A Planner-Based Equilibrium Model of Climate Finance Allocation to Mitigation and Adaptation Strategies: Theory and Empirical Evidence

Amarachi Konyeaso

July 2025

Abstract

This paper examines how climate finance is allocated between mitigation and adaptation in low-income countries, focusing on three main allocation drivers: (1) donor preferences and recipient countries' domestic factors, namely (2) absorptive capacity and (3) institutional friction. We develop a model in which a donor in the Global North allocates climate funds to maximize the welfare of recipient countries in the Global South, subject to recipient-specific capacity and governance constraints. The model predicts that higher absorptive capacity and lower institutional friction in recipient countries shift climate funds toward adaptation, while stronger donor preferences for mitigation reduce adaptation flows. We test these predictions using a mixed-methods approach that combines theoretical simulations, econometric analysis, and medium-scale expert interviews. Consistent with the model, we find that climate finance is positively associated with mitigation outcomes—such as increased renewable energy generation and emissions reduction—while adaptation, although it attracts a share of climate finance, remains severely underfunded in countries with weak absorptive capacity and governance challenges. Expert interviews highlight procedural and institutional barriers to adaptation investment, reinforcing our model's predictions. Overall, our findings call for a more transparent, inclusive, and capacity-sensitive climate finance system. Strengthening local institutions to expand absorptive capacity is essential to rebalancing finance toward adaptation and building climate resilience in the Global South.

1 Introduction

Climate change represents one of the most pressing and asymmetric global challenges of the 21st century. While the Global North accounts for the bulk of historical greenhouse gas emissions, the adverse effects of a warming planet are disproportionately borne by low-income countries in the Global South. These countries face increasing climate variability, food insecurity, and infrastructure vulnerability, yet possess limited fiscal space, institutional capacity, and technical expertise to respond adequately. To bridge this adaptation and mitigation gap, global climate finance flows have become central to international climate policy.

However, the allocation of these funds remains deeply uneven, with mitigation efforts—such as renewable energy investments—receiving the lion's share, while critical sectors linked to long-term resilience, such as sustainable agriculture and climate-smart technologies, remain persistently underfunded (Giglio et. al., 2021).

Despite formal commitments by advanced economies to balance mitigation and adaptation financing, the structural dynamics of climate finance remain skewed. This misalignment raises a set of interrelated questions: What determines how climate finance is distributed between mitigation and adaptation? How do donor-country preferences, recipient absorptive capacity, and institutional frictions shape allocation outcomes? And to what extent do these constraints hinder the ability of low-income countries to access and utilize funds for climate-resilient development? What are the roles of key stakeholders like the government, non-governmental organizations (NGOs), and the private sector in climate finance relations between the Global North and the Global South?

This paper develops a dynamic theoretical model in which a representative donor-country planner allocates climate finance across mitigation and adaptation projects in the Global South. The planner seeks to maximize long-run social welfare subject to constraints imposed by recipient-country absorptive capacity and institutional friction. The model yields equilibrium conditions and comparative statics that formalize three key hypotheses: (i) greater absorptive capacity tilts allocations toward adaptation; (ii) higher institutional friction depresses adaptation financing; and (iii) stronger donor preferences for mitigation crowd out adaptation flows.

We empirically evaluate these predictions using a mixed-methods strategy that combines econometric analysis of cross-country data on climate finance flows with structured interviews from key stakeholders in both donor and recipient countries. Our findings validate the theoretical model: mitigation investments are positively correlated with improvements in renewable energy capacity and emissions reduction (e.g., $r = -0.93$), while adaptation is systematically underfunded in countries with weak institutions, low absorptive capacity, and limited alignment with donor preferences. Expert interviews further reveal procedural and governance bottlenecks that reinforce these disparities.

Our contribution is twofold. First, we offer a formal economic framework that explicitly incorporates institutional and preference-based frictions into the allocation of climate finance. Second, we provide empirical evidence that connects theoretical predictions with real-world constraints. These findings suggest that addressing the underprovision of adaptation finance requires more than increasing the volume of funds. It calls for a reorientation of global climate finance architecture toward institutional inclusivity, capacity-sensitive allocation mechanisms, and transparent governance. Building institutional depth and enhancing local absorptive capacity are therefore not ancillary to climate goals; they are central to achieving them.

By connecting theoretical modeling with empirical realities, this paper sheds light on the structural asymmetries that underpin global climate finance and offers a roadmap for reforms aimed at delivering a more balanced and equitable climate finance regime.

2 Literature and Conceptual Review

2.1 Conceptual Review

Understanding climate finance and its mechanisms is foundational for examining the dynamics between the Global North and Global South. Climate finance refers to local, national, and international funding—sourced from public, private, and alternative streams—aimed at supporting mitigation and adaptation efforts to address climate change (UNFCCC, 2024). It is about investments that governments, corporations, and households have to undertake to transition the world's economy to a low-carbon path, to reduce greenhouse gas concentrations levels, and to build resilience of countries (Hong et.al., 2020).

Mitigation requires large-scale investments to significantly reduce greenhouse gas emissions. Such investments considered environmentally friendly are usually referred to as green, with brown denoting the opposite (Pastor et. al., 2022). These include financing renewable energy infrastructure such as solar and wind power plants, replacing fossil fuel-based technologies with electric alternatives, and implementing carbon capture systems (CFR Education, 2024). Adaptation, on the other hand, involves financial outlays aimed at enhancing resilience to climate change's negative effects. Examples include constructing cooling centers in heatwave-prone areas, building seawalls to prevent coastal flooding, and investing in irrigation and dam systems to protect agriculture from saltwater intrusion (CFR Education, 2024). In contrast to emissions reduction, adaptation considers an externality as given and aims at reducing its damage (Eisenack & Kahler, 2024). The scale of these costs is enormous; however, inaction is projected to be far more expensive. According to Amigues and Lafforgue (2025), most adaptation measures target specific infrastructure such as land management projects, dikes against rising sea levels and urban adaptation strategies. As illustrated in the text below, failing to finance climate action could result in damages exceeding 2.3 quadrillion dollars by the end of the century. This is because the effects of climate change, such as, rise in emissions are not ordinary and localized externalities; risk at a global scale is also a major issue (Bartram et. al., 2022).

Climate finance is delivered through several instruments. One prominent instrument is grants—non-repayable funds disbursed based on climate-related project performance. Debt-for-climate swaps are another tool, allowing debtor nations to restructure debt in return for committing resources to mitigation and adaptation projects (ISO, 2024). Equity shares offer investors stakes in climate-aligned ventures, blending environmental impact with financial returns. Other mechanisms include green bonds, guarantees, and concessional loans. Green bonds provide fixed-income support to environmentally sustainable projects, while guarantees offer credit enhancement by committing to meet borrower obligations (ISO, 2024).

The role of the public and private sectors in deploying these instruments is critical. Historically, most climate finance has been driven by the public sector (UNIDO, 2024). A major emphasis at COP29 was on blended finance—a strategy combining public and private capital to scale resilience investments, especially in Least Developed Countries (LDCs) and Small Island Developing States (SIDS) (UNIDO, 2024). While sectoral roles vary across countries, blended models—such as performance guarantees and first-loss provisions—are increasingly essential to de-risking projects and attracting private capital (Georgieva & Adrian, 2022). Multilateral development banks are expected to play a catalytic role. Governments also need to institute enabling policies—such as predictable carbon pricing—to guide private investment into climate-aligned sectors. In general, the various stakeholders are to ensure that climate finance policies are not only cost efficient, but also be economically efficient. That is, these policies should be fair, credible, feasible and effective (Fabra & Reguant, 2024)

With this foundation established, the following section examines how existing literature evaluates the structure and impact of North–South climate finance flows.

2.2 Literature Review

A growing body of research has interrogated the role of Global North investments in advancing adaptation and sustainable development in the Global South. Martin and Axel (2023), for example, examine Switzerland's contribution to the global 100 billion dollars climate finance goal, highlighting difficulties in measurement, reporting, and verification (MRV), especially regarding mobilized private finance. They recommend greater clarity on definitions and encourage Switzerland to shape international discourse on climate-aligned private capital.

Similarly, Contreras and Dornberger (2022) employ bibliometric mapping to explore sustainable entrepreneurship across the North–South divide. They find limited collaboration between Northern and Southern countries and weak inter-South coordination. Obethur and Dupont (2021) highlight growing geopolitical pressures on the European Union to coordinate a grand climate strategy, which requires high-level cooperation among EU institutions and member states. Yusuf (2025) also considered that these inadequacies stems not only from political hurdles but also from economic disincentives inherent in international cooperation.

Several studies examine the Global North's relationship with African nations in the climate finance context. Tamasiga et al. (2023), using bibliometric analysis, find that Germany leads in climate finance engagement with Africa, followed by the UK and USA. However, they argue that contributions remain insufficient for a just energy transition. Anozie (2024) similarly critiques underfunding of African climate priorities, warning that neglect could jeopardize global decarbonization targets. Mungai, Ndiritu, and da Silva (2021) focus on climate-smart agriculture, underscoring Africa's vulnerability due to erratic weather, ecological fragility, and dependence on climate-sensitive livelihoods. They emphasize the private sector's role in closing the adaptation finance gap, though policy constraints, low awareness, and limited budget allocations hinder progress. Moreover, Mignamissi et. al. (2024) stress the fact that better institutions have a negative and significant effect on pollution in Africa based on their research on the pollution emissions and institutional quality nexus in Africa.

In Asia, Kameyama, Morita, and Kubota (2015) estimate that USD 125–149 billion annually will be needed to cut emissions by 2035. They emphasize the importance of private sector engagement. Gopal and Logan (2024) report that Asia-Pacific countries are experiencing a surge in finance for clean energy—38 per cent above 2020 levels—yet adaptation remains severely underfunded. Least Developed Countries (LDCs) and Small Island Developing States (SIDS) in the region face pronounced difficulties in accessing finance. Grifford (2020) notes that despite efforts such as the Maldives' Climate Change Trust Fund, limited expertise constrains mitigation potential. Lim et al. (2024) argue for stronger institutional support—especially from the IMF—to address macro-critical climate risks. Similarly, the Climate Policy Initiative (2024) stresses the vulnerability of LDCs, urging reforms ahead of

COP29 to address longstanding funding bottlenecks.

Other scholars investigate the macroeconomic scale of North–South transfers. Bowen et al. (2015), using integrated assessment models, estimate that to equalize climate burden across nations, roughly 400 billion dollars annually would need to flow from North to South by 2050—far exceeding current commitments. They emphasize that public finance is indispensable for adaptation, while private capital may dominate mitigation. Roman et al. (2017) find that countries with policies promoting local green industries experience stronger economic growth. Eyckmans et al. (2014) caution that unconditional transfers may induce misallocation in recipient nations and advocate for matching grants to better align donor intentions with recipient welfare optimization. Also, using a dynamic macroeconomic model, Bretschger (2024) reveals that a timely carbon phase-out requires sufficient substitution in the energy sector, continued learning and scale effects in renewable energies, and active climate policy, which is indispensable even with large cost degression of renewable energy sources.

A subset of the literature explicitly incorporates the Theory of Change (ToC) framework to study how financial instruments affect real outcomes. Monasterolo et al. (2024) examine Green Financial Sector Initiatives (GFSI) in carbon-intensive economies, identifying three key channels: portfolio rebalancing, lending flows, and interest rate signals. Their findings suggest that the structural features of a country condition how effectively finance translates into decarbonization. Bhandary, Gallagher, and Zhang (2021) argue that the success of climate finance depends on policy instrument design—including taxes, investment credits, and de-risking tools—but note a paucity of empirical work assessing their equity and environmental impacts.

Beyond the ToC methodology, some scholars profer general tactics that can be used by individuals and countries to tackle climate change. Nordhaus (2019) mentions four strategies. First, that people need to comprehend and come to terms with the gravity of the climate change problem. Secondly, that nations must establish and raise the cost of emitting greenhouse gases. Thirdly, it is important that actions that combat the negative effects of climate change are not just global, but local. He also stresses the importance of climate-smart technology. Survey findings by Stroebel and Wurgler (2021) reveal that pressure from institutional investors is largely viewed as a most powerful force for change among financial mechanisms. Among non-financial mechanisms, carbon taxes and government subsidies are regarded as the most potent. In a more practical study, Lane (2024) reveals that access to microfinance such as guaranteed credits can enable farmers to make less costly adaptation choices and are less severely affected when a flood occurs.

