

# Evaluating Climate-Related Financial Policies with Machine Learning: Implications for Global Decarbonization



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## **Abstract**

This policy brief summarizes the main findings of the research described in D'Orazio & Pham, 2025. The study examines the impact of Climate-Related Financial Policies (CRFPs) on decarbonization and renewable energy production (REP) across 87 countries from 2000 to 2023. Using advanced machine learning techniques, it highlights disparities between advanced economies and emerging markets, emphasizing the role of institutions, policy sequencing, and enforcement in achieving climate goals. The findings underscore the potential of targeted CRFPs, particularly in Sub-Saharan Africa and South Asia, to drive renewable energy growth. By providing actionable insights, this research supports the development of tailored policies for a sustainable and equitable global response to climate challenges.

This study examines the influence of Climate-Related Financial Policies (CRFPs) in fostering decarbonization and renewable energy production (REP) across 87 countries from 2000 to 2023. By employing advanced machine learning methods, and using Policy Sequencing Scores (PSS) and bindingness-weighted adoption indicators, the analysis provides valuable insights into the intricate relationships between policy design, economic contexts, and environmental outcomes. The findings underscore significant global and regional variations, offering actionable guidance to align financial systems with climate objectives.

Climate-related financial Policies are crucial in aligning the financial sector with environmental objectives by managing climate-related risks and redirecting capital flows toward sustainable investments (D'Orazio & Thole, 2022). These policies are essential for achieving Article 2.1(c) of the Paris Agreement, which emphasizes the alignment of financial flows with pathways supporting low greenhouse gas (GHG) emissions and climate-resilient development. Instruments such as green bonds, mandatory disclosures, and climate risk assessments enable financial authorities to mitigate systemic risks and promote green investments (OECD, 2024). Green bonds, for instance, have significantly financed renewable energy and energy efficiency projects, particularly in Southeast Asia, although the allocation of proceeds to projects abroad limits their local impact. Similarly, mandatory climate risk disclosures have altered investment patterns, imposing "carbon risk premiums" on carbon-intensive industries. The role of green financial principles, disclosure requirements, and prudential regulations cannot be understated in this context. Financial authorities in Europe and parts of Asia have introduced mandatory disclosure regimes that address market inefficiencies and incentivize innovation in green technologies. Such measures have directly impacted the creditworthiness of carbon-intensive sectors, redirecting capital flows toward low-carbon alternatives.

