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Determinants of Climate Finance for Infrastructure: Toward a Fairer Green Transition?

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This article investigates the determinants of climate finance for infrastructure, focusing on whether allocations reflect recipient needs, merits, or donor and investors interests. While prior research has mainly examined aggregate flows, this study develops a sectoral perspective on transport, energy, and water and sanitation, integrating two infrastructure-related determinants: the profitability of infrastructure investments and sector-specific vulnerabilities. Using dynamic panel models with System GMM covering 2000–2022, the analysis disaggregates flows by climate theme (mitigation/adaptation) and financial instrument (grants/debt). Results show that profitability, proxied by private participation in infrastructure, is consistently associated with higher climate finance, especially in debt-based flows and mitigation projects. Vulnerability plays a more limited role, emerging primarily in grant allocations and selected sectors. Conventional determinants such as population, official development assistance (ODA) per capita, and extreme political events also matter. These findings highlight tensions between return and equality, suggesting that current allocation patterns risk reinforcing an "unjust" green transition unless vulnerability is more systematically prioritized.

KEYWORDS: infrastructure; climate finance; vulnerability; green transition.

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1. Introduction

Infrastructure plays a central role in promoting economic and social development. A well-functioning infrastructure system can enhance productivity, reduce transaction costs, facilitate trade, and enable the efficient allocation of resources across regions and sectors. Investments in transport, energy, and water infrastructure have been consistently linked to long-term economic growth, structural transformation, and improved access to markets and services (Bird and Straub, 2020; Medeiros *et al.*, 2025; Redding and Turner, 2015; Straub, 2011). Moreover, infrastructure development has the potential to reduce spatial inequalities and contribute to poverty alleviation by expanding opportunities in underserved areas (Lu *et al.*, 2022; Medeiros *et al.*, 2021, 2022).

However, the expansion of infrastructure—particularly when pursued through carbon-intensive models—can also lead to significant environmental degradation. Road construction, fossil fuel-based energy generation, and large-scale water projects often result in increased greenhouse gas emissions, habitat destruction, and heightened exposure to climate risks (Awad *et al.*, 2023; Churchill *et al.*, 2021; Emodi *et al.*, 2022). These tensions underscore the need to balance developmental goals with environmental sustainability, especially in the context of climate change and the global transition toward low-carbon, resilient infrastructure systems.

This is particularly important for developing countries that are the most vulnerable to climate related natural disasters (IPCC, 2023). Green infrastructure could reduce vulnerability to natural disasters, increasing resilience to climate change, simultaneously as improving the aforementioned economic and social indicators. However, developing countries are in a weaker fiscal position - often facing debt distress (Gallagher *et al.*, 2024) - to coordinate and finance domestically the necessary infrastructure projects. In addition, developing countries with higher exposure to climate vulnerability face higher cost of capital (Beirne *et al.*, 2021; Bosma *et al.*, 2025; Kling *et al.*, 2025). Increasing access to climate finance, including grants and concessional loans with improved terms, are extremely relevant to viable green infrastructure solutions (UNCTAD, 2025).

Climate finance has increasingly been promoted as a win–win strategy to address the environmental externalities of infrastructure while advancing economic and social goals (Venner *et al.*, 2024). By channeling resources toward low-carbon and climate-resilient investments, climate finance is framed as a means to simultaneously support growth, reduce risk, and foster long-term sustainability. This narrative positions climate-related spending not as a cost, but as an opportunity— particularly when targeted at sectors such as energy, transport, and water systems, where emissions reduction and resilience can be integrated with sustainable development gains. Within this broader discourse, climate finance is often cited as a case in point, offering so-called "triple dividends" by preventing future losses, stimulating growth, and delivering co-benefits for communities and ecosystems (Ki-moon *et al.*, 2019).

Understanding the allocation patterns of climate finance is crucial for evaluating the effectiveness and fairness of the current climate finance architecture. Previous studies have typically analyzed these patterns through three groups of conventional determinants: recipient needs, recipient merits, and donor interests (Batsy and Ghachem, 2022; Betzold and Weiler, 2017; Islam, 2022; Liu *et al.*, 2024; Persson and Remling, 2014; Xie *et al.*, 2023). Needs-based factors capture countries' exposure and sensitivity to climate risks, such as vulnerability to climate change, greenhouse gas emissions (GHG) intensity, poverty levels, income, population. Merit-based factors emphasize governance and absorptive capacity, reflecting how effectively finance can be used. Donor-interest factors relate to the strategic or economic motivations of providers, including trade ties and geopolitical considerations.

Empirical studies have shown that the weight of these determinants is uneven. While international agreements emphasize needs-based allocation— especially for adaptation— evidence suggests that vulnerability only partially drives funding, and often in inconsistent ways (Barrett, 2014; Halimanjaya, 2015; Islam, 2022). Instead, merit-based factors such as institutional readiness and absorptive capacity, and donor-interest factors linked to trade and political relationships, are frequently stronger predictors of climate finance flows (Doku *et al.*, 2021; Islam, 2022; Weiler and Klock, 2021). This raises concerns about the legitimacy of the system and the extent to which it truly supports the most climate-vulnerable countries.

A key gap in the existing literature is its predominant focus on aggregate climate-finance flows, with little attention to sector-level disaggregation. Yet, infrastructure sectors— such as energy, transport, and water and sanitation— differ markedly in their exposure to climate risks and in their ability to generate financial returns. Few exceptions are the studies by Basty and Ghachem (2022) and Fageda and Fioravanti (2025). Evaluating the determinants of adaptation finance in five sectors (food, water, health, infrastructure and habitat), Basty and Ghachem (2022) argue the current practice of adaptive financing for the infrastructure sector is confusing the costs of climate change impacts with the real costs of adaptation measures. This does not make donations affected by the level of vulnerability of the sector. Providing some evidence on the determinants of climate finance in the transport sector, Fageda and Fioravanti (2025) found that mitigation fund allocation is particularly correlated with the demographic characteristics of recipient countries, while equity considerations (especially related to vulnerability) appear to be the main determinants of adaptation fund allocation. While those papers provide relevant evidence on the determinants of climate finance under a sectorial view, they do not investigate some critical infrastructure-related determinants such as the expected returns on infrastructure investments and sectoral vulnerability. The lack of this sectoral perspective may obscure allocation dynamics that are crucial for understanding whether climate finance is aligned with both efficiency and equity objectives.

In this paper, we therefore incorporate two infrastructure-related determinants. The first is the returns on infrastructure investments, proxied by private participation in infrastructure (PPI), which captures the economic attractiveness and profitability of infrastructure projects. The second is infrastructure-related vulnerability, measured through indicators of infrastructure stock, quality, and access, which reflect the extent to which infrastructure systems are exposed to climate risks and insufficiently prepared to cope with them. While the first determinant reflects a merits-based and market-oriented logic, the second is closer to a needs-based allocation principle. Both can significantly influence how climate finance is distributed.

Moreover, allocation patterns may vary depending on the climate theme (mitigation or adaptation) and the financial instrument (grants or debt). Mitigation projects, particularly in energy and transport, often yield clearer revenue streams and attract debt-based instruments, while adaptation projects— such as those in water and sanitation— rely more heavily on grants. In practice, debt-based instruments are increasingly delivered through a mix of concessional and non-concessional instruments, including market-based loans mobilized by development finance institutions. This evolving composition underscores the need to examine not only the volume of climate finance, but also its financial nature and degree of concessionality when assessing alignment with development and equity goals. These heterogeneities underscore the importance of distinguishing not only between sectors, but also between instruments and objectives, when analyzing climate finance for infrastructure (Venner *et al.*, 2024).

These dynamics are central to the broader debate on a just—or unjust—green transition (Wang *et al.*, 2021). If climate finance continues to be steered primarily by profitability and delivered through debt instruments, flows may reinforce structural inequalities by privileging countries with stronger infrastructure baselines and institutional quality. Even when such debt instruments contain concessional elements, they still increase the debt burden of recipient countries— many of which already face high or unsustainable levels of indebtedness. In the context of developing economies, these dynamic risks create self-reinforcing debt trajectories that constrain fiscal space and limit the ability to invest in resilience or social inclusion. Conversely, when allocation is responsive to vulnerability, climate finance can play a redistributive role, supporting resilience and inclusion. The determinants analyzed here therefore provide a useful lens to assess whether climate finance advances infrastructure or hinders distributive justice in global climate governance.

This article investigates how infrastructure investment returns and infrastructure-related vulnerabilities affect the allocation of climate finance across countries and sectors.. To do so, we estimate dynamic panel models using the System GMM estimator, covering the period 2000–2022, and disaggregating climate finance by sector, theme, and financial instrument.

By doing so, we propose four key contributions. First, we advance empirical research on the determinants of climate finance by focusing on infrastructure sectors— transport, energy, and water and sanitation— that are central to both mitigation and adaptation. Second, we introduce two sector-specific determinants (profitability and vulnerability), offering a more contextually relevant perspective than conventional aggregate indicators. Third, we evaluate heterogeneity by climate theme and financial instrument, revealing how allocation logics differ between mitigation and adaptation, and between debt and grants. Fourth, we situate these findings within the debate on a (un)just green transition, showing how different determinants and financing modalities may reinforce or mitigate inequities in the global climate finance regime.

The remainder of the article is structured as follows. Section 2 reviews the related literature. Section 3 presents data and econometric strategy. Section 4 discusses our empirical findings. Finally, Section 5 outlines the policy implications of our analysis and discusses the prospects for a fairer green transition and concludes.

2. Related literature

2.1. Determinants of climate finance for infrastructure

A growing body of literature has investigated the factors that influence how climate-related funds are distributed across countries (Batsy and Ghachem, 2022; Betzold and Weiler, 2017; Liu *et al*., 2024; Persson and Remling, 2014; Xie *et al*., 2023). These determinants are commonly classified into three interrelated categories: recipient needs, recipient merits, and donor interests (Islam, 2022). This framework allows for an assessment of whether climate finance is being guided primarily by development and climate-related priorities, or by other strategic considerations.

