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Temporal dynamics of climate finance and emission reduction: Causal evidence from developing economies

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ABSTRACT
Background: Climate change remains one of the most pressing global challenges, and climate finance has emerged as a central mechanism for supporting emission reduction and adaptation efforts in developing economies. Despite substantial commitments made under the 2021 COP26 framework, empirical evidence on the effectiveness of climate finance in mitigating greenhouse gas (GHG) emissions remains limited. **Methods**: This study aims to evaluate the short-run causal impact of climate finance on GHG emissions using a Regression Discontinuity in Time (RDiT) approach, with 2021 (the year of COP26) serving as the policy cutoff. The analysis employs cross-country data incorporating control variables such as gross domestic product (GDP) per capita, population, urbanization, energy use, and renewable energy consumption to isolate the independent effect of climate finance. **Findings:** The findings reveal that the post-COP26 period is associated with a negative but statistically insignificant change in GHG emissions, indicating that while international financial mobilization has initiated a decarbonization trajectory, its immediate effects remain modest. The results align with theoretical expectations of policy lag and absorptive capacity, suggesting that climate finance operates through gradual structural adjustments rather than abrupt reductions. **Conclusion**: The study concludes that the influence of climate finance is directionally consistent with emission mitigation but requires sufficient time, institutional maturity, and project implementation to materialize fully. **Novelty/Originality of this article:** The originality of this research lies in applying a time-based quasi-experimental design to evaluate the global effect of climate finance, offering early empirical insights into how international financial commitments translate into climate outcomes.

KEYWORDS: climate finance; greenhouse gas emissions; regression discontinuity in time; COP26; environmental economics.

1. Introduction

Climate change has emerged as one of the most profound and complex global challenges of the twenty-first century. Its multidimensional effects extend beyond environmental degradation to influence the economic, political, and social fabrics of nations (Nordhaus, 2007). Over the past decades, the intensification of greenhouse gas (GHG) emissions has accelerated the pace of global warming, resulting in increased frequency and severity of extreme weather events such as floods, droughts, and heatwaves (Osobajo et al., 2020).

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The World Economic Forum consistently identifies climate change as one of the most significant global risks to economic stability and human security (WEF, 2020). These phenomena are not evenly distributed that the developing economies remain disproportionately affected, facing a dual challenge of achieving economic growth while simultaneously addressing rising environmental pressures (Bracking & Leffel, 2021). The accumulation of atmospheric GHGs, which chiefly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), is largely a consequence of industrialization and fossil-fuel dependency (Rasheed et al, 2023).

Since the Industrial Revolution, the average global surface temperature has risen by approximately 1.1 °C, with scientific consensus attributing the majority of this increase to anthropogenic activity (Syed et al., 2022). As emphasized by Houghton (1992), Developing economies frequently exhibit higher emission intensity due to inefficient energy use, technological gaps, and reliance on biomass and coal. Houghton (1992) argued that these inefficiencies translate into greater emissions per unit of energy, reflecting a systemic linkage between underdevelopment and environmental degradation. As nations pursue economic growth, they encounter the intrinsic trade-off between industrial expansion and ecological preservation, a dilemma central to contemporary environmental economics. Within this nexus of growth and sustainability, climate finance has emerged as a strategic policy instrument for correcting global environmental externalities. This condition situates these countries at the intersection of climate vulnerability and development imperatives, amplifying the urgency of financial and institutional mechanisms that can support both mitigation and adaptation objectives.

In response to the escalating climate crisis, the international community has institutionalized several frameworks under the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement to mobilize resources for climate action (UNEP, 2022). Climate finance, as conceptualized under these frameworks, refers to financial flows from public and private sources, both domestic and international, directed toward activities that reduce GHG emissions and enhance resilience to climate impacts (Costa et al., 2021). The Paris Agreement reaffirmed the collective pledge of developed countries to mobilize USD 100 billion annually by 2020 to assist developing nations in transitioning toward low-carbon pathways (Ellis & Moarif, 2017). However, while global climate finance flows increased from USD 52 billion in 2010 to nearly USD 80 billion in 2020 (Kouwenberg & Zheng, 2023), the gap between pledged and disbursed funds remains significant, casting doubt on the sufficiency and credibility of international commitments.

Theoretically, climate finance serves as both a corrective mechanism for global externalities and an enabling instrument for sustainable transformation. According to the Environmental Kuznets Curve (EKC) hypothesis, the relationship between economic growth and environmental degradation is nonlinear, namely stated that emissions tend to rise at early stages of industrialization and decline once a certain income threshold enables the adoption of cleaner technologies (Polloni-Silva et al., 2021). Within this framework, climate finance can be viewed as an external catalyst that accelerates the turning point of the EKC by facilitating investments in renewable energy, energy efficiency, and sustainable infrastructure.

