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An Empirical Analysis of Donors and Instruments over the Period 2019–2023

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Does Climate Change Vulnerability Matter for the Allocation of Adaptation Finance? An Empirical analysis of Donors and Instruments over the Period 2019–2023

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Abstract

Adaptation to climate change constitutes a central challenge for sustainable development of developing countries, particularly for countries exposed to climate shocks. Although international agreements explicitly prioritize the most vulnerable countries, the operational translation of this principle into the effective allocation of international adaptation finance remains uncertain.

This paper examines the extent to which structural vulnerability to climate change is taken into account by international donors in the allocation of public adaptation finance between 2019 and 2023. It relies on a harmonized database combining the main international sources tracking climate finance (TOSSD, CRS and CRDF), covering bilateral and multilateral public commitments.

Results show that, for donors as a whole, climate vulnerability does not emerge as a statistically significant determinant of per capita adaptation commitments, except at the most extreme levels of the vulnerability distribution. In contrast, income per capita and, especially, governance quality emerge as major and robust explanatory factors. Donors thus tend to allocate more resources to countries with more limited domestic fiscal capacity, while conditioning these allocations on the existence of sufficient institutional capacity, reflecting an allocation logic combining poverty targeting and institutional selectivity based on implementation capacity.

A differentiated analysis by donor type and financing instruments reveals distinct patterns. Multilateral donors appear primarily guided by governance and operational viability criteria, with limited sensitivity to structural climate vulnerability. Bilateral donors display greater attention to situations of extreme climate vulnerability, although this sensitivity remains partial and conditional on institutional capacity. Across instruments, grants are the most responsive to structural vulnerability, whereas concessional and non-concessional loans are primarily driven by income, solvency, and governance considerations.

Keywords
Climate finance, Climate change adaptation, Climate change vulnerability, Allocation of adaptation finance

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Résumé

L'adaptation au changement climatique constitue un enjeu central du développement durable, en particulier pour les pays exposés aux chocs climatiques. Bien que les accords internationaux consacrent explicitement la priorité aux pays les plus vulnérables, la traduction opérationnelle de ce principe dans l'allocation effective des financements internationaux d'adaptation demeure incertaine.

Ce papier analyse dans quelle mesure la vulnérabilité structurelle au changement climatique est prise en compte par les bailleurs internationaux dans l'allocation des financements publics d'adaptation sur la période 2019–2023. Il s'appuie sur une base de données harmonisée combinant les principales sources internationales de suivi des financements climatiques (TOSSD, CRS et CRDF), couvrant les engagements publics bilatéraux et multilatéraux.

Les résultats montrent que, pour l'ensemble des bailleurs, la vulnérabilité structurelle n'apparaît pas comme un déterminant significatif des engagements d'adaptation par habitant, sauf aux niveaux les plus extrêmes de la distribution de la vulnérabilité. En revanche, le revenu par habitant et, surtout, la qualité de la gouvernance ressortent comme des facteurs explicatifs majeurs et robustes. Les bailleurs tendent ainsi à orienter davantage de ressources vers les pays disposant de marges budgétaires domestiques plus limitées, tout en conditionnant ces allocations à l'existence de capacités institutionnelles jugées suffisantes, traduisant une logique combinant ciblage de la pauvreté et sélectivité institutionnelle fondée sur les capacités d'exécution.

Une analyse différenciée selon le type de bailleur et la nature des instruments révèle des comportements distincts. Les bailleurs multilatéraux apparaissent principalement guidés par des critères de gouvernance et de viabilité opérationnelle, avec une faible sensibilité à la vulnérabilité structurelle au changement climatique. Les bailleurs bilatéraux manifestent une attention plus marquée aux situations de vulnérabilité climatique extrême, bien que cette sensibilité demeure partielle et conditionnée par les capacités institutionnelles. Selon les instruments, les dons sont les financements les plus sensibles à la vulnérabilité structurelle, tandis que les prêts concessionnels et non concessionnels répondent avant tout à des critères de revenu, de solvabilité et de gouvernance.

Mots-clés

Finance climat ; adaptation au changement climatique ; vulnérabilité au changement climatique ; allocation des financements d'adaptation.

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Introduction

Climate change is today one of the greatest challenges for sustainable development, disproportionately affecting developing countries and, among them, those whose economies and societies display a high vulnerability to climate impacts. These countries, often characterised by a marked dependence on climate-sensitive sectors, limited institutional capacity and heightened exposure to climate disasters, have reduced room for manoeuvre to cope with climate shocks. This situation is part of what the literature terms the "double injustice" — the countries that have contributed least to emissions are also those most exposed and least endowed with adaptive capacity (Ciplet et al., 2013). In this context, adaptation appears as an unavoidable imperative to strengthen resilience, protect development gains and prevent the worsening of poverty and inequality (Hallegatte et al., 2016; IPCC, 2022). It is also becoming a major determinant of macroeconomic and social stability, given that climate impacts can jeopardise the growth trajectory, public investment and fiscal sustainability of many vulnerable economies (Blackman et al., 2025). This is why the question of adaptation to climate change has become a crucial element of international development policy.

The Paris Agreement in 2015 marked a decisive step in the international recognition of adaptation as a pillar of climate governance. Article 7 enshrines a global goal aimed at strengthening adaptive capacities, increasing resilience and reducing vulnerability to climate change, while emphasising the need to support as a priority the most vulnerable developing countries. Article 9 further reaffirms the commitment of developed countries to provide financial support, taking into account the principle of common but differentiated responsibilities and respective capabilities, which constitutes the normative foundation of international solidarity on climate matters (UNFCCC, 1992). This architecture thus enshrines a principle of differentiation explicitly grounded in vulnerability, intended to guide the distribution of international resources dedicated to adaptation. It is nevertheless important to distinguish this normative framework, stemming from international negotiations, from the operational functioning of climate finance. The principles of justice and differentiation established in the agreements do not translate mechanically into financing practices, which rest on heterogeneous definitions, classifications and reporting methods (Hall and Persson, 2018; Weikmans and Roberts, 2019).

A growing body of work examines the allocative coherence of adaptation finance. Several analyses show that the distribution of resources only partially aligns with vulnerability profiles, with allocations frequently influenced by administrative capacities, experience in project formulation or donors' strategic preferences (Betzold and Weiler, 2017; Beynon, 2025; Doshi and Garschagen, 2020; Robinson and Dornan, 2017). This tendency is explained in part by the fact that several of the most vulnerable countries also cumulate significant institutional fragilities. Yet donors, subject to high requirements of accountability and risk management, tend to favour administratively more stable contexts in order to reduce the operational risks associated with project implementation (Alesina and Weder, 2002; Dollar and Levin, 2006; Weiler and Klöck, 2021). The effectiveness of adaptation investments depends on structural constraints such as institutional capacities, existing infrastructure

and governance arrangements, which condition the absorption of financing and the effective implementation of projects (Manuamorn and Larsen, 2020; Pacillo et al., 2024). Moreover, a now well-established body of literature highlights that interventions insufficiently tailored to national contexts can reinforce existing vulnerabilities rather than reduce them — a phenomenon documented under the concept of maladaptation (Barnett and O'Neill, 2013; Juhola et al., 2016; Magnan et al., 2016).

These findings echo the broader literature on the allocation of official development assistance, which highlights the persistence of a tension between need criteria, performance considerations and geopolitical motivations (Alesina and Dollar, 2000; Hoeffler and Outram, 2011). Building on this work, several analyses apply the models of need, merit and interest to the study of climate finance, showing that allocation decisions simultaneously reflect normative, strategic and institutional considerations (Berthélemy, 2006; Tanner and Allouche, 2011). In principle, the allocation of adaptation finance should rest primarily on climate vulnerability, normatively supported by the principles of distributive justice and international equity (Duus-Otterstrøm, 2016). However, numerous studies show that the most vulnerable countries are not systematically those that receive the largest volumes of financing, with access to resources being closely linked to institutional capacities, administrative environments and donor priorities (Persson and Remling, 2014). Analyses conducted for Latin America and the Caribbean reach a similar conclusion, with climate finance not targeting in a preferential manner the most exposed countries (Blackman et al., 2025).

Allocation dynamics are also shaped by the specific mandate of development finance institutions. These operate under strict constraints of accountability, fiduciary risk management and legal compliance, which lead them to favour administratively stable environments endowed with sufficient absorption capacities. These requirements flow directly from their institutional design and structure the way in which climate commitments are articulated with their internal risk management obligations, as well as the capacity of recipient countries to formulate and manage financing projects (Bhandary, 2024; Browne, 2022).

At the same time, the estimation of adaptation needs and the measurement of mobilised financing remain marked by significant uncertainty. Cost assessments vary considerably depending on assumptions, methods, measurement points and perimeters retained, which limits their comparability and calls for caution in interpreting adaptation needs (Parry et al., 2009).

The measurement of financing faces analogous difficulties. The Rio markers, the component-based approaches implemented by multilateral development banks and the classifications used by climate funds rest on heterogeneous conventions, while the operational boundary between development and adaptation remains contested (Donner et al., 2016). In this context, risks of over-reporting coexist with risks of under-estimation, notably when development interventions implicitly contribute to strengthening adaptive capacities without being explicitly identified as such. These biases, combined with

inconsistencies between institutions — particularly for multi-sectoral projects — complicate the precise identification of expenditure effectively dedicated to adaptation (Michaelowa and Michaelowa, 2011; Weikmans and Roberts, 2019).

It is also important to recall that adaptation covers economically heterogeneous interventions. A non-negligible share of these interventions is not financed through external finance flows, but corresponds instead to private goods or local public goods, such as urban infrastructure, housing or municipal water management. These expenditures often fall under domestic or private financing, which mechanically limits their inclusion in international reporting systems, which are primarily centered on international public contributions (Hallegatte et al., 2016). Available data therefore constitute only a partial measure of the overall adaptation effort.

In this context, three questions structure the analysis. To what extent does the structural vulnerability of recipient countries influence the allocation of international adaptation finance? Do multilateral donors take vulnerability into account more than bilateral donors? Does the nature of financial instruments matter — in particular, are grants more sensitive to vulnerability than concessional or non-concessional loans?

This study draws on a database covering exclusively the international public finance declared by donors for adaptation activities. It captures neither private investments nor domestic financing, the measurement of which remains limited in the absence of harmonised international tracking systems. Despite this restricted perimeter, this database constitutes the most systematic and reliable source currently available, insofar as it rests on official donor declarations and reflects the way in which donors identify and classify their own interventions. The limitations observed are, however, not specific to this database, but are common to the main international frameworks for tracking adaptation finance, notably the OECD-DAC Rio markers, the component-based approaches of multilateral development banks and the classifications implemented by climate funds. The boundary between adaptation and development remains difficult to establish, particularly for multi-sectoral projects or those integrating co-benefits. Furthermore, the absence of a standardised global method for exhaustively measuring private contributions, combined with the marked heterogeneity of reporting practices between institutions, complicates the interpretation of available data (Jachnik et al., 2015), calling for a cautious reading of observed amounts.

This paper forms part of the AFD–FERDI project dedicated to the analysis of the allocation of international financing for adaptation to climate change. It constitutes the second deliverable of the contract, focused on the empirical and econometric assessment of the consideration given to structural vulnerability in the distribution of adaptation resources over the period 2019–2023. Unlike the majority of existing work, the study combines a strictly structural measure of vulnerability, coverage of recent public commitments and an econometric strategy that makes it possible to identify potentially non-linear relationships between vulnerability and allocations. It also contributes to distinguishing behaviours

according to donor types and financial instruments — an aspect still poorly documented in the allocation models inspired by the logics of need, merit and interest.

The analysis draws on a literature review, a presentation of the data, an empirical strategy and an analysis of results. It aims to shed light on the current logics of adaptation finance distribution, to identify potential biases in the consideration of vulnerability and to inform debates on the reform of allocation mechanisms. It thereby contributes to strengthening the understanding of the conditions of equity, transparency and effectiveness necessary for the credibility and legitimacy of international climate governance.

1. Literature Review

1.1. Climate change vulnerability and the question of prioritisation in adaptation finance

The literature on climate change vulnerability highlights the diversity of approaches available for identifying priority countries for adaptation, as well as the difficulties associated with their operational translation into allocation mechanisms. On the conceptual level, vulnerability to climate change refers to the propensity of a system to suffer harm when faced with a climate hazard, as a function of its exposure, sensitivity and adaptive capacity. Although this approach, derived from IPCC work, has structured international thinking (IPCC, 2014), its empirical translation remains contested.

As Füssel (2010) points out, any quantification of vulnerability involves normative choices in the selection of variables, the weighting of indicators and the scale of analysis, which introduces an element of subjectivity. The main indices available, such as the Notre Dame Global Adaptation Index (ND-GAIN) or the Climate Risk Index (CRI), rest on distinct methods and sometimes produce contradictory results depending on the importance accorded to physical exposure, sensitivity or adaptive capacity (Betzold and Weiler, 2017; Jämting, 2023). Related indices, such as the World Risk Index (WRI), which is more focused on natural disaster risk, also draw on climate variables but do not directly measure vulnerability to climate change.

Despite the proliferation of these indicators, measuring vulnerability remains a complex exercise. Adaptive capacity, in particular, remains difficult to assess (Feindouno and Guillaumont, 2019). It encompasses socio-economic and institutional dimensions that are often intertwined, such that low adaptive capacity is sometimes conflated with a lack of performance or governance. This confusion tends to influence donor decisions, whose legal frameworks and risk management imperatives lead them to favour institutionally stronger environments. Yet several of the most vulnerable countries combine high exposure with limited administrative capacities, which mechanically leads to lower allocations towards

these countries despite their high need — consistent with analyses establishing the role of fiduciary and institutional risks in allocation (Weiler and Klöck, 2021).

To move beyond these limitations, some work has sought to isolate the dimensions of vulnerability that are exogenous to national policies, by privileging its physical component — that is, exposure to climate hazards and the dynamics of shocks — which are independent of national policy choices and considered more stable and less correlated with other determinants of aid allocation (Feindouno and Guillaumont, 2019). This approach makes it possible to distinguish structural vulnerability, linked to durable geographical, demographic or environmental characteristics, from non-structural vulnerability, more strongly influenced by political or institutional circumstances. From this perspective, most global indices inspired by the IPCC framework do not clearly distinguish between these two dimensions, which often leads to a conflation of intrinsic vulnerability and institutional fragility. In line with this thinking, Feindouno et al. (2020) proposed the Physical Vulnerability to Climate Change Index (PVCCI), based solely on physical and climatic data such as the frequency of hydro-climatic shocks, the interannual variability of precipitation or exposure to tropical cyclones, in order to measure structural vulnerability independently of adaptation policies or the level of development. This indicator has been mobilised in several recent studies, including Jämting (2023) and Krupski (2024), to assess the effective consideration of structural vulnerability in the allocation of adaptation finance.

Along these lines, several earlier works laid the foundations for the link between climate vulnerability and the allocation of adaptation finance. Füssel et al. (2012) proposed a normative framework articulating responsibility, capacity and vulnerability to guide the international allocation of adaptation resources. Guillaumont and Simonet (2011) emphasised the need to use an exogenous measure of vulnerability to direct adaptation resources, avoiding indicators susceptible to being influenced by national policies. This reflection was developed further in the chapter by Guillaumont (2015) published in the volume Towards a Workable and Effective Climate Regime (Barrett et al., eds.), which proposes a formalisation of allocative criteria based on a physical vulnerability index designed to be strictly exogenous to public policy choices.[1]

This conceptual and methodological diversity helps explain the divergences observed in the empirical literature. Doshi and Garschagen (2020) show that the absence of consensus on the definition and measurement of vulnerability leads donors to adopt heterogeneous approaches, often guided by institutional feasibility and absorption capacity rather than genuine climate need. These operational constraints explain a significant share of the observed divergences, without however exhausting the normative and strategic dimensions that structure allocation choices. These divergences are also explained by the use of

[1] The question of the link between climate vulnerability and the allocation of adaptation funding had already been the subject of an important collective work during a workshop organized by FERDI in 2011 at the Maison de l'Amérique latine. This workshop brought together several key authors working on these issues, including Birdsall, Füssel, Fankhauser as well as Guillaumont and Simonet. It constituted one of the first structured discussion spaces on allocative principles based on physical vulnerability to climate change.

aggregate data, which mask infra-national disparities and differences in behaviour between donors (Dietrich, 2021; Hoeffler and Outram, 2011). Finally, vulnerability criteria are always interpreted within an institutional context specific to each donor, where shared values, procedures and representations influence the implementation of the prioritisation principle (Dietrich, 2021).