Recipient needs encompass indicators of countries' contribution, exposure and sensitivity to climate risks, such as greenhouse gas emissions, vulnerability to natural hazards, poverty rates, income, and population size. The underlying normative expectation— reinforced by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement— is that countries most vulnerable to climate change or contributing significantly to global emissions should be prioritized. However, empirical evidence remains inconclusive. While some studies do find a positive relationship between climate vulnerability and adaptation finance (Bayramoglu *et al*., 2023; Weiler and Sanubi, 2019), others reveal mixed or even inverse associations, with moderately vulnerable countries sometimes receiving more funding than the most exposed (Barrett, 2014; Islam, 2022). In the case of mitigation finance, needs-based criteria are even less central, with donors often prioritizing emissions reduction potential over vulnerability (Halimanjaya, 2015).

Recipient merits relate to a country's institutional, technical, and financial capacity to absorb and effectively manage climate finance. Variables such as readiness index, governance quality and political stability are commonly used to capture these dimensions. Numerous studies report a strong positive association between institutional capacity and climate finance inflows (Doku *et al*., 2021; Islam, 2022; Weiler and Klock, 2021), suggesting that donors may favor recipients with a greater likelihood of successful implementation and measurable outcomes. While such merit-based allocation may enhance aid effectiveness, it can also disadvantage low-capacity countries— often those most in need of climate support— creating a potential trade-off between efficiency and equity. Moreover, as adaptive capacity is often embedded within readiness measures, the distinction between needs and merits may become blurred, further complicating normative assessments of climate finance distribution.

Donor interests reflect the geopolitical and economic motivations of funders and are typically proxied by variables such as bilateral trade flows, colonial ties, geographic proximity, or aid dependency. Several studies suggest that donor countries are more likely to channel funds to recipients with whom they maintain strong economic or strategic relations (Bayramoglu *et al*., 2023; Weiler *et al*., 2018). While climate finance is formally positioned as a global public good, these patterns raise concerns that national interests may influence allocation decisions, potentially distorting the original climate rationale. When funding prioritizes strategic allies or trading partners over more vulnerable or less connected countries, it risks undermining the legitimacy and distributive justice of the climate finance regime.

While the allocation of climate finance has received increasing scholarly attention in recent years, most empirical studies have focused on aggregate flows, treating climate finance as a homogeneous category without disaggregating by sector. As a result, relatively little is known about how climate-related funding is distributed across infrastructure sectors such as energy, transport, and water supply and sanitation. To date, the majority of research has examined climate finance from a global perspective, focusing on country-level determinants deprived of accounting for sectoral specificities, with some few exceptions. Basty and Ghachem (2022) provides evidence that the infrastructure sector is dysfunctional in terms of adaptation financing needs and investments undertaken. Evaluating the transport sector, Fageda and Fioravanti (2025) suggest that mitigation fund allocation is correlated with demographic characteristics of recipient countries such as population and income, while equity considerations appear to be the main determinants of adaptation fund allocation.

To sum up, empirical studies have shown that climate finance flows are not primarily driven by recipient vulnerability, despite formal commitments to support the most climate-affected countries. Instead, donors' interests, demographic factors and features associated with recipient countries' level of development— such as institutional readiness and income— consistently emerge as stronger predictors of climate finance allocation. These patterns have also been observed in the infrastructure sector, where the allocation of climate finance appears misaligned with principles of distributive justice and a just green transition.

In this article, we seek to build on this literature by introducing two underexplored but sector-relevant groups of explanatory variables. First, we consider indicators related to the profitability and investment attractiveness of recipient countries in infrastructure sectors, such as levels of private participation in infrastructure. Second, we incorporate measures of sector-specific vulnerability, acknowledging that infrastructure systems face differentiated exposure to climate risks. By doing so, we aim to assess whether climate finance for infrastructure is shaped by economic incentives, actual climate need, or both. In the following section, we provide further elucidation on how those factors might influence climate finance for infrastructure in the light of a (un)just green transition.

2.2. Infrastructure-related determinants of climate finance for infrastructure and potential outcomes in terms of (un)just green transition

While climate finance has the potential to drive sustainable infrastructure and accelerate the low-carbon transition, concerns remain about the justice of its distribution. Some empirical studies show that climate finance is not primarily directed to countries most vulnerable to climate change. Instead, flows tend to favor countries with greater institutional readiness, relatively higher income levels, and stronger economic and political relationships with donors. These patterns risk reinforcing structural inequalities, especially when infrastructure in vulnerable countries remain underfunded despite facing acute climate risks.

In this context, the notion of a just green transition provides a critical normative framework for assessing the equity and legitimacy of climate finance allocation for infrastructure. A just transition involves fairness in the distribution of responsibilities, risks, and benefits among different social groups and geographies, and it requires attention to both distributive and procedural justice (Wang *et al.*, 2021). This means not only ensuring that vulnerable populations are supported and compensated, but also that they are meaningfully included in decision-making processes. The European Environment Agency (Tamm, 2024) expands on this perspective, emphasizing that just sustainability transitions must address structural inequalities, empower marginalized groups, and ensure inclusive governance across all stages of transition planning and implementation. From this standpoint, the way climate finance is mobilized and allocated— who benefits, who is left behind, and under what terms— plays a decisive role in determining whether transitions are just or unjust.

In this paper, we propose two infrastructure-specific variables to improve our understanding of how climate finance is allocated and whether it supports a just green transition. The first variable, returns on infrastructure investments, captures the economic attractiveness of countries to infrastructure capital. It might be proxied by the volume of private participation in infrastructure (PPI) projects, which signals the presence of profitable investment opportunities. Rather than incorporating political or institutional factors such as readiness and government quality, this variable focuses on the economic dimension— assuming that countries with higher private-sector infrastructure investment volumes are also those with higher expected returns. The second group of variables, infrastructure-related vulnerabilities, refers to the degree to which a country's infrastructure systems are exposed to climate-related risks and insufficiently prepared to withstand them. This vulnerability is operationalized through indicators of infrastructure stock, quality, and access, which are critical for both climate adaptation and equitable service provision.

Despite their relevance, infrastructure-related determinants of climate finance remain largely underexplored in the literature (Basty and Ghachem, 2022; Fageda and Fioravanti, 2025). These variables are particularly important because they capture sector-specific dynamics that conventional determinants often overlook. On the one hand, directing climate finance to countries with lower expected returns but greater infrastructure vulnerability— reflected in poor stock, quality, and/or access— could help address historical imbalances, improve resilience, and reduce global inequalities. On the other hand, if flows concentrate in countries with high profitability and better infrastructure baselines, they may reflect a market-driven logic that reinforces existing disparities. Those mechanisms are illustrated in Figure 1. Together with conventional determinants, our novel infrastructure-related dimensions might play a critical role in shaping whether climate finance contributes to a just transition— one that prioritizes equity and need— or perpetuates unjust patterns of development and climate adaptation.

This discussion on infrastructure-related determinants must also be situated within the broader financial architecture that governs climate finance flows— particularly the dominance of debt-based instruments over grants. While infrastructure has the potential to play a central role in promoting a just green transition, the way it is financed can either enable or undermine that potential. In recent years, a growing share of climate finance, including for infrastructure, has been delivered through loans rather than grants, despite repeated calls from developing countries for more equitable forms of support (Khan *et al*., 2020). This trend reflects an underlying logic that privileges financial viability and returns on investment as central criteria for funding decisions (Venner *et al*., 2024). As such, climate finance for infrastructure may disproportionately flow to countries offering higher profitability, rather than to those facing greater infrastructure vulnerability— which would be expected if justice were a guiding principle. In this sense, the instrumental form of climate finance might reinforce the broader market-oriented orientation of current climate governance and may help explain why vulnerability alone has limited explanatory power in empirical allocation models. Ultimately, while infrastructure could be a vector of equitable adaptation and mitigation, it also risks becoming a vehicle for deepening inequalities if its financing is shaped more by economic incentives than by climate justice.

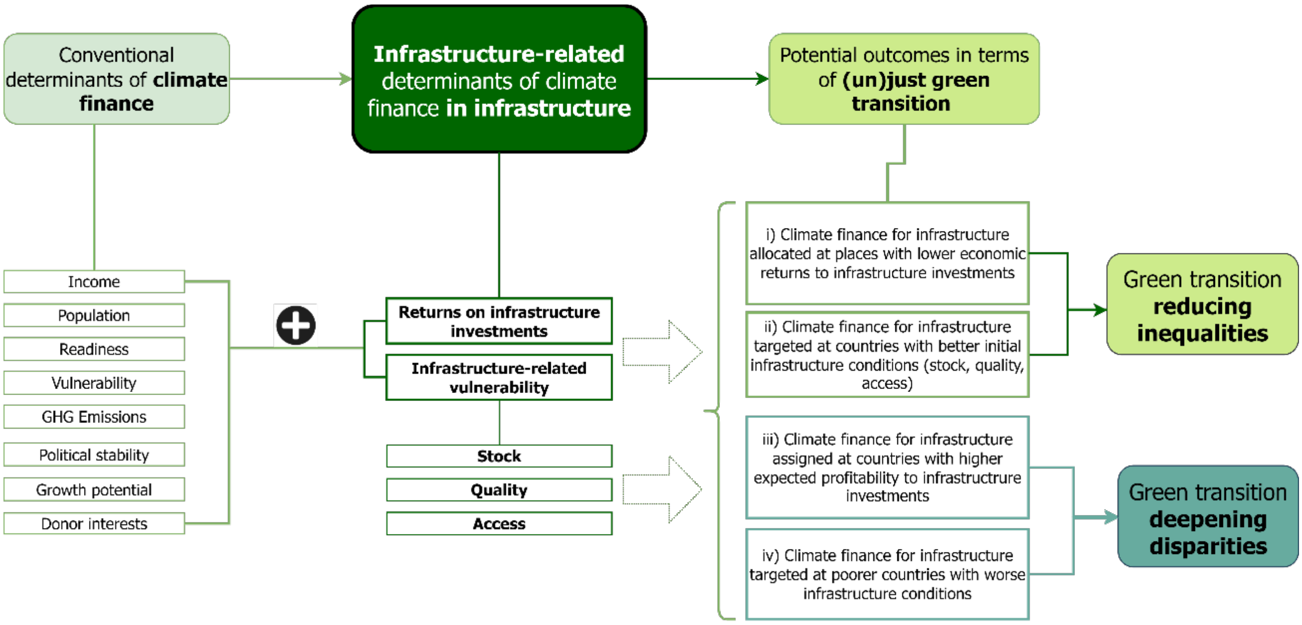
Traditional literature and policy debates on climate finance predominantly contrast two primary financial flows: Official Development Assistance (ODA), which typically comprises grants and concessional loans, and non-concessional loans. In contrast, the OECD's Development Assistance Committee (DAC) climate-related development finance dataset utilized in this study employs a distinct classification, dividing finance flows into two major subgroups: grants and debt instruments, the latter encompassing both concessional and non--concessional financing mechanisms. This distinction is analytically critical because it clearly differentiates non-repayable, burden-free transfers (grants) from all liability-creating instruments (debt), a dichotomy that is essential for assessing potential implications amid the increasing reliance on debt instruments to meet the growing scale of global climate finance needs.

