles of CO₂ (0.5 to 0.8) and energy efficiency equity (0.5 to 0.95). Conversely, a positive relationship emerges when CO₂ emissions are in the lower quantiles (0.05–0.2) across various regimes of energy efficiency (0.05 to 0.95). Additionally, another positive linkage is noted between higher CO₂ regimes and the lower to upper regimes of the energy efficiency index (0.05 to 0.8).

Moreover, the relationship between CO₂ emissions and the green fuel cell index also exhibits significant variation. A strong negative linkage is found across the middle to upper quantiles of CO₂ (0.5 to 0.7) and various quantile ranges of the fuel cell index (0.05 to 0.95). Similar to energy efficiency stocks, a positive linkage exists between lower quantiles of CO₂ and lower to higher quantiles of the fuel cell index (0.05 to 0.95). Weak relationships are observed at higher CO₂ quantiles (0.7–0.95) across various quantile ranges of fuel cell equity. Analyzing the connection between CO₂ emissions and green building equity reveals an

overall weak dependence. There is a strong negative dependence at lower quantiles of CO₂ (0.1 to 0.3) and the green buildings index (0.05 to 0.4). In contrast, a positive linkage appears at higher CO₂ regimes (0.7–0.95) across all quantiles of the green buildings index.

Nonetheless, the relationship between CO₂ emissions and green transportation stocks is generally weak across all quantiles. However, a strong negative linkage emerges at extremely low CO₂ quantiles (0.1) and lower to middle quantiles of green transportation (0.05 to 0.5). Positive dependence is noted at the extreme high regime of green transportation (0.95) and lower CO₂ regimes, as well as when CO₂ is high (0.8–0.95) across various quantiles of the green transportation index. In the case of the green pollution mitigation index, a strong negative relationship is found when CO₂ is low (0.05–0.2) across all quantiles of the index. Middle quantiles of CO₂ emissions (0.4 to 0.6) also show a negative linkage with lower quantiles (0.05 to 0.3) and middle quantiles (0.5–0.6) of the green index. Strong positive dependence appears at lower CO₂ quantiles and extreme quantiles of pollution mitigation equity, as well as at upper CO₂ regimes (0.8–0.9) across various quantiles of pollution mitigation equity (0.05–0.95).

Additionally, the green solar index exhibits a generally weak relationship with CO₂ emissions across various quantiles. Nonetheless, a strong negative association is found when CO₂ is low (0.2–0.3) across different quantiles of green solar equity (0.05 to 0.95). Another significant negative dependence exists at higher quantiles of both CO₂ (0.8) and the solar index (0.7 to 0.95). Conversely, a strong positive link is observed between higher solar stock quantiles (0.7 to 0.95) and lower CO₂ quantiles (0.3), as well as when CO₂ emissions are high (0.9) across different quantiles of the green asset (0.05 to 0.95). The green water index, once again, displays mixed dependence on CO₂ emissions. A negative association is present at lower quantiles of both assets (CO₂ at 0.2–0.3 and water stock at 0.05–0.4). In contrast, a positive linkage is confirmed between middle to upper quantiles of both variables (CO₂ at 0.4 to 0.9 and water energy index at 0.05 to 0.95). Other quantile linkages exhibit weaker relationships.

Meanwhile, the green wind energy index shows a strong negative linkage with CO₂ emissions in the upper quantile ranges of CO₂ (0.8) and green wind stock (0.7 to 0.95). Conversely, a positive relationship emerges when CO₂ is low (0.2 quantile) and the wind energy index is high (0.7 to 0.95 quantiles). At the upper regime of CO₂ (0.9) and lower regimes of the wind energy index (0.05–0.3), the green asset is positively linked to environmental degradation measures. Lastly, the relationship between global green bonds and CO₂ emissions also exhibits a strong negative association when both are at low quantiles (0.05 to 0.2 for CO₂ and 0.05 to 0.4 for green bonds). A strong positive linkage is found between higher green bond quantiles (0.8 to 0.95) and extremely lower CO₂ quantiles. The remaining quantiles show weaker linkages between both assets.