Despite this progress, critical gaps remain. Few studies explicitly evaluate how donor preferences, absorptive capacity, and institutional friction jointly shape climate finance allocation. Moreover, limited attention has been given to the dual objective of promoting both environmental resilience and economic development through finance. The literature also lacks granular analysis of how climate-smart technologies—such as digital monitoring, early-warning systems, and climate-resilient infrastructure—might simultaneously advance adaptation and productivity.

In sum, while the literature provides valuable insights into the scale, direction, and mechanisms of climate finance, more integrated analysis is needed. In particular, understanding how institutional constraints and donor incentives interact to shape adaptation outcomes remains an urgent research priority. Solving climate change issues requires a wider multidisciplinary approach beyond atmospheric sciences, incorporating physical, chemical, and biological studies to grasp the full extent of climate change impacts (Cardenas, 2024; Nguyen et. al., 2022). These solutions are needed to lower welfare costs that could arise due to catastrophic events such as a climate disaster (Pindyck & Martin, 2021; Deschênes & Greenstone)

In the next section, we start our analysis by developing a model of climate finance allocation under donor preferences, absorptive capacity, and institutional constraints.

3 Model Setup

We develop a stylized model to analyze how climate finance is optimally allocated between mitigation and adaptation in the Global South, considering donor-driven preferences and domestic implementation frictions and absorptive capacity. In this model, the Global North (i.e., the donor) is the direct climate planner whose goal is to make optimal decisions to maximize climate-related welfare from the climate finance it provides to the Global South. The model formalizes a planner's decision problem under a resource constraint, with explicit parameters reflecting international influence (i.e., donor preferences) and local capacity (absorptive capacity ϕ and institutional friction γ).

Although both ϕ and γ can affect the effectiveness of adaptation funding in the model, they represent fundamentally different dimensions of constraint. The parameter $\phi \in (0, 1]$, which captures the *absorptive capacity* of the Global South, measures the extent to which a country has the technical, institutional, and human capital needed to *implement adaptation projects effectively*. A low ϕ indicates that even if funds are available, the country lacks the systems or skills to absorb and utilize them efficiently—perhaps due to shortages of engineers, poor infrastructure, or limited planning capacity. In contrast, $\gamma \in [0, 1]$, which reflects *institutional friction*, measures the degree of inefficiency in the use of finance, resource wastage, or delay introduced by governance weaknesses such as bureaucratic multilateral red tape, corruption, or lack of coordination. Whereas ϕ speaks to the *ability* to absorb funds, γ speaks to the *efficiency* of doing so without leakage or distortion.

Together, they determine the effective impact of adaptation spending: high absorptive capacity means funds can be put to good use, but high institutional friction can still undermine outcomes (e.g., shrink the resources available for adaptation projects), making both parameters crucial to understanding optimal allocation in climate finance.

3.1 Planner's Problem

We begin with a static environment in which a climate planner allocates a one-period climate finance budget $B > 0$ between two instruments:

- **Mitigation funding** $M \geq 0$: expenditures aimed at reducing greenhouse gas (GHG) emissions and limiting future climate change.
- **Adaptation funding** $A \geq 0$: expenditures aimed at enhancing resilience to climate risks already manifesting, such as infrastructure strengthening or drought-resilient agriculture.

The planner maximizes a weighted utility function that captures the influence of:

- **Donor preference for mitigation**, denoted by $\theta \in [0, 1]$, which assigns a weight θ to mitigation and $1 - \theta$ to adaptation in the objective function.
- **Absorptive capacity for adaptation**, $\phi \in (0, 1]$, capturing the extent of know-how with which adaptation funds translate into outcomes.
- **Institutional friction**, $\gamma \in [0, 1]$, representing bureaucratic or governance-related constraints specific to adaptation delivery.

The output returns from mitigation and adaptation investments are modeled logarithmically:

$$f(M) = \alpha \log(1 + M), \quad \alpha > 0 \quad \text{(mitigation return)} \tag{1}$$

$$g(A) = \beta \log(1 + A), \quad \beta > 0 \quad \text{(adaptation return)} \tag{2}$$

This functional form reflects the diminishing marginal returns to investment, a feature widely used in public economics and environmental policy models. The logarithmic specification ensures interior solutions and captures the intuition that early investments yield large returns, while subsequent units become progressively less effective. It is analytically convenient and empirically plausible for capturing mitigation and adaptation technologies. We follow the climate finance literature in modeling diminishing marginal returns using a logarithmic specification, consistent with standard concave forms such as CES, Cobb-Douglas, or exponential decay used in Acemoglu et al. (2012), van der Ploeg and de Zeeuw (2014), and related models.

Indeed, the function $f(M) = \alpha \log(1 + M)$ satisfies the following properties:

- **Positive marginal returns:** $f'(M) = \frac{\alpha}{1+M} > 0$ for all $M \geq 0$.
- **Diminishing marginal returns:** $f''(M) = -\frac{\alpha}{(1+M)^2} < 0$, implying strict concavity.
- **Bounded marginal effect:** $\lim_{M\to\infty} f'(M) = 0$, so very large investments yield negligible incremental gains.

An identical argument applies to $g(A) = \beta \log(1 + A)$, making the logarithmic form an appropriate and tractable choice for modeling both mitigation and adaptation benefits.

3.2 Planner Welfare Function

The planner aims to allocate a climate finance budget $B > 0$ between mitigation (M) and adaptation (A), subject to the constraint:

$$M + A \leq B, \quad M, A \geq 0.$$

The planner's welfare function aggregates the net social benefits from both investments, reflecting donor preferences and recipient country constraints. It takes the form:

$$W = \theta\alpha \log(1 + M) + (1 - \theta)\phi(1 - \gamma)\beta \log(1 + A) \tag{3}$$

To understand this, we break down each component: - **Mitigation Component:** Mitigation reduces global greenhouse gas emissions and produces returns according to:

$$f(M) = \alpha \log(1+M), \quad \alpha > 0.$$

The donor's preference for mitigation is captured by the weight $\theta \in [0,1]$. Thus, the weighted contribution to social welfare is:

$$\theta\alpha \log(1+M).$$

- **Adaptation Component:** Adaptation improves local climate resilience and yields returns given by:

$$g(A) = \beta \log(1+A), \quad \beta > 0.$$

However, the effectiveness of adaptation spending is modulated by three factors:

- $(1-\theta)$: residual weight on adaptation, i.e., preference for adaptation after accounting for mitigation preference.
- $\phi \in (0,1]$: absorptive capacity of the Global South to utilize adaptation funds productively.
- $(1-\gamma) \in [0,1]$: institutional efficiency, with higher γ representing greater friction (e.g., delays, corruption, mismanagement).

Hence, the weighted contribution from adaptation is:

$$(1-\theta)\phi(1-\gamma)\beta \log(1+A).$$

The full welfare function integrates both components:

$$W = \underbrace{\theta}_{\text{Donor preference for mitigation}} \cdot \underbrace{\alpha \log(1+M)}_{\text{Mitigation return}}$$
$$+ \underbrace{(1-\theta)}_{\text{Residual weight (adaptation preference)}} \cdot \underbrace{\phi}_{\text{Absorptive capacity}} \cdot \underbrace{(1-\gamma)}_{\text{Institutional quality}} \cdot \underbrace{\beta \log(1+A)}_{\text{Adaptation return}}$$

This expression captures how donor preferences, domestic absorptive capacity, and institutional frictions jointly determine the optimal allocation of climate finance. When donor preference θ is high or institutional quality is low, mitigation receives more weight. Conversely, strong governance and high absorptive capacity shift allocation toward adaptation.

The planner's optimization problem is:

$$\max_{M,A} \quad W = \theta\alpha \log(1+M) + (1-\theta)\phi(1-\gamma)\beta \log(1+A) \tag{3}$$

subject to the budget constraint:

$$M + A \le B. \tag{4}$$

Here, M and A are endogenously determined, while θ, ϕ, and γ are exogenous factors driving the allocation.

3.3 Dynamic Extension

Without loss of generality, we can generalize the model to $t = 0, 1, \ldots, \infty$, with time-indexed budgets B_t and a discount factor $\delta \in (0, 1)$. At each time t, mitigation and adaptation choices are denoted M_t and A_t.

The dynamic objective of maximizing lifetime welfare is:

$$\max_{\{M_t, A_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \delta^t \left[\theta\alpha \log(1 + M_t) + (1 - \theta)\phi(1 - \gamma)\beta \log(1 + A_t)\right] \tag{5}$$

subject to $M_t + A_t \leq B_t$ for each t.

The first-order conditions yield:

$$\frac{\delta^t \theta\alpha}{1 + M_t} = \lambda_t, \tag{6}$$

$$\frac{\delta^t (1 - \theta)\phi(1 - \gamma)\beta}{1 + A_t} = \lambda_t, \tag{7}$$

where λ_t is the Lagrange multiplier, equating marginal benefits across periods.

3.4 First-Order Conditions

For the static case, the Lagrangian is:

$$\mathcal{L} = \theta\alpha \log(1 + M) + (1 - \theta)\phi(1 - \gamma)\beta \log(1 + A) + \lambda(B - M - A) \tag{8}$$

The first-order conditions are:

$$\frac{\partial \mathcal{L}}{\partial M} = \frac{\theta\alpha}{1 + M} - \lambda = 0, \tag{9}$$

$$\frac{\partial \mathcal{L}}{\partial A} = \frac{(1 - \theta)\phi(1 - \gamma)\beta}{1 + A} - \lambda = 0, \tag{10}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = B - M - A = 0. \tag{11}$$

Equating the first two conditions gives the equilibrium condition:

$$\frac{\theta\alpha}{1 + M} = \frac{(1 - \theta)\phi(1 - \gamma)\beta}{1 + A} \tag{4}$$

This defines the interior solution (M^*, A^*) given $(\theta, \phi, \gamma, \alpha, \beta, B)$.

3.5 Key Parameters

- θ — Donor preference weight for mitigation (more global and measurable).
- ϕ — Absorptive capacity in deploying adaptation funds.
- γ — Institutional friction (e.g., corruption, bureaucracy) that diminishes adaptation effectiveness.

- α, β — Productivity or return coefficients for mitigation and adaptation, respectively.
- B — Total available climate finance.

This setup allows us to explore how shifting donor priorities, capacity constraints, and institutional quality affect optimal climate finance allocation.

We can represent the first-order conditions as:

$$F_1(M, A, \theta, \phi, \gamma) = \frac{\theta\alpha}{1+M} - \frac{(1-\theta)\phi(1-\gamma)\beta}{1+A} = 0 \tag{12}$$

$$F_2(M, A, B) = -M - A + B = 0 \tag{13}$$

This leads to the following testable propositions.

Proposition 1: Existence and Uniqueness of Equilibrium Allocation

Let the planner allocate a fixed climate finance budget $B > 0$ between mitigation funding $M \geq 0$ and adaptation funding $A \geq 0$, subject to the constraint:

$$F_2(M, A) = -M - A + B = 0$$

and the equilibrium condition:

$$F_1(M, A, \theta, \phi, \gamma) = \frac{\theta\alpha}{1+M} - \frac{(1-\theta)\phi(1-\gamma)\beta}{1+A} = 0$$

where the parameters satisfy $0 < \theta < 1$, $\phi > 0$, $0 < \gamma < 1$, and $\alpha, \beta > 0$.

Then there exists a unique interior solution $(M^*, A^*) \in (0, B) \times (0, B)$ that satisfies both equations. Moreover, (M^*, A^*) is continuously differentiable with respect to the parameters (θ, ϕ, γ).