Between 2000 and 2022, total climate-related debt instruments for infrastructure reached approximately USD 520 billion, of which USD 273 billion were classified as *concessional and developmental*, and USD 234 billion as *not concessional or not primarily developmental*. The volume of non-concessional debt finance has expanded markedly, rising from USD 26 billion in 2018 to USD 37 billion in 2022. In contrast, grants totaled around USD 280 billion over the same period, and only USD 453 million of this amount were identified as *not concessional or not primarily concessional*, confirming that grant-based finance remains almost entirely concessional in nature.

This trend is particularly pronounced in mitigation-related debt finance, which accounted for roughly USD 375 billion, including USD 175 billion in non-concessional flows— an increase from USD 20 billion in 2018 to USD 25 billion in 2022. Adaptation-related debt finance displayed a similar, though smaller, pattern: out of USD 177 billion in total debt, USD 69 billion were non-concessional, increasing from USD 7 billion in 2018 to USD 15 billion in 2022. These figures underscore the growing role of market-based operations within climate-related debt flows, especially for mitigation purposes.

Building on this related literature, our study offers four main contributions to the literature on climate finance and just transitions. First, we contribute to filling a key empirical gap by focusing specifically on the determinants of climate finance allocated to infrastructure sectors— namely, transport, energy, and water and sanitation. While previous studies have largely adopted aggregated approaches to climate finance flows, we highlight the need to understand how allocation dynamics vary within sectors that are critical for both mitigation and adaptation. Second, we expand the analytical scope by incorporating two infrastructure-related determinants: the expected economic returns on infrastructure investments and the vulnerability of infrastructure sectors. These variables provide a more sector-relevant perspective and allow us to examine whether funding is being driven by need, opportunity, or both. Third, we assess whether the influence of these determinants varies by type of climate theme— that is, whether mitigation and adaptation finance in diverse infrastructure sectors respond differently to investment returns and vulnerability. Fourth, we examine how these relationships are shaped by the financial instruments used— particularly the distinction between debt and grants— and interpret our findings through the lens of a just (or unjust) green transition. Taken together, these contributions offer new insights into the determinants of climate finance in infrastructure, while situating the empirical results within broader debates about equity, justice, and global climate governance.

Figure 1. Determinants of climate finance for infrastructure and potential outcomes



Source: author's elaboration.

3. Methodology

3.1. Econometric approach

To identify the determinants of climate finance for infrastructure, we follow the specialized literature (Betzold and Weiler, 2017; Islam, 2022; Weiler *et al*., 2018) and run the following equation:

$$
\begin{aligned}
ClimateFinance_{i,t}^{Infra} &= \alpha + \phi * ClimateFinance_{i,t-1}^{Infra} + \gamma' * InfrastructrureRelated_{i,t-1} + \\
&\beta' * ConventionalDeterminants_{i,t-1} + \lambda_t + \delta_i + \varepsilon_{it} \qquad (1)
\end{aligned}
$$

Where $ClimateFinance_{it}^{Infra}$ is the amount of climate finance allocated to infrastructure sectors in period *t* and country *i*, $ClimateFinance_{i,t-1}^{Infra}$ is the one-period lagged value of climate finance for infrastructure, $InfrastructrureRelated_{it}$ is a vector of variables capturing the returns on infrastructure investments (or its profitability) and the sector-specific climate vulnerability, and $ConventionalDeterminants_{it}$ is a vector of variables controlling for conventional determinants of climate finance. α is a constant term, ϕ is an adjustment parameter capturing dynamic effects of climate finance, γ' is a vector of parameters related to infrastructure-related determinants, and β' is a vector of parameters related to conventional determinants, all of which will be estimated using econometric models. Finally, λ_t represent time fixed effects, δ_i captures country fixed effects, and ε_{it} is an idiosyncratic error term.

Equation (1) considers several specificities of climate finance allocation. First, we include all regressors with one period lag to circumvent potential reverse causality between climate finance determinants and climate finance itself. Crucially, this sequencing is also practical: a country's vulnerability status and the decision to approve funding are not determined simultaneously. Recipient countries must first submit an application, which is then subject to review by the relevant funding entity— a process that inevitably takes time before any allocation is made (Islam, 2022). Second, by including a one year-lagged value of the dependent variable, our model allows for dynamic effects of climate finance for infrastructure, which means that present climate finance amounts depend on its past values. Third, we aggregate the annual data from 2000 to 2022 into four-year averages to address both statistical and methodological concerns. On the one hand, annual data on climate finance are often highly volatile, with disbursements concentrated in specific years and zero values in many others— especially when disaggregated by climate objective (mitigation or adaptation) or by infrastructure sector. Such irregularity can introduce noise and obscure underlying patterns. In addition, this procedure has been followed by research related to the infrastructure sector for many years, especially due to the long maturation time of this investment (Straub, 2011; Redding and Turner, 2015). On the other hand, the use of four-year periods is consistent with the requirements of dynamic panel data models, which are designed for situations with a large number of cross-sectional units (in our case, countries) and a short time dimension (in our case, four-year windows).

To estimate Equation (1), we employ the System Generalized Method of Moments (System GMM) estimator proposed by Arellano and Bover (1995) and Blundell and Bond (1998). This dynamic panel estimator is particularly well suited to our context for several reasons. First, it addresses the endogeneity arising from the inclusion of a lagged dependent variable on the right-hand side, which would render standard fixed effects estimators biased and inconsistent. Second, it deals with potential simultaneity bias and measurement error in the explanatory variables, which are likely to affect both conventional and infrastructure-related determinants of climate finance. Third, System GMM is appropriate for panels with a relatively large number of countries and a short time dimension, which characterizes our dataset. In practical terms, the System GMM estimator combines the equation in first differences— instrumented with lagged levels of the variables— and the equation in levels— instrumented with lagged differences— under suitable moment conditions. We use two-step GMM estimation, with the Windmeijer (2005) correction for standard errors, to improve efficiency and address downward bias in the standard errors typical of two-step estimates. To avoid instrument proliferation, we apply instrument reduction techniques such as collapsing instruments and limiting the lag depth. Finally, we report standard diagnostics including the Arellano-Bond test for serial correlation in the residuals and the Hansen test of overidentifying restrictions. These checks allow us to assess the validity of the instrument set and the robustness of our estimates.

We estimate several different models of climate finance allocation. First, we estimate models for each infrastructure sector (infrastructure, transport, energy, and water and sanitation). Second, we replicate those estimates for each climate theme (mitigation and adaptation). Third, we also test different specifications by financial instrument (debt and grant). Given the highly skewed distribution of climate finance dependent variables, we apply the natural logarithm transformation after adding a small constant to all values. This approach allows us to retain observations with zero disbursements, which are analytically meaningful given the uneven distribution of climate finance across countries and years (Betzold and Weiler, 2017; Islam, 2022; Weiler *et al.*, 2018).

3.2. Data

The primary variable of interest— the allocation of climate finance— is sourced from the OECD-DAC database on *climate-related development finance*. Recognized as one of the most comprehensive and widely used datasets in this field (e.g., Betzold and Weiler, 2017; Halimanjaya, 2016; Robinson and Dornan, 2017; Weiler *et al.*, 2018), it provides detailed information on both bilateral and multilateral financial flows targeting climate objectives. The identification of climate-related activities follows the *Rio Markers* and/or the *Climate Components* methodology (Simon, 2018).

The dataset reports approved funding amounts across multiple financial instruments— primarily grants and debt instruments— as well as equity or investment shares. Each of these broad categories can be further disaggregated according to their concessionality, distinguishing flows that are "concessional and developmental" from those that are "not concessional or not primarily developmental." In addition, the datas*et al*lows us to identify whether the financial amounts are private or public. From this data, we can capture both the traditional segment of climate finance as the official development assistance (such as standard grants[1] and "soft" loans with below-market terms often through interest rates or grace periods) and the growing share of non-concessional or market-based operations (mainly classified as standard loans[2]), which are especially relevant

[1] Grants are transfers in cash or in kind for which no legal debt is incurred by the recipient.
[2] Transfers in cash or in kind for which the recipient incurs legal debt (and the resulting claim is not intended to be traded). Since payment obligations on standard loan are senior obligations, i.e. creditors are entitled to receive payments against their claims before anyone else, they are also referred to as senior loans.

for debt-based climate finance. Regarding grant-based climate finance, they are concessional and developmental by nature (even public or private). The dataset covers contributions from public donors— such as DAC member states and multilateral development banks— as well as private philanthropic actors.