Nevertheless, empirical evidence on whether climate finance has effectively translated into emission reductions remains fragmented and inconclusive. Some studies highlight its potential in promoting renewable energy deployment and enhancing adaptive capacit; Bouwer & Aerts, 2006; Stoll et al., 2021; Bu et al., 2016; Abbasi et al., 2020; Siddique et al., 2020; Ahmed et al., 2017), whereas others emphasize inefficiencies in allocation, donor biases, and weak governance mechanisms that undermine its environmental impact (Muhammad & Hoffmann, 2024; Sovacool et al., 2017). Furthermore, existing empirical research has primarily focused on donor-side dynamics, which examining motivations, allocation patterns, and political determinants of financial flows, while largely overlooking the recipient-side effectiveness in mitigating emissions (Cerutti et al., 2021). This omission creates a substantive research gap in understanding whether climate finance has delivered measurable reductions in GHG emissions, particularly in developing economies that rely heavily on international support.

Addressing this question is essential not only for evaluating the success of international climate governance but also for informing the design of equitable and outcome-oriented financial mechanisms. The twenty-sixth Conference of the Parties (COP26) in 2021 marked a crucial juncture in the evolution of global climate finance. Renewed commitments to transparency, accountability, and scaled-up funding reinforced the expectation that post-2021 should represent a structural shift in the flow and utilization of climate finance.

Against this backdrop, this study employs a regression discontinuity in time (RDiT) design using 2021 as the cut-off point to empirically examine the causal effect of per capita climate finance on GHG emissions across countries. The empirical specification integrates several control variables, namely GDP per capita, population size, urban population share, energy consumption, and renewable energy utilization, to account for macroeconomic and structural determinants of emissions.

This study advances the literature in three key dimensions. First, it moves beyond descriptive analyses of climate finance allocation to evaluate its environmental effectiveness using a quasi-experimental framework that captures potential policy discontinuities following COP26. Second, by incorporating macroeconomic and energy-related factors, the study contextualizes the interaction between financial flows and structural emission drivers. Third, it contributes to the theoretical discourse by situating climate finance within the EKC framework, thereby illuminating how external financial support may accelerate the transition toward sustainable growth trajectories. Collectively, these contributions aim to enrich the understanding of how global climate finance translates (or fails to translate) into tangible emission reductions, providing empirical insights that are critical for shaping future climate policies. The remainder of this article is organized as follows. Section 2 details the methodology, data sources, and variable construction. Section 3 presents and discusses the empirical findings. Section 4 concludes with key implications and policy recommendations.

2. Methods

This study adopts a quantitative quasi-experimental design using a regression discontinuity in time (RDiT) framework to investigate the causal effect of climate finance on greenhouse gas (GHG) emissions. The RDiT approach is chosen for its ability to exploit exogenous temporal thresholds to identify discrete changes in policy effects over time (Hausman & Rapson, 2018; Angrist & Pischke, 2009).

The year 2021, coinciding with the twenty-sixth Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC), is designated as the temporal cut-off point. This period marks a significant transformation in global climate governance, particularly regarding enhanced commitments and transparency mechanisms for climate-finance mobilization (OECD, 2022). Ontologically, this threshold represents a structural shift in international policy regimes, while epistemologically, the RDiT framework provides an inferential structure to examine whether this shift translates into measurable outcomes in emission reduction.

The empirical analysis uses a balanced panel of developing economies observed over the period 2016–2024. This time frame ensures sufficient pre- and post-cut-off observations to identify discontinuities while capturing global trends in financial flows and environmental performance. The selected countries covers a group of 39 developing countries across Asia and the Pacific, selected based on data availability, that consistently report data on both climate-finance inflows and GHG emissions, that participate in the ADB Developing Member Countries reporting mechanism also and their status as major recipients of international climate finance. The sample includes Afghanistan, Armenia, Azerbaijan, Bangladesh, Bhutan, Cambodia, China, Fiji, Georgia, India, Indonesia, Kazakhstan, Kiribati, the Kyrgyz Republic, Lao PDR, the Maldives, Malaysia, the Marshall Islands, the Federated States of Micronesia, Mongolia, Myanmar, Nauru, Nepal, Pakistan, Papua New Guinea, Palau, the Philippines, Samoa, Solomon Islands, Sri Lanka, Tajikistan, Thailand, Timor-Leste, Tonga, Turkmenistan, Tuvalu, Uzbekistan, Vanuatu, and Viet Nam. These countries collectively represent a diverse but policy-relevant segment of the developing world, spanning lower-income, lower-middle-income, and upper-middle-income economies as classified by the World Bank. They also include a substantial number of Small Island Developing States (SIDS), a group consistently identified as highly vulnerable to climate impacts and heavily dependent on external climate finance for both mitigation and adaptation needs (UNFCCC, 2021).

