GREEN FINANCE AND THE DECARBONIZATION PREMIUM: EVALUATING THE IMPACT OF GREEN BONDS ON DECARBONIZING THE TRANSPORT SECTOR IN THE EUROPEAN COUNTRIES

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ABSTRACT.

The European transport sector remains one of the largest contributors to greenhouse gas emissions, underscoring the need for effective financing mechanisms to support the transition to low-carbon mobility. This study examines the relationship between green bonds and transport-sector decarbonization across eleven European countries over the period 2020–2024. Specifically, it investigates whether regulatory stringency moderates the effectiveness of green bond financing in reducing transport-related carbon emissions. The study employs a fixed effects panel regression with Driscoll–Kraay standard errors to address heteroskedasticity, autocorrelation, and cross-sectional dependence. In addition, a Two-Stage Least Squares (2SLS) model using lagged green bonds as an instrumental variable is estimated to assess the robustness of the findings and address potential endogeneity. The results indicate that while lagged green bonds exhibit a positive direct association with transport emissions, the interaction between green bonds and regulatory stringency is negative and statistically significant, suggesting that green finance contributes to transport decarbonization only under stronger regulatory environments. These findings provide preliminary evidence that institutional quality plays a critical role in translating sustainable financial investments into measurable environmental outcomes.

Keywords: Green bonds, Transport decarbonization, Regulatory stringency, Sustainable finance, Panel data

INTRODUCTION.

The issue of carbon emissions from the European transport sector will be the main point of this study. Carbon-intensive transport harms ecological integrity and undermines global climate and environmental goals. In this context, this research seeks to explain how green bond issuance is used to accelerate the achievement of carbon neutrality in the transportation sector. It examines the existence of a "decarbonization premium," a concrete advantage for projects financed by these bonds. This research conducts an empirical analysis of data from European countries to evaluate the allocation of green bond proceeds to sustainable transport projects. The findings aim to provide policymakers, investors, and financial institutions with important information on how effectively green bonds serve as a strategic tool to achieve the EU's ambitious climate neutrality targets.

The emerging trend of green finance (GFIN) combines public- and private-sector funding to address environmental and ecological issues. Since 2008, green financing GFIN has grown significantly, with investments exceeding 360 billion dollars in 2022. Market participants and their items have extensively mobilized different strategies for investing and financial services since the start of the industrial era (Yuan et al., 2023). GFIN has actively promoted various initiatives, including green obligations, ecological inventory, green bonds, greenhouse finance, green property initiatives, vehicle financing, and environmental debit cards. The preceding analysis has clarified that green financing has implications for the economy and the natural world (Yu et al., 2023).

Green bonds are a key tool for financing ecologically sustainable initiatives and accelerating the transition to a low-carbon economy. As climate change mitigation becomes a global priority, authorities and investors are focusing on decarbonizing the transport sector, a major GHG emitter (Kwilinski et al., 2025). The transport sector is one of the largest and most persistent sources of GHG emissions in Europe, accounting for ~27% of the total (European Environment Agency, 2024). The European Green Deal highlights the importance of directing money flows towards green investments. One approach to accomplish this is to issue green bonds, which, as supported by the EU Sustainable Finance Framework, raise funds for initiatives that help meet environmental and climate goals. Green bond issuance in the EU increased significantly between 2014 and 2024, from 0.1% to 6.9% of total bonds issued. This indicates that the European Green Deal and the need to fund the transition to a low-carbon, green economy are driving demand for sustainable investments. In 2024, the percentage of green bonds varies across EU Member States, with the highest share exceeding 16% in Sweden, Denmark, and France (European Environment Agency, 2025).

Europe seeks to improve its global competitiveness and advance sustainable, inclusive regional development by creating a modern, integrated transport infrastructure. Establishing infrastructure that promotes efficiency and effectiveness is a vital step towards this goal, and by achieving this objective, can reduce greenhouse gas emissions from transport by at least 50 % by 2025 (International Maritime Organization–IMO, 2019). On the other side, through the European Investment Bank (EIB), the European Commission has offered significant funding for such initiatives (Panagakos et al., 2014). The EIB provides significant funding for climate action internationally and in Europe. The Paris Agreement and the European Green Deal aim to achieve climate neutrality by 2050 through the European Climate Law and Pact, which require trillions of dollars in investment (Machedon-Pisu & Borza, 2021). In line with the above and considering the literature by Deschryver & De Mariz, 2020; Tomfort, 2022, which emphasizes green bonds as a crucial mechanism for channeling public and private funds into transport decarbonization projects. These bonds, aligned with strict EU criteria and the European Green Bond Standard, provide investors with financial incentives to invest in electric vehicles, rail modernization, Sustainable Aviation Fuel, and charging infrastructure (Transport & Environment, 2024).