At the heart of these tensions lies an opposition between two visions of adaptation finance. On one side, a logic of equity, championed notably by countries of the Global South and grounded in the principles of need and the historical responsibility of emitting countries (Ciplet et al., 2013; Robinson and Dornan, 2017). On the other, a logic of efficiency, favoured by many donors, which rests on performance and good governance, deemed to guarantee an efficient use of funds (Weiler and Klöck, 2021). In practice, this duality can result in allocation in favour of countries endowed with solid institutions and higher administrative capacities, even when their level of vulnerability is lower.

1.2. The empirical evidence: does adaptation finance reach the most climate-vulnerable countries?

The empirical literature on the distribution of international adaptation finance yields contrasting results regarding the effective consideration of the vulnerability of recipient countries. Although vulnerability is recognised as a central criterion in climate agreements, notably since Copenhagen (2009), its operational role in allocation decisions remains uncertain. Many studies thus show that adaptation finance continues to follow the traditional logics of official development assistance, reflecting the persistent overlap between climate and development objectives. This institutional continuity leads donors to reproduce the allocation logics identified in the aid literature — namely the logic of need, the logic of donor interest and the logic of institutional performance, understood as administrative capacity and governance quality.

Empirical analyses generally rely on nominal commitments declared to the OECD CRS system, in the absence of harmonised data in grant-equivalent terms or disbursed amounts. Studies focusing on bilateral donors illustrate this situation. Betzold and Weiler (2017) show that indicators of physical exposure — such as coastal location, hazard frequency or the risk of extreme events — influence the distribution of financing more than socio-economic or institutional dimensions. Weiler et al. (2018) also observe the persistent influence of geopolitical considerations, confirming that bilateral adaptation aid does not entirely depart from the historical patterns of official development assistance. Other studies deepen this dynamic. Saunders (2019) demonstrates, through a selection-then-allocation model, that vulnerability slightly increases the probability of being selected as a recipient but has only a limited effect on the amounts actually granted. Krupski (2024), applied to the African context, underlines that physical vulnerability does not favour the selection of beneficiaries, but that the most exposed countries nonetheless receive more financing per capita when allocation does occur. These results converge on a common conclusion:

vulnerability is taken into account, but only partially and in a manner highly dependent on donor profiles.

Studies on multilateral institutions reach comparable conclusions. Garschagen and Doshi (2022), who analyse exclusively the adaptation finance of the Green Climate Fund, show that although officially priority countries — notably the Least Developed Countries (LDCs), Small Island Developing States (SIDS) and several African states — figure among the beneficiaries, they do not receive the highest amounts. Countries combining high vulnerability and weak institutional capacities remain structurally disadvantaged. The administrative and technical requirements of the GCF indeed favour states with relatively robust institutions, which limits access for countries whose adaptation needs are most pressing. These results are part of a broader literature highlighting the constraints associated with reporting and the harmonisation of financing data, particularly when it comes to identifying the share genuinely dedicated to adaptation (Michaelowa and Michaelowa, 2011; Roberts and Weikmans, 2017).

Empirical work also highlights strong heterogeneity in the link between vulnerability and received volumes — generally measured in nominal commitments across all instruments. Some identify a positive correlation between vulnerability and adaptation amounts (Betzold and Weiler, 2017; Mori et al., 2019; Robinson and Dornan, 2017; Weiler et al., 2018), while others emphasise that moderately vulnerable or better-governed countries attract more resources (Islam, 2022; Saunders, 2019). Others still find no significant relationship, or even observe a negative correlation between vulnerability and aid received (Beynon, 2025; Doshi and Garschagen, 2020; Robertsen et al., 2015; Xie et al., 2023). Similar findings emerge for Latin America and the Caribbean, where Blackman et al. (2025) highlight a significant gap between the needs associated with high vulnerability and the climate financing actually mobilised, particularly for Caribbean countries and SIDS. Part of these divergences is explained by methodological differences between studies, but also by the dimensions of vulnerability considered. Donors tend to privilege physical exposure to climate hazards, while adaptive capacities — often captured through income or development indicators — play a secondary role in empirical models (Han and Cheng, 2023). This leads to an incomplete representation of vulnerability, more centred on immediate risks than on structural fragilities.

The relationship between vulnerability and income also appears ambivalent. Some analyses highlight a negative correlation between income and financing, reflecting the fact that the poorest countries also tend to be among the most vulnerable (Mori et al., 2019; Robinson and Dornan, 2017), while others identify a non-linear relationship in which financing increases with income up to a certain threshold before declining (Betzold and Weiler, 2017; Weiler et al., 2018). Geographically, results remain contrasted. Some studies show that SIDS or certain African countries receive proportionally more adaptation finance per capita (Robinson and Dornan, 2017; Weiler et al., 2018), while others find the opposite (Islam, 2022). These discrepancies reflect the absence of a coherent pattern of prioritisation based on structural vulnerability.

A clearer convergence does emerge, however, in the analysis of the role of institutional capacities. The literature consistently shows that donors — both bilateral and multilateral — favour countries with stable governance, reliable administrative mechanisms and sufficient absorption capacity (Betzold and Weiler, 2017; Doshi and Garschagen, 2020; Weiler et al., 2018). Studies on the GCF confirm that technical and administrative requirements play a decisive role in the selection of beneficiaries (Tanner et al., 2019; Garschagen and Doshi, 2022). Countries combining high vulnerability and weak institutional capacities thus remain systematically disadvantaged, creating a tension between equity and efficiency objectives.

Regional studies complement this picture. Savvidou et al. (2021), as well as Ciplet et al. (2013) and Doshi and Garschagen (2020), show that in Africa vulnerability does not constitute a significant factor in the allocation of adaptation aid. Bosma et al. (2025), analysing combined climate and biodiversity financing, show that grants target more vulnerable countries, while return-based instruments concentrate on economies perceived as less risky. These results, observed mainly in multilateral channels, connect with those of Krupski (2024), which focuses specifically on bilateral mechanisms.

Finally, several studies devoted to multilateral institutions underscore the constraints associated with reporting and data harmonisation, the complexity of eligibility criteria and the tendency of donors to favour countries with stronger institutions (Weikmans and Roberts, 2019; Eisenstadt et al., 2021). Overall, the literature agrees on a persistent gap between the recognition of the prioritisation principle and its effective implementation, with countries combining structural vulnerability and weak administrative capacities remaining marginalised while adaptation finance concentrates in countries best equipped to absorb the available resources.

The body of work devoted to climate change adaptation finance yields contrasting and often uncertain results, owing to the diversity of vulnerability indicators mobilised, the heterogeneity of data sources and the methodological choices retained. The empirical methods used in these contributions are equally heterogeneous. The majority of studies rely on conventional parametric approaches, whether linear regressions in cross-section or panel models with fixed or random effects. Some authors use generalised linear models to analyse the probability of being selected as a recipient (Saunders, 2019), while others adopt two-stage selection models or standard multivariate regressions (Betzold and Weiler, 2017; Robinson and Dornan, 2017). A few more recent contributions draw on more advanced approaches, notably temporal network models of the TERGM type (Weiler and Klöck, 2021), but these works remain marginal in the literature.

A major cross-cutting limitation of these contributions lies in the strong dependence on linear parametric models, which impose a specific functional form between vulnerability and financial allocations. As a result, these approaches struggle to capture non-linearities, threshold effects or complex sensitivity relationships that may characterise the effective consideration of structural vulnerability by donors. None of these contributions systematically explores potential non-linear forms of the relationship between vulnerability and financing, even though these may play a decisive role in prioritisation mechanisms.

The present study situates itself within this context and makes three main contributions. First, it draws on a harmonised database covering all public adaptation commitments by bilateral and multilateral donors over the period 2019-2023, improving the comparability of results. Second, it rests on a strictly structural measure of vulnerability based on physical and climatic data, making it possible to isolate the dimensions that are genuinely exogenous to public policy choices. Third, it implements a flexible econometric strategy based on generalised additive models, making it possible to capture potentially non-linear relationships between vulnerability, country characteristics and committed financial volumes. This combination offers a robust empirical framework for assessing donor sensitivity to structural vulnerability and distinguishing allocation logics according to donors and instrument types.

2. Data and descriptive analysis

This section presents the empirical foundations of the analysis, describing the data mobilised and the methodological choices underpinning the assessment of the relationship between structural vulnerability to climate change and the distribution of international financing devoted to adaptation. It first sets out the main sources and characteristics of the data used, before examining the general trends that emerge from the observation of flows and their articulation with the vulnerability levels of recipient countries.

2.1. Sources and nature of the data

We present here the data sources mobilised for the analysis, along with their main characteristics. These combine information on climate change adaptation finance and the structural vulnerability of recipient countries, making it possible to assess the coherence between the resources committed and the needs associated with their exposure to climate risks.

2.1.1. Data on adaptation finance

The analysis draws on the database on public climate change adaptation finance developed within the framework of deliverable 1 by Hos et al. (2025). This database combines several international sources — primarily TOSSD, CRS and CRDF[2] — in order to offer as complete and coherent a coverage as possible of financial commitments devoted to adaptation over the period 2019–2023. The data record, for each recipient country, the

[2] TOSSD stands for 'Total Official Support for Sustainable Development'; CRS for 'Creditor Reporting System' and CRDF for 'Climate-Related Development Finance'.

commitments declared by bilateral and multilateral donors in favour of development projects incorporating an adaptation component.[3] Amounts are expressed in constant 2023 US dollars.[4]

The method for identifying climate finance combines the two reference approaches used at the international level: notifications made by certain Annex II Parties to the UNFCCC for bilateral donors, and the climate component approach adopted jointly by multilateral development banks (MDBs) and IDFC members.[5] Although reporting methodologies are not perfectly harmonised, most Parties rely on the OECD-DAC Rio marker system to identify adaptation-related projects and estimate the corresponding share of financing at the activity level:[6]

- 0% for activities identified as not targeting climate change adaptation,
- 40% for activities identified as pursuing adaptation as a significant objective,
- 100% for activities identified as pursuing adaptation as a principal objective.

Although this methodology does not guarantee perfect comparability between the treatment of financing by MDBs and that of UNFCCC Parties, it nonetheless constitutes the most relevant approach in light of current international measurement practices and limitations.

The international measurement of climate finance relies on reporting systems whose quality varies considerably between donors, due to methodological heterogeneities, uneven levels of detail and often limited verification procedures. These limitations, highlighted notably by Michaelowa and Michaelowa (2011), Roberts and Weikmans (2017) and Weikmans and Roberts (2019), weaken the comparability of available data and contribute to the recurring divergences observed in the literature on adaptation finance allocation. In this context, the database mobilised should be understood as representative of donors' effective reporting and classification practices, and not as an exhaustive or independent measure of the overall adaptation effort.

A harmonisation and verification exercise, conducted during the construction of the database used for this study, made it possible to avoid any double-counting, both for bilateral and multilateral donors, notably in cases of co-financing and between the inflows

[3] Adaptation flows are indeed considered as development flows, as highlighted in Blackman et al (2024).

[4] Data relate to commitments (not disbursements), which provide better coverage of international adaptation finance, with donor monitoring frameworks primarily designed for this stage in the financial chain. By convention, public policy objectives, such as adaptation to climate change, are measured at the level of commitments and not at the stage of disbursements.

[5] https://www.eib.org/en/publications/20220242-mdbs-joint-methodology-for-tracking-climate-change-adaptation-finance.

[6] The OECD/DAC Rio marker system classifies development activities according to whether adaptation to climate change is a principal objective, a significant objective or not targeted, in line with CRS reporting guidelines and the DAC annual questionnaire (OECD, 2024). As part of climate reporting exercises, particularly for UNFCCC notifications, countries usually apply coefficients to the amounts reported in order to estimate the share of funding actually attributable to adaptation. For activities identified as pursuing adaptation as a significant objective, these coefficients are most often between 30 % and 50 %, with 40 % being frequently used in practice, as documented in the OECD reports on climate finance provided and mobilized by developed countries.

and outflows of multilateral institutions. Donors are grouped into two broad categories: bilateral donors, comprising OECD-DAC members as well as other bilateral providers, and multilateral donors, which include regional and multilateral development banks, United Nations agencies, international vertical funds and other international organisations.

Financial instruments are differentiated according to their degree of concessionality, in accordance with the criteria of the International Monetary Fund and the World Bank, [7] as used in the TOSSD database. This classification makes it possible to identify grants, concessional loans and non-concessional loans, and to ensure their comparability across bilateral and multilateral providers, as well as — in a more marginal manner — other financial instruments such as equity participations or guarantees. The integration of TOSSD also broadens geographic and institutional coverage by including additional donors, notably from South-South cooperation, such as Brazil, Mexico or Indonesia, as well as countries that no longer appear on the OECD-DAC list of tracked recipients, notably certain high-income countries with significant structural vulnerabilities, such as Small Island Developing States (SIDS) like Barbados, the Bahamas or the Seychelles, as well as Chile and Uruguay.

The database covers exclusively international public financing devoted to adaptation, to the exclusion of private financing and domestic expenditure, the measurement of which remains limited in the absence of harmonised international tracking systems. Amounts aggregated by recipient country and by year were then expressed relative to the average population over the period considered, calculated from the World Development Indicators (WDI), in order to estimate adaptation finance per capita.

2.1.2. Data on structural vulnerability to climate change

The allocation of adaptation resources towards countries most vulnerable to climate change presupposes the ability to identify these countries using appropriate indicators. The analysis draws for this purpose on the Physical Vulnerability to Climate Change Index (PVCCI)[8], retained as the primary indicator of structural vulnerability to climate change. Designed to measure an exogenous vulnerability independent of national policies, the PVCCI assesses the physical predisposition of a country to suffer the effects of climate change due to geographical and environmental characteristics over which it exercises

[7] According to the criteria of the International Monetary Fund and the World Bank, a loan is considered concessional when it has a grant component of at least 35%, calculated using a 5% discount rate.

[8] Feindouno et al. (2020). The PVCCI was specifically designed to serve as a metric for allocating resources dedicated to climate change adaptation. By relying exclusively on physical and exogenous characteristics, it limits the risks of moral hazard in the allocation process, as levels of vulnerability cannot be influenced by current policies. Its structural nature also gives it a high degree of temporal stability, which favours the predictability of decisions for both donors and beneficiary countries, consistent with the long-term horizon specific to adaptation and development challenges. Finally, by excluding any institutional or governance component, the PVCCI reduces the risks of redundancy with the dimensions related to resilience, which strengthens its relevance for analyses focused on physical vulnerability.

limited control. It thus makes it possible to identify countries most exposed to climate risks for structural reasons.

The PVCCI rests exclusively on physical components and distinguishes two families of climate risks. The first concerns the intensification of recurrent shocks, notably temperature extremes, precipitation or storms. The second refers to long-term progressive phenomena such as sea-level rise or desertification. The index ranges from 0 to 100, with a higher value corresponding to a greater degree of physical vulnerability. It thus makes it possible to identify countries that are structurally most exposed to climate risks for reasons independent of their institutional or circumstantial choices.

This choice rests on the capacity of the PVCCI to capture a durable vulnerability, distinct from the socio-economic or institutional dimensions that relate more to resilience or public policy performance. Unlike other indices developed primarily for awareness-raising purposes, the PVCCI was designed to inform decisions on the allocation of concessional resources, which ensures that it does not duplicate the performance indicator nor contradict it, since the two rest on different and complementary analytical purposes. It therefore constitutes a relevant tool for assessing the correspondence between countries' structural needs and the effective distribution of adaptation finance.

For sensitivity analysis purposes, the ND-GAIN is also mobilised, after exclusion of its components reflecting governance or current policies.

2.1.3. Economic and institutional data

The analysis also draws on control variables classically used in empirical work on the allocation of international financing. These make it possible to isolate the structural factors of need — notably the level of economic development — and the institutional dimensions likely to influence donor decisions.

Income per capita is measured using Gross National Income per capita according to the Atlas method, drawn from the World Development Indicators. This indicator captures the level of economic development of recipient countries, often associated with their adaptive capacity and widely used as a need variable in the literature.

