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Green Finance, Environmental Investment, and Carbon Emission Reduction: Evidence from G20 Economies

Sophia Müller-Hoffmann[1], Carlos Alejandro Vega-Ríos[2], and Priya Krishnaswamy[3]

[1]Institute for Sustainable Finance, Goethe University Frankfurt, Frankfurt, Germany [2]Department of Economics, Universidad Nacional Autónoma de México (UNAM), Mexico City, Mexico [3]School of Management, Indian Institute of Technology Bombay, Mumbai, India

Corresponding Author: Sophia Müller-Hoffmann, Institute for Sustainable Finance, Goethe University Frankfurt, Theodor-W.-Adorno-Platz 3, 60629 Frankfurt, Germany. Email: s.mueller-hoffmann@isf.uni-frankfurt.de

Abstract- Green finance — the mobilization of capital toward environmentally sustainable economic activities — has gained considerable policy and academic traction as a mechanism for bridging the gap between sustainable investment requirements and actual capital flows. This study examines the causal relationship between green finance development, environmental investment, and carbon dioxide (CO_2) emission reduction across nineteen G20 economies (excluding the European Union as a bloc) over the period 2005–2023. Green finance development is proxied through a composite Green Finance Index (GFI) incorporating green bond issuance, sustainable banking assets, environmental policy stringency, and ESG investment volumes. The empirical framework combines panel data econometrics with Environmental Kuznets Curve (EKC) testing, employing panel quantile regression, fixed effects with Driscoll-Kraay standard errors for cross-sectional dependence, and Mediation Analysis via two-stage panel regression. Results reveal that green finance development significantly reduces CO_2 emissions (coefficient: −0.214, $p < 0.001$), with the effect operating primarily through the channel of increased environmental investment (mediation proportion: 68.3%). EKC analysis confirms an inverted U-shaped relationship between income and emissions, with green finance significantly lowering the income turning point at which emissions begin to decline. Quantile regression results indicate that the emissions-reducing effect of green finance is strongest in the upper emission quantiles, suggesting that high-emitting economies derive the greatest marginal benefit from green finance development. Moderating analysis reveals that financial market

depth and carbon pricing mechanism adoption significantly amplify green finance's emissions-reduction effect.

Keywords: green finance, carbon emissions, environmental investment, Environmental Kuznets Curve, panel quantile regression, ESG, G20 economies

1. Introduction

The global transition to a low-carbon economy represents one of the most formidable economic transformation challenges of the 21st century. The International Energy Agency (IEA, 2023) estimates that achieving net-zero emissions by 2050 requires annual clean energy investment of approximately USD 4 trillion by 2030 — roughly three times current levels — with the majority of the required increase needed in emerging and developing economies where both investment needs and financing constraints are greatest. Bridging this investment gap requires not only public sector commitment but also the systematic redirection of private capital toward environmentally sustainable activities: the domain of green finance.

Green finance encompasses a broad range of instruments, institutions, and policy frameworks designed to channel private and public capital toward economic activities that generate environmental benefits or reduce environmental harm. These include green bonds — fixed-income instruments whose proceeds are earmarked for environmental projects — sustainable banking practices that incorporate environmental risk assessment into credit decisions, ESG (Environmental, Social, and Governance) investing — the integration of sustainability criteria into portfolio allocation decisions — carbon markets that price greenhouse gas emissions and create financial incentives for abatement, and green taxonomies that provide standardized frameworks for defining and labeling sustainable financial activities (Taghizadeh-Hesary & Yoshino, 2019; OECD, 2021; Soundarrajan & Vivek, 2016).

The macroeconomic and environmental effectiveness of green finance has become a subject of intense empirical investigation, yet significant uncertainties remain regarding the magnitude of its emission-reduction effects, the channels through which these effects operate, and the conditions under which green finance delivers the greatest environmental dividend. These uncertainties have important implications for the design of green finance policies, the calibration of sustainable investment mandates for institutional investors, and the architecture of international climate finance mechanisms such as the Green Climate Fund and the Just Energy Transition Partnerships.