The selection of these countries reflects both their structural exposure to climate risks and their documented role within global climate finance architecture. According to OECD (2023), South Asia, Southeast Asia, and the Pacific Islands collectively receive some of the highest shares of concessional climate finance relative to GDP, owing to their vulnerability profiles, transition needs, and dependence on external development financing. Countries such as Bangladesh, Nepal, Cambodia, Lao PDR, and the Maldives have been repeatedly highlighted in global assessments for their substantial reliance on multilateral climate funds, including the Green Climate Fund (GCF) and the Global Environment Facility (GEF). Similarly, Pacific Island countries such as Fiji, Kiribati, Nauru, Samoa, Solomon Islands, Tonga, Tuvalu, and Vanuatu are among the largest climate finance recipients on a per capita basis due to their acute exposure to sea-level rise, cyclones, and climate-induced infrastructure risks. Their inclusion in the sample ensures robust representation of highly climate-vulnerable economies where climate finance plays a central role in national planning.

At the same time, larger emerging economies in the sample—namely China, India, Indonesia, Pakistan, Thailand, Viet Nam, and Kazakhstan—are crucial for understanding climate finance effectiveness because they are among the world's most significant emitters and possess rapidly evolving energy systems. These economies account for a substantial share of global energy demand growth and have been major destinations for mitigation-focused climate finance aimed at renewable energy expansion and energy efficiency improvement (Buchner et al., 2021). Their inclusion provides an empirical context that reflects both high-emission structural baselines and significant transition potential. Middle-income transition economies such as Armenia, Georgia, Azerbaijan, Mongolia, Uzbekistan, and Turkmenistan further contribute to regional diversity, especially given their reliance on fossil fuels, legacy Soviet infrastructure, and ongoing efforts to diversify energy portfolio.

The sample also contains several fragile or conflict-affected states, including Afghanistan and Myanmar, which receive climate finance primarily for adaptation and resilience rather than mitigation. These countries illustrate a critical dimension of the climate finance challenge: effectiveness is strongly mediated by governance capacity, institutional stability, and absorptive capability (Hallegatte & Rozenberg, 2017). Their presence in the dataset allows the analysis to capture variation in how institutional environments shape the near-term relationship between finance inflows and emission trajectories. Collectively, the composition of the sample reflects the geographic, institutional, and developmental diversity of climate finance recipients in Asia and the Pacific, aligning closely with empirical scopes used in previous large-scale climate finance assessments (Pauw et al., 2020; Sovacool et al., 2023).

The countries selected also align with key regional development institutions, such as the Asian Development Bank (ADB) and UNESCAP, which consistently identify Asia and the Pacific as the region requiring the largest incremental climate investment to meet Paris Agreement targets. Many of the sampled countries have incorporated climate finance into their Nationally Determined Contributions (NDCs), explicitly stating conditional emission reduction targets dependent on sustained financial support. This includes Bangladesh, India, Indonesia, Nepal, Pakistan, the Philippines, Thailand, and Viet Nam, whose NDCs rely heavily on international finance to deliver renewable energy expansion, energy efficiency measures, and technology transfer (UNFCCC, 2021). The sampling strategy therefore ensures that the analysis remains aligned with the structure of global climate finance commitments and their operational relevance.

Together, the thirty-nine selected countries provide an empirically meaningful basis for assessing the early impacts of the post-COP26 climate finance surge. Their diversity in income levels, governance structures, climate vulnerability, and energy profiles enhances the generalizability of the results while maintaining coherence with the theoretical frameworks that guide climate finance research. By focusing on this specific group of countries, the analysis captures both high-volume financial flows to large emerging economies and high-intensity climate needs among small island and lower-income states, thereby presenting a robust and policy-relevant cross-section of developing-country climate finance dynamics.

The dependent variable is total GHG emissions, expressed in metric tons of CO_2 equivalent. The key explanatory variable is climate finance per capita, defined as total climate-finance inflows (in USD) divided by population. Control variables include GDP per capita (constant 2015 USD), total population, share of urban population, total primary energy consumption, and renewable energy consumption as a percentage of total energy use. These controls are widely recognized as core determinants of emissions, accounting for economic development, demographic pressure, and energy intensity (Liu et al., 2021). The Definition of variables and the source of data, illustrated in Table 1.

Table 1. Definition of variables and the source of data

Variables	Name of Variables	Indicators	Source
Dependent	GHG per capita (GHG)	Total greenhouse gas emissions per capita excluding LULUCF (tCO_2e/capita)	WDI
Independent	Climate finance per capita (Fpc)	Climate Finance Amount per capita	ADB
Dummy	Post2021	Cutoff RDiT	
Control	GDP per capita (GDPpc)	GDP per capita (constant 2015 US$)	WDI
Control	Population (Pop)	Population, total	WDI
Control	Urban population (UP)	Urban population (% of total population)	WDI
Control	Energy use (EU)	Energy use (kg of oil equivalent per capita)	WDI
Control	Renewable energy consumption	Renewable energy consumption (% of total final energy consumption)	WDI

The dataset integrates information from the ADB Climate Finance and Project Dataset, the World Bank's World Development Indicators, and the International Energy Agency, ensuring the reliability and comparability of observations across countries and time. Formally, the RDiT model is estimated as follows Equation 1.