Institutional dimensions are captured through the Worldwide Governance Indicators (WGI) produced by the World Bank. The Country Policy and Institutional Assessment (CPIA) would in principle constitute the most appropriate indicator, insofar as it is explicitly used by several multilateral development banks in their concessional allocation mechanisms. However, the CPIA is published in detailed form only for countries eligible for concessional

windows, which severely limits its coverage. The WGI is retained as an alternative, as it is a composite governance indicator available for all countries and offering a harmonised measure of the quality of public institutions.

These variables thus make it possible to distinguish structural vulnerability — captured by the PVCCI — from the socio-economic and institutional determinants that may influence the effective distribution of adaptation finance.

2.2. Global analysis of international public commitments in favour of adaptation

The analysis examines the recent dynamics of global public adaptation finance commitments over the period 2019–2023, focusing on the progression of volumes, the composition of financial instruments and the institutional distribution of resources.

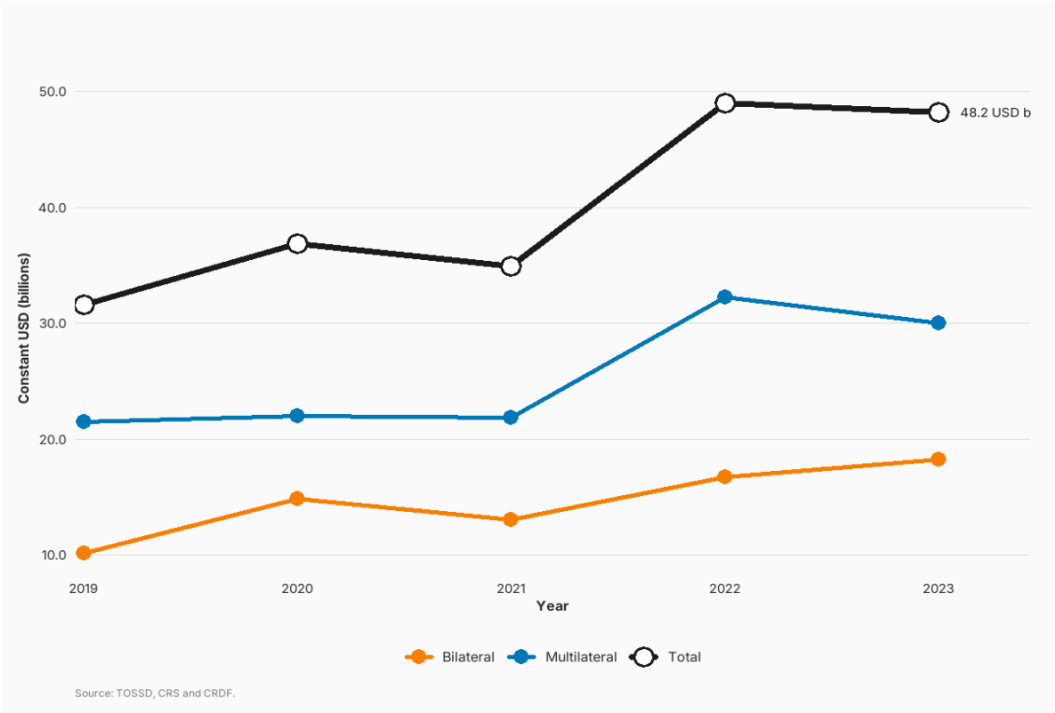
2.2.1. General trends in financing volumes

Between 2019 and 2023, global financing volumes devoted to adaptation display a clearly upward trend, reflecting a progressive intensification of international commitments in favour of climate resilience and an evolution of accounting and reporting practices, which have progressively broadened the coverage of declared financing, primarily before 2019. Total flows rose from approximately USD 31 billion in 2019 to nearly USD 48 billion in 2023, an increase of around 50% over the period. This evolution reflects both the expansion of adaptation-related financing mechanisms and the consolidation of climate priorities in multilateral and bilateral agendas.

Analysis by financing channel highlights the persistent dominance of multilateral actors, who remain the primary source of adaptation finance. Their commitments, relatively stable between 2019 and 2021 at around USD 22 billion, experienced a significant increase in 2022, followed by a slight stabilisation in 2023 at a level close to USD 24 billion. This progression reflects the growing importance of multilateral climate finance, notably through dedicated adaptation windows and sectoral or regional support programmes.

Bilateral financing, for its part, stands at a lower level in volume but displays stronger growth in relative terms. Flows rose from approximately USD 10 billion in 2019 to nearly USD 18 billion in 2023, a progression of around 80% over the period. This dynamic attests to the growing involvement of bilateral donors in the direct financing of adaptation projects, often oriented towards local, community-based or geographically specific interventions.

Figure 1: International adaptation finance (2019–2023)

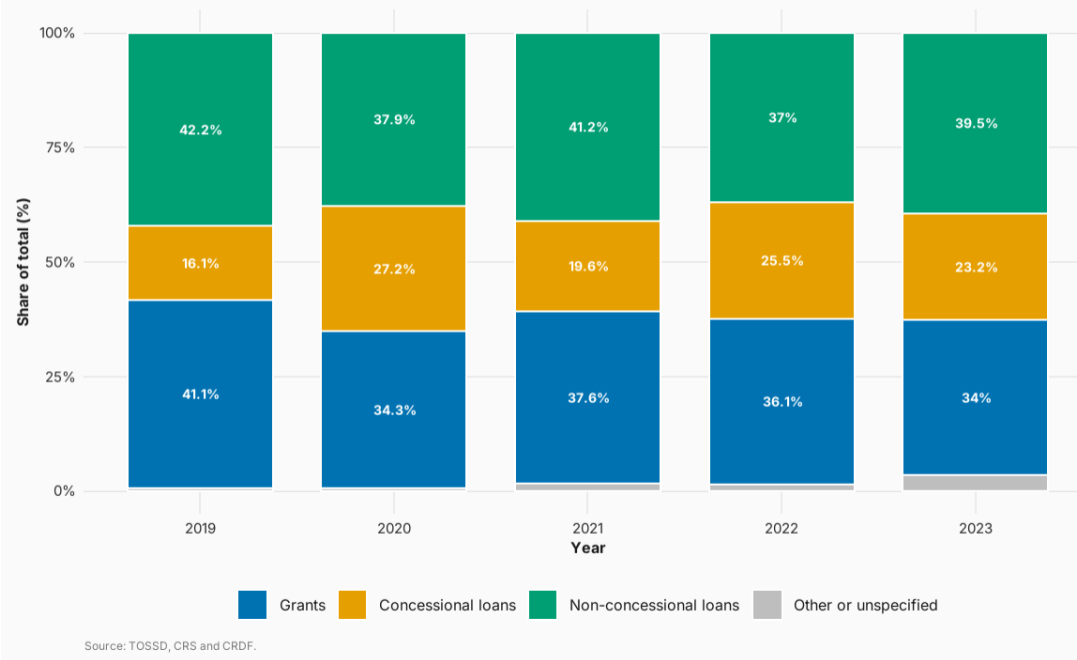


Taken together, these results suggest a gradual recomposition of the international adaptation finance landscape. While multilateral institutions retain a preponderant role in the mobilisation and channelling of resources, bilateral donors appear increasingly active, contributing to a diversification of support modalities. This joint evolution — characterised by the consolidation of the multilateral pillar and the continuous progression of bilateral contributions — reflects a dynamic of overall reinforcement of the collective adaptation effort, but within an architecture that remains asymmetric, where multilateral leverage capacity remains decisive.

2.2.2. Structure of financing according to the nature of financial instruments

Analysis of the nature of the financial instruments mobilised for international adaptation finance makes it possible to assess the degree of concessionality of these flows. It distinguishes grants, concessional loans, non-concessional loans and a residual set of operations classified as “other or unspecified.” Observation of their evolution between 2019 and 2023 provides complementary insight into the qualitative structure of adaptation finance and the underlying dynamics of its implementation.

Figure 2: Structure of international adaptation financing according to the nature of financial instruments (2019–2023)



The structure of international public adaptation finance between 2019 and 2023 reveals a relatively stable composition, in which loans — concessional or otherwise — represent a majority share, complemented by a significant though not majority share of grants. This configuration illustrates the persistent duality between solidarity logics and repayable financing mechanisms that still characterise international climate finance.

Non-concessional loans constitute the primary component over the entire period, with shares ranging between 37 and 42% of the annual total. This relative stability highlights the persistent weight of non-concessional instruments in adaptation financing, often associated with a conventional development lending logic. This tendency may reflect the difficulty of aligning financial flows with the nature of adaptation needs, which relate more to collective protection than to economic profitability.

Concessional loans represent between 16 and 27% of the annual total. Their share reached a peak in 2020, then stabilised at around 20 to 25% in the more recent period. This evolution reflects a temporary strengthening of concessional windows at the time when multilateral climate financing increased, without a profound modification of the overall structure.

Grants occupy a significant though sub-majority share, ranging between 34 and 41%. Their contribution, relatively stable over time, reflects a maintained budgetary transfer effort, but without notable progression. The observed level remains insufficient in relation to the needs

of the most vulnerable countries, for whom non-repayable financing constitutes a central lever for durable adaptation.

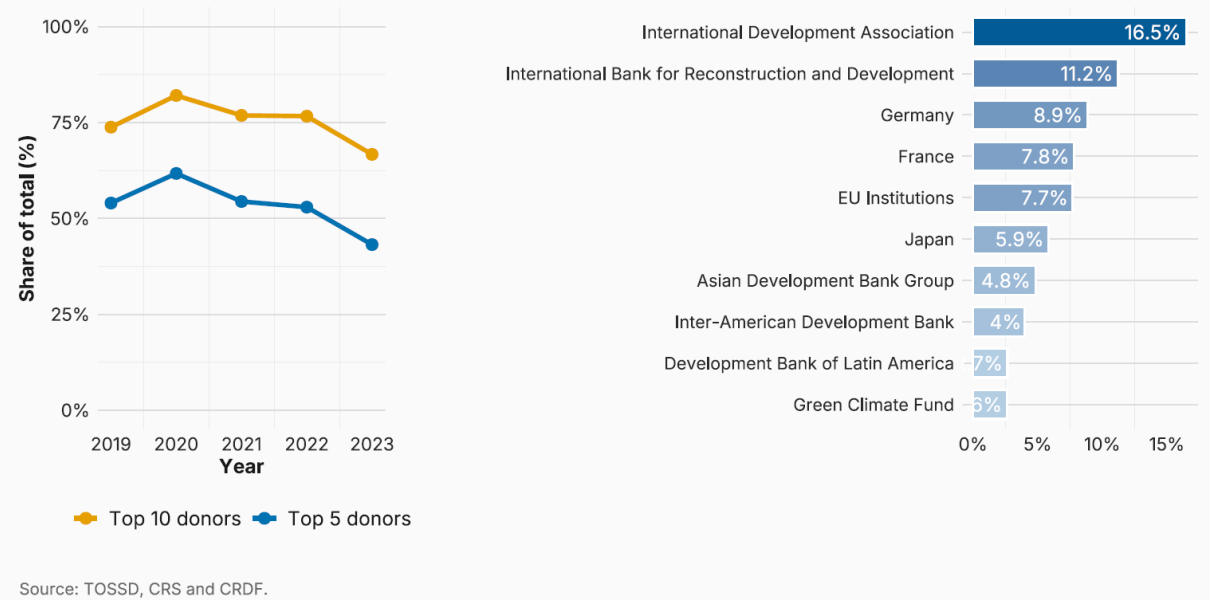
Flows classified as "other or unspecified" remain marginal, representing less than 2% of the total, reflecting both the good homogeneity of instrument classification and the limited diversity of financing modalities beyond the three main categories.

The financing structure observed between 2019 and 2023 thus highlights a strong predominance of loan instruments — particularly non-concessional — and a still restricted place for grants, despite the growing recognition of adaptation needs in the most vulnerable countries.

2.2.3. Concentration of financing supply and the role of the main donors

Analysis of the concentration of financing supply makes it possible to assess the structure of the adaptation finance market, identifying the extent to which resources come from a small number of dominant donors or a more diversified set of actors. This measure sheds light on the dependence of international adaptation finance on certain institutions and the relative stability of the resulting flows.

Figure 3 : Concentration of international adaptation finance (2019–2023)



Source: TOSSD, CRS and CRDF.

The financing structure observed between 2019 and 2023 shows a high concentration among a limited number of multilateral donors. The top ten actors account on average for more than three-quarters of total adaptation financing, while the top five represent

approximately half. This concentration has slightly eased over the period, falling from around 75% in 2019 to just over 65% in 2023 for the top 10, and from nearly 55% to less than 45% for the top 5, reflecting a moderate but perceptible diversification of the donor base.

The list of the ten main donors highlights the predominance of international financial institutions. The International Development Association (16.5%) and the International Bank for Reconstruction and Development (11.2%) head the ranking. These two entities belong to the World Bank Group, which alone concentrates nearly 27.7% of global adaptation financing. This dominant position illustrates the Group's central role in the programming and distribution of resources, both through its concessional window (IDA) and its lending capacity to middle-income countries (IBRD). Behind the World Bank Group, the European bloc occupies an equally structural position. Aggregating the shares of Germany (8.9%), France (7.8%) and European Union institutions (7.7%), the European contribution reaches 24.4% of the total, i.e. nearly a quarter of global adaptation financing. This weight reinforces the centrality of the European framework in climate finance, where complementarity between bilateral and multilateral channels remains decisive.

Regional development banks constitute a third important grouping. The Asian Development Bank (4.8%), the Inter-American Development Bank (4%) and the Development Bank of Latin America (2.7%) together represent approximately 11.5% of the total. Their role, although secondary in volume, is essential in the regional implementation of adaptation projects, notably through the financing of infrastructure and sectoral programmes. The Green Climate Fund (2.6%) completes the list of major donors, with a still limited weight despite its political visibility and specific adaptation mandate.[9]

Aggregating these results highlights the concentration of international adaptation finance around two major institutional poles. The World Bank Group and the European bloc together represent more than half of the total over the period 2019–2023. Regional banks and multilateral climate funds contribute in a complementary manner, but with a significantly smaller weight. This configuration reflects a strong dependence on a small number of systemic actors in the programming of adaptation financing and underscores the importance of diversifying sources in the medium term to ensure a more balanced distribution and greater stability of flows.

These general trends, which describe the structure and concentration of financing supply, raise the question of how these resources are distributed among recipient countries and

[9] 2.4% for the African Development Bank and 1.4% for the African Development Fund.

the degree to which they are effectively oriented towards the countries most vulnerable to the effects of climate change.[10]

2.3. Selectivity and targeting of financing according to country vulnerability

This section assesses the extent to which financing devoted to adaptation is oriented towards countries most vulnerable to the effects of climate change. It examines the relationships between countries' structural vulnerability and the volumes of financing received, as well as differences in behaviour between donor types and financial instruments.

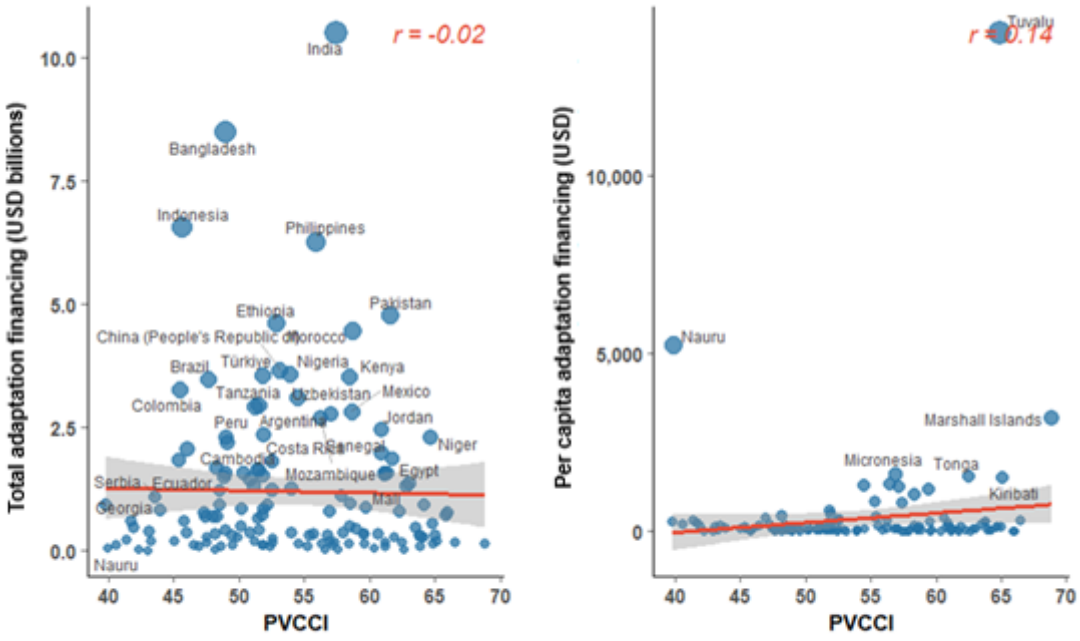
2.3.1. Relationship between climate change vulnerability and adaptation finance

Examination of the link between structural vulnerability to climate change — measured by the PVCCI — and the volumes of adaptation financing received makes it possible to assess the extent to which international resources are effectively oriented towards the most exposed countries. Figure 4 illustrates this relationship over the period 2019–2023, both in aggregate terms (left) and per capita (right).