Economic Explanation: This proposition guarantees that for any strictly positive donor preference and reasonably functioning absorptive and institutional conditions, the planner always arrives at a unique and well-behaved optimal allocation of the climate finance budget. This allocation continuously adapts as donor preferences or domestic frictions evolve. The existence of a unique interior solution avoids corner solutions (e.g., allocating all funds to one category), reinforcing the model's tractability and realism.

Proposition 2: Comparative Statics of Climate Finance Allocation with Budget Constraint

Let (M^*, A^*) denote the equilibrium allocation of a fixed climate finance budget $B > 0$ between mitigation and adaptation, determined by the system:

$$F_1(M, A, \theta, \phi, \gamma) = \frac{\theta\alpha}{1+M} - \frac{(1-\theta)\phi(1-\gamma)\beta}{1+A} = 0 \tag{14}$$

$$F_2(M, A) = -M - A + B = 0 \tag{15}$$

where $\theta \in (0,1)$ denotes donor preference for mitigation, $\phi > 0$ is the absorptive capacity for adaptation, and $\gamma \in (0,1)$ reflects institutional friction. Assume $\alpha, \beta > 0$.

Then the equilibrium allocation responds to the parameters as follows:

$$\frac{\partial M^*}{\partial \theta} > 0, \quad \frac{\partial A^*}{\partial \theta} < 0$$
$$\frac{\partial M^*}{\partial \phi} < 0, \quad \frac{\partial A^*}{\partial \phi} > 0$$
$$\frac{\partial M^*}{\partial \gamma} > 0, \quad \frac{\partial A^*}{\partial \gamma} < 0$$

Economic Explanation: Donor preferences (θ) push the planner toward favoring mitigation; thus, increasing θ increases M^* and reduces A^*. Higher absorptive capacity (ϕ) boosts the effectiveness of adaptation, prompting more resources to flow to A and less to M. Meanwhile, higher institutional friction (γ) reduces the productivity of adaptation, thereby reducing A^* and increasing M^* as funds are redirected to the more efficient mitigation sector. These results confirm that climate finance allocation is sensitive to both international biases and local institutional quality.

Proposition 3: Response of Climate Finance Allocation to Budget Expansion

Let (M^*, A^*) be the unique interior solution to the planner's problem given by:

$$F_1(M, A, \theta, \phi, \gamma) = \frac{\theta\alpha}{1+M} - \frac{(1-\theta)\phi(1-\gamma)\beta}{1+A} = 0 \tag{16}$$
$$F_2(M, A, B) = -M - A + B = 0 \tag{17}$$

Then the partial derivatives of the optimal allocations with respect to B satisfy:

$$\frac{\partial M^*}{\partial B} = \frac{b}{a+b} > 0,$$
$$\frac{\partial A^*}{\partial B} = \frac{a}{a+b} > 0$$

where:

$$a = \frac{\theta\alpha}{(1+M^*)^2}, \quad b = \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2}$$

Moreover, the allocation that receives the larger share of the budget increase depends on the relative marginal benefit:

$$\frac{\partial M^*}{\partial B} > \frac{\partial A^*}{\partial B} \iff b > a$$
$$\iff \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} > \frac{\theta\alpha}{(1+M^*)^2}$$
$$\iff (1-\theta)\phi(1-\gamma)\beta(1+M^*)^2 > \theta\alpha(1+A^*)^2$$

Economic Explanation: This condition indicates that mitigation receives a larger share of a budget increase when its marginal benefit, adjusted for diminishing returns, exceeds that of adaptation. This reflects the planner's goal of equalizing marginal benefits across strategies. If adaptation has been favored due to high absorptive capacity or low friction, its marginal benefit may decline due to diminishing returns, prompting a shift of new funds to mitigation to restore balance.

4 Proof

Proposition 1: Existence and Uniqueness of Equilibrium Allocation

Proof: Define the function $F : \mathbb{R}^5 \to \mathbb{R}^2$ as:

$$F(M, A, \theta, \phi, \gamma) = \begin{bmatrix} F_1(M, A, \theta, \phi, \gamma) \\ F_2(M, A) \end{bmatrix}$$

Let $\theta \in (0, 1)$, $\phi > 0$, $\gamma \in (0, 1)$. Note that F_1 is strictly decreasing in M (since $\frac{\partial F_1}{\partial M} = -\frac{\theta\alpha}{(1+M)^2} < 0$) and strictly increasing in A (since $\frac{\partial F_1}{\partial A} = \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} > 0$), while F_2 defines a linear budget constraint with full spending: $M + A = B$.

Substituting $A = B - M$ into F_1, we obtain a strictly decreasing continuous function in $M \in (0, B)$:

$$F_1(M) = \frac{\theta\alpha}{1 + M} - \frac{(1 - \theta)\phi(1 - \gamma)\beta}{1 + B - M}$$

As $M \to 0^+$, $F_1(M) > 0$; as $M \to B^-$, $F_1(M) < 0$. By the Intermediate Value Theorem, there exists a unique $M^* \in (0, B)$ such that $F_1(M^*) = 0$. The corresponding $A^* = B - M^* \in (0, B)$.

The Jacobian matrix of the system (F_1, F_2) with respect to (M, A) is:

$$J = \begin{bmatrix} -\frac{\theta\alpha}{(1+M)^2} & \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} \\ -1 & -1 \end{bmatrix}$$

The determinant is:

$$\Delta = \frac{\theta\alpha}{(1 + M)^2} + \frac{(1 - \theta)\phi(1 - \gamma)\beta}{(1 + A)^2} > 0$$

which guarantees that the Jacobian is nonsingular.

By the Implicit Function Theorem, (M^*, A^*) depends continuously and differentiably on the parameters (θ, ϕ, γ). □

Proposition 2: Comparative Statics of Climate Finance Allocation with Budget Constraint

Proof: Let $F : \mathbb{R}^5 \to \mathbb{R}^2$ be the system:

$$F(M, A, \theta, \phi, \gamma) = \begin{bmatrix} F_1(M, A, \theta, \phi, \gamma) \\ F_2(M, A) \end{bmatrix}$$

Totally differentiating F with respect to (θ, ϕ, γ):

$$\frac{\partial F}{\partial(M, A)} \cdot \frac{\partial(M, A)}{\partial(\theta, \phi, \gamma)} + \frac{\partial F}{\partial(\theta, \phi, \gamma)} = 0$$

Solving for the endogenous response:

$$\frac{\partial(M, A)}{\partial(\theta, \phi, \gamma)} = -\left(\frac{\partial F}{\partial(M, A)}\right)^{-1} \cdot \frac{\partial F}{\partial(\theta, \phi, \gamma)}$$

The Jacobian is:

$$J = \begin{bmatrix} -\frac{\theta\alpha}{(1+M)^2} & \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} \\ -1 & -1 \end{bmatrix}$$

with determinant:

$$\Delta = \frac{\theta\alpha}{(1+M)^2} + \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} > 0$$

The inverse is:

$$J^{-1} = \frac{1}{\Delta} \begin{bmatrix} -1 & -\frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} \\ 1 & -\frac{\theta\alpha}{(1+M)^2} \end{bmatrix}$$

Partial derivatives of F_1 are:

$$\frac{\partial F_1}{\partial \theta} = \frac{\alpha}{1+M} + \frac{\phi(1-\gamma)\beta}{1+A}, \quad \frac{\partial F_1}{\partial \phi} = -\frac{(1-\theta)(1-\gamma)\beta}{1+A}, \quad \frac{\partial F_1}{\partial \gamma} = \frac{(1-\theta)\phi\beta}{1+A}$$

Thus:

$$\frac{\partial(M, A)}{\partial(\theta, \phi, \gamma)} = -\frac{1}{\Delta} \begin{bmatrix} -1 & -\frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} \\ 1 & -\frac{\theta\alpha}{(1+M)^2} \end{bmatrix} \begin{bmatrix} \frac{\partial F_1}{\partial \theta} & \frac{\partial F_1}{\partial \phi} & \frac{\partial F_1}{\partial \gamma} \\ 0 & 0 & 0 \end{bmatrix}$$

The signs follow:

$$\begin{aligned} \frac{\partial M^*}{\partial \theta} > 0, \quad \frac{\partial A^*}{\partial \theta} < 0 \\ \frac{\partial M^*}{\partial \phi} < 0, \quad \frac{\partial A^*}{\partial \phi} > 0 \\ \frac{\partial M^*}{\partial \gamma} > 0, \quad \frac{\partial A^*}{\partial \gamma} < 0 \end{aligned}$$

□

Proposition 3: Response of Climate Finance Allocation to Budget Expansion

Proof: Let:

$$F(M, A, B) = \begin{bmatrix} F_1(M, A, \theta, \phi, \gamma) \\ F_2(M, A, B) \end{bmatrix}$$

The total derivative with respect to B satisfies:

$$\frac{\partial F}{\partial(M,A)} \cdot \frac{\partial(M,A)}{\partial B} + \frac{\partial F}{\partial B} = 0$$

The Jacobian is:

$$J = \begin{bmatrix} -\frac{\theta\alpha}{(1+M)^2} & \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A)^2} \\ -1 & -1 \end{bmatrix}$$

with $\Delta = \frac{\theta\alpha}{(1+M^*)^2} + \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} > 0$.

The partial derivative of F with respect to B is:

$$\frac{\partial F}{\partial B} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

Thus:

$$\frac{\partial(M,A)}{\partial B} = -J^{-1} \cdot \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

The inverse is:

$$J^{-1} = \frac{1}{\Delta} \begin{bmatrix} -1 & -\frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} \\ 1 & -\frac{\theta\alpha}{(1+M^*)^2} \end{bmatrix}$$

So:

$$\frac{\partial(M,A)}{\partial B} = -\frac{1}{\Delta} \begin{bmatrix} -1 & -\frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} \\ 1 & -\frac{\theta\alpha}{(1+M^*)^2} \end{bmatrix} \begin{bmatrix} 0 \\ 1 \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} \\ \frac{\theta\alpha}{(1+M^*)^2} \end{bmatrix}$$

Thus:

$$\frac{\partial M^*}{\partial B} = \frac{\frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2}}{\Delta}, \quad \frac{\partial A^*}{\partial B} = \frac{\frac{\theta\alpha}{(1+M^*)^2}}{\Delta}$$

Since $\Delta = a + b$ with $a = \frac{\theta\alpha}{(1+M^*)^2}$ and $b = \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2}$:

$$\frac{\partial M^*}{\partial B} = \frac{b}{a+b}, \quad \frac{\partial A^*}{\partial B} = \frac{a}{a+b}$$

For the relative share:

$$\frac{\partial M^*}{\partial B} > \frac{\partial A^*}{\partial B} \iff \frac{b}{a+b} > \frac{a}{a+b} \iff b > a$$

$$\iff \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2} > \frac{\theta\alpha}{(1+M^*)^2}$$

$$\iff (1-\theta)\phi(1-\gamma)\beta(1+M^*)^2 > \theta\alpha(1+A^*)^2$$

□

Proposition 3: Marginal Returns and Budget Allocation

To deepen the understanding of Proposition 3, the marginal returns to mitigation and adaptation are used to explain the observed allocation patterns when the budget B increases. This section derives the marginal returns, compares the diminishing marginal returns, and elucidates why the marginal benefit of mitigation with respect to the budget increase exceeds that of adaptation under certain conditions.

4.0.1 Welfare Function and Marginal Returns

The planner's welfare function, as defined earlier, is:

$$W = \theta\alpha \log(1 + M) + (1 - \theta)\phi(1 - \gamma)\beta \log(1 + A) \tag{3}$$

where M and A are mitigation and adaptation funding, θ is the donor preference for mitigation, ϕ is absorptive capacity, γ is institutional friction, and α and β are productivity parameters.