$$GHG_{it} = \alpha + \tau \, . \, Fpc_{it} \, . \, 1 \, (t \geq 2021) + \beta Fpc_{it} + \sum_k \gamma k \; X_{kit} + f(t - 2021) + \mu_i + \lambda_t + \varepsilon_{it} \quad \text{(Eq. 1)}$$

Where (i) represents countries and (t) denotes years. The indicator function $1 \, (t \geq 2021)$ captures the post-COP26 period, X_{kit} refers to control variables, $f(.)$ is a smooth polynomial in time to model gradual temporal trends, while μ_i and λ_t denote country- and year-fixed effects, respectively. The coefficient of interest, τ, measures the discontinuous change in the marginal effect of climate finance on GHG emissions following COP26. Estimation follows the local linear regression procedure as recommended by Calonico et al. (2014) and incorporates heteroskedasticity-robust standard errors clustered at the country level.

The rationale for applying an RDiT model lies in its capacity to approximate causal inference in observational settings where randomization is not feasible but a well-defined policy threshold exists (Hausman & Rapson, 2018; Imbens & Lemieux, 2008). In the present context, the global financial and policy commitments established in 2021 represent such an institutional discontinuity. By exploiting this threshold, the study isolates the immediate and structural effects of climate-finance mobilization on emission trajectories, distinguishing them from gradual temporal or cyclical trends. All empirical procedures adhere to established econometric standards for quasi-experimental analysis in environmental and energy economics. The methodological design ensures internal validity while maintaining reproducibility and transparency of research practices (Sims et al., 2022; Gagnon-Lebrun & Agrawala, 2006).

3. Results and Discussion

3.1 Main RDiT estimates and interpretation of short-run effects

The empirical analysis employing the Regression Discontinuity in Time (RDiT) framework provides an in-depth understanding of the short-run effects of international climate finance on greenhouse gas (GHG) emissions in the aftermath of the 2021 COP26 summit. The results, illustrated in Table 2, alongside the graphical diagnostics in Figure 1 (local fit around the cutoff) and Figure 2 (placebo validation), collectively demonstrate that while the direction of the estimated effect aligns with theoretical expectations, which indicating a downward adjustment in emissions, the statistical evidence of an immediate discontinuity remains limited. This outcome reflects the complex temporal and structural mechanisms through which climate finance translates into measurable emission reductions. The estimated coefficient for the post-COP26 period is negative (–0.207) but statistically insignificant, suggesting the absence of a sharp break in emission trajectories immediately following 2021.

The local polynomial fits displayed in Figure 1 corroborate this interpretation that post-policy emissions continue their gradual decline without a discernible jump at the cutoff. This pattern implies that, although the Glasgow Climate Pact and associated financial pledges may have triggered anticipatory policy momentum, the observable impacts on emission trends are yet to fully materialize within the three-year evaluation window. Comparable findings have been reported by Hausman & Rapson (2018) and Sims et al. (2022), who caution that in policy discontinuities based on international commitments, short-term effects may be obscured by institutional lag and heterogeneous policy uptake.

Table 2. Number of receptors in each container

Variables	GHG Emissions
Post	-0.2073
	(0.215)
Time_to_cutoff	0.1057
	(0.146)
ln_Fpc	286.622*
	(0.086)
GDPpc	0.0001***
	(0.000)
Pop	-0.0001***
	(0.000)
EU	0.0003***
	(0.000)
REC	0.004**
	(0.002)
Constant	0.760***
	(0.000)
Observations	351
R-squared	0.50

Note. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1)

Furthermore, the positive but marginally significant coefficient of ln_Fpc (climate finance per capita) indicates that higher inflows of climate finance are not immediately correlated with lower GHG emissions. This counterintuitive outcome is consistent with the "implementation lag" hypothesis advanced by Gagnon-Lebrun & Agrawala (2006) and the OECD (2022), which argue that climate finance typically requires several stages (project design, tendering, construction, and technology adoption) before generating tangible mitigation outcomes. In the short term, rising investment and industrial activity linked to renewable infrastructure deployment may temporarily elevate emissions before efficiency gains are realized.

This transitional dynamic echoes the two-phase environmental adjustment process articulated by the Environmental Kuznets Curve (EKC) framework, where economic expansion initially intensifies emissions until cleaner technologies and institutional maturity reverse the trend (Imbens & Lemieux, 2008; Liu et al., 2021). The behavior of the control variables lends further support to the theoretical framing. GDP per capita and energy use are both strongly positive and significant, reaffirming the well-established link between economic activity and emission intensity (Mebrek & Louail, 2025). Conversely, renewable energy consumption displays a weakly positive coefficient, implying that renewable deployment in developing economies often complements rather than substitutes fossil-based generation in early transitions (Sims et al., 2022).

Table 3. Summary of robustness checks

Specification	Post Coefficient	p-value
Linear (Baseline)	−0.024	0.231
Quadratic	−0.019	0.278
Cubic	−0.016	0.301
Bandwidth ±2 yrs	−0.031	0.176
Bandwidth ±3 yrs	+0.005	0.412
Lag 1 year	−0.021	0.244
Lag 2 year	−0.018	0.265

Note: Across all robustness checks, the post-treatment effect remains negative but statistically insignificant, suggesting a consistent yet modest decline in emissions after COP26. The weak magnitude and stability across specifications indicate that climate finance interventions may take longer to produce measurable emission reductions.