The correlation between the PVCCI and the total volume of adaptation financing appears almost zero (r = -0.02), indicating the absence of a systematic relationship between structural vulnerability to climate change and the overall level of commitments recorded over the period 2019–2023. Certain large recipient countries, such as India, Bangladesh, Indonesia or the Philippines, stand out for their high volumes of financing, primarily owing to the size of their economies and populations and the scale of their investment needs, rather than their relative level of vulnerability. Conversely, several countries with high vulnerability — often small in size — record very low total amounts.

[10] The analysis of these general trends can be completed by the Ferdi report based on the same data source: Tomáš Hos, Sylviane Guillaumont Jeanneney, Clara Pugnet (2026) "Climate finance for adaptation".

Figure 4 : Relationship between the PVCCI and adaptation finance: total and per capita



Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

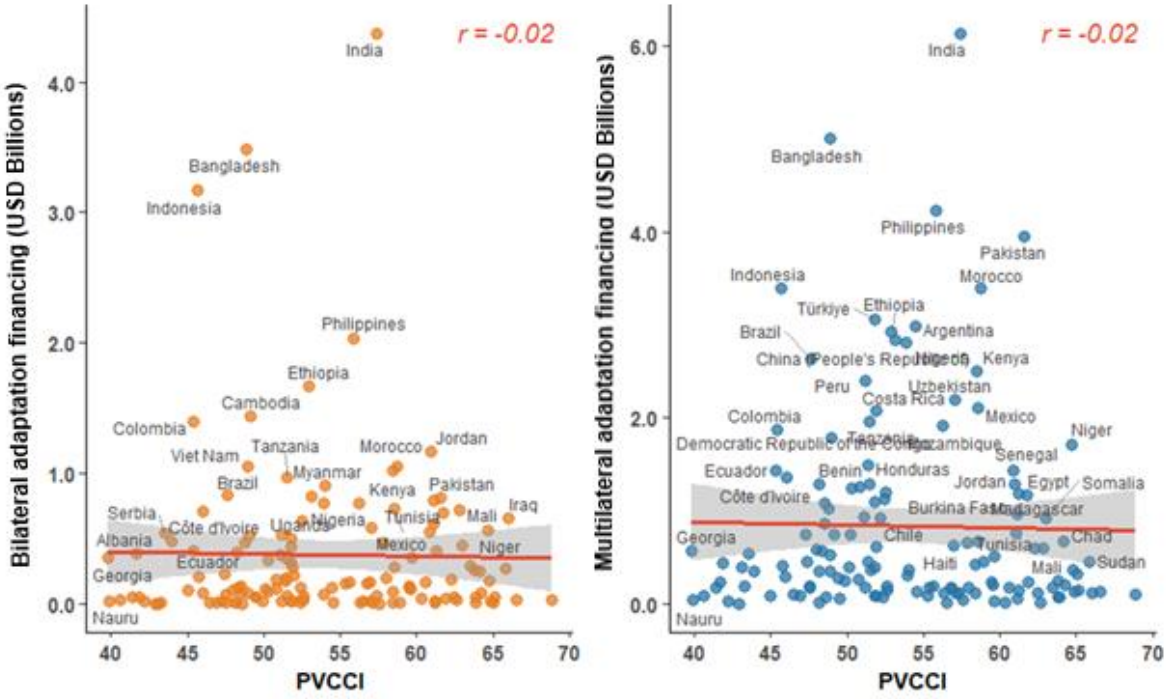
When flows are expressed per capita (right), the relationship becomes slightly positive (r = 0.14), but remains weak. Small Pacific island states, such as Tuvalu, Nauru, the Marshall Islands or Kiribati, stand out for per capita adaptation amounts well above the global average, reflecting a partial consideration by certain donors of their specific vulnerability and structural constraints. These results suggest that, despite certain priorities accorded to the most exposed countries, the distribution of adaptation finance remains largely influenced by the demographic size and absorption capacity of recipient economies, rather than by the sole intensity of their structural vulnerability to climate change.

A complementary analysis, presented in the annex (Figure A1), refines this reading by distinguishing the types of instruments used in adaptation finance. The results indicate that grants display a weak but positive correlation with the PVCCI (r = 0.14), suggesting a limited consideration of structural vulnerability in their allocation. Concessional loans also display a weak correlation (r = 0.07), while non-concessional loans display a slightly negative correlation (r = -0.07). These differences, though modest, highlight contrasting allocation profiles according to instrument type.

2.3.2. Relationship between structural vulnerability and adaptation financing by donor type

Figure 5 presents the relationship between the PVCCI and cumulative adaptation financing commitments over the period 2019–2023, distinguishing bilateral donors (left) from multilateral donors (right).

Figure 5: Relationship between the PVCCI and adaptation financing commitments by donor type



Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

The correlation coefficients are identical and very low for both groups (r = -0.02), indicating the absence of a significant link between structural vulnerability to climate change and recorded commitments, regardless of the financing channel. Bilateral flows are characterised by strong heterogeneity between recipient countries, with no clear tendency to favour the most vulnerable. Multilateral commitments display a comparable pattern, with a marked dispersion of volumes for a given level of vulnerability. These results suggest that, despite institutional differences between donors, structural vulnerability does not constitute a major explanatory factor in their adaptation commitments over the period considered.

A deepened analysis, based on per capita commitments, is presented in the annex (Figure A2). Correlation coefficients remain low but slightly positive (r = 0.1 for bilateral donors and r = 0.15 for multilateral donors), suggesting a partial consideration of vulnerability in the case

of certain small island states, without notably modifying the trends observed in the main analyses.

The descriptive results presented thus far shed light on certain tendencies in the distribution of adaptation financing relative to countries' structural vulnerability. The following section seeks to verify whether these relationships are confirmed in a statistical analysis aimed at establishing significant relationships by assessing the role that vulnerability effectively plays in the allocation of adaptation resources, taking into account other structural factors such as income per capita.

3. Inferential assessment of the consideration of vulnerability in adaptation finance

3.1. Methodological framework and empirical approach

The analysis rests on the estimation of a generalised additive model (GAM), particularly well suited to the study of potentially non-linear relationships between adaptation commitments and the structural characteristics of countries. Unlike ordinary linear models, the GAM makes it possible to estimate smoothed functions without imposing a functional form a priori, which offers greater flexibility for exploring the empirical structure of observed relationships.

The general model takes the following form:

$$\ln(A_i) = \alpha + \sum_{j=1}^{k} f_j(X_{ji}) + \varepsilon_i$$

Where $\ln(A_i)$ represents the logarithm of per capita adaptation commitments for country i over the period 2019–2023; $f_j(.)$ denotes a smoothing function estimated in a non-parametric or semi-parametric manner for the explanatory variable X_j — notably the PVCCI and, in certain specifications, income per capita or other variables such as the Worldwide Governance Indicators (WGI) for measuring governance quality; ε_i is the error term.

The interest of the GAM lies in its capacity to represent complex relationships between variables without imposing a specific functional form.[11] In the context studied, it is plausible

[11] Therefore, it reduces the risks of misspecification by allowing a semi-parametric estimation of smoothed effects.

that the relationship between vulnerability and adaptation flows is not monotone: the most vulnerable countries may receive more financing up to a certain threshold, before the trend reverses or stabilises. The GAM makes it possible to capture these potentially non-linear or threshold behaviours without restrictive assumptions. Estimation is carried out using penalised splines, ensuring a balance between flexibility and parsimony. The smoothing parameter is selected by cross-validation in order to minimise the risk of overfitting.

The use of the GAM constitutes a methodological advance relative to earlier work, which primarily mobilises linear parametric regressions or limited probability models focused on beneficiary selection. Unlike these approaches, the GAM imposes no functional form a priori and makes it possible to reveal any non-linearities or threshold effects in donor reactions to vulnerability. This flexibility is particularly relevant in a context where allocation behaviours may vary according to the intensity of vulnerability or interact with other structural determinants such as income or governance.

3.2. Results for all donors

The results presented in Table 1 show that no statistically significant relationship is observed between the PVCCI and per capita adaptation financing commitments. This absence of a robust link suggests that structural vulnerability to climate change does not constitute, at this stage, an explanatory factor of the commitments made by international donors. Commitment volumes thus do not appear to be directly guided by the degree of physical vulnerability of countries.

The introduction of income per capita into the model substantially modifies this reading. Income appears significant, with a negative effect: low-income countries tend to receive more per capita commitments, all else being equal. This relationship reflects a compensation logic: donors orient a larger share of resources towards economies with more limited internal budgetary capacity to finance their adaptation needs. The addition of governance reinforces this interpretation: this variable becomes the most strongly associated with commitments, with a markedly positive effect across almost the entire distribution. This influence reflects donors' preference for stable and high-performing institutional environments, perceived as guarantors of better fund efficiency and lower implementation risk.

Table 1: ***GAM estimates applied to per capita adaptation commitments***

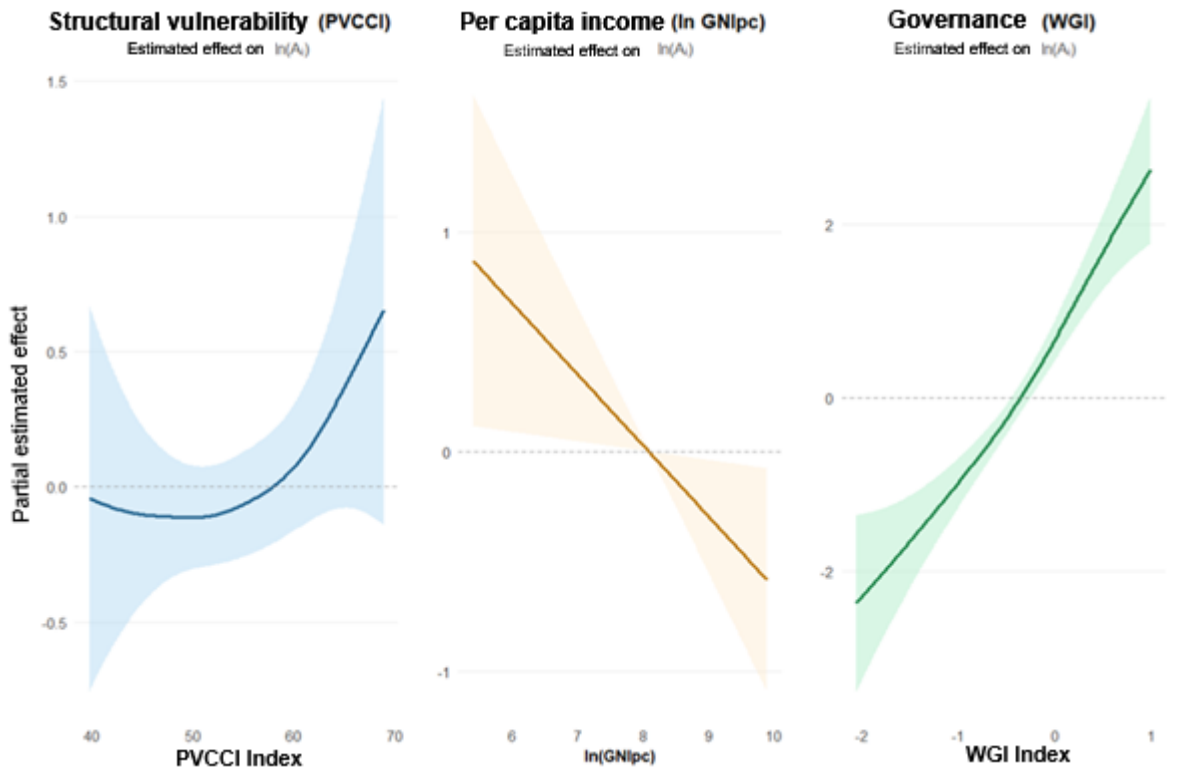
Explanatory variables	**(1) PVCCI only**	**(2) + GNIpc**	**(3) + GNIpc and WGI**
s(PVCCI)	F = 1.63, p = 0.13, edf = 3.92	F = 0.98, p = 0.37, edf = 1.90	F = 0.97, p = 0.34, edf = 1.86
s(ln GNIpc)	—	F = 6.79**, p = 0.010, edf = 1.00	F = 5.31**, p = 0.023, edf = 1.00
s(WGI)	—	—	F = 26.63***, p < 0.001, edf = 1.93
Constant	4.44*** (0.13)	4.44*** (0.13)	4.44*** (0.11)
Estimation method	REML	REML	REML

*Notes: Estimates are based on a thin plate spline generalised additive model. The dependent variable is the logarithm of per capita adaptation commitments (ln A_i). The edf values (effective degrees of freedom) indicate the degree of non-linearity of the estimated relationship. The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively. Models were estimated on the aggregated sample of recipient countries for the period 2019–2023.*

As shown in Table A1 in the annex, estimates carried out on the most vulnerable countries (last quartile of the PVCCI) provide complementary insight: vulnerability then becomes significant and positively associated with commitments. This result indicates that donors react to structural vulnerability to climate change only when it reaches extreme levels, suggesting a partial and non-systematic consideration of this dimension in allocation decisions.

Examination of the smoothed functions (Figure 6) illustrates these dynamics. The function associated with the PVCCI remains globally flat for the majority of countries, before turning upward at the highest levels of vulnerability, indicating that the effect only emerges at the extremes. By contrast, the function relating to income per capita is downward-sloping, confirming that low-income countries receive proportionally more adaptation commitments. Governance, finally, displays an upward relationship across the entire distribution, underlining that it constitutes a central determinant of commitment distribution.

Figure 6: Estimated partial effects of the PVCCI, income per capita (ln GNIpc) and governance (WGI) on per capita adaptation commitments [12]



These results reflect a structural trade-off between needs and capacities in donor allocation logic. Income captures the dimension of financial need, governance that of institutional feasibility, while physical vulnerability remains a morally recognised criterion but one that is weakly operationalised. Poor and well-governed countries thus appear as the main relative beneficiaries, while the most vulnerable but institutionally fragile countries remain under-financed. This hierarchy reveals a gap between the equity principles that underpin climate justice and the effective logics of allocation, which remain largely structured by considerations of efficiency, institutional performance and development objectives, without necessarily coinciding with structural vulnerability profiles.

3.3. Selectivity of multilateral and bilateral donors

The analysis first distinguishes the behaviour of multilateral institutions, then that of bilateral donors, in order to identify any differences in sensitivity to structural vulnerability, income level and governance quality.

[12] The estimated partial effects are from the model in column (3). This specification is used for the rest of the paper.