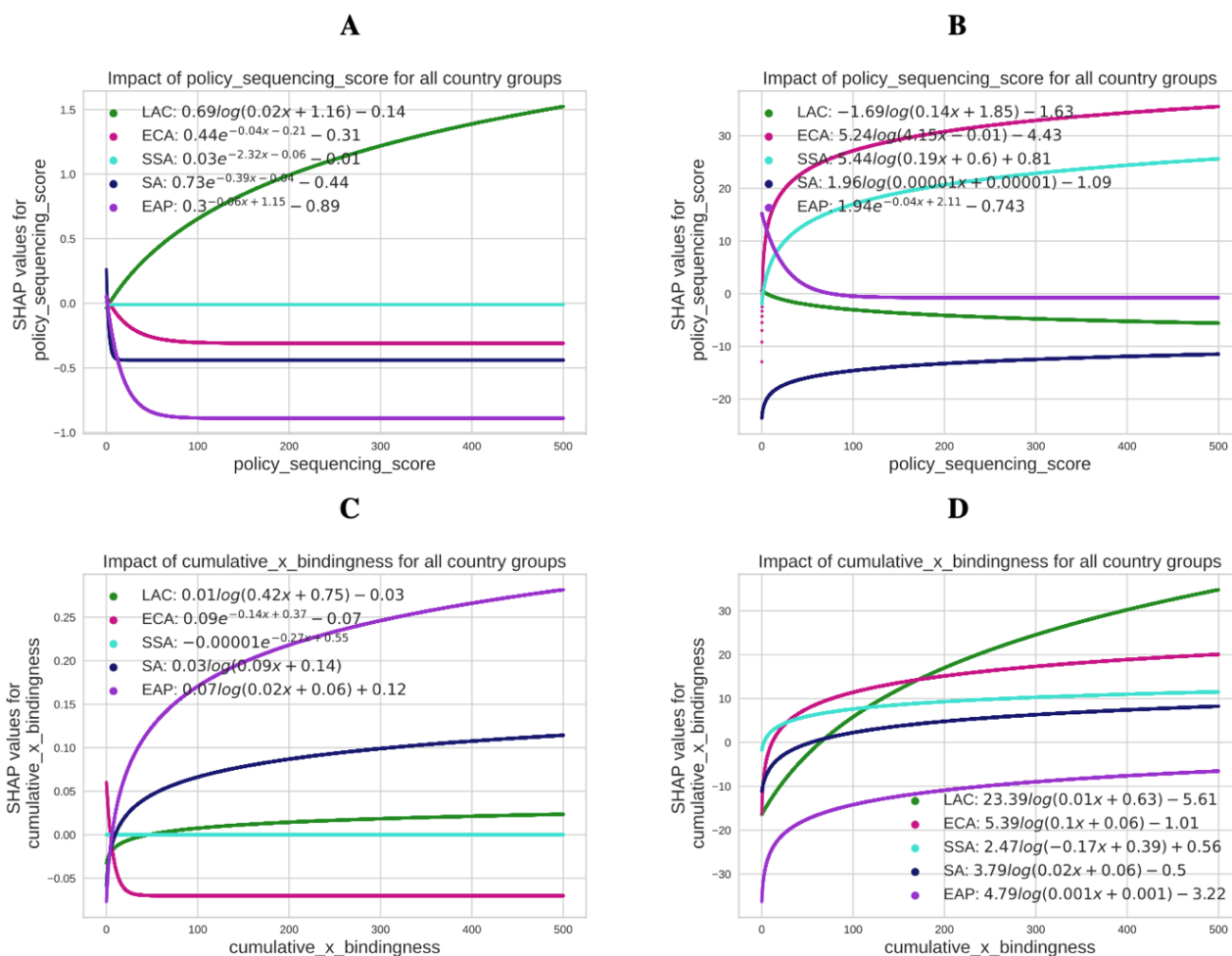
The study employs machine learning techniques, including Shapley Additive Explanations (SHAP), to evaluate the effects of CRFPs on key environmental indicators such as CO<sub>2</sub> emissions and REP (Lundberg, 2017). The Policy Sequencing Score (PSS) quantifies a country's policy alignment with global best practices, while the Cumulative Policy Index  $\times$  Bindingness (CumBind) assesses the enforceability and intensity of policy adoption. These metrics enable nuanced analyses across various country groups and economic contexts. Using these methods, the study overcomes traditional econometric limitations, allowing for a more dynamic understanding of causal relationships and policy synergies (Mullainathan, S. & Spiess, 2017).

The findings reveal that advanced economies benefit from structured policies and robust institutions that consistently drive reductions in emissions and growth in renewable energy production. For G20 and OECD countries, the effects are particularly pronounced in economies with strong enforcement mechanisms, where policies such as mandatory disclosures and green financial principles have led to measurable shifts in investment patterns. However, diminishing returns are observed at higher levels of policy adoption, highlighting the need for continued innovation to sustain progress. Emerging markets and developing economies (EMDEs), on the other hand, face institutional and structural constraints that limit policy effectiveness. Despite these challenges, targeted CRFPs in EMDEs show substantial potential, particularly in Sub-Saharan Africa and South Asia, where renewable energy growth has been noteworthy.

Figure 1 provides a comprehensive analysis of the regional impacts of CRFPs on CO<sub>2</sub> emissions and REP. The fitted SHAP values in Panels A and B illustrate region-specific trends for the Policy Sequencing Score (PSS). Panel A reveals that East Asia and the Pacific experience a steep decline in SHAP values for CO<sub>2</sub> emissions as PSS increases, indicating a strong relationship between sequencing and emissions reductions. Conversely, Latin America and the Caribbean display a sharp increase in SHAP values, reflecting difficulties in effective sequencing. Panel B shows that Sub-Saharan Africa exhibits a nonlinear positive relationship between PSS and REP, highlighting significant responsiveness to improved sequencing, whereas East Asia and the Pacific present a flatter trend, suggesting diminishing marginal returns due to an already advanced renewable energy sector.