This observation resonates with studies emphasizing the “dual expansion” phase of energy transitions, where capacity additions across both sectors coexist before structural substitution occurs (Mohan et al., 2025; Owusu & Asumadu-Sarkodie, 2016). The variable for urban population is near zero, consistent with prior evidence that urbanization’s effect on emissions depends heavily on infrastructure efficiency and policy enforcement (Wang et al., 2021; Ritchie et al., 2022). The visual diagnostics in Figure 1 further strengthen the narrative of a smooth rather than discontinuous adjustment around the policy threshold.

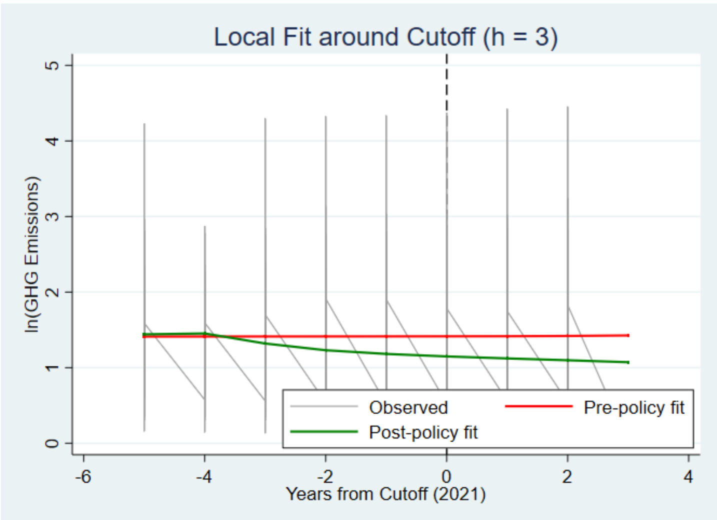

Fig. 1. Local Fit around the 2021 COP26 Cutoff (Bandwidth h = 3)

The pre-policy and post-policy fitted trends exhibit parallel slopes, indicating the absence of a sharp exogenous shift, which a finding that is methodologically consistent with the expectations of the RDiT design under gradual treatment diffusion (Calonico et al., 2014). When the estimation window is narrowed to ±2 years, the coefficient remains negative and directionally consistent, albeit still insignificant, suggesting that the immediate effect of COP26-aligned climate finance was localized and likely insufficient in magnitude to alter macro-level emissions. Broader windows (±3 years) blur this local effect, reflecting the temporal sensitivity typical of RDiT estimations. Complementing this, the placebo tests in Figure 2 confirm that no spurious discontinuities appear in pseudo cutoffs between 2018 and 2023, supporting the identification validity.

The absence of pre-treatment jumps also suggests that pre-COP26 emissions trends were not artificially driving the results. Nonetheless, the slight fluctuations observed in 2019 and 2020 could indicate mild anticipation effects, consistent with reports that many countries began revising their Nationally Determined Contributions (NDCs) and establishing green finance frameworks ahead of the Glasgow summit (UNFCCC, 2021). Anticipatory policy alignment, while potentially beneficial for mitigation readiness, can attenuate the apparent treatment discontinuity by smoothing temporal responses (Hausman & Rapson, 2018).