Importantly, the OECD-DAC datas*et al*so classifies projects according to their climate objectives—mitigation, adaptation, or overlapping interventions— and distinguishes across sectors and sub-sectors. In this study, our dependent variables are the approved amounts of climate-related finance in three infrastructure sectors, following the OECD-DAC classification: II.1 Transport and Storage, II.3 Energy, and I.4 Water Supply and Sanitation. We aggregate these sectors to construct a measure of total climate finance for infrastructure. Next, we classify the data by sector and climate theme (mitigation or adaptation) and further stratify by financial instrument (debt or grant).

Regarding infrastructure-related determinants, the returns on infrastructure investments (or their profitability) are proxied by the volume of private participation in infrastructure (PPI) measured in constant USD as reported by the World Bank's PPI Database. This measure captures the value of infrastructure projects in which private capital plays a significant role, including concessions, public–private partnerships, and privatizations, across sectors such as energy, transport, water and sanitation, and telecommunications. Controlled for institutional quality, PPI data reflects the business environment's capacity to attract and sustain private investment in infrastructure, which is closely related to the expected profitability of such projects. Importantly, this proxy differs conceptually from climate-related development finance as reported by the OECD, which covers flows— primarily public, but also private mobilized by official support— explicitly targeted at climate change mitigation and adaptation objectives. While both may overlap in certain climate-relevant infrastructure projects, PPI primarily reflects market-driven investment decisions irrespective of environmental goals, whereas climate finance is defined by its explicit climate-related purpose rather than by the ownership or financing structure. In the empirical model, PPI is included with a one-period lag to mitigate potential endogeneity concerns and to better capture the temporal sequence in which private investment conditions may shape subsequent flows of climate-related development finance.

We measure country-level climate vulnerability using the Notre Dame Global Adaptation Initiative (ND-GAIN) Country Index vulnerability score (Chen *et al*., 2015), which aggregates 36 core indicators across six life-supporting sectors (food, water, health, ecosystem services, human habitat, and infrastructure). Those indicators capture the adaptive capacity, exposure and sensitivity to climate change for those different life-supporting sectors for several countries from 1995 to 2022. In ND-GAIN, higher vulnerability scores indicate greater challenges and urgency to act. In addition to the overall vulnerability score, we exploit sector-specific ND-GAIN indicators to capture the dimensions most relevant to infrastructure climate finance. For the aggregated infrastructure-related vulnerability, we use the infrastructure and habitat ND-GAIN scores. For transport-related vulnerability, we use quality of trade and transport-related infrastructure (ID_HABI_05) and paved roads (ID_HABI_06) as proxies for transport quality, access and coverage. For energy-related vulnerability, we use dependency on imported energy (ID_INFR_03) and electricity access (ID_INFR_05), which together proxy both sensitivity to external energy shocks, national energy stocks and baseline grid electricity coverage. For water and sanitation, we include access to reliable drinking water (ID_WATE_06) and the water dependency ratio (ID_WATE_04), which capture domestic service coverage and reliance on transboundary water resources, respectively. These indicators follow ND-GAIN's sector/indicator mapping and sources and allow us to combine a common, aggregated vulnerability metric with sector-targeted measures reflecting exposure, sensitivity, and adaptive capacity in infrastructure-relevant domains.

To mitigate potential omitted variable bias— particularly from unobserved infrastructure-related determinants that could confound the relationship between private participation in infrastructure, vulnerability and climate finance for infrastructure— we include a comprehensive set of control variables. These comprise GHG emissions per capita, which capture the scale of emissions and may influence the prioritization of climate finance; population size, reflecting market size and infrastructure demand; the agriculture share of GDP, which can shape sectoral investment priorities and vulnerability profiles; the ND-GAIN readiness score, a composite indicator of a country's ability to leverage investments for adaptation and mitigation; the import index, which reflects trade openness and integration into global supply chains; the official development assistance (ODA) per capita, capturing broader aid inflows that could correlate with climate finance allocations and donor interests; GDP growth, to control for macroeconomic performance and investment attractiveness; and extreme political events, measured as the sum of the number of realized coups, unrealized coups, conspiracies, and attempted coups, which may disrupt investment flows or alter donor priorities. Including these controls helps isolate the independent effect of private infrastructure investment on climate finance flows, reducing the risk that our estimated coefficients are driven by correlated but omitted factors. Table 1 presents the sources and summary statistics of the described variables.

Table 1. Summary statistics

Type	Variable	Obs	Mean	Std. Dev.	Extracted from
Dependent (log)	Climate Finance in Infrastructure	720	8.23	4.11	OECD-DAC Climate Finance Database
	Mitigation Finance in Infrastructure	720	7.79	4.10	
	Adaptation Finance in Infrastructure	720	5.50	4.82	
	Grant Climate Finance in Infrastructure	720	7.16	3.53	
	Debt Climate Finance in Infrastructure	720	5.48	5.48	
	Grant Mitigation Finance in Infrastructure	720	6.72	3.46	
	Debt Mitigation Finance in Infrastructure	720	4.97	5.39	
	Grant Adaptation Finance in Infrastructure	720	4.76	4.25	
	Debt Adaptation Finance in Infrastructure	720	3.55	4.82	
	Climate Finance in Transport	720	4.32	4.86	
	Mitigation Finance in Transport	720	3.47	4.53	
	Adaptation Finance in Transport	720	2.89	4.20	
	Grant Climate Finance in Transport	720	2.83	3.68	
	Debt Climate Finance in Transport	720	3.24	4.77	
	Grant Mitigation Finance in Transport	720	2.22	3.25	
	Debt Mitigation Finance in Transport	720	2.30	4.32	
	Grant Adaptation Finance in Transport	720	1.85	3.22	
	Debt Adaptation Finance in Transport	720	2.13	3.88	
	Climate Finance in Energy	720	6.95	4.28	
	Mitigation Finance in Energy	720	6.89	4.29	
	Adaptation Finance in Energy	720	3.11	3.77	
	Grant Climate Finance in Energy	720	5.91	3.63	
	Debt Climate Finance in Energy	720	4.34	5.21	
	Grant Mitigation Finance in Energy	720	5.85	3.62	
	Debt Mitigation Finance in Energy	720	4.30	5.20	
	Grant Adaptation Finance in Energy	863	2.66	3.33	
	Debt Adaptation Finance in Energy	720	1.38	3.13	
	Climate Finance in Sanitation	720	6.38	4.12	
	Mitigation Finance in Sanitation	720	5.12	3.90	
	Adaptation Finance in Sanitation	720	4.92	4.58	
	Grant Climate Finance in Sanitation	720	5.59	3.67	
	Debt Climate Finance in Sanitation	720	3.41	4.72	
	Grant Mitigation Finance in Sanitation	720	4.39	3.41	
	Debt Mitigation Finance in Sanitation	720	2.40	4.05	
	Grant Adaptation Finance in Sanitation	720	4.27	4.06	
	Debt Adaptation Finance in Sanitation	720	2.68	4.41	
Infrastructure returns (log)	PPI Infrastructure Investments	720	2.47	2.93	World Bank PPI Database
	PPI Transport Investments	720	1.33	2.41	
	PPI Energy Investments	720	2.05	2.74	
	PPI Sanitation Investments	720	0.46	1.45	
Infrastructure vulnerability	Vulnerability	705	0.48	0.08	ND-GAIN
	Infrastructure-specific vulnerability	615	0.35	0.15	
	Habitat-specific vulnerability	710	0.54	0.10	
	Quality of trade and transport infrastructure	615	0.69	0.10	
	Paved roads	670	0.60	0.31	
	Dependence on imported energy	520	0.28	0.31	
	Access to electricity	710	0.30	0.33	
	Access to reliable drinking water	405	0.52	0.28	
	Water dependence ratio	700	0.24	0.29	
Conventional determinants	GHG emissions (pc), Log	700	1.41	0.70	World Bank Indicators
	Population, Log	720	15.55	2.20	World Bank Indicators
	Agriculture (% GDP)	686	14.67	10.85	World Bank Indicators
	Readiness	710	0.35	0.09	ND-GAIN
	Import Index, Log	699	4.23	0.59	World Bank Indicators
	ODA per capita, Log	720	3.64	1.59	World Bank Indicators
	GDP growth	706	4.14	3.53	World Bank Indicators
	Extreme political events	720	0.27	0.76	Peyton *et al.* (2025)

Source: author's elaboration.

4. Empirical Results

4.1. Contextualizing the climate finance for infrastructure

Figure 2 displays the evolution of climate finance provided and mobilized for infrastructure between 2000 and 2022, expressed in constant 2022 USD billions. The figure captures both total infrastructure-related climate finance and its disaggregation by sector (Energy, Transport, and Water and Sanitation), climate theme (Mitigation, Adaptation, and Overlap), and financial instrument (Debt and Grant). The "Infrastructure" category represents the aggregate sum of the three sectors.

The data reveals a pronounced increase in climate finance for infrastructure over the period, with a marked acceleration after 2011. Among the three sectors, Energy mostly receives the highest volume of financing, followed by Transport and then Water and Sanitation. Across all sectors, mitigation remains the dominant climate theme, particularly in the Energy sector, while adaptation finance has gained relative importance in areas such as Water and Sanitation. Finance targeting both adaptation and mitigation simultaneously (Overlap) remains modest throughout.

These patterns mirror, but also diverge in important ways from, the broader trends reported by the OECD (OECD, 2024) across all sectors, including others than infrastructure. In 2022, mitigation accounted for 60% of total global climate finance, while adaptation represented 28%, with the remaining 12% allocated to overlapping objectives. The infrastructure sectors analyzed here show an even greater skew toward mitigation, which may reflect the fact that mitigation projects— especially in energy and transport— tend to generate more predictable revenue streams and are therefore more attractive and less risky to potential investors. In contrast, adaptation projects often yield diffuse public benefits and may struggle to attract commercial financing, particularly in low-income or highly vulnerable countries. These characteristics could explain the relatively lower share of adaptation finance, especially in infrastructure where marketable viability plays a significant role in investment decisions.