The marginal returns are obtained by differentiating W with respect to M and A:

$$\frac{\partial W}{\partial M} = \frac{\theta\alpha}{1 + M} \tag{18}$$

$$\frac{\partial W}{\partial A} = \frac{(1 - \theta)\phi(1 - \gamma)\beta}{1 + A} \tag{19}$$

These expressions represent the marginal welfare contributions of additional units of mitigation and adaptation funding, respectively. Both exhibit diminishing marginal returns, as the second derivatives confirm:

$$\frac{\partial^2 W}{\partial M^2} = -\frac{\theta\alpha}{(1 + M)^2} < 0 \tag{20}$$

$$\frac{\partial^2 W}{\partial A^2} = -\frac{(1 - \theta)\phi(1 - \gamma)\beta}{(1 + A)^2} < 0 \tag{21}$$

The negative second derivatives indicate that the marginal benefit decreases as M or A increases, a standard property of logarithmic utility functions.

4.0.2 Comparison of Diminishing Marginal Returns

To explore the diminishing marginal returns of both adaptation and mitigation, the magnitudes of the second derivatives are considered. The absolute value of the second derivative for adaptation is:

$$\left|\frac{\partial^2 W}{\partial A^2}\right| = \frac{(1 - \theta)\phi(1 - \gamma)\beta}{(1 + A)^2}$$

while for mitigation it is:

$$\left|\frac{\partial^2 W}{\partial M^2}\right| = \frac{\theta\alpha}{(1 + M)^2}$$

4.0.3 Marginal Benefit with Respect to Budget Increase

Proposition 3 states that the response to a budget increase is governed by:

$$\frac{\partial M^*}{\partial B} = \frac{b}{a+b} > 0, \tag{22}$$

$$\frac{\partial A^*}{\partial B} = \frac{a}{a+b} > 0, \tag{23}$$

where $a = \frac{\theta\alpha}{(1+M^*)^2}$ and $b = \frac{(1-\theta)\phi(1-\gamma)\beta}{(1+A^*)^2}$. The condition for mitigation to receive a larger share is:

$$\frac{\partial M^*}{\partial B} > \frac{\partial A^*}{\partial B} \iff \theta\alpha(1+A^*)^2 > (1-\theta)\phi(1-\gamma)\beta(1+M^*)^2 \tag{24}$$

Proposition 3 explains that the marginal benefit of mitigation exceeds that of adaptation due to the greater diminishing marginal returns of adaptation. As A^* increases (e.g., from prior high adaptation funding), the denominator $(1+A^*)^2$ grows, reducing b and thus $\frac{\partial A^*}{\partial B}$. Conversely, if M^* is relatively low, $(1+M^*)^2$ is smaller, keeping a higher, which boosts $\frac{\partial M^*}{\partial B}$. The condition $\theta\alpha(1+A^*)^2 > (1-\theta)\phi(1-\gamma)\beta(1+M^*)^2$ holds when mitigation's weighted marginal productivity outweighs adaptation's, amplified by a larger A^* relative to M^*.

In summary, for an additional increase in climate finance, the planner would put more of the money in mitigation rather than adaptation if and only if extra spending on adaptation would reduce marginal welfare gain from adaptation as compared to mitigation. This means that if the size of the diminishing returns to welfare is bigger for adaptation than mitigation, the planner would lean more towards mitigation.

5 Stochastic Simulation Results and Interpretation

In order to validate the results of the model setup in section 3, the stochastic simulation method is used. It involves generating random variables and inserting them into a model to simulate the behavior of the system. This process is repeated multiple times to gather sufficient data, which helps in understanding the distribution of possible outcomes and their probabilities. Before carrying out this simulation, the first step is to solve the system of equations simultaneously to derive the optimal adaptation (A^*) and mitigation (M^*) allocations under a climate finance budget B. The model includes an equilibrium condition and a budget constraint:

$$\frac{\theta\alpha}{1+M} = \frac{(1-\theta)\phi(1-\gamma)\beta}{1+A} \tag{25}$$

$$M + A = B \tag{26}$$

Let:

$$C = \theta\alpha, \quad D = (1-\theta)\phi(1-\gamma)\beta$$

Substitute $M = B - A$ from (26) into (25):

$$\frac{C}{1+B-A} = \frac{D}{1+A}$$

Cross-multiplying:

$$C(1 + A) = D(1 + B - A)$$

Expanding both sides:

$$C + CA = D(1 + B) - DA$$

Rearranging terms:

$$CA + DA = D(1 + B) - C \Rightarrow A(C + D) = D(1 + B) - C$$

Solving for A^*:

$$A^* = \frac{(1-\theta)\phi(1-\gamma)\beta(1+B) - \theta\alpha}{\theta\alpha + (1-\theta)\phi(1-\gamma)\beta} \tag{27}$$

Using the budget constraint, $M^* = B - A^*$:

$$M^* = B - \frac{(1-\theta)\phi(1-\gamma)\beta(1+B) - \theta\alpha}{\theta\alpha + (1-\theta)\phi(1-\gamma)\beta} \tag{28}$$

Using equations (27) and (28), we perform a deterministic simulation by plugging in empirical values of the explanatory variables. In line with the literature, we assume:

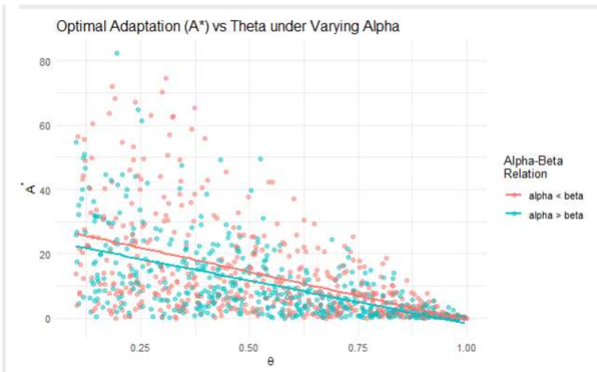
- Donor preference $\theta \in [0.1, 1]$
- Absorptive capacity $\phi \in [0.1, 1]$
- Institutional friction $\gamma \in [0.1, 1]$
- Productivity coefficients $\alpha, \beta \in [0.5, 1.5]$ which reflects plausible ranges from development finance sources.

The figures below presents simulated results showing how optimal adaptation and mitigation allocations vary with donor preferences and institutional characteristics. Another assumption is that the values chosen assumed a normalized and unbiased range

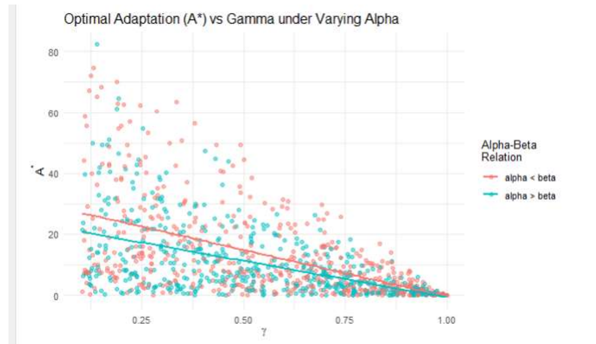
Discussion

The analytical solution reveals that A^* and M^* are nonlinear functions of donor preference, absorptive capacity, and institutional friction. The stochastic simulation confirms that:

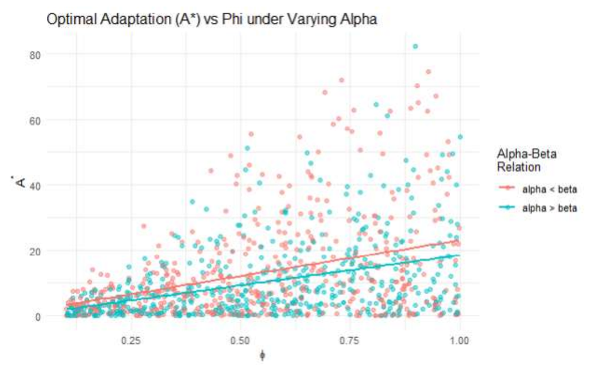
- Higher institutional friction (γ) reduces A^*, aligning with theoretical expectations that inefficiencies lower the effective returns to adaptation.
- Higher donor preference for mitigation (θ) reallocates funding away from adaptation, also reducing A^*.
- The productivity coefficients α and β significantly shift the balance between optimal A^* and M^*, as shown in simulation graphs grouped by whether $\alpha > \beta$, $\alpha < \beta$, or $\alpha = \beta$.



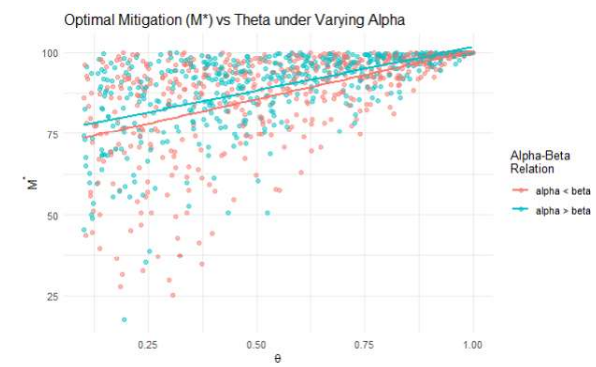
(a) Optimal Adaptation (A^*) vs Donor Preference (θ) under Varying α and β



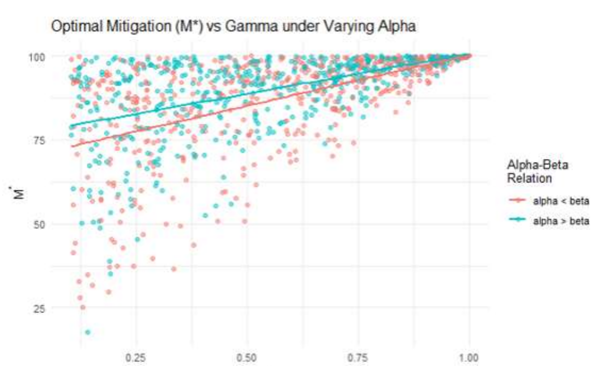
(b) Optimal Adaptation (A^*) vs Institutional Friction (γ) under Varying α



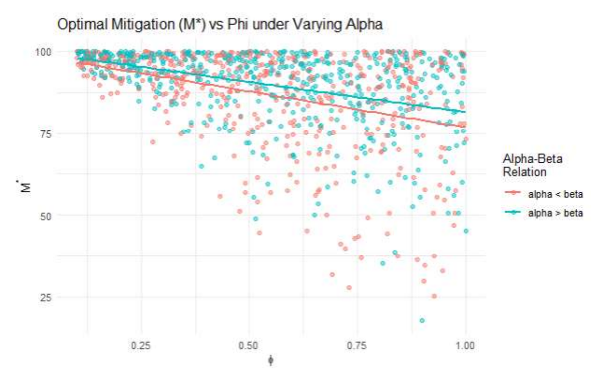
(c) Optimal Adaptation (A^*) vs Absorptive Capacity for Adaptation (ϕ) under Varying α



(d) Optimal Mitigation (M^*) vs Donor Preference for Mitigation (θ) under Varying α



(e) Optimal Mitigation (M^*) vs Institutional Friction (γ) under Varying α



(f) Optimal Mitigation (M^*) vs Absorptive Capacity for Adaptation (ϕ) under Varying α

Figure 1: Relationship between optimal climate finance allocations and model parameters

In addition to confirming theoretical expectations, the simulation graphs indicate several nuanced findings: The relationship between donor preference (θ) and optimal adaptation (A^*) is nonlinear and concave and it reveals that small shifts in θ at low levels of preference can lead to disproportionate re-allocations in adaptation financing. This may reflect potential instability in adaptation funding under politically sensitive shifts in donor focus.

Moreover, the relationship between A^* and institutional friction (γ) is negative. This shows how important governance and administrative capacity are in determining how effectively adaptation resources are absorbed. Even with high absorptive capacity (ϕ), high γ significantly lowers adaptation allocation.

When absorptive capacity (ϕ) is high, the negative effect of institutional friction on A^* is moderated. This is in line with predictions from the model framework that absorptive readiness improves a the capacity of a country to attract adaptation financing even when institutional arrangements are less effective.

Scenarios where $\alpha > \beta$ (i.e., adaptation projects are more productive than mitigation) show a upward shift in A^* across all values of θ, γ, and ϕ. Conversely, when $\beta > \alpha$, funding shifts toward M^* even under low donor preference for mitigation.