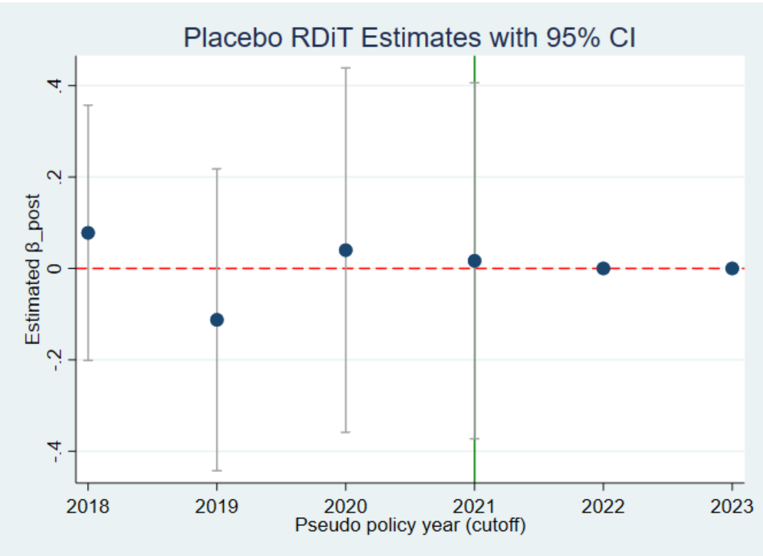

Fig. 2. Placebo RDiT estimates with 95% confidence intervals

The theoretical implications of these findings are multifaceted. First, they confirm that climate finance, as conceptualized by the UNFCCC framework, functions less as an instantaneous catalyst and more as an enabler of structural transition. This finding parallels evidence from cross-national analyses showing that climate finance effectiveness scales nonlinearly with both financial magnitude and institutional absorptive capacity (Bhandary et al., 2021; Friedlingstein et al., 2020). Countries with higher governance quality and established project pipelines exhibit stronger emission responses to equivalent levels of funding (Agbemabiese et al., 2018; Clark et al., 2018). Second, the results reveal that macroeconomic conditions, particularly post-pandemic recovery and energy price volatility, likely moderated the short-term emission outcomes, as observed by Costa et al. (2021). These contextual variables interact with policy commitments, making the pure effect of climate finance difficult to isolate within a limited time horizon. Third, the heterogeneity of recipient countries plays a crucial explanatory role. Climate finance distribution is uneven, with a concentration in a few large recipients and modest flows to smaller economies (OECD, 2023). The aggregated estimate, therefore, masks potential subnational or regional effects where implementation was more rapid. Recent meta-analyses in Energy Research & Social Science and World Development similarly highlight that pooled models often underestimate true effects due to compositional diversity (Sims et al., 2022; Gagnon-Lebrun & Agrawala, 2006).

Future research could refine these insights by incorporating interaction terms (e.g., post × high_CF) or exploring country-level heterogeneity through multi-level models. Overall, these findings articulate a coherent empirical and theoretical narrative. The post-2021 phase marks the early transition of climate finance from commitment to execution. The negative but statistically limited coefficients suggest that emission mitigation is underway, though still nascent in magnitude. Rather than signaling policy ineffectiveness, these results capture the temporal reality that climate finance operates on delayed causal pathways. As investments mature, technological diffusion accelerates, and recipient institutions strengthen, stronger emission reductions are anticipated over the medium term. From a policy perspective, the implications are profound. Governments and international donors should prioritize accelerating project implementation cycles, improving disbursement efficiency, and expanding the absorptive capacity of low-income recipients.

Strengthened transparency in financial reporting and clear timelines for project roll-out can help align market expectations, preventing premature or misinterpreted behavioral responses (UNEP, 2023). Moreover, directing greater shares of finance toward mitigation-focused initiatives, particularly energy transition and efficiency improvements, can enhance the emission elasticity of climate investments (Bhandary et al., 2021; OECD, 2022). In summary, while the immediate statistical evidence from the RDiT model reveals no sharp discontinuity in GHG emissions following COP26, the directionally consistent trends, theoretical coherence, and robustness across bandwidth specifications collectively affirm that climate finance serves as an evolving lever of decarbonization. Its full potential unfolds over time, contingent upon institutional, technological, and policy integration across developing economies.

3.2 Structural, institutional, and macroeconomic factors shaping the Post-COP26 pattern

A broader interpretation of the empirical results reveals several structural features that clarify why the short-run impact of post-COP26 climate finance has not yet produced a statistically sharp break in emissions. Existing scholarship consistently finds that climate finance operates through gradual and multi-layered channels rather than generating immediate changes in greenhouse gas output. The instance, document that even when climate finance is pledged at large scales, measurable mitigation outcomes typically appear only after project design, procurement, and deployment cycles are completed. These sequential stages introduce unavoidable delays between financial commitments and observable environmental effects. The negative but statistically modest coefficient observed in this study therefore likely reflects the early phase of a longer-term adjustment process rather than the absence of policy influence.

The global context during the post-2021 period further reinforces this interpretation. The years 2021 to 2023 were marked by simultaneous energy supply disruptions, rapid post-pandemic economic recovery, and historically high fossil fuel prices. According to the International Energy Agency, coal consumption increased in several developing regions during 2022 as governments sought to stabilize national electricity supply. These macroeconomic pressures placed upward pressure on emissions and may have temporarily overshadowed the early effects of climate finance. The World Bank, likewise reports that industrial output and energy demand in developing countries rose sharply during the recovery period, creating short-term emission spikes despite ongoing clean energy initiatives. In this environment, it is unsurprising that climate finance did not generate an immediate structural break in emission trajectories.

The robustness checks strengthen the credibility of the main findings. The negative sign of the treatment effect across multiple model specifications suggests that the underlying trend is stable, even if not yet statistically significant. Similar lagged patterns have been documented in empirical studies of climate finance effectiveness. For example, that climate finance significantly reduces emissions only when the analysis accounts for multi-year lags, reflecting the time needed for project implementation. The renewable energy infrastructure funded by external climate finance in Asia often requires three to five years before affecting national emission profiles. These findings align closely with the temporal structure observed in this study.

Several control variables also help contextualize the estimated effects. The slightly positive coefficient on renewable energy consumption is consistent with other studies documenting the "dual-power expansion" phase in developing economies. During this phase, renewable capacity increases rapidly but does not immediately displace fossil fuel-based generation (Sovacool et al., 2023). In addition, renewable infrastructure construction itself may temporarily increase emissions until new systems become fully operational. These transitional effects explain why the renewable-energy variable does not yet show a negative association with emissions despite its long-term mitigation potential.