Overall, the relationship between global carbon emissions and green finance instruments reveals significant findings. We observe a strong linkage between green fi-

Table 1. Descriptive statistics

	CO ₂	Gr.En.Ef	Gr.Fu.Ce	Gr.Bui	Gr.Trans	Gr.Po.Mi	Gr.Solar	Gr.Water	Gr.Wind	Gr.Bond
Mean	0.011	0.140	0.237	0.005	0.184	0.084	0.345	0.129	0.220	-0.026
Median	0.001	0.321	-0.295	0.233	0.268	0.190	0.315	0.282	0.543	0.031
Maximum	0.522	9.698	37.515	23.930	17.026	10.242	16.653	10.747	14.384	4.302
Minimum	-0.492	-13.164	-34.508	-30.308	-16.826	-15.542	-23.246	-13.474	-19.204	-5.185
Std. Dev.	0.157	2.777	8.072	3.477	4.105	2.599	4.824	2.439	3.849	0.772
Skewness	0.269	-0.471	0.298	-1.208	0.006	-0.629	-0.141	-0.666	-0.640	-1.213
Kurtosis	3.394	5.487	5.243	25.498	5.991	7.095	4.823	8.842	5.656	13.138
JB	8.698 **	138.502 ***	105.473 ***	10026.780 ***	175.215 ***	359.285 ***	66.663 ***	703.088 ***	170.222 ***	2128.080 ***

CO₂, Gr.En.Ef, Gr.Fu.Ce, Gr.Bui, Gr.Trans, Gr.Po.Mi, Gr.Solar, Gr.Water, Gr.Wind, and Gr.Bond represent CO₂ emissions, green energy efficiency, green fuel cell, green buildings, green transportation, green pollution mitigation, green solar, green water, green wind, and green bond, respectively. JB represents the Jarque-Bera test of normality. ** and *** are the significant levels at 5% and 1%, respectively.