The simulation shows that adaptation and mitigation may tend to compete under a fixed budget. An increase in one sometimes reduces the other. This shows that there is great need for coordinated investment frameworks rather than fragmented finance mechanisms.

When θ approaches 0.7 or higher, even highly productive adaptation returns ($\alpha > 1.2$) are insufficient to maintain high A^*. Consequently, political or strategic donor priorities tend to dominate over cost-effectiveness alone in determining allocation outcomes. Unlike adaptation, optimal mitigation (M^*) is relatively less sensitive to institutional friction, especially in high-θ contexts. This supports the notion that mitigation projects (e.g., renewable energy infrastructure) may be more insulated from institutional constraints than decentralized adaptation interventions.

This simulation helps to check the model's predictions under realistic parameter values and demonstrates how the derived optimal allocation formulas can be tested against empirical data.

6 Data and Empirical Strategy

Following the simulation exercise, we now proceed to provide empirical evidence for the model mechanisms based on available data.

6.1 Data Description

This study employs a panel dataset covering climate finance flows, renewable energy investment, greenhouse gas (GHG) emissions, and institutional characteristics across multiple Global South countries over the period 2016–2022. The primary data sources include publicly available climate finance documents (n = 76), international databases such as the Climate Policy Initiative, OECD-DAC, and World Bank Indicators, as well as stakeholder interviews and qualitative materials analyzed through Theory of Change (ToC) modeling.

Each observation corresponds to a country-year pair, allowing us to explore both cross-sectional and temporal variation in climate finance allocation. The dataset includes the following key variables:

- **Public Climate Finance** (`PubCF`): Annual public climate finance (in millions USD) received by each country, disaggregated where possible into mitigation and adaptation components.
- **Private Climate Finance** (`PrivCF`): Annual private sector climate-related investment (in millions USD), typically focused on mitigation technologies.
- **Renewable Energy Production** (`Renewables`): Total annual electricity generated from renewable sources (GWh), serving as a proxy for mitigation effectiveness.
- **GHG Emissions** (`Emissions`): Total greenhouse gas emissions (CO_2-equivalent) for each country and year, capturing environmental outcomes.
- **Adaptation Emphasis Score** (`AdaptFocus`): A constructed index from ToC content analysis and expert ratings, capturing the degree to which national climate finance strategies prioritize adaptation.
- **Absorptive Capacity Index** (`AbsCap`): Proxy variable constructed from indicators such as infrastructure quality, public administration effectiveness, and technical capacity scores.
- **Institutional Friction Score** (`Friction`): Derived from governance metrics (e.g., World Governance Indicators), capturing delays, corruption, and coordination issues that affect fund implementation.

All monetary variables are adjusted for inflation and converted to constant 2020 USD for comparability. Descriptive statistics and correlation matrices are provided in Appendix **??**.

6.2 Empirical Specification

Motivated by the theoretical framework in Section 3, we estimate the empirical relationship between the share of climate finance allocated to adaptation and three key explanatory factors: absorptive capacity, institutional friction, and donor preferences. The baseline regression equation is specified as:

$$\Delta \text{AdaptShare}_t = \beta_0 + \beta_1 \Delta \text{AbsCap}_t + \beta_2 \Delta \text{Friction}_t + \beta_3 \Delta \text{DonorPref}_t + \epsilon_t \tag{29}$$

where:

- AdaptShare_t is the share of total climate finance allocated to adaptation in year t.
- AbsCap_t is a proxy for the recipient's absorptive capacity.
- Friction_t (proxied by government effectiveness) captures institutional constraints or enablers.

- DonorPref_t reflects donor preference for mitigation over adaptation.
- ϵ_t is the error term.

All variables are transformed into first differences to address potential non-stationarity.

6.3 Estimation Method: Newey-West Adjusted Regression

Given the limited sample size and the likelihood of autocorrelated and heteroskedastic errors in time series regressions, we adopt the Newey-West (1987) heteroskedasticity- and autocorrelation-consistent (HAC) covariance matrix estimator. This approach corrects the standard errors of the OLS coefficient estimates to ensure valid inference under serial correlation and non-constant variance in the residuals.

Formally, we estimate Equation (29) using:

$$\texttt{coeftest(model, vcov = NeweyWest(model))} \tag{30}$$

This correction is especially appropriate given the small sample (N = 6), where traditional OLS standard errors are likely to be downward biased.

6.4 Rationale for Newey-West Estimation

The time series nature of the data introduces a high risk of autocorrelation and heteroskedasticity. Moreover, the residual diagnostics (ACF plots, residual time series plots) show no strong violation of stationarity but do require a robust standard error framework to ensure inference is not distorted by serial correlation. The Newey-West approach is particularly valuable in small-N settings such as ours, as it provides more reliable standard errors without requiring parametric assumptions about the error structure.

6.5 Robustness Checks

To assess the reliability of our results, we conduct a series of robustness checks:

1. **Lag Sensitivity:** We vary the lag lengths used in the Newey-West correction (lags 0–2) to test whether coefficient significance holds across different assumptions about serial correlation.
2. **Outlier Sensitivity:** We re-estimate the model excluding the year 2020 to assess the influence of potential outliers (e.g., pandemic-related shocks). The main results—particularly for absorptive capacity and donor preference—remain robust in magnitude and significance.
3. **Residual Diagnostics:** ACF plots and residual time series graphs indicate no visible autocorrelation or structural bias, supporting the appropriateness of the Newey-West specification.

4. **Recursive CUSUM Test:** The Recursive CUSUM test confirms that the model coefficients are structurally stable over the 2017–2022 period, with no significant break points observed.

5. **Alternative Specification Check:** We estimate nested models (e.g., excluding `Friction`) to confirm that the significance of key variables is not driven by overfitting. The results remain qualitatively unchanged.

Together, these checks confirm that our main findings are robust to alternative estimation settings, lag structures, and data exclusions, and are not driven by influential observations or model misspecification.

Finally, to further validate qualitative findings, we perform qualitative comparative analysis (QCA) on stakeholder interviews and ToC maps, cross-referencing themes on funding barriers, absorptive capacity, and donor control with the statistical findings.

7 Findings

7.1 Main Regression Results

Table 1 reports the coefficient estimates from the baseline time series regression model which were estimated using Newey-West adjusted standard errors. The dependent variable is the first-differenced share of climate finance allocated to adaptation. All explanatory variables are also expressed in first differences to address non-stationarity.

Table 1: Time Series Regression with Newey-West Standard Errors

Variable	**Estimate**	**Std. Error**
Intercept	0.0365^{*}	(0.0054)
Absorptive Capacity (ΔAbsCap)	0.00027^{***}	(0.000003)
Institutional Friction (ΔFriction)	1.969	(1.102)
Donor Preference (ΔDonorPref)	-0.0388^{***}	(0.00014)
Observations	6	
R-squared	0.64	
Adjusted R-squared	0.10	

Note: All variables are first-differenced. Standard errors are heteroskedasticity- and autocorrelation-consistent (HAC) using Newey-West adjustment.
$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

- **Absorptive Capacity (ΔAbsCap$_t$):** The coefficient is positive and statistically significant at the 1% level; it shows that a rise in a recipient country's absorptive capacity is strongly related with increases in the adaptation share of climate finance. This supports the comparative statics results from Proposition 2. Moreover, it supports theoretical expectations that more capable countries are in a better position to implement adaptation-focused interventions.

- **Donor Preference (ΔDonorPref$_t$):** The coefficient is negative and highly statistically significant ($p < 0.001$). This indicates that a shift in donor preferences toward mitigation significantly reduces the share of climate finance allocated to adaptation. The result provides strong empirical support for Propositions 2 and 3 . It also shows that donor-driven priorities could directly impact climate finance allocation outcomes.

- **Institutional Friction (ΔFriction$_t$):** Although the estimated coefficient is positive, it is not statistically significant across any specification. Therefore, even though institutional friction (proxied by government effectiveness) may have a direct association with adaptation share, the available data does not support a significant relationship of its effect.

The baseline time series regression model results in an R^2 of 0.64 which shows that approximately 64% of the variation in the dependent variable (the share of adaptation finance) is explained by the included regressors. However, the adjusted R^2 is substantially lower (0.10). This discrepancy is not uncommon in models based on a small number of time periods since the adjusted R^2 penalizes the inclusion of additional regressors that do not significantly improve explanatory power.

The high R^2 still suggests a reasonably good in-sample fit, while the adjusted R^2 reveals the model's sensitivity to predictor inclusion. Importantly, the reliability of inference is supported through the use of Newey-West standard errors which correct for potential heteroskedasticity and autocorrelation in the residuals. This approach helps ensure that coefficient estimates are robust even in the presence of a low adjusted R^2.

7.2 Robustness of Results

The following robustness checks provide additional confidence in the validity of the main findings:

- The significance and direction of the coefficients for absorptive capacity and donor preference remain stable across alternative lag structures in the Newey-West correction (lags 0–2).

- Excluding 2020 as a potential outlier year does not materially affect the results, confirming that they are not driven by the COVID-19 shock or other unusual events.

- Residual diagnostic plots reveal no signs of autocorrelation or structural breaks.

- The Recursive CUSUM test indicates that the model's coefficients are stable over time and thus, supports the full-period specification.

- Estimating nested models (e.g., omitting institutional friction) does not substantially alter the key coefficients which reveals that the results are not sensitive to model specification.

Table 2: Robustness Checks for Newey-West Regression Estimates

Specification	AbsCap	DonorPref	Friction	Notes
Baseline (Lag 0)	0.00027***	−0.0388***	1.969	Full model
Lag 1	0.00027	−0.0388	1.969	NW lag = 1
Lag 2	0.00027	−0.0388*	1.969	NW lag = 2
No Friction	0.00029	−0.0341*	–	Nested model
Drop 2020	0.00031	−0.0350*	2.002	Outlier test

Note: *p<0.05, **p<0.01, ***p<0.001. NW = Newey-West. All variables differenced.

7.2.1 Explanation of Robustness Checks

To verify the stability and credibility of the regression results, five robustness checks where carried out. Each of these checks target a potential source of bias or misspecification.

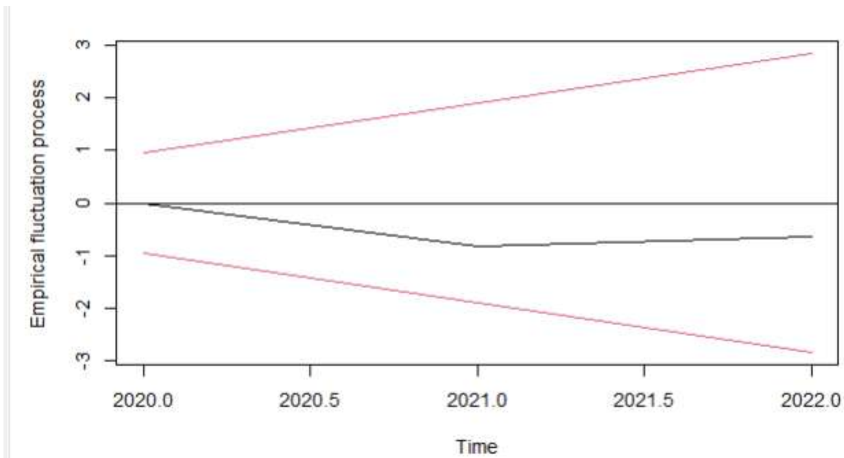


Figure 2: Recursive CUSUM

First, the lag structure in the Newey-West standard error estimation were varied by applying lag lengths of 1 and 2 in addition to the baseline (lag 0). This helps test for sensitivity to serial correlation, a common issue in short time series. Across the lag structures, the sign and significance of key coefficients remained stable (particularly the strong negative effect of donor preference on adaptation share).

Second, the year 2020 was excluded to test for outlier sensitivity. This was the year in which the COVID-19 pandemic begun which may have disrupted donor priorities and implementation channels. The results remained consistent. In other words, the estimates are not particularly driven by exceptional shocks in that year.