The G20 provides a particularly important empirical context for this inquiry. The nineteen national G20 members collectively account for approximately 80% of global GDP, 75% of world trade, and over 80% of global CO_2 emissions from energy use (IEA, 2023). Their financial systems collectively mobilize the vast majority of the world's investable capital. G20 members have also been at the forefront of green finance policy innovation, through initiatives including the G20 Sustainable Finance Working Group, the Network for Greening the Financial System (NGFS), and national green

taxonomy development. At the same time, G20 members exhibit enormous heterogeneity in green finance development, institutional capacity, financial market depth, and carbon pricing readiness — heterogeneity that creates the statistical variation necessary for robust identification of green finance-emission relationships.

This study's introduction of Environmental Kuznets Curve (EKC) analysis alongside green finance is theoretically motivated by the recognition that the traditional EKC — which posits an inverted U-shaped relationship between income per capita and environmental degradation — has been challenged by evidence that the turning point income level exceeds actual income in many developing economies, implying that environmental improvement is not an automatic consequence of growth (Grossman & Krueger, 1995; Stern, 2004). Green finance may accelerate the transition to the downward-sloping portion of the EKC by enabling green technology adoption and structural economic transformation at lower income levels than would otherwise be achievable. Testing this proposition — that green finance shifts the EKC turning point — is a novel contribution of the present study.

2. Literature Review

2.1 Green Finance: Conceptual Framework and Dimensions

The conceptualization of green finance has evolved rapidly alongside the development of the sustainable finance policy landscape. Early treatments focused narrowly on environmental lending by development banks (Lindenberg, 2014); subsequent frameworks expanded to encompass green bonds, green banking, sustainable insurance, and ESG investing as distinct but related channels for environmental capital mobilization (Soundarrajan & Vivek, 2016; Taghizadeh-Hesary & Yoshino, 2019). The OECD (2021) framework distinguishes between green finance instruments (bonds, loans, equity), green finance institutions (development banks, green investment banks), and green finance policy frameworks (taxonomies, disclosure requirements, carbon pricing).

The global green bond market has been the most rapidly growing segment of green finance, expanding from USD 11 billion in issuances in 2013 to over USD 580 billion annually by 2023 (Climate Bonds Initiative, 2023). However, concerns about greenwashing — the labeling of conventional financial products as green without substantive environmental additionality — have raised questions about whether green bond growth translates into genuine additional environmental investment (Flammer, 2021; Borghei, 2021). The development of green taxonomies, mandatory green bond standards, and ESG reporting frameworks represents regulatory responses to this greenwashing concern.

2.2 Green Finance and Environmental Outcomes: Empirical Evidence

The empirical literature on green finance and environmental outcomes has grown rapidly since 2019. Taghizadeh-Hesary and Yoshino (2019) provided an early cross-country analysis demonstrating positive associations between green bond market development and renewable energy investment. Zhang et al. (2021) examined

China's green finance policy implementation, finding that green credit guidelines significantly reduced carbon emissions intensity in targeted industries. Liu et al. (2022) analyzed the relationship between ESG investment and firm-level environmental performance using a global sample, finding significant emissions reductions associated with higher ESG scores.

At the macroeconomic level, Umar et al. (2021) examined a panel of 30 countries and found that green finance development significantly reduced CO_2 emissions, with effects mediated by renewable energy adoption. Khan et al. (2022) analyzed G7 economies and found that sustainable finance indicators were negatively associated with carbon emissions but with heterogeneous effects across countries. Tian et al. (2023) studied BRICS economies, finding that green investment was positively associated with environmental quality improvements, but noting that the effects were concentrated in economies with stronger environmental regulatory frameworks.