RESEARCH AIM AND OBJECTIVES.

The purpose of this research is to evaluate the impact of green bonds on advancing decarbonization in the transport sector across European countries, focusing on their effectiveness, limitations, and pathways for improvement. Although the increasing issuance of green bonds has facilitated substantial flows of both private and public capital into sustainable transport projects, research gaps still exist regarding their actual environmental Contribution towards emission reduction. In this regard, the research work by Haas et al., 2025, emphasized that Green bonds are essential for financing projects designed to mitigate carbon emissions in the transportation sector. However, their efficacy is questioned due to the small scale of investment relative to the vast financial demands of decarbonization. Similarly, the research contribution by

Oke et al. (2024) demonstrated that although green bonds can facilitate funding for sustainable initiatives, they may not consistently yield substantial additional emission-reduction benefits relative to conventional financing alternatives.

The research **aims** to evaluate the impact of green bonds on accelerating the decarbonization of the transport sector within the European Union. This research pursues the following **objectives.**

1. To examine the effect of green bonds on transport-sector decarbonization in European countries.
2. To investigate the mediating role of technological intensity in the relationship between green bonds and transport-sector decarbonization.
3. To evaluate the moderating role of regulatory stringency in the relationship between green bonds and transport-sector decarbonization.

RESEARCH METHODOLOGY.

1. Research Hypothesis.

Based on the research aims and objectives outlined above, the following hypotheses are proposed.

H1 Green bonds issued for transport have a significant positive effect on transport-sector decarbonization in European countries.

H2 Technological intensity mediates the relationship between green bonds and transport Sector decarbonization.

H3 Regulatory stringency moderates the relationship between green bonds and transport Sector decarbonization.

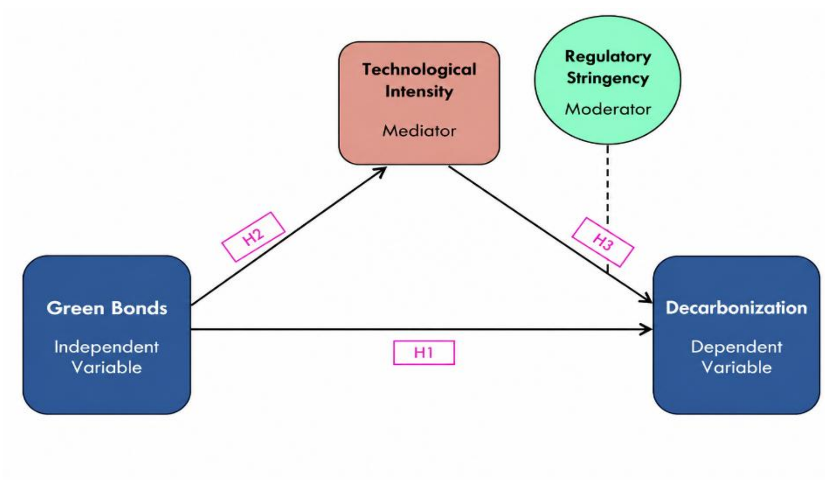

Fig.1. Conceptual Framework of the Study.

2. Description of the Research Design.

The study employs a quantitative, longitudinal panel design using secondary green bonds, macroeconomic, and carbon emissions data for European countries.

The study examines a panel of 11 European countries, namely Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Luxembourg, Netherlands, Poland, and Spain, over the period 2020–2024.

The research design incorporates analyses of direct effects, mediation, moderation, and robustness. The Fixed-Effects Panel Model with Driscoll-Kray Standard Errors is the primary estimation technique.