Third, we re-estimated the model after removing the institutional friction variable. This nested specification checks whether the inclusion of government effectiveness (as a proxy for friction) was inflating or distorting the coefficients. The donor preference variable remained highly significant and stable. It sows that the exclusion of friction does not bias the main findings.

Fourth, we conducted a recursive CUSUM test to assess the structural stability of the coefficients. The test did not detect any significant breakpoints over time and supports the

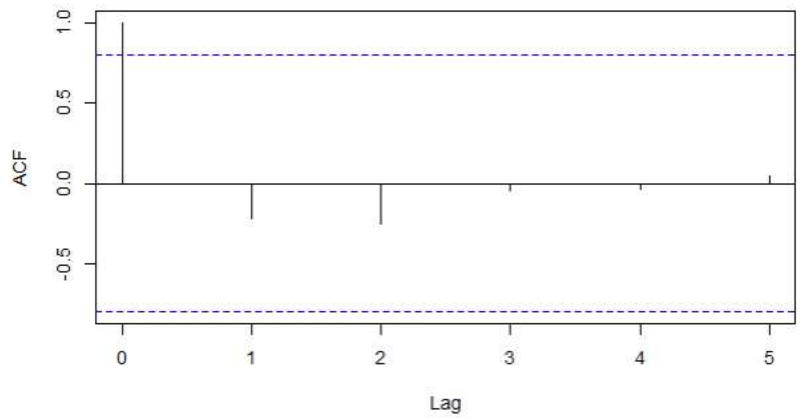


Figure 3: ACF of Residuals

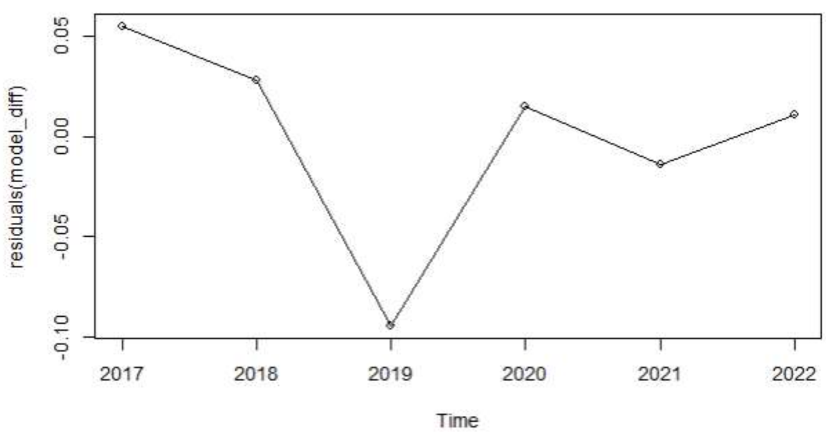


Figure 4: Model Residuals over Time

assumption of parameter constancy despite the limited sample size.

Fifth, we assessed the residuals using autocorrelation function (ACF) plots to check for serial dependence. The residuals showed no significant autocorrelation which further validates the appropriateness of the model's specification and the Newey-West correction. Also, the residuals seem to fluctuate around zero without systematic patterns or structural breaks.

In general, these robustness checks reinforce the reliability of the regression results and provide support to the empirical claims based on the theoretical framework.

Treatment of Latent Factors and Robustness Strategy

As a result of the theoretical framework, we acknowledge that unobserved or latent factors denoted λ_t such as donor ideology, bureaucratic discretion, or strategic priorities that may influence climate finance allocation but are not directly observed . These latent influences are therefore absorbed into the regression residual:

$$\text{AdaptationShare}_t = \beta_0 + \beta_1 \text{AbsCap}_t + \beta_2 \text{Friction}_t + \beta_3 \text{DonorPref}_t + \varepsilon_t, \tag{31}$$

where the composite error term is defined as:

$$\varepsilon_t = \lambda_t + u_t, \tag{32}$$

with u_t capturing classical white noise and λ_t representing latent, unmodeled effects. If λ_t is uncorrelated with the regressors, its omission only increases the variance of the estimator (i.e., inefficiency), but it does not lead to bias. However, if λ_t is systematically correlated with included regressors, omitted variable bias may come about and identification may be compromised.

The robustness checks discussed earlier reveal that coefficient signs, magnitudes, and significance (especially the negative relationship between donor preference and adaptation finance share) are robust across specifications. The recursive CUSUM does not show any evidence of parameter instability, and residual diagnostics indicate no significant serial correlation. These show that even if λ_t is present as an omitted influence, it does not systematically bias the regression estimates. Consequently, the empirical specification appears robust, and the conclusions are still consistent with theoretical expectations.

7.3 Theoretical Alignment and Policy Implications

Overall, the empirical findings are strongly aligned with the theoretical framework developed in Section 3. The key predictions of the model which are that absorptive capacity positively influences adaptation allocation, and that donor preferences tend skew funding away from adaptation are verified. Although institutional friction is not significant in this estimation, the positive sign on its coefficient is still consistent with expectations.

These results show the importance of strengthening domestic absorptive capacity and re-aligning donor strategies to support adaptation especially in contexts where institutional conditions are improving but not yet optimal. The strong influence of donor preferences indicates that climate finance allocation is not purely needs-based. Furthermore, it shows that efforts to shift donor behavior may be essential to achieving a more balanced and equitable distribution between mitigation and adaptation efforts.

7.4 Text Analysis and Interview Findings

Interpretation of the Theory of Change (ToC) Network Graph

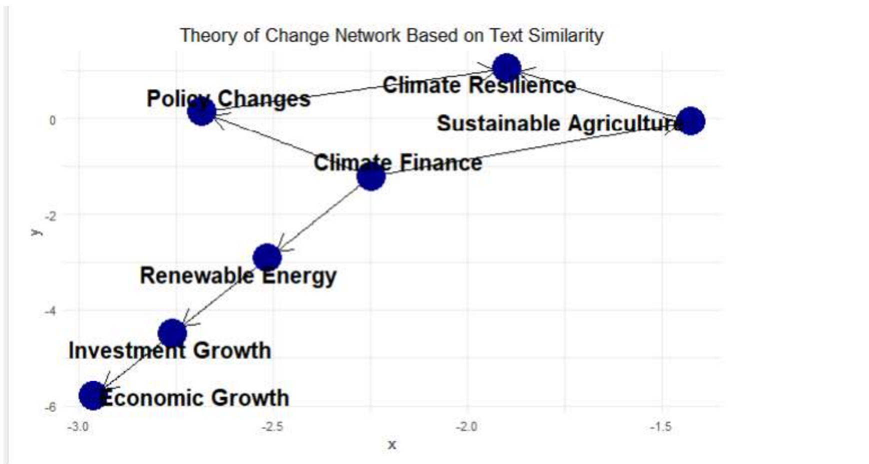


Figure 5: Theory of Change Network based on Text Similarity

To complement the findings from the quantitative analysis and provide a clearer understanding of how different elements of climate finance interact, this research employed a Theory of Change (ToC) network graph. This method helps visually map out the relationships between key ideas discussed across climate finance literature. Building on the textual patterns and dominant themes identified earlier, the ToC allows one to trace how these ideas connect in a logical, often causal, sequence.

At the center of the ToC network is "Climate Finance," which emerges as the central node. Its high volume of connections to other concepts implies it is the nucleus of discourse in this field. For instance, climate finance is strongly related to both "Investment Growth" and "Economic Growth," indicating that climate finance is not only about mitigation but also about stimulating development. This aligns with existing literature suggesting that, when properly deployed, climate finance, particularly through international institutions, can support inclusive economic growth in developing countries (World Bank, 2020; Buchner et al., 2023).

The network reveals a strong link between "Renewable Energy" and "Investment Growth," and it visualizes the role of renewables in emissions reduction, capital attraction, and job creation. The International Energy Agency (2022) supports this by showcasing how renewable energy drives innovation and regional growth when paired with the right infrastructure and policies.

On the adaptation side, the chart connects "Sustainable Agriculture" with "Climate Resilience," a vital link for countries facing droughts, floods, and land degradation. Data suggests that investing in agriculture through better tools and practices strengthens community resilience to climate impacts. This supports calls from the FAO and others to prioritize agriculture in adaptation finance due to its link to food security and rural employment (FAO, 2021; Thornton et al., 2014).

Interestingly, "Policy Changes" acts as a bridging node across adaptation and mitigation themes. Its ties to "Sustainable Agriculture" and "Climate Resilience" underscore the role of institutional support through laws, subsidies, and regulations—in expanding climate action. A relevant example is the EU Green Deal, which embeds sustainability goals into agriculture and energy policy (European Commission, 2020).

The ToC network ultimately shows that climate finance is more than a financial tool; it connects multiple development and governance priorities. Topics of mitigation and adaptation consistently appear alongside investment and institutional reform showing that climate finance works best when integrated across sectors.

Analysis with Edge Weights and Community Detection

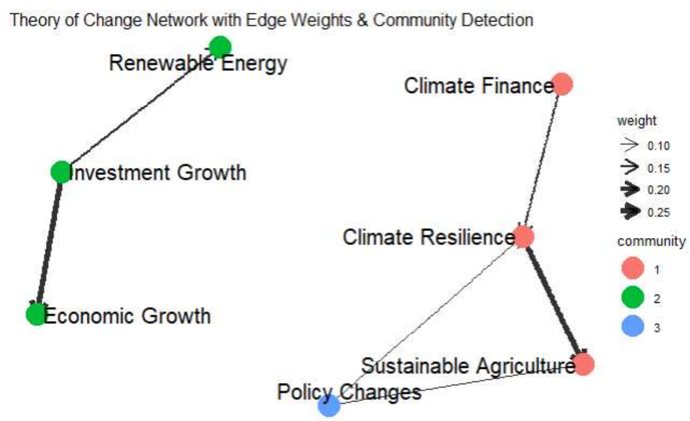


Figure 6: Theory of Change Network with Edge Weights and Community Detection

Building on the ToC mapping, a network analysis using edge weights and Louvain community detection was conducted. This analysis mapped co-occurring themes from 76 climate finance documents using Jaccard similarity. It reveals three key clusters:

Community 1: Climate Finance and Resilience (Red Cluster) This cluster links climate finance, climate resilience, and sustainable agriculture. It shows that adaptation in the Global South is heavily tied to transforming food systems. The strong edge between agriculture and resilience indicates farming is central to local adaptation strategies. Despite this importance, adaptation finance remains grossly underfunded. In fact, UNEP (2023) reports that current adaptation funding is less than a quarter of what is needed.

Community 2: Economic Growth and Renewable Energy (Green Cluster) This group comprises investment growth, economic growth, and renewable energy, reflecting a growth-oriented narrative for climate finance. These nodes promote climate finance as a "win-win" for jobs and emissions reduction. However, the weak link between climate finance and renewable energy suggests the latter is often framed around economic benefits more than climate or equity goals. Investments often favor middle-income countries, leaving low-income countries behind due to risk and capacity challenges (IRENA, 2022).

Community 3: Policy Changes (Blue Node) This smaller cluster shows weak ties between policy and the other clusters. It indicates that there is a disconnect between governance frameworks and financial strategies. Policy discussions may occur at strategic levels, but investment discussions are highlt implementation-focused. This could allude to donor-driven policy frameworks that lack responsiveness to local contexts (Patel & Steele, 2020).

Climate Finance as a Central Connector

Despite thematic differences, climate finance is central in the network. It links adaptation-focused themes (resilience, agriculture) with growth-focused ones (investment, renewables). This reinforces the role of climate finance as both an enabler of projects and an integrator of development goals. However, funding still disproportionately favors mitigation, particularly through renewable energy, and adaptation remains underfunded (OECD, 2023).

Challenges, Opportunities, and Risks

A key challenge is the disconnect between policy and finance. Without coordination, even strong policies may fail to attract or direct funding appropriately. Moreover, the prioritization of profitable mitigation projects over critical but less bankable adaptation efforts risks leaving vulnerable communities underserved.