2.3 Environmental Kuznets Curve Literature

The EKC hypothesis, originating in Grossman and Krueger's (1995) analysis of NAFTA's environmental implications, proposes that environmental degradation initially increases with economic growth but eventually declines as income rises above a threshold level. The theoretical mechanisms include structural transformation from manufacturing to services at higher income levels, increased demand for environmental quality as a normal good, and the resources and political will to implement stricter environmental regulation at higher incomes.

The empirical EKC literature is extensive and contested. Stern (2004) provided a comprehensive critical review, noting that EKC estimates are sensitive to specification choices, sample selection, and functional form assumptions. Subsequent studies have found mixed evidence: some confirm the inverted U-shape for particular pollutants and samples (Apergis & Payne, 2009), while others find monotonically increasing or N-shaped relationships (Nasir & Rehman, 2011). The role of institutional quality, technological innovation, and trade openness as determinants of EKC turning point income levels has been a productive area of more recent research (Asongu & Nwachukwu, 2016).

2.4 Panel Quantile Regression

Panel quantile regression (Koenker, 2004; Lamarche, 2010) offers significant advantages over mean regression methods for analyzing heterogeneous environmental relationships. By estimating the effect of covariates at different quantiles of the conditional distribution of the dependent variable, panel quantile regression reveals whether the green finance-emission relationship differs across high- and low-emission economies — a question of direct policy relevance given the urgency of reducing emissions in the highest-emitting countries. Canay (2011) proposed a computationally tractable fixed effects quantile regression estimator that is increasingly applied in environmental economics panel research.

2.5 ESG Investment and Corporate Environmental Performance

ESG investing has grown from a niche strategy to a mainstream approach, with global ESG assets under management reaching approximately USD 35 trillion in 2023 (BloombergNEF, 2023). The academic literature on ESG-financial performance relationships is extensive and generally finds either positive or neutral effects of ESG integration on risk-adjusted returns (Friede et al., 2015; Eccles et al., 2014). The environmental effectiveness of ESG investing — whether ESG capital allocation actually changes firm behavior and reduces emissions — is a more contested empirical question. Dimson et al. (2015) found that active ESG engagement by institutional investors generated significant improvements in targeted firms' environmental practices. Flammer (2021) found that green bond issuance by corporations was associated with subsequent improvements in environmental performance.

3. Research Gap

Three gaps motivate this study. First, no existing study has integrated EKC analysis with green finance within a unified G20 panel framework to test whether green finance shifts the EKC income turning point. Second, panel quantile regression has not been applied to the green finance-emissions relationship, leaving unexplored whether high-emitting economies benefit more or less from green finance development. Third, the channel analysis of green finance-emission linkages — specifically distinguishing between environmental investment, renewable energy adoption, and energy efficiency improvement channels — has not been comprehensively conducted at the G20 level.

4. Objectives

Objective 1: To construct a comprehensive Green Finance Index (GFI) for G20 economies covering 2005–2023.

Objective 2: To estimate the causal effect of green finance on CO_2 emissions using panel fixed effects and mediation analysis.

Objective 3: To test whether green finance development lowers the income turning point in the EKC relationship.

Objective 4: To employ panel quantile regression to estimate heterogeneous green finance-emission effects across the emission distribution.

Objective 5: To identify and quantify the channels through which green finance reduces CO_2 emissions.

5. Hypotheses

H1: Green finance development is negatively associated with CO_2 emissions in G20 economies.

H2: Environmental investment significantly mediates the green finance-CO_2 emission relationship.

H3: Green finance development reduces the income turning point in the EKC relationship.

H4: The negative effect of green finance on emissions is larger at higher emission quantiles.

H5: Carbon pricing mechanism adoption and financial market depth significantly amplify the green finance-emission reduction relationship.

6. Methodology

6.1 Data

Annual panel data for 19 G20 national economies were collected for 2005–2023. CO_2 emissions per capita were obtained from the Global Carbon Project (Friedlingstein et al., 2023). The GFI was constructed using PCA to weight four indicators: green bond issuance (Climate Bonds Initiative database), sustainable banking assets (UNEP Finance Initiative), environmental policy stringency index (OECD), and ESG fund assets (Morningstar). Environmental investment was measured as environmental protection expenditure as a share of GDP (OECD/Eurostat). GDP per capita, renewable energy share, trade openness, urbanization, and industrialization rate were obtained from World Bank WDI.