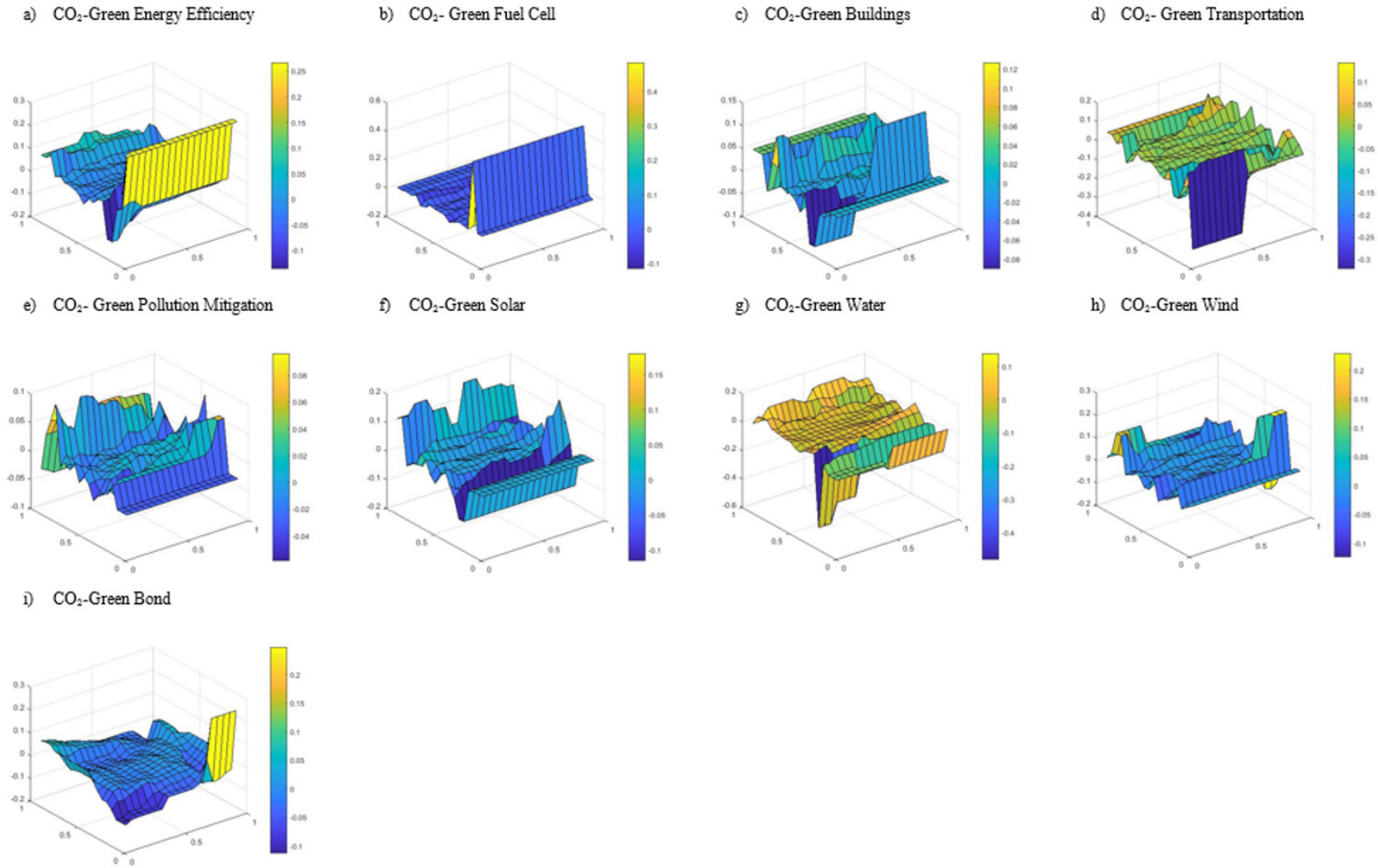


Figure 1. QQ dependence between global CO₂ emissions and green finance assets

The estimate of the slope coefficient, $\beta_1(\theta, \varphi)$ placed on the z-axis, which captures the linkage between the θ^h quantile of CO₂ emissions placed on the x-axis and the φ^h quantile of green assets placed on the y-axis.

nance and environmental degradation, which varies across quantiles. Specifically, there is a negative relationship when CO₂ emissions are lower (lower quantiles), regardless of the quantile ranges of green instruments (from lower to higher quantiles). This finding suggests that both green equities and green bonds contribute to the reduction of carbon dioxide emissions. Furthermore, in most cases, we observe a positive association across higher quantiles of CO₂ emissions and different quantile ranges of various green index regimes (i.e., bearish, normal, and bullish regimes). This finding suggests that an increase in global CO₂ emissions corresponds to an increase in the demand for green financial instruments. Conversely, the negative linkage across lower quantiles of CO₂ emissions and higher quantiles of green finance assets confirms the asymmetric relationship between CO₂ emissions and green assets. Our results are consistent with findings from Meo & Karim (2022), Wang et al. (2018), and Wang et al. (2021). We support the notion that green investment assets provide practical benefits for addressing environmental issues.

The study's findings have profound implications for various stakeholders. For instance, policymakers can use these insights to craft effective environmental regulations and incentives for green investments, promoting sustainability goals. Moreover, investors gain a dual advantage from green financial assets, which not only help reduce CO₂ emissions but also present lucrative market opportunities as demand grows. Financial institutions can expand their green product offerings to attract eco-conscious investors. Additionally, corporations can integrate green finance into their sustainability strategies to manage risks and enhance their appeal.

IV. Conclusion

This study aims to investigate the relationship between green equities, green bonds, and global CO₂ emissions across various conditional distributions using quantile-on-quantile regression. Our analysis confirms that green assets exhibit both negative and positive correlations with carbon dioxide emissions, indicating asymmetric connectivity based on quantile linkage. We find that eco-friendly assets reduce CO₂ emissions, reflecting an inverse relationship with green assets during bearish or bullish market conditions and lower quantiles of CO₂. Conversely, we confirm that the increase in global CO₂ emissions stimulates the demand for green financial products, as evidenced by a positive nexus during bullish CO₂ emission regimes and various market conditions of green finance indices.

The study's limitation lies in using global data for CO₂ emissions and green investment prices, without considering country-specific data on both green assets and CO₂ emissions. Consequently, the dependence between green financial markets and environmental pollution may vary depending on each country's CO₂ emission levels, environmental policies, and economic circumstances. Future research should aim to overcome this limitation by examining the dependence across different countries and time horizons, as the linkage can vary across various frequencies.

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