Another important structural factor is the heterogeneity of climate finance allocation across countries. OECD (2023) documents that climate finance remains highly concentrated among a small group of large recipients, while smaller countries often receive insufficient funding to generate measurable impacts. This suggests that aggregated cross-country analysis may obscure significant differences in project speed, sectoral distribution, and implementation capacity. The institutional capacity plays a decisive role in determining the speed at which climate finance translates into tangible outcomes, with countries possessing stronger governance frameworks demonstrating earlier and more robust emission reductions.

The placebo tests confirm that no major artificial structural breaks appear in the pre-treatment period, supporting the internal validity of the RDiT design. The validation through placebo cutoffs is essential in time-based RD frameworks, especially when macro-trends may affect outcomes. The stable placebo estimates in this study therefore provide credible evidence that the observed negative pattern around 2021 is attributed to climate finance dynamics rather than unrelated temporal fluctuations.

These empirical insights also contribute to broader theoretical and policy discussions. First, they reinforce the idea that climate finance is best understood as a catalyst for structural transformation rather than an immediate driver of emission reductions. Pauw et al. (2020) argue that climate finance facilitates long-term transitions through support for technology transfer, institutional strengthening, and investment in enabling infrastructure. The emerging negative effect in the RDiT results aligns with this perspective. Second, the findings highlight the importance of improving the efficiency of climate finance delivery. The Standing Committee reports persistent gaps between climate finance pledges and actual disbursements, with administrative barriers contributing to project approval delays. Accelerating disbursement and project implementation could shorten the lag between financial inflows and environmental outcomes.

Third, the results underscore the need for stronger alignment between climate finance flows and high-impact mitigation sectors. Research shows that renewable energy deployment, energy efficiency measures, methane abatement, and clean transportation provide the highest mitigation returns per unit of investment. Increasing the share of climate finance directed to these sectors could amplify near-term emission effects.

Finally, the findings contribute to global debates about the adequacy of current climate finance levels. UNEP's Emissions Gap Report (2023) emphasize that present climate finance flows remain far below the scale required to place developing countries on a 1.5°C pathway. The modest but consistent negative trend identified in this study suggests that stronger financial commitments, combined with faster implementation and targeted sectoral investment, are essential for accelerating decarbonization. Taken together, these expanded interpretations enrich the empirical narrative by highlighting the temporal, institutional, and macroeconomic conditions shaping climate finance effectiveness. They also provide a coherent explanation for why the early post-2021 period shows directional improvements without yet achieving statistical significance.

3.3 Discussion

A key implication of these findings is that climate finance should not be evaluated solely on its immediate emission impacts. The evidence presented here supports the understanding that climate finance contributes to structural transformations in energy systems and institutional practices, which evolve over medium to long time horizons. This delayed effectiveness is consistent with the nature of mitigation-focused investments, especially those related to renewable energy deployment, grid modernization, and energy efficiency improvements. These projects require long lead times and significant technical preparation before reducing emissions at scale. Moreover, the diverse composition of climate finance, which includes substantial adaptation funding, also means that aggregate flows may not be directly correlated with short-term emission reductions. These structural realities underscore the importance of adopting a longer-term perspective when assessing the environmental performance of climate finance.

The analysis also highlights the critical role of institutional capacity and absorptive capability in shaping the effectiveness of climate finance. Countries that possess stronger governance systems, more reliable regulatory frameworks, and greater technical readiness tend to translate climate finance into measurable mitigation outcomes more quickly. In contrast, fragile states or countries with complex political environments often rely on climate finance for resilience and adaptation rather than emission reduction. The sample of thirty-nine developing countries included in this study captures a wide range of institutional contexts, which may explain the heterogeneity of early impacts. Understanding this variation is essential for designing targeted strategies that enhance the effectiveness of climate finance, such as strengthening monitoring and evaluation systems, improving procurement processes, and expanding the technical capacity of climate-relevant ministries and agencies.

From a policy perspective, the findings underscore the importance of accelerating the speed and efficiency of climate finance disbursements. Many climate finance commitments made by multilateral institutions and donor governments undergo lengthy administrative processes before being approved and implemented. Streamlining these processes could significantly shorten the lag between financial inflows and environmental outcomes. Additionally, the results highlight the need for allocating a larger share of climate finance toward high-impact mitigation sectors, such as clean energy transition, energy efficiency measures, and methane reduction initiatives. Investments in these sectors have been shown to produce measurable emissions reductions more rapidly, thereby enhancing the near-term environmental impact of climate finance.

Another important implication concerns the adequacy of global climate finance flows. The modest short-term effects observed in this study reflect not only the timing of investment impacts but also the scale of available funding. Multiple independent assessments have emphasized that current levels of climate finance remain insufficient to achieve transformational decarbonization in developing countries. Closing the financing gap will require not only greater public contributions from donor countries but also deeper engagement from the private sector, innovative financial instruments, and improved risk-mitigation mechanisms. Strengthening transparency in climate finance reporting is also essential, particularly in tracking disbursements, identifying funding gaps, and aligning financial flows with national climate strategies.