The distribution of financial instruments further reinforces this trend. In 2022, debt instruments accounted for 69% of total climate finance globally, compared to 29% in the form of grants. In the infrastructure sectors examined in Figure 2, the reliance on debt is even more pronounced (more than 90%), particularly in mitigation finance. This may be partially explained by the capital-intensive nature of infrastructure projects, which are often structured through long-term debt financing, including project finance and public-private partnerships. Moreover, debt-based instruments allow development finance institutions to leverage limited donor resources and mobilize additional private capital. While grants represent a smaller share overall, they appear more prominently in adaptation finance, especially within Water and Sanitation— highlighting the need for greater concessionality in sectors where financial returns are lower or harder to capture.

To sum up, Figure 2 highlights the continued growth in climate finance for infrastructure but also exposes structural imbalances in both thematic allocation and financial instruments. The prevailing emphasis on mitigation and debt-based instruments may reflect underlying market incentives, sectoral and institutional maturity, and investment logic, but it also raises important concerns regarding the adequacy and accessibility of finance for adaptation— particularly in sectors and regions where resilience is urgently needed but financial returns are uncertain or indirect.

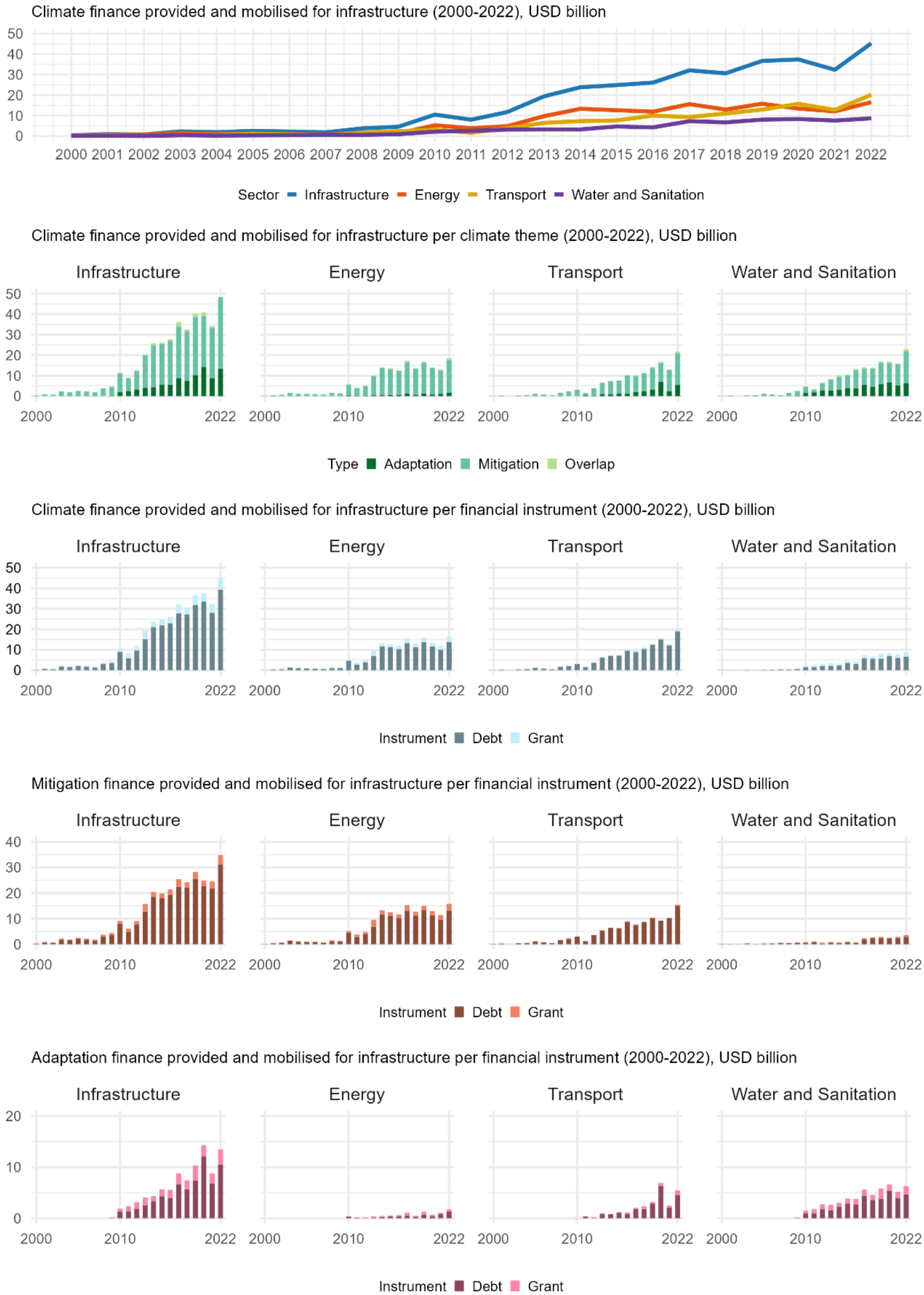
Figure 3 presents the correlation coefficients between different categories of climate finance for infrastructure (disaggregated by sector, climate objective, and financial instrument) and a range of potential explanatory variables. The analysis includes indicators related to private participation in infrastructure (PPI), vulnerability and exposure to climate risks, infrastructure quality, access to basic services, environmental and demographic conditions, and macroeconomic and institutional factors.

The results suggest that private sector participation—particularly PPI in infrastructure, energy, and transport—is positively associated with higher volumes of climate finance, especially for mitigation and debt-based flows. Conversely, indicators of vulnerability (both general and sector-specific) and greenhouse gas emissions tend to show weaker correlations with climate finance. This may reflect the persistent bias in climate finance toward projects with higher commercial viability or co-benefits, rather than toward need-based or vulnerability-driven allocation.

Several structural variables, such as population size, agricultural dependence, and GDP growth, are also positively associated with climate finance across most dimensions. Readiness scores and import index appear to be positively correlated with total and mitigation finance, indicating the importance of institutional and market capacity in attracting investment. In contrast, aid dependence (ODA per capita), GDP growth, and extreme political events exhibit weaker or more mixed associations.

Overall, the figure highlights potential mismatches between the allocation of climate finance and indicators of climate vulnerability, while suggesting that investment environments and infrastructure markets may play a stronger role in shaping flows. In the next section, we provide some empirical evidence from econometric models.

Figure 2. Contextualizing climate finance for infrastructure (2000-2022, constant USD)



Source: author's elaboration.

Figure 3. Correlation between climate finance for infrastructure (disaggregated by sector, climate theme and financial instrument) and potential determinants (2000-2022)

DETERMINANTS	INFRASTRUCTURE					TRANSPORT					ENERGY					WATER AND SANITATION				
	TOTAL	MITIGATION	ADAPTATION	GRANT	DEBT	TOTAL	MITIGATION	ADAPTATION	GRANT	DEBT	TOTAL	MITIGATION	ADAPTATION	GRANT	DEBT	TOTAL	MITIGATION	ADAPTATION	GRANT	DEBT
PPI Infrastructure Investments	0.44	0.47	0.29	0.34	0.46															
PPI Transport Investments						0.29	0.35	0.15	0.20	0.33										
PPI Energy Investments											0.43	0.44	0.29	0.37	0.43					
PPI Sanitation Investments																0.19	0.25	0.11	0.13	0.23
Vulnerability	0.01	-0.02	0.07	0.20	-0.23	-0.05	-0.16	0.11	0.15	-0.18	-0.05	-0.05	0.02	0.09	-0.21	0.07	-0.02	0.07	0.23	-0.21
Infrastructure specific vulnerability	-0.05	-0.06	-0.02	0.07	-0.17															
Habitat-specific vulnerability	0.06	0.04	0.07	0.14	-0.10															
Quality of trade and transport infrastructure						-0.19	-0.27	-0.05	-0.07	-0.27										
Paved roads						0.07	0.00	0.15	0.19	-0.01										
Dependence on imported energy											0.10	0.10	0.03	0.06	0.08					
Access to electricity											-0.07	-0.07	-0.03	0.04	-0.14					
Access to reliable drinking water																0.14	0.06	0.14	0.27	-0.09
Water dependency ratio																0.08	0.10	0.05	0.07	0.08
GHG Emissions (pc)	-0.24	-0.22	-0.21	-0.36	-0.04	-0.15	-0.06	-0.21	-0.24	-0.04	-0.19	-0.19	-0.19	-0.28	-0.06	-0.24	-0.18	-0.21	-0.33	-0.02
Population	0.41	0.43	0.26	0.35	0.38	0.33	0.39	0.17	0.24	0.37	0.38	0.39	0.26	0.34	0.38	0.44	0.49	0.32	0.39	0.39
Agriculture (% GDP)	0.15	0.13	0.10	0.29	-0.05	0.08	0.00	0.16	0.21	-0.01	0.09	0.09	0.10	0.19	-0.02	0.15	0.11	0.10	0.26	-0.05
Readiness	-0.18	-0.15	-0.14	-0.28	0.00	0.00	0.04	-0.05	-0.08	0.04	-0.11	-0.11	-0.06	-0.18	0.02	-0.22	-0.17	-0.17	-0.31	0.01
Import Index	0.32	0.27	0.57	0.26	0.36	0.39	0.29	0.44	0.30	0.36	0.34	0.33	0.49	0.29	0.35	0.32	0.19	0.51	0.25	0.31
ODA per capita	0.14	0.10	0.19	0.25	-0.04	0.04	-0.06	0.15	0.14	-0.09	0.11	0.10	0.12	0.18	-0.05	0.12	0.00	0.14	0.18	-0.06
GDP growth	0.13	0.14	0.09	0.11	0.16	0.11	0.12	0.04	0.12	0.09	0.13	0.13	0.07	0.11	0.15	0.12	0.15	0.10	0.11	0.13
Extreme political events	-0.06	-0.06	-0.05	-0.02	-0.10	-0.09	-0.10	-0.08	-0.07	-0.08	-0.04	-0.04	-0.09	-0.02	-0.07	-0.03	-0.06	-0.03	0.03	-0.10

Source: author's elaboration.