6.2 Empirical Strategy

A sequential empirical strategy was employed. First, baseline fixed effects regressions with Driscoll-Kraay standard errors were estimated to address cross-sectional dependence. Second, a mediation framework using two-stage panel regression tested the environmental investment channel. Third, EKC specifications including GFI × income interaction terms tested whether green finance shifts the EKC turning point. Fourth, the Canay (2011) fixed effects quantile regression estimator was applied to examine emission-distribution heterogeneity. Fifth, interaction terms with carbon pricing and financial development were incorporated to test moderating effects.

7. Data Analysis and Findings

7.1 Descriptive Statistics

Table 1: Descriptive Statistics (N = 19, T = 19, Observations = 341)

Variable	Mean	SD	Min	Max
CO_2 Emissions (tons per capita)	7.84	5.23	1.12	18.47
GFI Score (0–100)	38.47	24.31	5.12	89.34
Green Bond Issuance (USD bn)	18.73	34.21	0.01	187.34
Environmental Investment (% GDP)	0.87	0.54	0.12	2.43
GDP per capita (USD 1000s)	24.87	21.34	2.31	67.84
Renewable Energy Share (%)	22.43	16.87	3.42	71.34
Carbon Pricing Dummy	0.52	0.50	0	1

7.2 Baseline Regression Results

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Table 2: Fixed Effects Panel Regression — Dependent Variable: CO_2 Emissions Per Capita (Log)

Variable	(1) FE	(2) FE + DK SE	(3) FE + Mediation	(4) Full Controls
GFI	-0.198***	-0.214***	-0.187**	-0.214***
	(0.038)	(0.041)	(0.039)	(0.043)
GDP per capita (log)	0.847***	0.834***	0.811***	0.791***
	(0.087)	(0.091)	(0.094)	(0.098)
GDP per capita squared (log)	-0.312***	-0.298***	-0.287***	-0.273***
	(0.067)	(0.071)	(0.074)	(0.078)
Renewable Energy Share	-0.187***	-0.194***	-0.178**	-0.182***
	(0.041)	(0.044)	(0.043)	(0.046)
Trade Openness	0.087*	0.091*	0.084*	0.088*
	(0.044)	(0.047)	(0.046)	(0.049)
Urbanization	0.134**	0.141**	0.128**	0.132**
	(0.056)	(0.059)	(0.057)	(0.061)
R^2 (within)	0.712	0.698	0.721	0.734
Countries/	19/34	19/34	19/341	19/341
Observations	1	1		

*Note: Driscoll-Kraay standard errors in column (2) address cross-sectional dependence. *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.*

7.3 EKC Turning Point Analysis

EKC specifications confirm an inverted U-shaped relationship (H3). The income turning point in the baseline EKC (without GFI) is USD 28,430 per capita. Incorporating GFI and its interaction with income reduces the turning point to USD 19,870 per capita — a reduction of approximately 30%, indicating that green finance development enables economies to reach the emission-reducing phase of the EKC at lower income levels. This finding is consistent with the hypothesis that green finance accelerates low-carbon structural transformation.

7.4 Mediation Analysis

Table 3: Mediation Analysis — Environmental Investment as Mediator

Stage	Path	Coefficient	SE	p-value
Stage 1	GFI → Environmental Investment	0.312	0.044	< 0.001
Stage 2	Environmental Investment	-0.463	0.067	< 0.001

Stage	Path	Coefficient	SE	p-value
	→ CO_2			
Indirect Effect	GFI → Env. Inv. → CO_2	-0.144	0.032	< 0.001
Direct Effect	GFI → CO_2 (controlling for mediator)	-0.070	0.028	0.013
Total Effect		-0.214	—	—
Mediation Proportion		67.3%	—	—

Note: Environmental investment mediates 67.3% of the total green finance-CO_2 relationship, supporting H2.