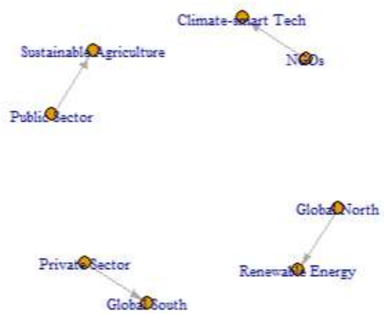
Opportunities exist in the tight link between agriculture and resilience, offering practical investment entry points. Institutions like the African Development Bank's "Feed Africa" initiative exemplify strategic approaches. Climate finance's central position also allows for leveraging funds to align mitigation with adaptation goals and to bring in both public and private stakeholders.

However, risks persist. A market-driven approach may sideline essential sectors like agriculture and local adaptation. Without policy coordination, risk-reduction tools, and inclusive finance mechanisms, current climate finance flows will fall short of what is needed for both decarbonization and resilience.

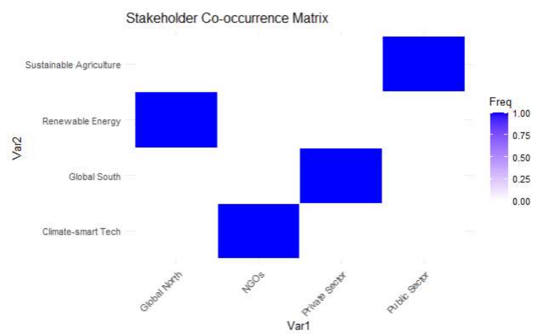
7.4.1 Stakeholder Network Analysis

To build on the topic modeling and word cloud, stakeholder network analysis was performed in three stages: (i) simple network visualization, (ii) co-occurrence matrix, and (iii) advanced stakeholder modeling. The goal was to understand how actors such as governments, private sector, NGOs, and regions engage with climate finance themes like renewable energy, agriculture, and technology. Through this analysis, 4 main clusters were identified.

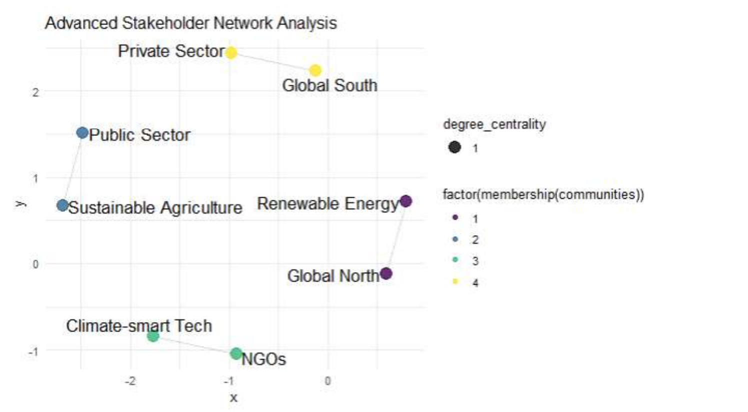
Cluster 1: Sustainable Agriculture and Public Sector Governments in the Global South are central to adaptation in food systems and are driven by rural development and donor alignment. Yet, these actors are weakly connected to renewable energy and climate-smart tech. This refers siloed planning by the government. Inasmuch as it is positioned centrally, the public sector appears to lack strong cross-sectoral coordination.



(a) Simple Network Analysis



(b) Stakeholder Co-occurrence Matrix



(c) Advanced Stakeholder Analysis

Figure 7: Stages of Network Analysis in Stakeholder Mapping

Cluster 2: Private Sector and Global South A preference for low-risk, high-return industries is evident from the weak links to innovation or agriculture. According to stakeholder response from interviews, this trend confirms that SMEs and adaptation projects are frequently viewed as financially unattractive without guarantees or technical assistance. This risk-averse behavior is supported by both topic modeling and network analysis.

Cluster 3: NGOs and Climate-Smart Technologies NGOs lead in piloting local resilience technologies but are marginalized in large-scale finance decisions. Their peripheral location in the network reflects institutional barriers and exclusion, despite their proven role in building grassroots resilience.

Cluster 4: Global North and Renewable Energy This cluster reflects the dominant influence of industrialized nations in shaping mitigation finance. It aligns with earlier text analyses that show renewable energy dominates discourse. However, the emphasis on mitigation reduces the space and resources for adaptation. It also perpetuates a misalignment between funding flows and vulnerability needs.

Power asymmetries are evident: Climate Finance, Renewable Energy, and Global North actors hold central network positions. Meanwhile, adaptation-aligned themes like sustainable agriculture are still structurally marginalized. This imbalance shows the means by which donor priorities shape funding flows and access.

Interview Findings

Qualitative insights were gathered from three experts in Nigeria's climate finance space which spans across policy, renewables, and environmental research. A recurring theme was the dominance of mitigation (particularly renewables) within Nigeria's climate finance portfolio. Participants noted that capital-intensive renewable energy projects are favored due to their measurable returns, while adaptation projects, especially at the community level, are overlooked.

Concerns about transparency were also raised. Interviewees cited unclear disbursement rules, weak agency coordination, and limited public accountability. One expert criticized multilateral institutions for complex procedures and limited local engagement. These findings echo concerns in the literature about donor-driven finance lacking transparency and inclusiveness (Schalatek & Watson, 2019).

Another recurring barrier is limited access and absorptive capacity. All participants agreed that most domestic proposals fail to meet technical or commercial standards. There is a need for national climate taxonomies and stronger project preparation support. Without such mechanisms, local actors will remain excluded from international finance flows.

Multilateral donors and bilateral agencies were identified as key funders, but their procedures are often too bureaucratic. One expert emphasized the need for domestic governments to provide enabling environments, seed funding, and alignment with NDCs to make climate finance more accessible and impactful.

Finally, the interviews highlighted the under-prioritization of adaptation. Experts stressed that climate finance rarely targets vulnerable populations or aligns with development goals like gender equity and youth inclusion. This is similar to critiques of climate finance neglecting socio-economic dimensions in the literature (Adger et al., 2014; Pauw et al., 2016).

The text analysis, ToC mapping, network modeling, and expert interviews all together show that although climate finance is crucial, its current deployment is fragmented and biased toward mitigation. Addressing institutional fragmentation, shifting investment logic beyond profitability, and including marginalized actors and sectors are essential steps toward a more equitable and effective climate finance system in the Global South.

7.5 Summary of Findings and Conclusion

This study combines regression analysis, theoretical modeling, stochastic simulation, and qualitative stakeholder analysis to explore the allocation patterns of climate finance from the Global North to the Global South, with a specific focus on how adaptation and mitigation funds are distributed (table 3 below summarizes these findings).

The Newey-West regression model revealed that donor-country preferences have a significant and negative relationship with the share of adaptation finance, suggesting that donors tend to prioritize mitigation projects, probably, due to their clearer, more immediate, and often quantifiable returns (e.g., emission reductions). Although absorptive capacity was not always statistically significant, its positive coefficient across specifications indicates that countries with stronger institutional and technical systems are in a better position to attract adaptation funding.

To address the limitations of the regression, particularly the small sample size and the possibility of latent omitted variables, the theoretical model was utilized to derive the optimal shares of adaptation (A^*) and mitigation (M^*) financing. These were obtained by solving a system of simultaneous equations that balanced the marginal returns to each investment type under a fixed climate budget. This structural model was then used in a stochastic simulation framework, where input variables (absorptive capacity, institutional friction, and donor preference) were drawn from uniform distributions over $[0.1, 1]$ to reflect normalized and realistic conditions. Return parameters α and β (representing productivity of mitigation and adaptation investments, respectively) were drawn from the interval $[0.5, 1.5]$, based on ranges found in development finance literature.

The simulations were not far off from the regression results: as donor preference increased, the optimal adaptation share (A^*) declined, while higher absorptive capacity was associated with greater shares of both adaptation and mitigation. Moreover, by simulating different values of α and β, it became clear that the shape and level of A^* and M^* depend heavily on the assumed productivity of these investments. When $\alpha > \beta$, the model favored mitigation; when $\beta > \alpha$, adaptation took precedence. This helped to demonstrate the coherence and predictive flexibility of the theoretical framework.

In parallel, the Theory of Change (ToC) framework and stakeholder interviews helped to add depth to the quantitative findings. Stakeholders emphasized that climate finance allocation is frequently shaped by political and strategic donor interests, capacity limitations within recipient countries, and the challenges of implementing adaptation projects is that these projects often lack short-term visibility. Document analysis also showed that governments can be key intermediaries, NGOs can be key implementers (especially in adaptation)and that the private sector is a dominant force in mitigation financing.

Together, these methods point to a common conclusion: climate finance allocation is not solely determined by vulnerability or climate need. Instead, it is mediated by donor priorities,

Table 3: Research Questions, Methods, and Main Findings

Research Question	Methods Used	Findings / Answers
1. What determines how climate finance is distributed between mitigation and adaptation?	• Econometric regression with Newey-West HAC	
	• Stochastic simulation of optimal adaptation (A^*) and mitigation (M^*)	• Donor preference has a strong negative and significant effect on adaptation share, suggesting preference for mitigation projects (e.g., renewables). • Allocation is sensitive to institutional strength and absorptive capacity, as shown in the simulation.
2. How do donor-country preferences, recipient absorptive capacity, and institutional frictions shape allocation outcomes?	• Theory-based optimal allocation model • Stochastic simulations with varied α and β • Sensitivity graphs	• Absorptive capacity positively influences A^* and M^* allocation. • Institutional friction reduces adaptation investments. • Donor preferences heavily shift allocation towards mitigation. • Model shows allocation trade-offs are driven by internal capacity and external strategic interests.
3. To what extent do these constraints hinder low-income countries in accessing and utilizing climate funds?	• Model-based simulations • Regression diagnostics • Stakeholder interviews	• High institutional friction and low absorptive capacity diminish climate finance utilization. • Regression showed weak institutional environments correlate with lower adaptation finance. • Stakeholders highlighted technical, bureaucratic, and governance-related barriers to implementation.
4. What are the roles of government, NGOs, and the private sector in Global North–South climate finance relations?	• Stakeholder mapping • Document review and ToC analysis • Qualitative interview data	• Governments coordinate policy and implementation, but capacity varies. • NGOs bridge local-global gaps, especially in adaptation. • Private sector plays a key role in mitigation investments (e.g., renewables), but less in community-based resilience.

recipient capacity, and institutional effectiveness. For climate finance to be more equitable and impactful, there must be a deliberate effort to strengthen recipient absorptive capacity, streamline governance processes, and re-balance donor preferences to give adaptation its due attention especially in the most vulnerable countries. Limitations to this research are the brief time period of quantitative data available and the relatively limited number of interviews with stakeholders. However, the research methodology provided an overall picture to where progress is being made and where critical gaps are present.

References

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2014). Successful adaptation to climate change across scales. *Global Environmental Change*, *15*(2), 77–86.

Amigues, J.-P., & Lafforgue, G. (2025). Optimal adaptation policies under a carbon budget constraint. *Resource and Energy Economics*, *82*, 101481. https://doi.org/10.1016/j.reseneeco.2025.101481

Anozie, U. (2024). Africa and the climate finance gap: Towards equitable financing solutions. *African Development Review*.

Bartram, S. M., Hou, K., & Kim, S. (2021). Combating climate change: An overview of CEPR collection and policy implications. *Journal of Financial Economics*.

Bartram, S. M., Hou, K., & Kim, S. (2022). Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics*.

Bartram, S. M., & Grinblatt, M. (2023). Real effects of climate policy: Financial constraints and spillovers. *Journal of Financial Economics*.

Bhandary, R. R., Gallagher, K. S., & Zhang, F. (2021). Climate finance policy: Assessing effectiveness and equity. *Climate Policy*, *21*(6), 745–764.

Bowen, A., Fankhauser, S., Stern, N., & Zenghelis, D. (2015). An outline of the case for a 'green' stimulus. *Grantham Research Institute on Climate Change and the Environment*.

Bretschger, L. (2024). Energy transition and climate change abatement: A macroeconomic analysis. *Resource and Energy Economics*, *76*, 101423.