3.3.1. Multilateral donors

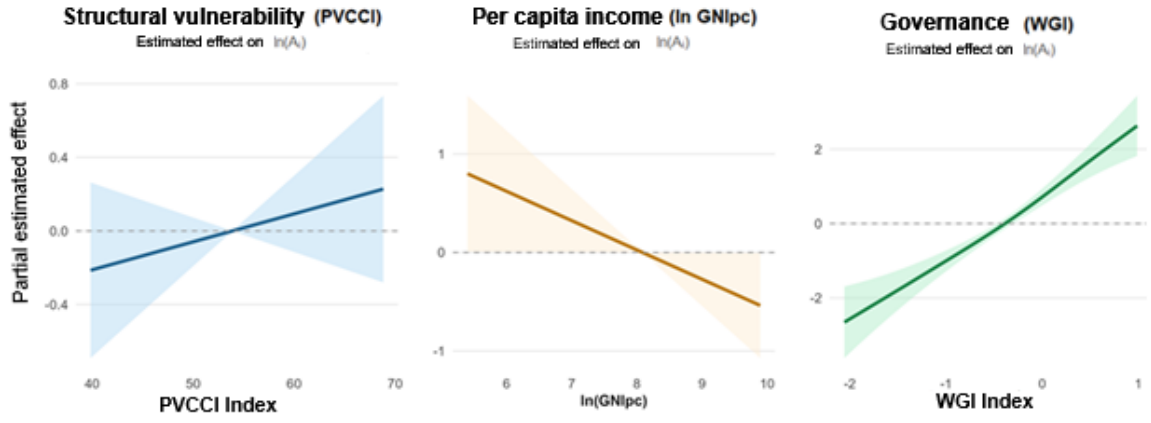
The results presented in Table 2 and Figure 7 show that structural vulnerability does not appear as a significant explanatory factor of adaptation commitments made by multilateral donors. The smoothed function of the PVCCI suggests that no systematic relationship exists between the degree of vulnerability and the per capita amounts committed. In other words, the most vulnerable countries do not benefit from a statistically identifiable advantage in multilateral allocations, despite the prioritisation principles set out in international climate agreements.

Table 2 : GAM estimates — Multilateral donors

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 1.11, p = 0.28, edf = 3.75	F = 0.51, p = 0.48, edf = 1.00	F = 0.81, p = 0.37, edf = 1.00
s(ln GNIpc)	—	F = 4.34**, p = 0.013, edf = 1.45	F = 4.08**, p = 0.046, edf = 1.00
s(WGI)	—	—	F = 30.72***, p < 0.001, edf = 1.59
Constant	4.10*** (0.14)	4.10*** (0.14)	4.10*** (0.11)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure 7: Estimated partial effects of the GAM — Multilateral donors



Income per capita emerges as significant with a negative effect, indicating that lower-income countries receive, all else being equal, more per capita adaptation commitments. This result reflects a redistributive logic inherited from development allocation practices, in which relative poverty remains an implicit eligibility criterion. Governance, for its part, displays a positive and significant relationship, with an upward slope across almost the

entire distribution: countries considered institutionally solid or with better absorption capacity tend to attract more financing.

These results suggest that multilateral allocation practices remain more oriented towards criteria of income, institutional performance and operational viability than towards climate vulnerability itself. This tendency reflects a logic of redistribution, efficiency and risk management that continues to structure allocation behaviours, including in the context of climate finance, without however excluding margins of evolution towards a better consideration of structural vulnerabilities.

3.3.2. Bilateral donors

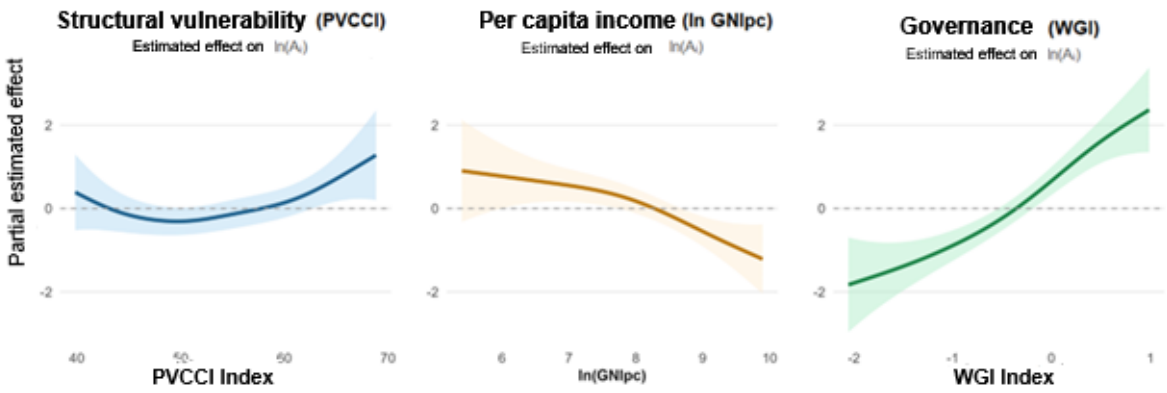
The results relating to bilateral donors (Table 3, Figure 8) reveal a noticeably different configuration. Structural vulnerability emerges as significant here, with a non-linear effect: per capita adaptation commitments tend to grow in the upper part of the PVCCI distribution, which reflects particular attention paid to the most exposed countries. This heightened sensitivity to situations of extreme vulnerability suggests a more reactive and contextual approach by bilateral donors, more oriented towards immediate needs than towards a systematic and continuous consideration of vulnerability in their allocation mechanisms.

Table 3 : GAM estimates — Bilateral donors

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 3.24**, p = 0.010, edf = 3.68	F = 3.24**, p = 0.013, edf = 3.59	F = 2.90**, p = 0.032, edf = 2.72
s(ln GNIpc)	—	F = 0.19, p = 0.860, edf = 1.21	F = 5.95***, p = 0.0018, edf = 1.98
s(WGI)	—	—	F = 18.35***, p < 0.001, edf = 2.25
Constant	2.95*** (0.13)	2.95*** (0.13)	2.95*** (0.11)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure 8: Estimated partial effects of the GAM — Bilateral donors



Income per capita retains a negative effect, reflecting the fact that lower-income countries benefit, all else being equal, from higher per capita adaptation commitments. This relationship confirms the persistence of a redistributive logic within bilateral aid, in which relative poverty remains an implicit prioritisation criterion. Conversely, governance emerges as the most significant variable and exerts a clearly positive effect on commitments. Bilateral donors thus tend to favour countries with institutional frameworks deemed solid, considering that these offer better guarantees in terms of project implementation, monitoring and accountability. Overall, the results highlight a dual allocation logic: heightened sensitivity to contexts of extreme climate vulnerability, combined with a persistent institutional requirement oriented towards performance and resource management capacity.

3.4. Selectivity according to the nature of financial instruments: grants, concessional loans and non-concessional loans

3.4.1. Grants

Analysis of grant commitments reveals a coherent evolution of donor behaviour according to the determinants taken into account in the different model specifications. When grants are explained solely by structural vulnerability to climate change, the observed relationship is significant and non-linear (see Table 4). The estimates indicate that grant sensitivity to vulnerability varies according to the level of exposure: the most vulnerable countries benefit from higher per capita grant volumes, while those displaying intermediate vulnerability receive relatively fewer commitments. This configuration reflects a selective consideration of structural vulnerability, rather than a strictly proportional response to its intensity. The non-linear form of this relationship is illustrated in Figure A3 presented in the annex.

When income per capita is introduced, the relationship between vulnerability and grants remains significant, confirming that vulnerability exerts its own effect, distinct from that of the level of economic development. Non-linearity persists, while income displays a decreasing relationship with grants: lower-income countries receive proportionally more financing, consistent with the redistributive logic of grant aid. These results suggest that vulnerability is indeed taken into account, but that its effect is not strictly proportional, reflecting donors' internal trade-offs rather than a strictly linear prioritisation mechanism.

The introduction of governance in the third specification modifies the structure of the model. At this stage, governance and income become the main determinants of commitments, while the direct effect of structural vulnerability to climate change loses its statistical significance. The relationship between grants and governance appears positive but non-linear: amounts increase with institutional quality up to a certain threshold, before stabilising. This dynamic reflects donors' preference for countries with institutions deemed sufficiently solid to guarantee the proper use of resources, without the highest-performing institutional contexts necessarily being the most financed.

Structural vulnerability to climate change thus remains a factor of attention for donors, but its effect on commitments depends closely on governance and implementation capacities. Countries that are highly vulnerable but weakly governed do not necessarily receive more grants, while the estimates show that financing sensitivity to vulnerability varies with institutional quality.[13] Examination of the three successive specifications highlights a coherent analytical sequence: vulnerability first influences commitments in a non-linear manner, this effect persists when income is controlled for, then becomes conditioned by governance when the latter is explicitly introduced into the model. This pattern of results suggests that donors simultaneously take into account structural needs, economic conditions and institutional capacities, according to a trade-off logic specific to the nature of grant commitments.

Table 4: GAM estimates explaining grant commitments

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 3.13**, p = 0.010, edf = 3.79	F = 3.28***, p = 0.007, edf = 4.17	F = 1.98, p = 0.126, edf = 2.38
s(ln GNIpc)	—	F = 0.71, p = 0.400, edf = 1.00	F = 17.37***, p < 0.001, edf = 1.00

[13] The interaction between structural vulnerability (PVCCI) and governance (WGI) was empirically tested using a GAM model including a ti(PVCCI, WGI) tensor term. The interaction appears to be significant (F = 2.68, p = 0.022), indicating that the impact of vulnerability on grants varies according to the level of governance. The marginal effects of vulnerability and governance remain significant in this specification.

s(WGI)	—	—	F = 8.94***, p < 0.001, edf = 5.39
Constant	3.33*** (0.15)	3.33*** (0.15)	3.33*** (0.13)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

3.4.2. Concessional loans

Unlike grants, concessional loan commitments show no sensitivity to structural vulnerability to climate change. When considered alone, this variable exerts no statistically significant effect on loan volumes, and the estimated relationship remains linear and almost horizontal. In other words, the degree of structural exposure to climate risk does not constitute an allocation criterion for these financing flows. The smoothed form of the PVCCI, almost flat in Figure A3bis in the annex, visually confirms this absence of donor reaction.

By contrast, taking income per capita into account introduces a distinct dynamic. It becomes significant and describes a non-linear relationship: commitments increase with income up to a certain threshold, then decline beyond it. This curved form suggests that donors favour countries with a sufficiently solid economic base to guarantee the sustainability of their debt, even when lending conditions are concessional. Conversely, structural vulnerability to climate change remains without measurable effect, indicating that need considerations carry no weight in the distribution of these flows.

The introduction of governance profoundly modifies the model configuration. Institutional quality then becomes the main determinant of commitments, according to a strongly non-linear relationship. As illustrated by the WGI curve in Figure A3bis, concessional loan volumes increase substantially beyond a certain level of governance, reflecting donors' preference for countries offering minimum institutional guarantees of stability, transparency and efficient resource management. Income retains a marginal effect, while structural vulnerability to climate change remains without direct influence.

The overall estimates highlight an allocation logic distinct from that observed for grants. Concessional loans obey primarily an institutional and economic selectivity, based on the credibility of governance frameworks and repayment capacity, rather than on the severity of structural vulnerabilities. This contrast underlines the duality of aid instruments: grants follow a solidarity logic in the face of vulnerability, while concessional loans respond to a logic of financial prudence and institutional efficiency.

Table 5: GAM estimates explaining concessional loan commitments

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 0.00, p = 1.000, edf = 1.00	F = 0.08, p = 0.774, edf = 1.00	F = 1.00, p = 0.321, edf = 1.00
s(ln GNIpc)	—	F = 3.37**, p = 0.027, edf = 1.87	F = 2.20*., p = 0.084, edf = 2.61
s(WGI)	—	—	F = 8.07***, p < 0.001, edf = 3.42
Constant	2.88*** (0.15)	2.88*** (0.14)	2.88*** (0.12)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

3.4.3. Non-concessional loans

Estimates relating to non-concessional loans reveal a behaviour distinct from that observed for grants and concessional loans. Structural vulnerability to climate change exerts a limited and weakly non-linear influence on the amounts allocated. The most vulnerable countries tend to receive slightly lower volumes of non-concessional loans, reflecting a low sensitivity of this type of financing to structural needs. The effect remains moderate and barely significant, suggesting that vulnerability does not intervene in a determining manner in allocation decisions when the market dimension predominates.

Income per capita constitutes the most influential explanatory variable. Commitments increase regularly with income level, according to an essentially linear relationship. Middle- or high-income countries obtain larger amounts, while vulnerability loses all explanatory power. This configuration corresponds to an economic selection logic in which repayment capacities and macroeconomic soundness become predominant criteria. The shift to a non-concessional financing mode is thus accompanied by a refocusing towards countries displaying a controlled financial risk profile.

Governance confirms and amplifies this orientation. The estimates indicate a linear and increasing relationship between institutional quality and per capita non-concessional loan amounts. Countries characterised by stable institutions, reliable regulation and higher administrative efficiency attract more of this type of resource. Governance thus appears as a selective filter, acting jointly with income to orient commitments towards countries deemed safest.

Table 6 presents the detailed results of the three successive specifications. It highlights the progressive disappearance of vulnerability as an explanatory factor, alongside the growing importance of income and governance. These effects are confirmed by the smoothed functions associated with the GAM models (see Figure A3ter in the annex): the relationship

with vulnerability is slightly decreasing, that with income is quasi-linear and increasing, while that with governance appears linear and strongly positive. These visual profiles clearly illustrate the hierarchy of determinants according to the nature of financial instruments: vulnerability remains determinant for grants, governance plays a central role for concessional loans, and non-concessional loans depend primarily on income and institutional stability.

Table 6: GAM estimates explaining non-concessional loan commitments

Explanatory variables	**(1) PVCCI only**	**(2) + GNIpc**	**(3) + GNIpc and WGI**
s(PVCCI)	F = 2.37*, p = 0.058, edf = 2.92	F = 2.32, p = 0.131, edf = 1.00	F = 2.65, p = 0.107, edf = 1.00
s(ln GNIpc)	—	F = 54.92***, p < 0.001, edf = 1.00	F = 7.54***, p < 0.001, edf = 1.96
s(WGI)	—	—	F = 23.50***, p < 0.001, edf = 1.00
Constant	3.15*** (0.14)	3.15*** (0.11)	3.15*** (0.10)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

3.5. Sensitivity analysis

3.5.1. Comparison of results according to the vulnerability indicator used

In order to test the robustness of the preceding results, a sensitivity analysis was conducted by replacing the PVCCI with the vulnerability component of the ND-GAIN Index. Developed by the University of Notre Dame, the ND-GAIN[14] assesses countries' capacity to cope with climate change on the basis of two broad dimensions: vulnerability and readiness. In the framework of this study, only the "vulnerability" component is retained, the "readiness"[15] dimension having been deliberately excluded in order to focus on the structural characteristics of vulnerability to climate change and to ensure better comparability with the PVCCI. This component of the ND-GAIN rests on the three conceptual pillars proposed by the IPCC (2014): exposure to climate hazards, the sensitivity of human and natural systems to potential impacts and the adaptive capacity to these changes. Thus isolated, it provides a composite measure of structural vulnerability to climate change based on

[14] https://gain.nd.edu/.

[15] The "readiness" dimension reflects a country's ability to mobilize public and private investments and convert them into adaptation actions, thanks to favorable economic, institutional and social conditions.

sectoral data covering notably agriculture, water resources, health, habitat, ecosystems and infrastructure, normalised at the global scale.

Comparison of the results obtained from the PVCCI and the ND-GAIN vulnerability component reveals substantial differences in the reading of adaptation financing allocation behaviours. Whereas the PVCCI, focused on the physical and exogenous dimensions of vulnerability, revealed only a partial and selective consideration of structural vulnerability by donors, the ND-GAIN vulnerability component reveals more regular, linear and statistically robust relationships. This difference stems from the explicit integration, in the ND-GAIN, of sectoral adaptive capacity — understood as the structural aptitude of agricultural, water, health, habitat, ecosystem and infrastructure systems to cope with climate impacts. In the ND-GAIN approach, a higher score corresponds to greater vulnerability and therefore to lower structural adaptive capacity.[16] The estimates show that adaptation commitments increase when ND-GAIN vulnerability scores rise, indicating that donors orient more of their financing towards countries displaying higher vulnerability according to this indicator. This result underlines the decisive role of the choice of vulnerability indicator in the interpretation of allocation behaviours.

For all donors, estimates based on the PVCCI did not indicate any significant relationship between structural vulnerability and commitment volumes, with the exception of countries situated at the most extreme levels of vulnerability. By contrast, with the ND-GAIN vulnerability component, the relationship becomes significant, stable and linear across the entire distribution. Donors thus appear more sensitive to dimensions related to structural adaptive capacity and climate risk management than to raw physical exposure to hazards, this selectivity being reinforced when income per capita and governance are introduced into the models.