3. Description of the Data Sources and Data Collection Procedures.

Variables	Description	Data Source
Green Bonds Issuance (Independent Variable)	Total value of green bonds issued in USD and Euro.	Refinitiv Eikon.
Regulatory Stringency (Moderator)	Index for quantifying the strictness of regulations in a country, particularly environmental policy for climate and air pollution.	Regulatory stringency is proxied using the World Governance Indicators, focusing on 3 dimensions: Regulatory Quality, Government Effectiveness, and Rule of Law.
Technology Intensity (Mediator)	Gross Spending / Expenditure on R&D (% of GDP).	Eurostat
Transport Carbon Emissions (Dependent Variable)	Annual Ground Transport Carbon Emissions in $MtCO_2$/year (Million tonnes of carbon dioxide per year).	carbonmonitor.org
Control Variables		
GDP per capita (PPP, constant 2021 USD)	The economic output per person, adjusted for cost-of-living differences between countries.	World Development Indicators (WDI)
Energy use (kg of oil equivalent per capita)	The total amount of primary energy consumed by an average person.	World Development Indicators (WDI)
Share of renewable energy in gross final energy consumption for Transport.	The share of renewable energy in gross final energy consumption for transport.	Eurostat

4. Description of the Analytical Procedure and justification of methodological choices.

The analysis proceeds through several stages:

Data cleaning and panel structuring, STATA integration, Construction of lagged variables, natural logarithm transformation of key variables, Descriptive Statistics, Correlation Analysis, Hausman Test, Mediation analysis, Moderation analysis, and Robustness analysis.

Panel data econometrics is appropriate because the study investigates multiple countries over several years. The Fixed-Effects Panel Model with Driscoll-Kray Standard Errors is the primary estimation technique because it controls for unobserved country-specific heterogeneity. Lagged green bond variables are incorporated because the environmental effects of sustainable finance are unlikely to occur immediately. Infrastructure development and technological implementation generally require time before observable emission reductions emerge. Furthermore, to address potential endogeneity concerns and assess the stability of the baseline findings, a Two-Stage Least Squares (2SLS) estimation was conducted as a robustness check.

The primary econometric specification is:

$$\ln(CO2_{it}) = \beta_0 + \beta_1 \ln(GB_{it-1}) + \beta_2 Tech_{it} + \beta_3 Reg_{it} + \beta_4(\ln GB_{it-1} \times Reg_{it}) + \beta_5 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

FINDINGS.

The findings primarily emphasize the Lag-1 and Lag-2 model (Table 1), which provides stronger evidence of the delayed environmental effects of green finance. The results indicate that two-year lagged green bond issuance is positively associated with transport-sector carbon emissions, suggesting that green-financed projects may initially involve infrastructure development and transition activities that temporarily increase emissions. However, the interaction between lagged green bonds and environmental regulatory stringency is negative and statistically significant, demonstrating that stronger regulatory frameworks enhance the effectiveness of green bond investments in promoting transport-sector decarbonization. Technology intensity also has a significant negative effect in the Lag-2 specification, implying that technological advancements require time to translate into measurable emission reductions. Furthermore, GDP remains positively associated with transport emissions, reflecting the continued influence of economic expansion on transport demand, while renewable energy adoption in transport contributes to emission reductions. Overall, the Lag-2 model suggests that the environmental benefits of green bond financing emerge over time and are substantially strengthened by supportive regulatory environments. The robustness analysis (Table 2) using Two-Stage Least Squares (2SLS) confirms the stability of these findings and supports the reliability of the estimated relationships.

Table 1. Fixed Effects Regression with Driscoll Kraay Standard Errors

Variables	Lag-1 Model Coefficient	Std. Error	p-value	Lag-2 Model Coefficient	Std. Error	p-value
Green Bonds	0.206**	0.046	.021	0.028***	0.002	.004
Regulatory Stringency	0.061***	0.010	.009	0.012**	0.003	.043
Green Bonds × Regulation	-0.003**	0.001	.017	-0.0004**	0.00005	.013
Technology Intensity	-0.014	0.033	.690	-0.118**	0.022	.032
ln_GDP	0.502***	0.030	.000	0.458*	0.142	.084
ln_Energyuse	0.005	0.041	.903	-0.200**	0.026	.016
Share of RE in Transport.	-0.002**	0.001	.032	-0.003*	0.001	.072
Constant	-6.307**	1.353	.019	-0.495	1.575	.783
Within R^2	0.745			0.501		

**** p < .01, ** p < .05, * p < .10*

Table2. Two-Stage Least Squares Robustness Analysis

Variables	Coefficient	Robust Std. Error	z-statistic	p-value
L1_ln_GB	0.624***	0.059	10.57	0.000
Reg	-0.052***	0.011	-4.52	0.000
TI	0.698***	0.078	8.95	0.000
ln_GDP	-1.414***	0.300	-4.71	0.000
ln_Energyuse	-1.119***	0.145	-7.72	0.000
Share of RE in Transport	-0.084***	0.017	-4.90	0.000
Constant	18.852***	2.237	8.43	0.000

*** $p < .01$, ** $p < .05$, * $p < .10$

CONCLUSION.