7.5 Panel Quantile Regression Results

Table 4: Fixed Effects Quantile Regression — GFI Coefficient by Emission Quantile

Quantile	GFI Coefficient	SE	95% CI
Q10 (low emission)	-0.098**	0.044	[-0.184, -0.012]
Q25	-0.134***	0.038	[-0.208, -0.060]
Q50 (median)	-0.187***	0.041	[-0.267, -0.107]
Q75	-0.243***	0.048	[-0.337, -0.149]
Q90 (high emission)	-0.298***	0.054	[-0.404, -0.192]

Note: Monotonically increasing (in absolute value) GFI coefficients across quantiles confirm H4 — green finance delivers the largest emission-reduction benefits to highest-emitting economies.

7.6 Moderating Effects

Table 5: Moderation Analysis

Moderator	Interaction Coefficient	p-value	Interpretation
GFI × Carbon Pricing	-0.087	0.004	Carbon pricing amplifies green finance effect
GFI × Financial Development	-0.064	0.019	Deeper markets amplify green finance effect

Both interactions are negative and significant, confirming H5 — carbon pricing and financial market depth amplify green finance's emission-reduction effect.

8. Discussion

The robust negative association between the GFI and CO_2 emissions, confirmed across

multiple estimators and specifications, provides strong empirical support for green finance's environmental effectiveness in the G20 context. The mediation finding — that environmental investment channels 67.3% of the total effect — validates the theoretical mechanism whereby green finance mobilizes capital for environmentally productive investments that directly reduce emissions through renewable energy deployment, energy efficiency improvements, and low-carbon technology adoption.

The EKC turning point reduction finding is particularly policy-relevant, suggesting that green finance can be a lever for accelerating the environmental dividend of economic growth in middle-income G20 economies including China, India, Brazil, and South Africa. The quantile regression finding that high-emitting economies derive the greatest marginal benefit from green finance development suggests that green finance policy interventions should be prioritized in the highest-emitting economies to maximize aggregate emission reduction potential.

9. Theoretical Implications

These results contribute to three bodies of economic and environmental theory. First, they enrich the EKC literature by demonstrating that green finance is an active determinant of the EKC turning point, moving beyond the static income-environment framework to incorporate financial system development as a driver of environmental transition. Second, the mediation findings contribute to environmental finance theory by confirming the investment channel as the primary mechanism linking green finance to environmental outcomes. Third, the quantile regression results provide new evidence of distributional heterogeneity in green finance effectiveness, enriching the theoretical understanding of how financial system development interacts with emission levels to determine environmental transition pathways.

10. Practical Implications

For G20 policymakers, the findings support prioritizing green finance development as part of a comprehensive climate policy toolkit, complementary to carbon pricing and regulatory approaches. The amplification effect of carbon pricing suggests that green finance and carbon markets are policy complements rather than substitutes, reinforcing the case for concurrent development of both. For financial regulators, the finding that financial market depth amplifies green finance effectiveness suggests that promoting deep, liquid sustainable debt and equity markets is a precondition for maximizing green finance's environmental impact. For the international community, the EKC turning point reduction finding suggests that channeling climate finance to middle-income high-emitting economies could deliver disproportionate global emission reductions by enabling earlier environmental transition.

11. Conclusion

This study provides comprehensive panel econometric evidence that green finance

development significantly reduces CO_2 emissions in G20 economies, primarily through the channel of increased environmental investment, and that this effect is largest for the highest-emitting economies. Green finance significantly lowers the EKC income turning point, suggesting it can accelerate the environmental dividend of economic growth. Carbon pricing and financial market depth amplify these effects, highlighting the importance of policy complementarities in the clean energy transition. Future research should investigate the additionality of green finance instruments — the degree to which green-labeled capital flows represent genuinely incremental environmental investment rather than relabeling of conventional finance — using project-level data and quasi-experimental methods.

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