4.2. Econometric findings

4.2.1. Baseline results

Tables 2,3, 4 and 5 show baseline findings for the infrastructure, transport, energy and water and sanitation sectors, respectively. All models are estimated by applying the GMM-System. The lagged climate finance values are enabled by internal instruments, which are valid based on Hansen test p-values above 0.10 and no greater than 0.30 in the vast majority of cases. In addition, AR(2) test p-values indicate that there is no second-order correlation between the residuals. We start our analysis by briefly presenting the statistical relevance of our proposed determinants considering different infrastructure sectors. Then, we provide further elucidation on the strength of those determinants considering different models in terms of infrastructure sectors and climate theme.

Starting with the aggregate infrastructure sector (Table 2), results show that returns on infrastructure investments, proxied by private participation in infrastructure (PPI), are strongly and positively associated with climate finance. This suggests that countries offering higher expected returns attract more climate-related resources, consistent with the merits-based allocation perspective highlighted by some studies (Doku *et al.*, 2021; Islam, 2022; Weiler and Klock, 2021). Regarding vulnerability, the evidence is weaker. Among the three ND-GAIN measures tested, only the infrastructure-related vulnerability index yields statistically significant results, with a positive coefficient indicating that more vulnerable countries tend to receive higher flows. Among the conventional controls, population size and ODA per capita emerge as robust predictors, while GDP growth and GHG emissions per capita show effects in some specifications. Extreme political events appear to deter climate finance inflows.

Turning to the transport sector (Table 3), the results largely confirm the aggregate pattern: PPI, population, and ODA per capita are consistently positive, while extreme political events remain a negative determinant. Vulnerability measures yield mixed results. On the one hand, higher road density (paved roads) is positively associated with adaptation finance, indicating that more vulnerable countries benefit when infrastructure gaps are acute. On the other hand, better trade and transport infrastructure quality reduces climate finance inflows, suggesting that donors may perceive less urgency where transport systems are already relatively developed. In addition, readiness—

capturing absorptive capacity—emerges as a relevant determinant, while GDP growth and the agricultural share of GDP occasionally increase climate finance allocations.

For the energy sector (Table 4), PPI in energy is again positive and significant, underscoring the centrality of expected returns for attracting climate resources. On the vulnerability side, countries with lower electricity access and higher energy import dependence receive more climate finance, indicating that allocation partially reflects structural energy vulnerabilities. As in other sectors, population and ODA per capita remain strong predictors, while GDP growth and political instability play relevant roles.

In the water and sanitation sector (Table 5), PPI investments are also positively correlated with climate finance flows. However, no vulnerability measure shows a significant effect, suggesting that climate finance allocation in this domain is less responsive to structural needs, following some previous findings on the infrastructure sector (Basty and Ghachem, 2022). Population and ODA per capita again exert robust positive effects, while GHG emission.

Comparing across sectors, two key insights emerge. First, returns on infrastructure investments (PPI) consistently drive climate finance, with effects generally stronger for mitigation than for adaptation. This aligns with the literature's emphasis on the financial viability of projects as a decisive factor, particularly in transport, where the effect is most pronounced. Second, the role of vulnerability is more nuanced and sector-specific. While aggregate infrastructure shows weak positive effects, transport yields mixed evidence, energy reveals vulnerability sensitivity (but only partially for adaptation), and water and sanitation show none. These patterns illustrate the tension between needs-based and merits-based logics: although financial returns dominate, vulnerability considerations emerge selectively, depending on sector characteristics and possibly the nature of donor engagement.

Table 2. Determinants of climate finance in infrastructure sectors: GMM-System (2000-2022, 4-year windows)

	Climate 1	Climate 2	Climate 3	Mitigation 4	Mitigation 5	Mitigation 6	Adaptation 7	Adaptation 8	Adaptation 9
Infrastructure Climate Finance, Lagged	0.267***	0.260***	0.275***						
	(0.06)	(0.06)	(0.06)						
Infrastructure Mitigation Finance, Lagged				0.268***	0.210***	0.278***			
				(0.07)	(0.07)	(0.06)			
Infrastructure Adaptation Finance, Lagged							0.295***	0.372***	0.310***
							(0.06)	(0.07)	(0.06)
PPI Infrastructure Investments	0.178***	0.154***	0.182***	0.190***	0.176***	0.197***	0.162***	0.128***	0.164***
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)
Vulnerability index	-2.946			-3.664			1.584		
	(2.22)			(2.55)			(1.64)		
Infrastructure-specific vulnerability		1.633*			1.746*			1.904***	
		(0.86)			(1.04)			(0.68)	
Habitat-specific vulnerability			-0.346			-0.261			0.500
			(1.26)			(1.25)			(1.02)
GHG emissions (pc)	-0.333	-0.175	-0.213	-0.300	-0.094	-0.168	-0.468***	-0.355**	-0.461***
	(0.27)	(0.22)	(0.22)	(0.30)	(0.25)	(0.25)	(0.18)	(0.16)	(0.16)
Population	0.751***	0.861***	0.770***	0.827***	0.995***	0.840***	0.573***	0.614***	0.564***
	(0.14)	(0.13)	(0.13)	(0.15)	(0.16)	(0.14)	(0.10)	(0.11)	(0.10)
Agriculture (% GDP)	0.012	-0.001	0.006	0.018	0.001	0.010	-0.001	-0.001	0.006
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
Readiness index	0.613	1.284	0.490	1.667	2.550	1.774	0.033	-0.917	-0.854
	(1.79)	(1.94)	(1.95)	(1.90)	(2.10)	(2.09)	(1.65)	(1.72)	(1.79)
Import Index	-0.064	0.125	0.013	0.151	0.331	0.244	-0.066	-0.080	0.022
	(0.35)	(0.39)	(0.34)	(0.40)	(0.44)	(0.39)	(0.25)	(0.30)	(0.25)
ODA per capita	0.910***	0.916***	0.871***	0.929***	0.988***	0.874***	0.747***	0.697***	0.737***
	(0.18)	(0.17)	(0.17)	(0.19)	(0.19)	(0.17)	(0.11)	(0.12)	(0.10)
GDP growth	0.054	0.077*	0.050	0.043	0.081*	0.041	0.062*	0.059*	0.059*
	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.03)	(0.03)	(0.03)
Extreme political events	-0.234*	-0.398***	-0.262*	-0.284**	-0.425***	-0.309**	-0.182	-0.243*	-0.187*
	(0.14)	(0.15)	(0.13)	(0.14)	(0.15)	(0.14)	(0.11)	(0.14)	(0.11)
Constant	-6.230*	-11.328***	-8.017***	-9.288**	-14.885***	-11.255***	-5.257**	-5.979**	-4.980*
	(3.33)	(3.12)	(3.10)	(3.92)	(3.77)	(3.54)	(2.59)	(2.78)	(2.60)
Observations	656	574	661	656	574	661	656	574	661
Instruments	17	17	17	18	18	18	17	18	17
AR(2) p-value	0.13	0.12	0.25	0.68	0.71	0.86	0.12	0.21	0.11
Hansen p-value	0.23	0.15	0.19	0.21	0.20	0.20	0.18	0.11	0.32

All regressions include window fixed effects. Robust standard errors clustered at the country level are in parentheses. *p<0.10, **p<0.05, ***p<0.01.

Table 3. Determinants of climate finance in the transport sector: GMM-System (2000-2022, 4-year windows)

	Climate	Climate	Climate	Mitigation	Mitigation	Mitigation	Adaptation	Adaptation	Adaptation
	1	2	3	4	5	6	7	8	9
Transport Climate Finance, Lagged	0.282***	0.286***	0.276***						
	(0.06)	(0.07)	(0.06)						
Transport Mitigation Finance, Lagged				0.279***	0.285***	0.287***			
				(0.07)	(0.07)	(0.08)			
Transport Adaptation Finance, Lagged							0.340***	0.353***	0.342***
							(0.07)	(0.07)	(0.07)
PPI Transport Investment	0.211***	0.155**	0.192***	0.222***	0.186**	0.200**	0.164***	0.150**	0.154**
	(0.07)	(0.07)	(0.07)	(0.08)	(0.08)	(0.08)	(0.06)	(0.06)	(0.06)
Vulnerability	-4.397			-6.064*			1.891		
	(2.81)			(3.09)			(2.30)		
Quality of trade and transport infrastructure		-3.690*			-4.143			0.830	
		(1.99)			(2.74)			(1.80)	
Paved roads			0.700			0.377			1.127**
			(0.64)			(0.78)			(0.47)
GHG Emissions (pc)	-0.524**	-0.454	-0.398	-0.222	-0.074	-0.109	-0.409***	-0.464*	-0.418*
	(0.22)	(0.36)	(0.31)	(0.26)	(0.43)	(0.36)	(0.15)	(0.24)	(0.22)
Population	0.891***	0.984***	0.950***	1.012***	1.058***	1.042***	0.416***	0.470***	0.424***
	(0.16)	(0.18)	(0.15)	(0.19)	(0.21)	(0.18)	(0.12)	(0.13)	(0.12)
Agriculture (% GDP)	0.041*	0.026	0.026	0.013	-0.002	-0.007	0.042**	0.041**	0.045***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Readiness	7.029***	6.356**	8.579***	6.951***	6.567**	8.450***	3.278*	3.013	4.050*
	(2.37)	(2.58)	(2.63)	(2.51)	(2.99)	(2.93)	(1.94)	(2.19)	(2.17)
Import Index	0.234	0.217	0.516	0.163	0.137	0.387	0.226	0.204	0.403
	(0.48)	(0.51)	(0.49)	(0.50)	(0.55)	(0.50)	(0.38)	(0.41)	(0.38)
ODA per capita	0.850***	0.889***	0.777***	0.869***	0.859***	0.739***	0.538***	0.515***	0.533***
	(0.19)	(0.22)	(0.19)	(0.22)	(0.27)	(0.22)	(0.14)	(0.16)	(0.13)
GDP growth	0.091*	0.116**	0.093*	0.082	0.109*	0.104*	0.081*	0.092**	0.066
	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)
Extreme political events	-0.315*	-0.298*	-0.362**	-0.389**	-0.423**	-0.410**	-0.280*	-0.233	-0.324**
	(0.18)	(0.17)	(0.18)	(0.18)	(0.17)	(0.18)	(0.15)	(0.15)	(0.15)
Constant	-13.232***	-14.004**	-18.184***	-14.718***	-15.478**	-19.384***	-11.013***	-7.359	-8.057**
	(4.40)	(5.58)	(4.32)	(5.06)	(6.72)	(4.77)	(3.82)	(4.49)	(3.70)
Observations	656	582	634	656	582	634	656	582	634
Instruments	17	17	17	23	28	23	17	17	18
AR(2) p-value	0.314	0.080	0.284	0.572	0.553	0.507	0.598	0.278	0.556
Hansen p-value	0.261	0.334	0.238	0.153	0.152	0.157	0.108	0.142	0.228