The preliminary findings suggest that the environmental benefits of green bond financing are not immediate but emerge over time, particularly when supported by stringent environmental regulations. The results indicate that green bonds and regulatory quality operate as complementary mechanisms in promoting transport-sector decarbonization. Strong environmental regulations appear to facilitate the successful conversion of green bonds proceeds into measurable decarbonization outcomes. Theoretically, the study contributes to the sustainable finance literature by highlighting the moderating role of regulatory stringency in enhancing the effectiveness of green bonds. From a practical perspective, policymakers should complement green bond issuance with strong regulatory frameworks, while investors should prioritize projects implemented in supportive institutional environments.

REFERENCES.

Deschryver, P., & De Mariz, F. (2020). What Future for the Green Bond Market? How Can Policymakers, Companies, and Investors Unlock the Potential of the Green Bond Market? *Journal of Risk and Financial Management*, *13*(3), 61. https://doi.org/10.3390/jrfm13030061

European Environment Agency. (2024, June 26). *Greenhouse gas emissions from transport.* [Online post]. https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport

European Environment Agency. (2025, July 1). *Green bonds in Europe* [Online post]. https://www.eea.europa.eu/en/analysis/indicators/green-bonds-8th-eap?activeAccordion=ecdb3bcf-bbe9-4978-b5cf-0b136399d9f8

Haas, W., Baumgart, A., Eisenmenger, N., Virág, D., Kalt, G., Sommer, M., Kratena, K., & Meyer, I. (2025). How decarbonization and the circular economy interact: Benefits and trade-offs in the case of the buildings, transport, and electricity sectors in Austria. *Journal of Industrial Ecology*, *29*(2), 531–545. https://doi.org/10.1111/jiec.13619

International Maritime Organization–IMO. (2019, January 1). *Actions to reduce greenhouse gas emissions from international shipping—Implementing the initial IMO strategy for reduction of GHG emissions from ships.* [Online post]. http://www.imo.org/en/MediaCentre/H otTopics/Documents

Kwilinski, A., Lyulyov, O., & Pimonenko, T. (2025). The role of green finance in attaining environmental sustainability within a country's ESG performance. *Journal of Innovation & Knowledge*, *10*(2), 100674. https://doi.org/10.1016/j.jik.2025.100674

Machedon-Pisu, M., & Borza, P. N. (2021). A Methodological Approach to Assess the Impact of Energy and Raw Materials Constraints on the Sustainable Deployment of Light-Duty Vehicles by 2050. *Sustainability*, *13*(21), 11826. https://doi.org/10.3390/su132111826

Oke, D., Dunn, J. B., & Hawkins, T. R. (2024). Reducing Economy-Wide Greenhouse Gas Emissions with Electrofuels and Biofuels as the Grid Decarbonizes. *Energy & Fuels*, *38*(7), 6048–6061. https://doi.org/10.1021/acs.energyfuels.3c04833

Panagakos, G. P., Stamatopoulou, E. V., & Psaraftis, H. N. (2014). The possible designation of the Mediterranean Sea as a SECA: A case study. *Transportation Research Part D: Transport and Environment*, *28*, 74–90. https://doi.org/10.1016/j.trd.2013.12.010

Tomfort, A. (2022). Making Green Bonds Greener: Proposals to Increase the Efficiency of Green Bonds. *Journal of Applied Finance & Banking*, 39–59. https://doi.org/10.47260/jafb/1315

Transport & Environment. (2024). *Financing Transport Decarbonisation. Study on investments for sustainable transport in the EU*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.transportenvironment.org/uploads/files/202411_investment_needs_study.pdf

Yu, M., Umair, M., Oskenbayev, Y., & Karabayeva, Z. (2023). Exploring the nexus between monetary uncertainty and volatility in global crude oil: A contemporary approach of regime-switching. *Resources Policy*, *85*, 103886. https://doi.org/10.1016/j.resourpol.2023.103886

Yuan, H., Zhao, L., & Umair, M. (2023). Crude oil security in a turbulent world: China's geopolitical dilemmas and opportunities. *The Extractive Industries and Society*, *16*, 101334. https://doi.org/10.1016/j.exis.2023.101334