This configuration is found for multilateral donors. When vulnerability is measured by the PVCCI, it does not appear as a significant determinant of commitments. By contrast, the ND-GAIN vulnerability component reveals a positive and monotone relationship between vulnerability and commitments. Multilateral donors thus tend to orient more of their financing towards countries that are more exposed, more sensitive and have lower adaptive capacities according to the ND-GAIN, while maintaining a marked preference for contexts characterised by solid governance and a higher income level.

[16] The sectoral adaptability included in the vulnerability component of ND-GAIN should not be confused with the readiness component of the overall index. The first refers to the structural and long-term ability of agricultural, water, health, habitat, ecosystem and infrastructure systems to absorb climate impacts, as measured by relatively stable sectoral indicators. The "readiness", excluded from this study, measures on the contrary a country's economic, institutional and social capacity to mobilize and use adaptation investments effectively, and therefore reflects contemporary political and institutional rather than structural characteristics.

Among bilateral donors, the allocation pattern also evolves when vulnerability is apprehended from the ND-GAIN. With the PVCCI, the relationship was non-linear and only became significant for the most vulnerable countries. With the ND-GAIN vulnerability component, the relationship is linear and significant across the entire distribution, reflecting a more systematic orientation towards countries displaying high vulnerability. Income per capita retains a non-linear effect that attenuates when governance is introduced, while the latter remains a central determinant of commitments.

The shift from the PVCCI to the ND-GAIN vulnerability component leads to a substantially different reading of allocation behaviours. The former, focused on a physical and exogenous vulnerability, reflects structural needs but only partially explains the effective distribution of commitments. The latter, which integrates exposure, sensitivity and sectoral adaptive capacities, reveals a robust relationship between vulnerability and allocations. These results show that the diagnosis made on the consideration of vulnerability to climate change in adaptation finance depends closely on the indicator mobilised and the importance accorded to adaptive capacities in its construction, underscoring the need to clarify the objectives assigned to vulnerability metrics used for allocative purposes. Tables A2, A2bis and A2ter, as well as Figures A4, A4bis and A4ter presented in the annex, offer a complementary illustration of the estimated relationships.

3.5.2. Post-Covid period (2021–2023): evolution of the consideration of structural vulnerability by donors

The period after 2020 offers a relevant analytical framework for assessing any changes in donor sensitivity to structural vulnerability to climate change. The exercise consists of verifying whether the allocation behaviours observed over the full period (2019–2023) are maintained after the health crisis, or whether new dynamics emerge. Estimates are carried out on the basis of the PVCCI, according to the same specifications as previously, but restricted to the period 2021–2023. The corresponding tables are presented in the annex (Tables A3, A3bis and A3ter).

For all donors, results confirm the low overall responsiveness to structural vulnerability. As over the full period, no statistically significant relationship is observed between the PVCCI and per capita adaptation commitments. The introduction of income per capita does not modify this reading: income remains significant, with a negative effect, indicating that low-income countries continue to benefit from higher commitments. However, the main difference relative to the 2019–2023 period lies in the reinforced role of governance. This becomes the most determinant variable, its positive effect reflecting heightened selectivity in favour of countries with institutions deemed solid. These results suggest that donors, in

the post-Covid context, have more strongly conditioned their allocations on institutional quality and implementation capacity, to the detriment of direct recognition of physical vulnerability. The corresponding figures (Figure A5) illustrate this continuity, showing a globally flat smoothed function for the PVCCI and a clearly ascending slope for governance.

Multilateral institutions display a comparable profile. Structural vulnerability remains without statistically significant influence, while income and above all governance retain a determining role. Model adjustment shows a notable increase in explanatory power when governance is introduced, confirming that multilateral allocation practices remain oriented by criteria of efficiency and operational viability. Relative to the 2019–2023 period, continuity is thus clear: multilateral institutions favour institutional performance as a guarantee of efficient resource use, without a differentiated reaction to levels of structural vulnerability. The smoothed functions (Figure A5bis) confirm this orientation, with the slope associated with the PVCCI remaining quasi-horizontal.

The behaviour of bilateral donors again distinguishes itself from that of multilateral institutions. Structural vulnerability emerges as significant in the first specification and remains marginally significant even after introduction of income and governance. Although the statistical strength of the relationship is slightly attenuated, the maintenance of a significant effect of the PVCCI suggests that bilateral donors continue to integrate, at least partially, structural vulnerability among their allocation criteria. The estimated relationship remains non-linear, indicating that attention to vulnerability concentrates on certain ranges of the distribution, often intermediate or high. By contrast, income and governance gain in importance in the last specification, suggesting that bilateral donors have also integrated, in the recent period, a dimension of institutional feasibility and economic sustainability into their allocation logic. Figure A5ter, presented in the annex, illustrates this evolution by showing a slightly curved relationship between the PVCCI and commitments, and a more marked ascending slope for governance.

Thus, the reduction of the analysis period highlights a relative stability of multilateral behaviours and a more nuanced evolution on the bilateral side. Multilateral donors remain guided by criteria of institutional efficiency, while bilateral donors maintain a sensitivity to structural vulnerability, but increasingly framed by governance and performance considerations. These evolutions suggest that the selectivity observed after 2020 has become more centred around criteria of credibility and implementation capacity, further reducing the effective place of physical vulnerability to climate change in the logic of distribution of adaptation commitments.

4. Discussions

4.1. Institutional vulnerability groups and the allocation of adaptation finance

International climate and development negotiations have historically relied on the recognition of groups of countries considered structurally vulnerable, without recourse to a composite vulnerability indicator. Least Developed Countries (LDCs) and Small Island Developing States (SIDS) were thus designated by the United Nations Conventions as priority beneficiaries of climate financing, owing to their heightened exposure to economic, environmental and climatic shocks. This categorical approach rests on an institutional designation rather than an empirical continuous measure of climate vulnerability to climate change. Yet within these groups, structural situations are highly heterogeneous: some countries classified as LDCs or SIDS display relatively high levels of resilience, while others, not included in these categories, face marked structural fragilities. Furthermore, the allocation of financing takes place at the country level and not at the group level. Hence the value of a metric capable of differentiating and identifying countries according to objective and continuous criteria, consistent with the principles that a vulnerability index intended for allocation purposes should satisfy (Guillaumont, 2024, 2025; United Nations, 2024).

In order to assess the actual reach of these institutional categories in the distribution of financing, a complementary estimation was conducted by replacing the structural vulnerability index (PVCCI) with two dummy variables identifying countries classified as LDCs and SIDS. The objective is to examine whether the logic of adaptation financing allocation responds more to a political and institutional recognition than to a measured vulnerability. The models incorporate, as previously, income per capita and governance, in order to isolate the specific effect of the institutional status recognised in international agreements. The corresponding results appear in the annex in Table A4 for all donors, and in Tables A4bis and A4ter for bilateral and multilateral donors respectively. The adjusted average effects of LDC and SIDS status are presented in Figure A6 (in the annex).

For all donors (Table A4), the estimates highlight a clear hierarchy of average per capita adaptation financing levels according to institutional status. Non-classified countries constitute the reference and display the lowest amounts, followed by LDCs, then SIDS, while countries combining both statuses benefit from the highest commitments. The average gap is particularly marked for SIDS, whose effect remains positive and strongly significant across all specifications. These gaps persist after controlling for income and governance, indicating that allocation behaviours reflect a preference for countries whose vulnerability is recognised on the basis of an institutional status rather than an empirical measure.

Figure 9 illustrates this hierarchy: average per capita amounts increase progressively from the group of other countries to that of LDCs, then SIDS, reaching a maximum in the category combining both statuses. These gaps suggest that donors react more to the institutional labelling of vulnerability than to its empirical measurement.

Multilateral institutions display a similar profile, though more stable and narrower (Table A4ter). SIDS status remains systematically and strongly significant, reflecting particular sensitivity to island vulnerability, which concentrates a significant share of multilateral adaptation financing. The effect of LDC status, for its part, appears positive but of lesser magnitude and often significant at a lower threshold, indicating that structural poverty remains a recognised targeting criterion but one progressively superseded by other considerations. As for all donors, governance exerts a positive and highly significant effect, revealing the growing importance of institutional feasibility criteria in allocation practices. Income retains a negative effect but loses its significance after the introduction of governance, highlighting a logic of institutional selectivity favoured by multilateral donors.

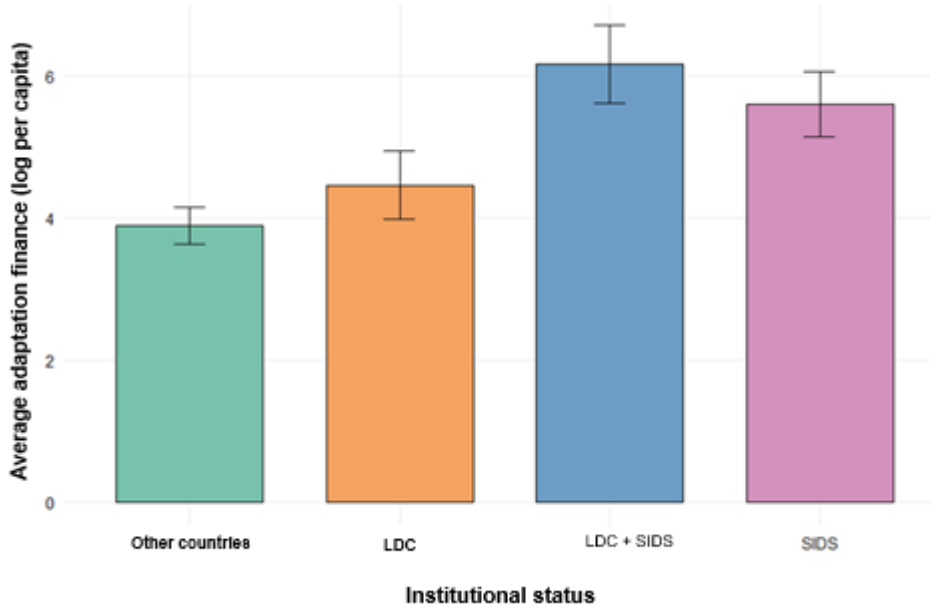
The behaviour of bilateral donors diverges slightly from this pattern (Table A4bis). SIDS status remains associated with significantly higher commitment levels, but the effect of LDC status is more marked here than in multilateral models. This result reflects a more pronounced sensitivity to structural needs and the budgetary constraints of low-income countries. However, the introduction of income and governance partially attenuates this effect, suggesting that recognition of LDC status is accompanied by growing consideration of absorption and resource management capacities. Governance also emerges as significant and positive, reflecting a more selective orientation combining institutional recognition with administrative performance requirements.

These results show that institutional recognition of vulnerability, through LDC and SIDS statuses, remains a notable determinant of climate allocations, often more influential than empirical indices of structural vulnerability. Multilateral donors favour an approach based on performance and governance, while bilateral donors retain a more marked sensitivity to the needs and structural vulnerability of low-income economies. This dual logic reveals a balance between normative recognition — linked to international commitments — and the pursuit of performance in financing implementation.

These findings argue for moving beyond simple categorical recognition based on institutional statuses, in favour of allocation mechanisms drawing on continuous and empirically grounded measures of vulnerability. Such measures can be mobilised directly as continuous metrics — through multidimensional indices such as the PVCCI or the MVI — or used to identify, on the basis of these indices, homogeneous classes of vulnerability. Such

an approach appears essential to reinforce coherence between the principles of climate justice and effective financing practices.

Figure 9: Adjusted average effects of LDC and SIDS statuses — All donors (2019–2023)



Note: Estimate derived from the GAM model with income and governance over the period 2019–2023. Vertical bars represent 95% confidence intervals.

4.2. Implications for research and allocation policy

The body of literature on international adaptation finance highlights a fundamental paradox: although priority for the most climate-vulnerable countries is universally recognised as a central principle of the climate regime, its operational translation remains incomplete. This tension between climate justice and institutional constraints recurs in the results presented here. The empirical analyses shed light on several essential dimensions of the relationship between structural vulnerability and the selectivity of adaptation financing. Three main lessons emerge, which call for both methodological deepening and adjustments in the design of international climate financing policies.

First, the estimates confirm the existence of a structural gap between the political recognition of vulnerability and its empirical measurement. The prioritisation of LDCs and SIDS remains a central component of global climate governance, but this categorical approach, based on institutional recognition, does not always reflect the diversity of vulnerability and resilience situations within these groups. This observation echoes the findings of Klein and Möhner (2011) and Garschagen and Doshi (2022), according to whom

the definition of priority groups, while politically legitimate, does not guarantee precise targeting of the most fragile countries. Similarly, several empirical studies (Saunders, 2019; Savvidou et al., 2021; Garschagen and Doshi, 2022) show that the correlation between climate vulnerability and effective allocations remains weak, with financing volumes more closely linked to income or governance than to measured vulnerability. Conversely, empirical indices such as the PVCCI or, in a broader and multidimensional perspective, the MVI, offer a continuous representation of structural vulnerability, making it possible to differentiate national situations more finely and to orient financing on the basis of objectively measured needs. It should nevertheless be underlined that the choice of indicator influences results. For example, country rankings according to vulnerability and the observed sensitivity of financing to that vulnerability vary depending on whether the PVCCI or the ND-GAIN is mobilised. This highlights the need for in-depth reflection on the robustness and methodological relevance of the indicators employed. The analyses of Lee et al. (2025) on World Bank financing allocation point in the same direction, showing that countries combining high exposure and low adaptive capacity remain significantly under-financed despite their recognised institutional priority. Overall, these findings call for a closer articulation between institutional recognition and empirical measurement in order to reinforce the coherence and legitimacy of international targeting.

Second, the results highlight a growing importance of institutional selectivity in donor behaviours. Governance emerges systematically as an important determinant of allocation, reflecting a shift towards a logic based on performance rather than needs. This tendency, also observed by Garschagen and Doshi (2022) in the case of the Green Climate Fund, reflects the determining role of institutional capacities in effective access to resources. Countries characterised by high vulnerability but low institutional readiness form a “difficult-to-reach” category, often concentrated in sub-Saharan Africa, which struggles to mobilise available financing. As Samuwai and Hills (2018) have underlined, institutional readiness capacity strongly conditions access to funds, limiting the effective consideration of structural vulnerability. The gaps observed between these countries and those with better administrative capacities are substantial, underscoring the need to strengthen support mechanisms for institutional readiness and absorption capacities, while simplifying access procedures. In this perspective, the establishment of bonus mechanisms or financing supplements intended for the most vulnerable and least prepared countries could help correct this asymmetry. Lee et al. (2025) propose in this regard a bonus or “top-up” mechanism intended for countries that are both fragile and highly vulnerable, in order to compensate for the biases of the performance-based allocation system and strengthen equity in the distribution of resources.

Third, the comparison between bilateral and multilateral donors reveals persistent differences in allocation logics. Bilateral donors retain a more marked sensitivity to

structural needs and poverty, while multilateral institutions combine logics of redistribution, institutional performance and operational viability, according a central role to governance criteria. These divergences reflect distinct mandates but also reflect a lack of systemic coordination. This finding echoes the analyses of Bosma et al. (2025), who argue for a more coherent and complementary use of available instruments. The analysis conducted on the different instrument types confirms this duality: grants appear as the instruments most sensitive to structural vulnerability, while concessional and non-concessional loans respond primarily to criteria of governance, income and solvency. However, the growing differentiation between instruments creates new inequalities of access. Grants, which best respond to structural needs, remain concentrated but limited in volume, while return-based instruments — principally concessional and non-concessional loans — favour solvent and institutionally stable countries, accentuating the financial dependence of the most vulnerable (Bosma et al., 2025; Perry, 2021). Conversely, grants and concessional loans remain the most appropriate forms of financing for taking into account structural vulnerability to climate change. Their place in allocation mechanisms must, however, be understood in relation to multiple objectives, including financial sustainability, operational efficiency and fiduciary credibility. In this framework, their use would benefit from being accompanied by technical assistance and institutional support components, in order to reconcile equity, efficiency and absorption capacity.