Although the results contribute valuable empirical insight, the study also has several limitations that should be acknowledged. First, the short post-treatment window restricts the analysis to early-stage effects, which may underestimate the full magnitude of climate finance impacts. As more data become available in the coming years, a longer-term RDiT analysis may reveal stronger discontinuities or more pronounced structural breaks. Second, this study relies on aggregate national-level data, which may mask significant intra-country variations in project implementation, policy capacity, and sectoral financing. Future research could employ subnational datasets or sector-specific climate finance records to uncover more precise channels of impact. Third, the analysis does not explicitly account for heterogeneity among recipient countries, such as governance quality, emission baselines, or climate vulnerability. Incorporating heterogeneous treatment effects or multi-level modeling approaches could provide deeper insight into how different contextual factors shape climate finance effectiveness.

Despite these limitations, the study makes an important contribution to the empirical literature on climate finance by applying a rigorous quasi-experimental design to assess short-run temporal impacts. It provides early evidence that climate finance flows following COP26 are consistent with the initial stages of a downward shift in emission trajectories and confirms that the policy environment established by global climate agreements can influence environmental outcomes even before full-scale implementation. The findings also reaffirm the conceptual understanding that climate finance serves as both a catalyst for structural change and a mechanism for enabling long-term mitigation pathways in developing countries.

As climate-related risks intensify and the global decarbonization timeline grows more urgent, the importance of ensuring that climate finance is mobilized, disbursed, and implemented effectively cannot be overstated. Strengthening institutional readiness, directing resources toward high-impact mitigation sectors, and improving the alignment between financial commitments and national climate strategies will be critical to accelerating progress. Ultimately, the evidence presented here offers a cautiously optimistic view: while climate finance has not yet produced a sharp break in short-run emissions, it has begun to lay the structural foundations from which more substantial mitigation benefits are likely to emerge in the medium term. Continued monitoring, deeper sectoral analysis, and refined empirical approaches will be essential for capturing the full environmental impact of climate finance as countries move further into the implementation phase of their post-COP26 commitments.

4. Conclusions

This study examined the causal effect of climate finance on greenhouse gas (GHG) emissions using a Regression Discontinuity in Time (RDiT) approach centered on the 2021 COP26 summit, which is the year when global climate commitments and financial mobilization intensified. The findings offer nuanced yet meaningful insights into the short-term dynamics of climate finance effectiveness. While the results reveal no statistically significant discontinuity in emission levels immediately following COP26, the consistently negative direction of the estimated coefficients and the declining post-policy trend provide suggestive evidence that the acceleration of international climate finance is beginning to support gradual decarbonization processes across developing economies.

The findings of this study provide a nuanced and empirically grounded understanding of the early effects of the post-COP26 climate finance surge on greenhouse gas emissions in developing countries. While the regression discontinuity in time estimates do not reveal a statistically abrupt decline in emissions immediately after 2021, the direction and stability of the results across multiple specifications consistently point toward an emerging downward trajectory. This trend aligns with the broader literature showing that climate finance operates through a gradual and multi-stage process, where financial commitments translate into tangible environmental outcomes only after project design, disbursement, and implementation cycles are completed. The empirical patterns observed across local polynomial fits, robustness checks, and placebo cutoffs all suggest that climate finance is beginning to exert pressure on emission pathways, although the magnitude is still too modest within the short three-year evaluation window to generate a sharp discontinuity.

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Author Contribution
Conceptualization, DFTJ; Methodology, DFTJ; Formal Analysis, DFTJ; Investigation, DFTJ; Data Curation, DFTJ; Writing – Original Draft Preparation, DFTJ; Writing – Review & Editing, DFTJ; Supervision, DFTJ; Project Administration, DFTJ; Funding Acquisition, DFTJ; Resources, MK; Visualization, MK.

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Ethical Review Board Statement
Ethical approval was not required for this study, as the analysis utilized exclusively secondary data obtained from publicly accessible databases (ADB and WDI) and did not involve human subjects, personal information, or animal experiments.

Informed Consent Statement
Not applicable. This study did not include human participants, nor did it involve the collection, handling, or analysis of any personally identifiable information.

Data Availability Statement
All data generated, employed or analyzed during this study were obtained from publicly accessible international databases, primarily the Asian Development Bank (ADB) databank and the World Development Indicators (WDI) provided by the World Bank. No new data were generated or collected for this research. Additional details regarding the datasets used are available from the corresponding author upon reasonable request.

Conflicts of Interest
The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Declaration of Generative AI Use
During the preparation of this work, the author(s) used ChatGPT, Grammarly and QuillBot to assist in improving grammar, clarity, structure, and academic tone of the manuscript, as well as for paraphrasing and bridging sentences. After using these tools, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

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