All regressions include window fixed effects. Robust standard errors clustered at the country level are in parentheses. *$p<0.10$, **$p<0.05$, ***$p<0.01$.

Table 4. Determinants of climate finance in the energy sector: GMM-System (2000-2022, 4-year windows)

	Climate 1	Climate 2	Climate 3	Mitigation 4	Mitigation 5	Mitigation 6	Adaptation 7	Adaptation 8	Adaptation 9
Energy Climate Finance, Lagged	0.267***	0.314***	0.300***						
	(0.08)	(0.09)	(0.07)						
Energy Mitigation Finance, Lagged				0.277***	0.324***	0.289***			
				(0.06)	(0.08)	(0.07)			
Energy Adaptation Finance, Lagged							0.258***	0.295***	0.310***
							(0.06)	(0.06)	(0.06)
PPI Energy Investment	0.176***	0.152***	0.142**	0.176***	0.120**	0.143**	0.116**	0.093*	0.095**
	(0.05)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)	(0.05)
Vulnerability	-3.600			-3.467			-0.319		
	(2.44)			(2.63)			(2.08)		
Dependence on imported energy		1.202**			1.297***			0.410	
		(0.47)			(0.46)			(0.44)	
Access to electricity			-1.571***			-1.582***			-0.651
			(0.56)			(0.57)			(0.50)
GHG Emissions (pc)	-0.236	-0.066	-0.335	-0.253	-0.259	-0.319	-0.443***	-0.242	-0.501***
	(0.23)	(0.37)	(0.25)	(0.28)	(0.41)	(0.27)	(0.14)	(0.25)	(0.16)
Population	0.825***	0.913***	0.817***	0.832***	0.927***	0.857***	0.555***	0.701***	0.527***
	(0.14)	(0.22)	(0.13)	(0.14)	(0.21)	(0.14)	(0.10)	(0.13)	(0.10)
Agriculture (% GDP)	0.010	0.023	0.015	0.008	0.012	0.016	0.021	0.022	0.024*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)
Readiness	1.594	1.233	0.659	2.014	1.163	0.852	2.681*	0.993	1.510
	(1.73)	(3.44)	(1.77)	(1.76)	(3.18)	(1.81)	(1.51)	(1.84)	(1.53)
Import Index	0.152	0.157	0.109	0.182	0.316	0.194	0.225	0.059	0.172
	(0.38)	(0.55)	(0.39)	(0.39)	(0.48)	(0.40)	(0.31)	(0.42)	(0.34)
ODA per capita	0.987***	0.800***	0.914***	0.985***	0.745***	0.944***	0.565***	0.546***	0.519***
	(0.17)	(0.23)	(0.16)	(0.17)	(0.20)	(0.17)	(0.11)	(0.13)	(0.10)
GDP growth	0.066*	0.095**	0.057	0.068	0.090*	0.064	0.069**	0.104**	0.071*
	(0.04)	(0.05)	(0.04)	(0.04)	(0.05)	(0.04)	(0.03)	(0.04)	(0.04)
Extreme political events	-0.093	-0.113	-0.042	-0.096	-0.078	-0.061	-0.308***	-0.284*	-0.249**
	(0.15)	(0.20)	(0.15)	(0.15)	(0.19)	(0.15)	(0.12)	(0.16)	(0.12)
Constant	-9.555***	-13.758***	-10.028***	-10.313***	-13.636***	-11.284***	-7.928***	-9.559**	-6.438**
	(3.20)	(4.97)	(3.22)	(3.36)	(4.58)	(3.24)	(2.94)	(3.68)	(2.89)
Observations	656	495	661	656	495	661	656	495	661
Instruments	23	24	23	23	26	23	17	21	20
AR(2) p-value	0.568	0.882	0.520	0.411	0.818	0.336	0.988	0.926	0.729
Hansen p-value	0.285	0.226	0.242	0.243	0.294	0.177	0.316	0.169	0.359

All regressions include window fixed effects. Robust standard errors clustered at the country level are in parentheses. $^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$.

Table 5. Determinants of climate finance in the water and sanitation sector: GMM-System (2000-2022, 4-year windows)

	Climate 1	Climate 2	Climate 3	Mitigation 4	Mitigation 5	Mitigation 6	Adaptation 7	Adaptation 8	Adaptation 9
Sanitation Climate Finance, Lagged	0.197***	0.185**	0.205***						
	(0.07)	(0.09)	(0.07)						
Sanitation Mitigation Finance, Lagged				0.274***	0.205*	0.272***			
				(0.10)	(0.10)	(0.10)			
Sanitation Adaptation Finance, Lagged							0.244***	0.221**	0.255***
							(0.08)	(0.09)	(0.09)
PPI Sanitation Investment	0.175**	0.151	0.166**	0.176**	0.192*	0.172*	0.130**	0.105	0.127**
	(0.08)	(0.10)	(0.08)	(0.09)	(0.11)	(0.09)	(0.06)	(0.07)	(0.06)
Vulnerability	0.567			-2.618			2.134		
	(2.54)			(2.81)			(1.87)		
Access to reliable drinking water		0.488			-0.099			0.133	
		(0.94)			(1.10)			(0.77)	
Water dependency ratio			-0.286			-0.100			-0.187
			(0.43)			(0.51)			(0.32)
GHG Emissions (pc)	-0.503	-0.472	-0.505	-0.282	-0.197	-0.215	-0.571**	-0.642**	-0.609***
	(0.38)	(0.40)	(0.37)	(0.35)	(0.27)	(0.32)	(0.23)	(0.27)	(0.24)
Population	1.108***	1.137***	1.100***	1.208***	1.240***	1.217***	0.893***	0.838***	0.870***
	(0.15)	(0.16)	(0.15)	(0.20)	(0.21)	(0.20)	(0.10)	(0.12)	(0.11)
Agriculture (% GDP)	-0.019	-0.025	-0.016	-0.001	-0.004	-0.007	-0.023**	-0.017	-0.015
	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
Readiness	1.785	2.729	1.285	2.913	3.806	3.407	1.125	2.172	0.329
	(2.12)	(2.70)	(2.08)	(2.34)	(2.67)	(2.19)	(1.81)	(2.82)	(1.80)
Import Index	0.234	0.614	0.222	0.625	1.202**	0.657	-0.023	-0.199	-0.022
	(0.37)	(0.54)	(0.36)	(0.41)	(0.54)	(0.42)	(0.29)	(0.38)	(0.29)
ODA per capita	1.112***	1.214***	1.084***	1.104***	1.253***	1.054***	0.891***	0.995***	0.882***
	(0.20)	(0.20)	(0.20)	(0.25)	(0.22)	(0.24)	(0.14)	(0.14)	(0.15)
GDP growth	0.066	0.024	0.065	0.035	-0.021	0.036	0.083**	0.116**	0.082**
	(0.04)	(0.06)	(0.04)	(0.05)	(0.05)	(0.05)	(0.03)	(0.05)	(0.04)
Extreme political events	-0.100	-0.248	-0.098	-0.258*	-0.359**	-0.277*	-0.093	-0.031	-0.083
	(0.14)	(0.15)	(0.14)	(0.15)	(0.17)	(0.16)	(0.13)	(0.15)	(0.13)
Constant	-15.767***	-18.185***	-15.065***	-20.491***	-24.426***	-21.768***	-11.537***	-9.063**	-9.912***
	(4.11)	(4.50)	(3.73)	(4.98)	(4.95)	(4.73)	(3.07)	(3.79)	(2.82)
Observations	656	378	661	656	378	661	656	378	661
Instruments	18	20	18	24	18	24	19	20	19
AR(2) p-value	0.173	0.637	0.174	0.168	0.602	0.170	0.124	0.186	0.133
Hansen p-value	0.272	0.103	0.193	0.268	0.217	0.237	0.352	0.175	0.296

All regressions include window fixed effects. Robust standard errors clustered at the country level are in parentheses. *p<0.10, **p<0.05, ***p<0.01.

4.2.2. Financial instrument models

To further explore heterogeneity in the determinants of climate finance, we re-estimate the sectoral models (Tables 2–5) distinguishing between grant- and debt-based flows. To present results parsimoniously, we rely on the most representative vulnerability measure for each sector: the infrastructure-vulnerability score, paved roads, access to electricity, and the water dependence ratio for infrastructure, transport, energy, and water and sanitation, respectively. Figure 4 summarizes the findings. Additional estimations using alternative vulnerability indicators (unreported) confirm the robustness of the results.