On the public policy front, these lessons invite a move beyond the simple normative recognition of vulnerability towards its effective operationalisation in allocation mechanisms. In this perspective, reinforcing coherence between the international financial architecture and the real needs of adaptation requires integrating structural vulnerability as an effective allocation criterion, and not merely as a declaratory reference. This implies a revision of instruments, reporting practices and performance criteria, so that international commitments bearing a climate justice objective translate into a genuinely differentiated allocation according to vulnerability, while resting on credible financial objects compatible with donors' fiduciary constraints. The challenge is not only to increase the amounts allocated, but to ensure that these principles are effectively integrated into operational mechanisms, despite the limitations inherent in current measurement systems. The results highlight the central role of institutional capacities in effective access to adaptation financing, which contributes to limiting the consideration of structural vulnerability in allocation practices. In this context, reinforcing complementarity between long-term structural support and targeted institutional assistance appears as a coherent orientation for reconciling operational efficiency with vulnerability-based differentiation.

On the research front, these results call for a more systematic integration of empirical and institutional approaches to vulnerability. Multidimensional indices, by capturing the complexity of structural and contextual factors, constitute valuable tools for analysing the

coherence of adaptation flows and designing more equitable allocation mechanisms. They can also be used to assess the effectiveness of readiness mechanisms and financing access policies, by observing their impact on countries' capacity to mobilise international resources. The challenge is to better articulate the dimensions of vulnerability, resilience and governance in an integrated approach, combining distributive equity and operational efficiency.

The convergences observed between this study and recent work by Bosma et al. (2025), Garschagen and Doshi (2022), Lee et al. (2025) and Liu et al. (2024) thus highlight a common requirement: aligning justice, empirical evidence and capacity for action. Strengthening the empirical foundations of decisions, while supporting the institutional capacities of vulnerable countries, constitutes an essential condition for building a more coherent, more equitable and more durable adaptation financing system.

4.3. Limitations and perspectives

The objective of this study was not to identify all the explanatory factors of adaptation financing allocation, but to analyse the extent to which and the forms in which structural vulnerability to climate change is effectively taken into account by donors in their commitment decisions.[17] This positioning differs from that of most studies centred on the econometric modelling of the global determinants of aid flows or allocation behaviours. The analysis is situated here within a logic of normative and empirical assessment of donor selectivity with regard to vulnerability, rather than in an exhaustive search for explanatory factors.

The main limitation concerns the temporal scope of the exercise. The analysis covers the period 2019–2023, corresponding to the homogeneous availability of data, but it would be relevant to extend it over a longer period in order to assess the evolution of donor behaviour over time. A more extended series would make it possible to verify whether the weak consideration of vulnerability observed in the recent period constitutes a stable tendency or the result of conjunctural dynamics linked, for example, to post-Covid reallocations or institutional reforms underway in climate finance.

[17] This approach is in line with recent work by Feindouno and Guillaumont (2025), who propose an empirical measure of the "selectivity" of multilateral and bilateral donors vis-à-vis structural vulnerability and income. Their analysis shows that, despite an average profile of relatively vulnerable beneficiaries, the main multilateral development banks do not systematically differentiate their allocations according to the degree of vulnerability of the countries, thus confirming the need to empirically evaluate the actual consideration of vulnerability in allocation practices.

A second limitation concerns the nature of the data used. The study rests on declared financing commitments, which do not necessarily reflect the amounts actually disbursed. Several analyses have underlined the often marked gap between announced commitments and actual disbursements, as well as the weak synchronisation between their respective evolutions. Celasun and Walliser (2008) show that effectively disbursed flows frequently differ from initial commitments, notably owing to delays, budgetary reallocations and the volatility of aid promises. Similarly, Canavire-Bacarreza et al. (2015) highlight persistent gaps between planned and realised flows, reflecting a structural unpredictability of aid. Analysis of disbursements, when possible over a coherent and comparable period, would thus offer a more precise view of the support actually mobilised in favour of adaptation in the most vulnerable countries.

On the methodological front, the use of a generalised additive model (GAM) with restricted maximum likelihood (REML) estimation guarantees good robustness to variations in sample size and to non-linear forms of relationships. However, this statistical approach does not make it possible to capture the internal decision-making mechanisms of donors or the political and institutional trade-offs that guide the distribution of resources. A mixed approach, combining quantitative analyses and qualitative studies of allocation processes, would make it possible to enrich the understanding of the logics underlying the observed selectivity. The study by Krupski (2024) on the distribution of adaptation financing in Africa illustrates the value of this approach: the author combines regression models and interviews to show that vulnerability influences the amounts allocated, but far less the probability of selection, donors often favouring countries with stable institutions or close historical ties with them.[18]

Finally, it would be useful to extend the analysis to the sectoral level in order to examine whether the consideration of vulnerability varies according to the domains of intervention, notably in agriculture, natural resource management, health or infrastructure. Such an approach would make it possible to assess more finely the implicit priorities of donors and the coherence of allocations with the structural needs of recipient countries.

These limitations do not affect the solidity of the results but specify their scope: the study highlights the recent tendencies of donors in the consideration of structural vulnerability, while opening the way to more in-depth longitudinal, sectoral and comparative analyses of the evolution of adaptation financing practices.

[18] However, Krupski's quantitative approach differs from the one adopted here: it is part of the tradition of classic explanatory models for aid allocation, based on a distinction between the logics of 'recipient needs', 'recipient merit' and 'donor interests'. The present study, on the other hand, aims above all to analyze the effective consideration of structural vulnerability in donor behaviors, rather than to estimate the relative weights of these three dimensions in allocation decisions.

5. Conclusion

This study sought to assess, on an empirical and normative basis, the extent to which structural vulnerability to climate change effectively influences the allocation of international financing devoted to adaptation. Drawing on harmonised data covering the period 2019–2023 and a flexible econometric approach, it highlights a persistent gap between the political recognition of the principle of prioritising vulnerable countries and its operational translation into allocation practices.

The results show that structural vulnerability, measured by the PVCCI, exerts only a partial and often non-linear influence on adaptation commitments. This effect only appears significant for the most exposed countries, revealing a selective and belated recognition of extreme climate needs. By contrast, governance and income level emerge as far more marked and systematic determinants. Institutional quality, in particular, acts as a central filter in allocation decisions, reflecting a growing preference among donors for environments perceived as stable, viable and capable of ensuring efficient fund management.

This hierarchy of determinants highlights an observed trade-off between the consideration of structural vulnerability — as defined in the normative frameworks of climate finance — and the operational efficiency and risk management constraints that structure effective allocation practices. Poor countries with solid institutional capacities benefit relatively more from resources, while those combining high structural vulnerability and weak institutional capacities remain under-represented in adaptation flows. This finding indicates that, despite the formal recognition of the principle of prioritising the most vulnerable countries in the international climate regime, allocation decisions remain largely conditioned by considerations of institutional feasibility, fiduciary credibility and implementation capacity, inherited from the traditional logics of official development assistance.

The differences observed between bilateral and multilateral donors confirm this duality of allocation logics. Bilateral donors retain a more marked sensitivity to situations of extreme vulnerability and to constraints related to income level, while multilateral institutions favour stricter institutional and financial criteria, linked to governance, operational viability and the sustainability of commitments. Grants appear as the instruments most directly aligned with the consideration of structural vulnerability to climate change, whereas concessional and non-concessional loans respond more to considerations of institutional credibility and financial risk management. This differentiation by instrument, combined with the concentration of flows among a limited number of dominant actors, contributes to structuring a persistent asymmetry in the international financial architecture of adaptation.

The sensitivity analysis conducted with the ND-GAIN vulnerability component confirms the main findings, while highlighting a different modality of consideration of vulnerability in allocation behaviours. When vulnerability is measured from the ND-GAIN, the estimated relationships become significant and linear across the entire distribution: commitments increase with higher levels of vulnerability, understood here as a combination of exposure, sensitivity and sectoral adaptive capacities. This difference relative to the results obtained with the PVCCI does not stem from an inversion of the sign of the relationship, but from the distinct conceptual content of the indicators mobilised. The PVCCI, focused on a physical and exogenous vulnerability, reflects structural needs independently of institutional capacities, while the ND-GAIN vulnerability component integrates dimensions related to sectoral adaptive capacities, and is associated, in the estimates, with an orientation of financing towards situations where vulnerability is perceived as compatible with sufficient absorption capacity. These results show that the diagnosis made on the consideration of vulnerability in adaptation finance depends closely on the indicator mobilised and the importance accorded to adaptive capacities in its construction, underscoring the need to clarify the objectives assigned to vulnerability metrics used for allocative purposes.

The results of the post-2020 period confirm the continuity of behaviours observed over the entire period. The health crisis did not modify the hierarchy of determinants: governance retains its predominant role and structural vulnerability remains weakly taken into account, except among certain bilateral donors where its effect remains significant but limited. This stability reflects the maintenance of a reinforced institutional selectivity, centred on the credibility of national implementation frameworks rather than on the intensity of structural needs.

The institutional recognition of vulnerability, through the LDC and SIDS categories, retains an important weight in allocation decisions. SIDS benefit on average from higher commitments, while the effect of LDC status, although positive, remains more moderate. This hierarchy indicates that donors accord greater weight to institutional statuses of vulnerability than to continuous empirical measures. However, the strong internal heterogeneity of these groups limits the scope of a strictly categorical approach. A differentiation based on continuous indices such as the PVCCI or the MVI would offer a more equitable and more coherent framework for the allocation of adaptation financing, whether mobilised directly as continuous metrics or used to characterise comparable vulnerability profiles between countries.

In this perspective, the future of adaptation finance will depend jointly on the collective capacity to place structural vulnerability to climate change back at the centre of decisions — not as a mere analytical observation, but as a structuring criterion of justice and solidarity — and on the availability of credible, transparent and comparable mechanisms for measuring financial flows. The credibility of the international climate regime now rests on

this dual condition: making the recognition of vulnerability an operational norm of allocation, while guaranteeing a sufficiently robust measurement of financing so that the distribution of resources is no longer primarily a reflection of existing capacities, but an effective instrument for the durable reduction of inequalities in the face of climate risk.

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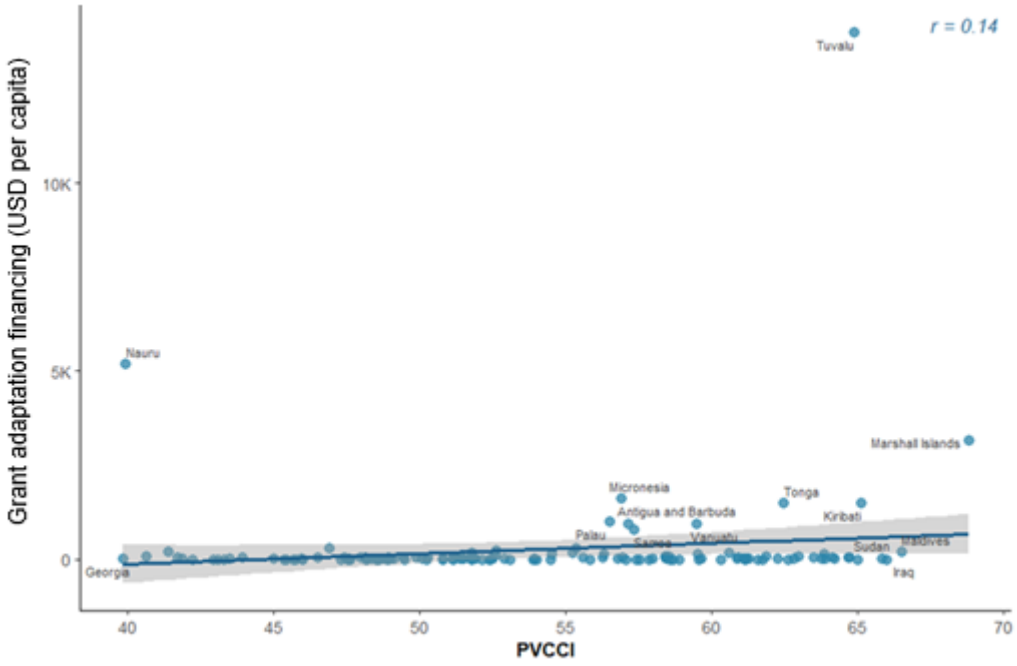
List of acronyms and abbreviations

AFD	Agence française de développement
UNFCCC	United Nations Framework Convention on Climate Change
CPIA	Country Policy and Institutional Assessment
CRI	Climate Risk Index
IPCC	Intergovernmental Panel on Climate Change
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
ND-GAIN	Notre Dame Global Adaptation Initiative
PVCCI	Physical Vulnerability to Climate Change Index
LDC	Least Developed Countries
SIDS	Small Island Developing States
WDI	World Development Indicators
WGI	World Governance Indicators
WRI	World Risk Index

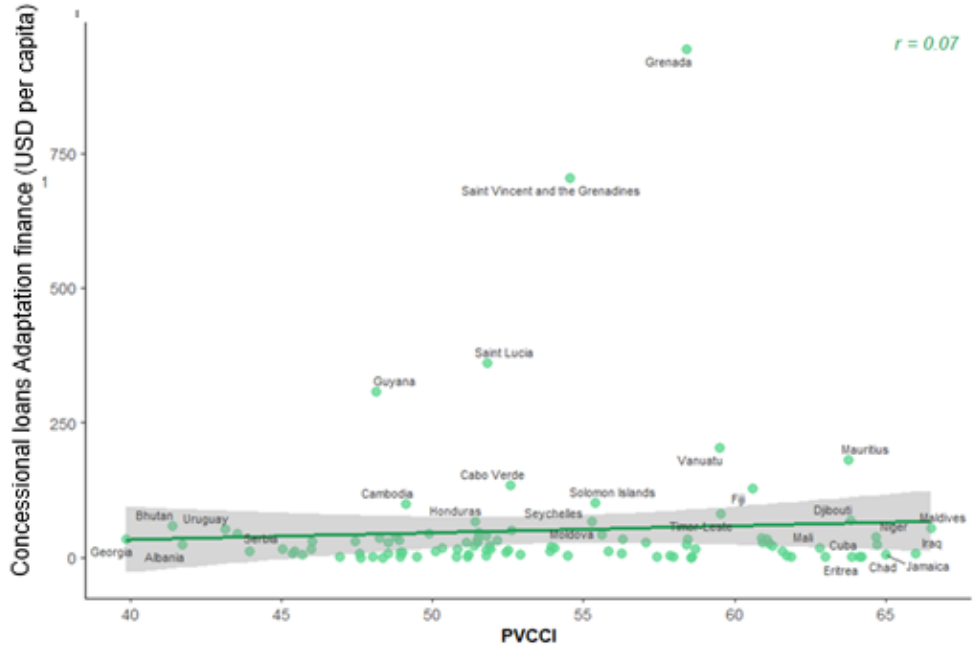
Appendix

Figure A1: PVCCI Correlation – Adaptation finance by grants (2019–2023)



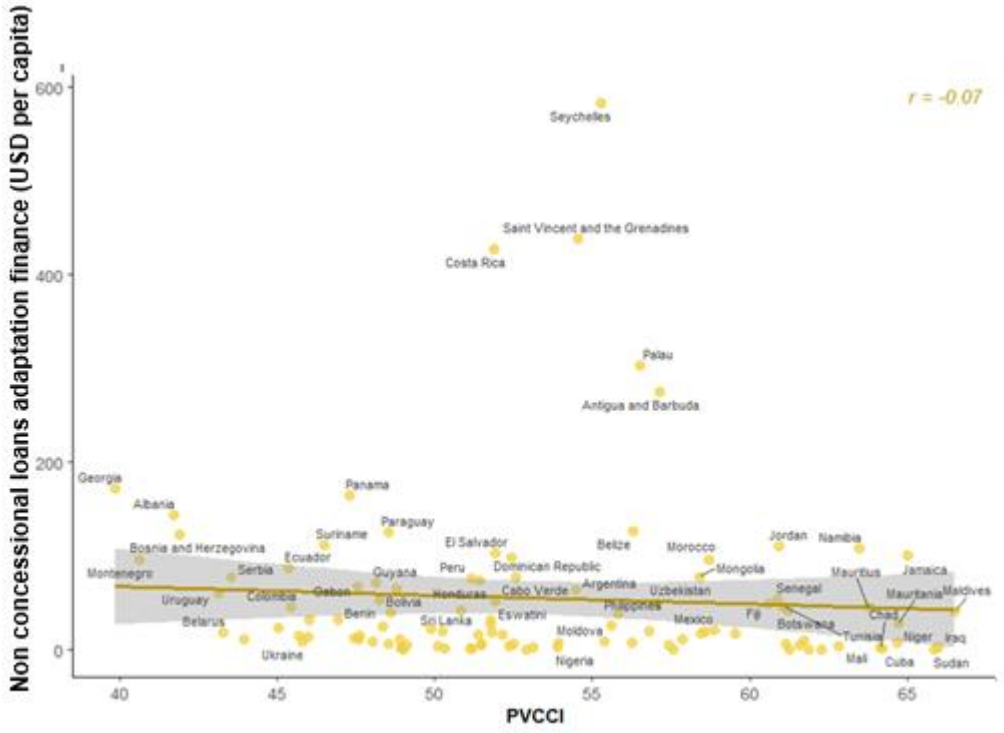
Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