Panels C and D examine the impact of bindingness-weighted policies (CumBind). Panel C identifies a positive relationship between CumBind and CO<sub>2</sub> emissions in regions like South Asia, Latin America, and the Caribbean, indicating implementation gaps or reliance on carbon-intensive industries. Europe and Central Asia, by contrast, demonstrate a downward trend, reflecting a more established policy landscape. Panel D emphasizes the critical role of binding policies in driving REP growth in Sub-Saharan Africa, Latin America, the Caribbean, Europe, and Central Asia, underscoring their importance in expanding renewable energy capacities.

**Figure 1. Regional Impacts of Climate-related Financial Policy Sequencing and Adoption on CO2 Emissions and Renewable Energy Production.**



Panel (A) displays the SHAP values for the effect of the PSS score on CO2 emissions for regions: Latin America and the Caribbean (LAC), Europe and Central Asia (ECA), Sub-Saharan Africa (SSA), South Asia (SA), and East Asia and the Pacific (EAP). Panel (B) shows the SHAP values for the PSS score’s impact on renewable energy production for the same regions. Panels C and D depict the SHAP values for the effect of cumulative bindingness-weighted policy adoption on CO2 emissions (Panel C) and renewable energy production (Panel D) across these regions. The fitted SHAP values are calculated using logarithmic transformations, capturing region-specific variations in the influence of policy adoption and sequencing.

In addition to regional analysis, the study explores temporal patterns in CRFP adoption and impact. Advanced economies exhibit an early adoption of comprehensive policies, often aligning them with technological advancements and market incentives. Emerging markets, on the other hand, display a lagged adoption pattern but show accelerated impacts when policies are appropriately enforced. Temporal lags between policy adoption and measurable outcomes are most pronounced in sectors reliant on long-term investments, such as renewable energy infrastructure. These findings highlight the importance of sustained policy efforts and the need for mechanisms that ensure continuity across political cycles.

The study emphasizes the importance of tailoring CRFPs to specific economic and institutional contexts. Advanced economies, particularly within the G20 and OECD, should focus on cross-sectoral integration and fostering innovation to overcome policy saturation. For EMDEs, strengthening international cooperation and expanding access to green finance is essential to addressing structural constraints. In emerging G20 economies, ensuring the enforceability of

policies and aligning CRFPs with fiscal priorities could bridge existing gaps in effectiveness. Globally, enhancing policy coherence and enforcement mechanisms is crucial to ensure effective implementation across diverse contexts. Furthermore, the integration of CRFPs with broader fiscal and monetary policies could amplify their effectiveness, particularly in economies undergoing rapid industrialization or energy transitions.

This study offers valuable insights for policymakers by examining the relationships between Climate-Related Financial Policies (CRFPs), CO2 emissions, and renewable energy production (REP). The findings reveal significant disparities between advanced economies and emerging markets and developing economies (EMDEs), as well as within G20 and OECD countries. Addressing these differences through tailored policies is essential to establishing effective and equitable pathways for global decarbonization. The research emphasizes the importance of policy sequencing, bindingness, and regional context in facilitating a low-carbon transition. These findings highlight the critical need for targeted, context-specific interventions to promote a sustainable and inclusive global response to climate challenges. By advancing a data-driven approach to climate finance and policy implementation, this study contributes to the growing body of literature and serves as a valuable resource for future research and practical policymaking.

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**Paola D’Orazio** is a Junior Professor of Economics at Technische Universität Chemnitz. In her research, she examines the relationship between climate-related financial policies and the stability and evolution of financial systems towards a sustainable, low-carbon economy. Her research interests cover International Macroeconomics, Central Banking, Financial Instability, and Climate and Environmental Risks.

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