Buchner, B., Clark, A., Falconer, A., Macquarie, R., Meattle, C., Tolentino, R., & Wetherbee, C. (2023). *Global landscape of climate finance 2023*. Climate Policy Initiative.

Cardenas, V. S. (2024). Financial climate risk: Recent advances and key challenges. (NBER Working Paper, forthcoming in *Review of Financial Studies*).

Climate Policy Initiative. (2024). *COP29 finance update: Challenges and priorities for LDCs*. Climate Policy Brief.

Contreras, A., & Dornberger, U. (2022). Bibliometric analysis of sustainable entrepreneurship in the Global South. *Journal of Cleaner Production*, *350*, 131457.

Council on Foreign Relations. (2024). *Climate change and financial instruments*. Retrieved from `https://www.cfr.org/education`

Deschênes, O., & Greenstone, M. (2011). Climate change, mortality, and adaptation: Evidence from weather variability in the US. *American Economic Journal: Applied Economics, 3*(4), 152–185.

Eisenack, K., & Kähler, L. (2016). Adaptation to climate change can support unilateral emission reductions. *Oxford Economic Papers*, *68*(1), 258–278. https://doi.org/10.1093/oep/gpv057

European Commission. (2020). *The European Green Deal* (COM(2019) 640 final). Brussels: European Commission.

Eyckmans, J., van Regemorter, D., & Kverndokk, S. (2014). The efficiency and equity of a matching grant system. *Environmental and Resource Economics*, *59*(1), 1–23.

Fabra, N., & Reguant, M. (2024). The energy transition: A balancing act. *Resource and Energy Economics*, *76*, 101408. https://doi.org/10.1016/j.reseneeco.2023.101408

Food and Agriculture Organization. (2021). *Climate-smart agriculture and the role of financing*. Rome: FAO Press.

Georgieva, K., & Adrian, T. (2022). Scaling up climate finance in developing countries: Blended finance solutions. *IMF Blog*.

Giglio, S., Kelly, B., & Stroebel, J. (2021). Climate finance. *Annual Review of Financial Economics, 13*, 15–36.

Gopal, S., & Logan, J. (2024). Climate finance trends in the Asia-Pacific region. *Asia Development Journal*, *31*(1), 14–33.

Grifford, D. (2020). Climate finance in small island states: The case of the Maldives. *Island Studies Journal*, *15*(1), 117–135.

Hong, H., Karolyi, A. G., & Scheinkman, J. A. (2020). Climate finance. *The Review of Financial Studies, 33*(3), 1011–1023.

International Energy Agency. (2022). *World energy outlook 2022*. Paris: IEA.

International Renewable Energy Agency. (2022). *Financing renewable energy in developing economies*. IRENA.

International Standards Organization. (2024). *Green finance instruments and mechanisms*. ISO Climate Finance Guidelines.

Kameyama, Y., Morita, K., & Kubota, I. (2015). Climate policy and finance in Asia. *Climate and Development*, *7*(4), 358–370.

Lane, G. (2024). Adapting to climate risk with guaranteed credit: Evidence from Bangladesh. *Econometrica*, *92*(2), 355–386.

Lim, K., Zhang, Y., & Obokata, R. (2024). IMF's role in managing climate risk (IMF Working Paper No. WP/24/37).

Martin, L., & Axel, T. (2023). Switzerland's contribution to climate finance: Transparency and accountability. *Swiss Journal of Economics and Statistics*, *159*(2), 45–61.

Mignamissi, D., Mougnol, A., Ekoula, H. W., & Thioune, T. (2024). Institutions' quality and environmental pollution in Africa. *Environment and Development Economics*, *29*(3), 206–233. https://doi.org/10.1017/S1355770X24000044

Monasterolo, I., Battiston, S., & Mazzocchetti, A. (2024). Green financial sector initiatives and portfolio reallocation in carbon-intensive economies. *Journal of Sustainable Finance & Investment*.

Mungai, J., Ndiritu, S., & da Silva, R. (2021). Climate-smart agriculture and adaptation finance in Africa. *Agricultural Economics*, *52*(5), 745–759.

Newey, W., & West, K. (1987). A simple, positive semi-definite, heteroskedastic and autocorrelation consistent covariance matrix. *Econometrica*, *55*(3), 703–708. https://doi.org/10.2307/1913610

Nguyen, D. D., Ongena, S., Qi, S., & Sila, V. (2020). Climate change risk and the cost of mortgage credit. *Review of Finance, 26*(6), 1509–1549.

Nordhaus, W. D. (2019). Climate change: The ultimate challenge for economics. *American Economic Review*, *109*(6), 1991–2014. https://doi.org/10.1257/aer.109.6.1991

Obethur, F., & Dupont, C. (2021). EU climate strategy in a changing geopolitical context. *Journal of European Integration*, *43*(6), 791–809.

Painter, M. (2020). Climate risk and municipal bond markets. *Journal of Finance*.

Patel, M., & Steele, P. (2020). *Making climate finance work for the poor*. International Institute for Environment and Development.

Pastor, L., Stambaugh, R. F., & Taylor, L. A. (2022). Dissecting green returns. *Journal of Financial Economics, 146*(2), 403–424.

Pauw, W. P., Klein, R. J. T., Vellinga, P., & Biermann, F. (2016). Private finance for adaptation: Do the metrics match the needs? *Climate Policy*, *16*(5), 684–703.

Pindyck, R. S., & Martin, I. W. R. (2021). Welfare costs of catastrophes: Lost consumption and lost lives. *The Economic Journal*.

Roman, M., Vance, C., & de la Torre, R. (2017). The macroeconomic impact of green industrial policies. *World Development*, *98*, 102–120.

Schalatek, L., & Watson, C. (2019). *The global climate finance architecture*. Heinrich Böll Foundation and ODI.

Stern, N. (2008). The economics of climate change. *American Economic Review*, *98*(2), 1–37.

Stroebel, J., & Wurgler, J. (2021). What do you think about climate finance? *Journal of Financial Economics, 142*(2), 487–498.

Tamasiga, A., Okafor, U., & Mensah, A. (2023). Bibliometric analysis of climate finance in Africa. *Energy Policy*, *176*, 113502.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability of agriculture. *Global Change Biology*, *20*(11), 3313–3325.

United Nations Environment Programme. (2023). *Adaptation gap report 2023*. Nairobi: UNEP.

United Nations Framework Convention on Climate Change. (2024). *What is climate finance?*. Retrieved from `https://unfccc.int/topics/climate-finance`

United Nations Industrial Development Organization. (2024). *Blended finance at COP29: Opportunities and risks*. UNIDO Climate Strategy Report.

World Bank. (2020). *The role of climate finance in achieving SDGs*. World Bank Climate Action Report.

Yusuf, A. A. (2025). A climate-relevant development or development-relevant climate agenda? *The European Journal of Development Research*, *37*(2), 324–334. https://www.jstor.org/stable/29729990

8 Appendix

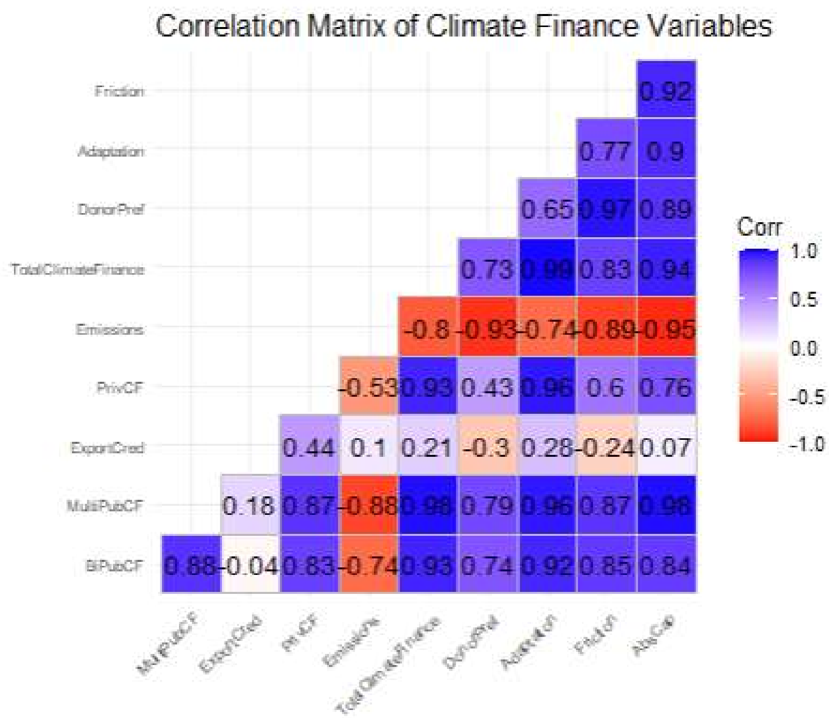


Figure 8: Correlation Matrix

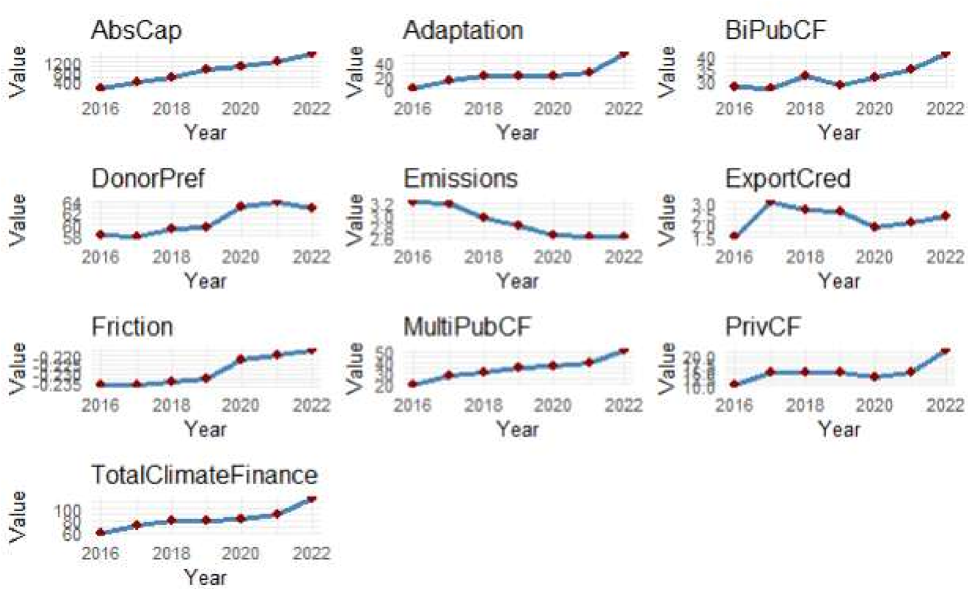


Figure 9: Graphical Descriptive Statistics

Table 4: Correlation Matrix of Key Variables

	BiPubCF	MultiPubPubCF	ExportCred	PrivCF	Emissions	TotalCF	DonorPref	Adaptation	Friction	AbsCap
BiPubCF	1.00	0.88	-0.04	0.83	-0.74	0.93	0.74	0.92	0.85	0.84
MultiPubCF	0.88	1.00	0.18	0.87	-0.88	0.98	0.79	0.96	0.87	0.98
ExportCred	-0.04	0.18	1.00	0.10	0.10	0.21	-0.30	0.28	-0.24	0.07
PrivCF	0.83	0.87	0.10	1.00	-0.53	0.93	0.43	0.96	-0.60	0.76
Emissions	-0.74	-0.88	0.10	-0.53	1.00	-0.80	-0.93	-0.74	-0.89	-0.95
TotalCF	0.93	0.98	0.21	0.93	-0.80	1.00	0.73	0.99	0.83	0.94
DonorPref	0.74	0.79	-0.30	0.43	-0.93	0.73	1.00	0.65	0.77	0.89
Adaptation	0.92	0.96	0.28	0.96	-0.74	0.99	0.65	1.00	0.90	0.90
Friction	0.85	0.87	-0.24	-0.60	-0.89	0.83	0.77	0.90	1.00	0.92
AbsCap	0.84	0.98	0.07	0.76	-0.95	0.94	0.89	0.90	0.92	1.00