Within each sector, results are presented in three categories: (i) total, which corresponds to our baseline estimates pooling all financial instruments; (ii) debt, capturing the effects on climate finance delivered through debt instruments; and (iii) grant, referring to climate finance flows provided in the form of grants.

Two main patterns emerge. First, the profitability of infrastructure investments— captured by private participation in infrastructure— consistently exhibits a positive association with climate finance, regardless of the financial instrument or sector. This finding reinforces the merits-based perspective emphasized in previous studies (Venner *et al*., 2024), suggesting that climate finance tends to reward projects with higher expected returns and stronger absorptive capacity. The positive effect also extends to both mitigation- and adaptation-oriented finance, supporting the idea that economic returns remain central even when the stated objective is climate resilience.

Second, comparing across instruments, the effects of infrastructure returns are systematically stronger for debt-based flows than for grants, in line with the expectation that lenders prioritize financially viable projects where repayment is more likely. This pattern echoes the broader literature on aid modalities, which stresses that loans tend to be channeled toward projects with clearer revenue streams, while grants are more often used in contexts of limited repayment capacity.

Figure 4. Summary of results: elasticities of climate finance for infrastructure in relation to infrastructure-related determinants

Positive and statiscally significant | Positive and statiscally significant | Negative and statiscally significant | Not statiscally significant

EFFECTS ON CLIMATE FINANCE		Infrastructure				Transport				Energy				Water and sanitation			
			Total	Debt	Grant		Total	Debt	Grant		Total	Debt	Grant		Total	Debt	Grant
PPI Investments in Infrastructrure (or related sector), Lagged	Climate	+	0.154	0.200	0.136	+	0.192	0.199	0.169	+	0.142	0.180	0.131	+	0.166	0.144	0.092
	Mitigation	+	0.176	0.194	0.140	+	0.200	0.192	0.200	+	0.143	0.095	0.134	+	0.172	0.271	0.139
	Adaptation	+	0.128	0.224	0.108	+	0.154	0.143	0.067	+	0.095	-0.009	0.086	+	0.127	0.200	0.005
Infrastructure Vulnerability (or related sector), Lagged	Climate	+	1.633	-0.339	2.384	0	0.700	0.527	1.217	−	-1.571	-1.226	-0.544	0	-0.286	0.248	-0.392
	Mitigation	+	1.746	1.422	2.170	0	0.377	0.026	1.246	−	-1.582	-4.322	-0.586	0	-0.100	0.723	-0.286
	Adaptation	+	1.904	-0.104	2.727	+	1.127	0.998	0.735	0	-0.651	-0.494	-0.038	0	-0.187	-0.158	-0.113

Source: author's elaboration. Note: Green (PPI Investments in Infrastructure) – positive and statistically significant; Blue (Infrastructure Vulnerability) – positive and statistically significant; Red (Infrastructure Vulnerability) – negative and statistically significant; Gray – not statistically significant.

Turning to the needs-based dimension, our findings show that infrastructure-related vulnerabilities are positively associated with climate finance, but only in specific contexts. For grants, vulnerability matters for the aggregated infrastructure and transport sectors, suggesting that when concessionality is higher, donor allocation responds more strongly to developmental needs. This resonates with some studies highlighting that vulnerability considerations are more visible in grant allocations (Fageda and Fioravanti, 2025). By contrast, in the energy sector, we find a negative association between vulnerability (proxied by access to electricity) and climate finance, particularly for mitigation flows, which may reflect risk aversion on the part of financiers or the prioritization of projects in countries with more stable energy systems. Finally, in the water and sanitation sector, no significant link emerges between vulnerability and climate finance, irrespective of the instrument, indicating a possible mismatch between vulnerability and allocation in this domain.

Overall, these results corroborate and nuance our baseline findings: while profitability remains a central driver of climate finance across all instruments, grants appear more sensitive to vulnerability considerations, whereas debt instruments are more strongly associated with financial returns. This duality mirrors the broader tension in the literature between needs-based and merits-based allocation logics and highlights the importance of considering the composition of climate finance when assessing its fairness in addressing global climate challenges. In addition, the empirical finding that profitability systematically influences debt-based climate finance suggests that even concessional lending— whose allocation should, in principle, respond to vulnerability— has increasingly reflected market incentives and expected returns. This reinforces the importance of distinguishing between concessional and non-concessional components when assessing the distributive fairness, concessionality, and developmental orientation of global climate finance for infrastructure.

5. Policy Implications and Concluding Remarks

Our findings carry important policy implications for the design of climate finance allocation and the pursuit of a fairer green transition. The empirical evidence shows that profitability of infrastructure investments is a consistent driver of climate finance flows, whereas vulnerability considerations only matter in selected contexts—mostly through grants and specific sectors. These results highlight both opportunities and risks within the current climate finance architecture.

First, infrastructure related climate finance remains strongly market-oriented. The positive association between private participation in infrastructure (PPI) and climate finance allocation suggests that projects with clear revenue streams and investment returns are more likely to be financed. While this enhances efficiency and mobilizes private capital, it risks neglecting highly vulnerable countries where infrastructure projects are less financially attractive. Policymakers and international financial institutions should therefore complement profitability-based criteria with explicit vulnerability thresholds to ensure that allocation aligns with equity goals embedded in the Paris Agreement.

Second, grants play a central role in addressing vulnerability. Our results indicate that vulnerability considerations emerge primarily in grant allocations, particularly in transport and aggregate infrastructure. However, the relative share of grants in total climate finance has remained modest and has declined over time, even as grants represent the main channel through which equity-oriented allocations materialize. Between 2000 and 2022, grants accounted for only around one-third of total climate-related finance for infrastructure, and their proportion has gradually fallen in recent years— reflecting broader international trends that foresee an even smaller role for grant-based instruments in the coming decade. This trajectory raises concern that, under current patterns, an increasing share of climate-related investment will be directed toward financially viable contexts rather than the most vulnerable countries.

Third, the contraction of grants may also reinforce a structural feedback loop linking vulnerability, cost of capital, and investment. Highly vulnerable countries tend to face higher borrowing costs, which reduce expected returns and discourage investment— thereby perpetuating low resilience and further vulnerability. In this sense, the structural reorientation towards non-concessional debt-based climate finance with the erosion of grant components risks entrenching a "vulnerability trap," where limited access to affordable finance exacerbates both fiscal and climatic fragility. Expanding the share of grant-based and highly concessional finance for infrastructure would therefore be crucial to break this cycle and strengthen the distributive justice dimension of global climate finance.

Fourth, sector-specific vulnerabilities require targeted attention. The heterogeneous effects across sectors suggest that a "one-size-fits-all" approach is insufficient. In energy, for instance, climate finance appears to reward countries with more stable access and lower vulnerability, possibly reflecting risk aversion. Conversely, transport and aggregate infrastructure reveal greater sensitivity to vulnerability when funding is concessional. A more balanced allocation strategy should explicitly account for these sectoral dynamics, ensuring that resilience-building investments in the most exposed systems are not sidelined.

Fifth, debt-dominated financing structures may exacerbate inequalities. The heavy reliance on loans reinforces the emphasis on financial viability and risks adding debt burdens to already vulnerable countries. Without adequate concessionality, infrastructure climate finance could paradoxically deepen fiscal vulnerabilities rather than alleviating climate risks. A policy priority should therefore be to increase the provision of grants and highly concessional instruments in adaptation-related infrastructure finance.

Taken together, these policy implications underscore the tension mapped in Figure 1: when climate finance is primarily guided by expected returns, it gravitates toward unjust outcomes by reinforcing market-driven patterns of allocation. Conversely, when vulnerability is adequately recognized—particularly through grants and targeted sectoral strategies—climate finance can become a tool for advancing distributive justice and a genuinely fair green transition.

Expanding on this perspective, the results highlight that the current system sits at a crossroads between just and unjust trajectories of the green transition. On the one hand, prioritizing profitability and debt-based flows risks perpetuating an unjust green transition in which already advantaged countries consolidate infrastructure upgrades while vulnerable ones remain underfunded and locked into risk-prone systems. On the other hand, integrating vulnerability-sensitive allocations, especially through grants, offers a pathway toward a just green transition, in which climate finance addresses structural imbalances, enhances resilience in marginalized regions, and broadens access to essential infrastructure services. In this sense, the allocation of climate finance does not merely redistribute financial resources; it also redistributes opportunities, risks, and capacities for long-term sustainable development. Ensuring that this redistribution is fair requires deliberate policy choices: strengthening concessionality, embedding vulnerability criteria in allocation frameworks, and promoting inclusive governance in decision-making processes.

Despite these contributions, some limitations remain and point to avenues for future research. First, the relatively low volume of grant- and adaptation-related flows in certain sectors constrains the variability of our data and may attenuate the robustness of some estimates. Extending the temporal coverage as more years of climate finance data become available would allow for a more comprehensive assessment of long-term patterns. Second, our analysis is conducted at the country-aggregated level, which inevitably masks the heterogeneity of individual project flows. Future studies employing project-level or bilateral flow data could uncover more nuanced interactions between profitability, vulnerability, and donor characteristics, thereby advancing our understanding of how climate finance allocation mechanisms operate in practice. Third, it remains essential to evaluate the actual returns of climate finance across instruments, climate themes, and sectors, going beyond allocation patterns to assess whether flows effectively contribute to environmental outcomes. Linking allocation models to variables of a more explicit climatic nature— such as greenhouse gas emissions, deforestation, or ecosystem degradation— would provide a clearer picture of how climate finance affects mitigation and adaptation trajectories on the ground, allowing policymakers to make more certain valuation of the cost-benefit of this type of finance.

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