Figure A1bis: PVCCI correlation – Adaptation finance by concessional loans (2019–2023)



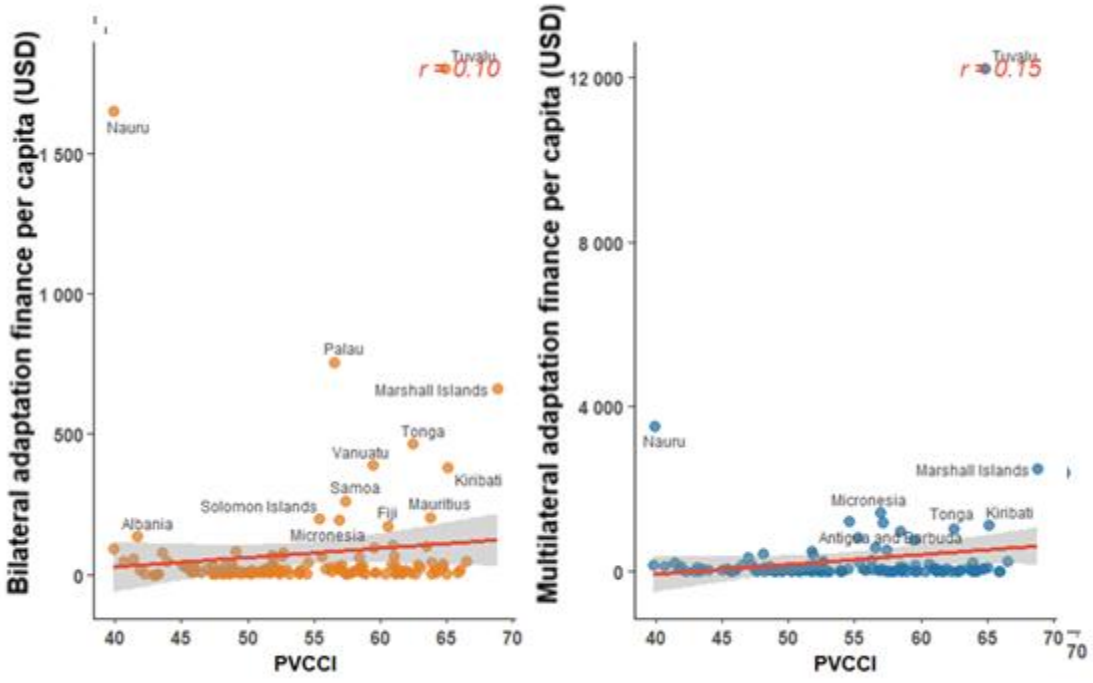
Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

Figure A1ter : PVCCI correlation – Adaptation finance by non concessional loans (2019–2023)



Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

Figure A2: Relationship between PVCCI and per capita bilateral and multilateral adaptation finance



Authors, from TOSSD, CRS and CRDF (2019-2023) data and from PVCCI (Feindouno et al., 2020).

Table A1: GAM model segmented estimations according to vulnerability (PVCCI)

Explanatory variables	Countries with weak to intermediate vulnerability	Countries with high vulnerability (last PVCCI quartile)
s(PVCCI)	F = 0.97 p = 0.34 edf = 1.86	F = 12.20*** p = 0.0017 edf = 1.00
s(ln GNIpc)	F = 5.31** p = 0.023 edf = 1.00	F = 7.69*** p = 0.0099 edf = 1.00
s(WGI)	F = 26.63*** p < 0.001 edf = 1.93	F = 15.58*** p < 0.001 edf = 2.40
Constant	4.44 (0.11)	4.43 (0.20)
Estimation method	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure A3: GAM model partial estimated effects – Grants

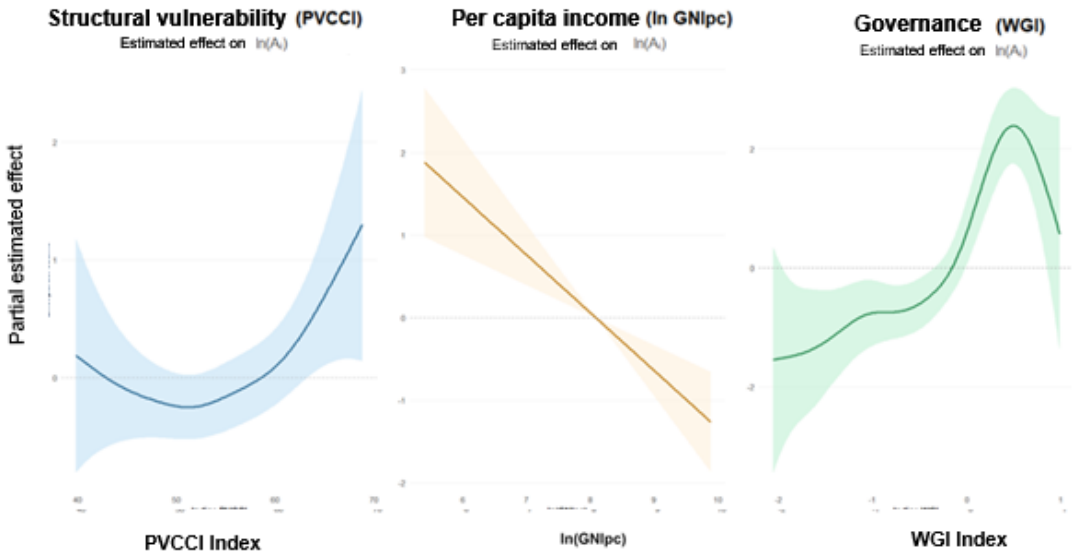


Figure A3bis: GAM model partial estimated effects – Concessional loans

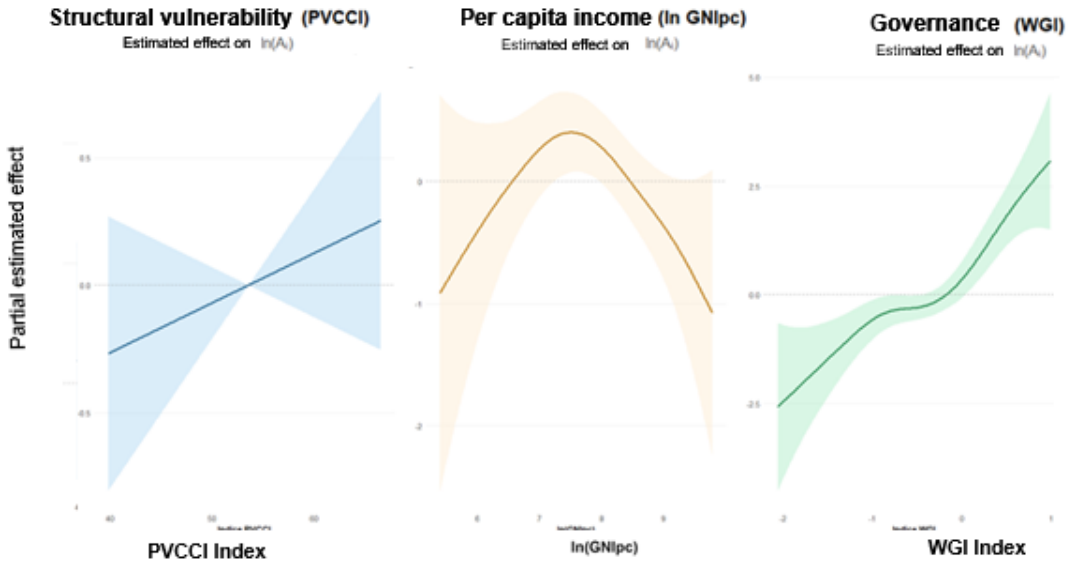


Figure A3ter: GAM model partial estimated effects – Non concessional loans

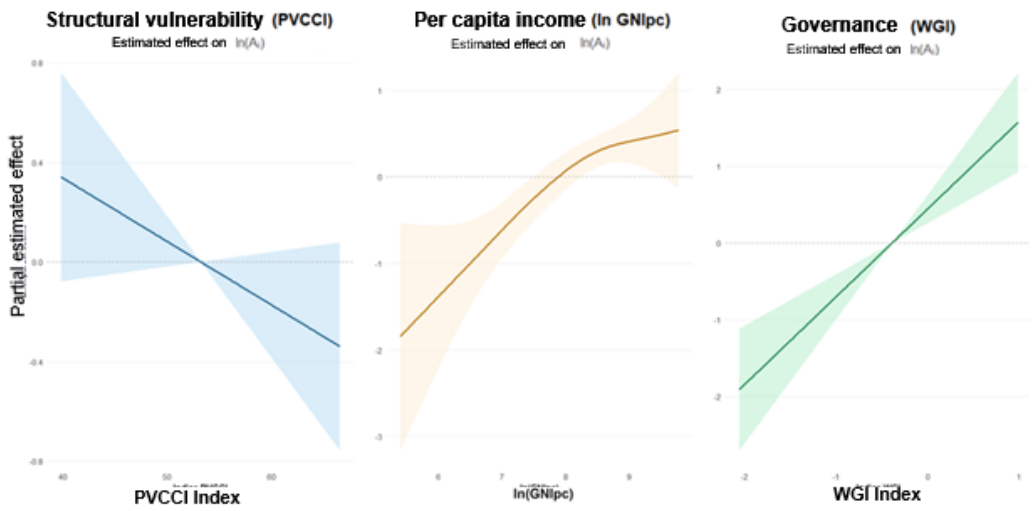


Tableau A2: GAM model estimations – All donors (ND-GAIN)

Explanatory variables	(1) ND-GAIN only	(2) + GNIpc	(3) + GNIpc and WGI
s(ND_GAIN_vuln)	F = 11.28***, p = 0.001, edf = 1.00	F = 59.30***, p < 0.001, edf = 1.00	F = 45.03***, p < 0.001, edf = 1.00
s(ln GNIpc)	—	F = 55.24***, p < 0.001, edf = 1.00	F = 4.87**, p = 0.029, edf = 1.00
s(WGI)	—	—	F = 49.12***, p < 0.001, edf = 1.00
Constant	4.47*** (0.13)	4.47*** (0.11)	4.47*** (0.09)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Table A2bis: GAM model estimations – Multilateral donors (ND-GAIN)

Explanatory variables	(1) ND-GAIN seul	(2) + GNIpc	(3) + GNIpc and WGI
s(ND_GAIN_vuln)	F = 9.24***, p = 0.003, edf = 1.00	F = 53.22***, p < 0.001, edf = 1.00	F = 39.07***, p < 0.001, edf = 1.00
s(ln GNIpc)	—	F = 53.11***, p < 0.001, edf = 1.00	F = 4.40**, p = 0.038, edf = 1.00
s(WGI)	—	—	F = 48.33***, p < 0.001, edf = 1.00
Constant	4.13*** (0.14)	4.13*** (0.12)	4.13*** (0.10)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Table A2ter: GAM model estimations – Bilateral donors (ND-GAIN)

Explanatory variables	(1) ND-GAIN only	(2) + GNIpc	(3) + GNIpc and WGI
s(ND_GAIN_vuln)	F = 18.64***, p < 0.001, edf = 1.00	F = 47.91***, p < 0.001, edf = 1.00	F = 29.32***, p < 0.001, edf = 1.00
s(ln GNIpc)	—	F = 11.78***, p < 0.001, edf = 1.82	F = 1.55, p = 0.233, edf = 2.33
s(WGI)	—	—	F = 11.93***, p < 0.001, edf = 2.56
Constant	2.97*** (0.12)	2.97*** (0.11)	2.97*** (0.10)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure A4: GAM model partial estimated effects – NDGAIN (all donors)

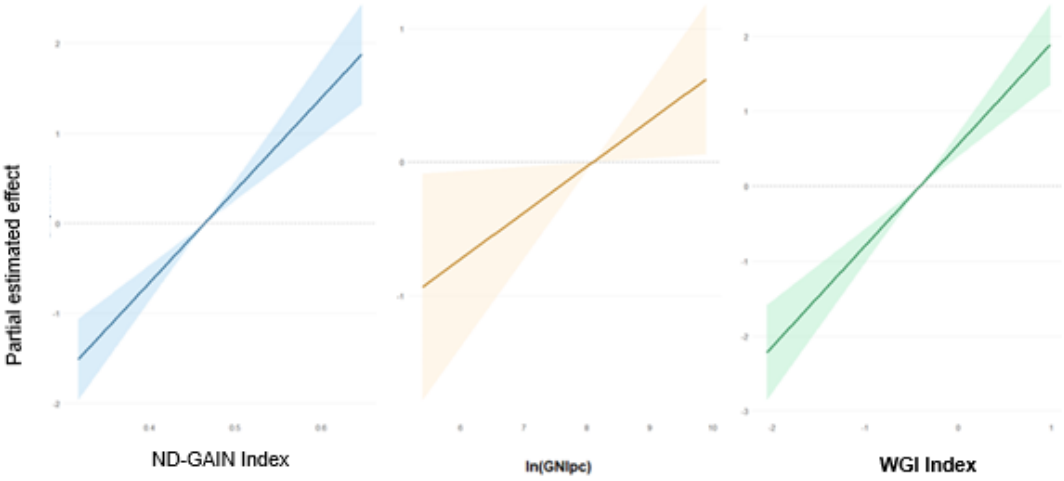


Figure A4bis: GAM model partial estimated effects – NDGAIN (multilateral donors)

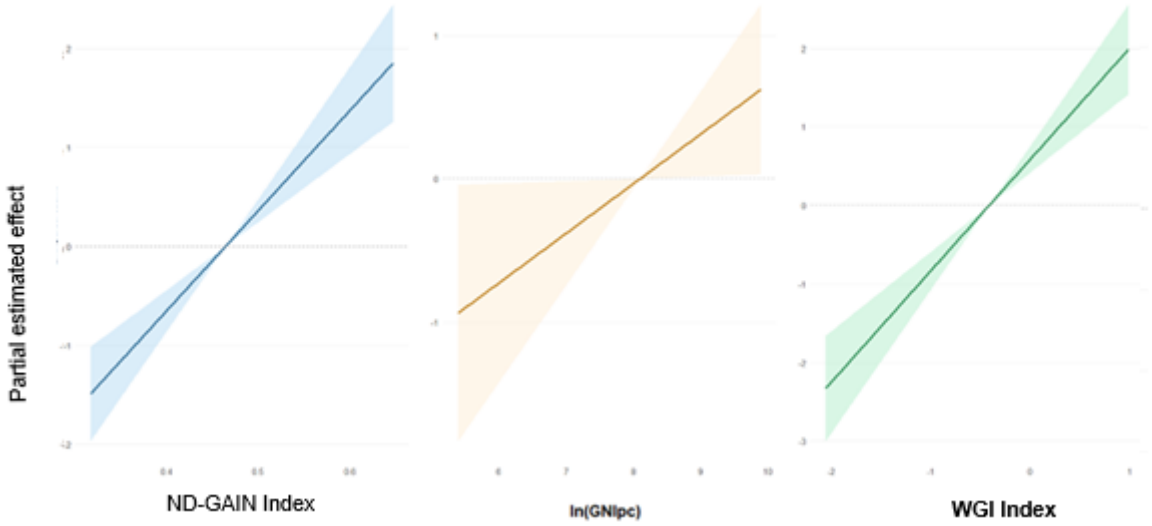


Figure A4ter: GAM model partial estimated effects – NDGAIN (bilateral donors)

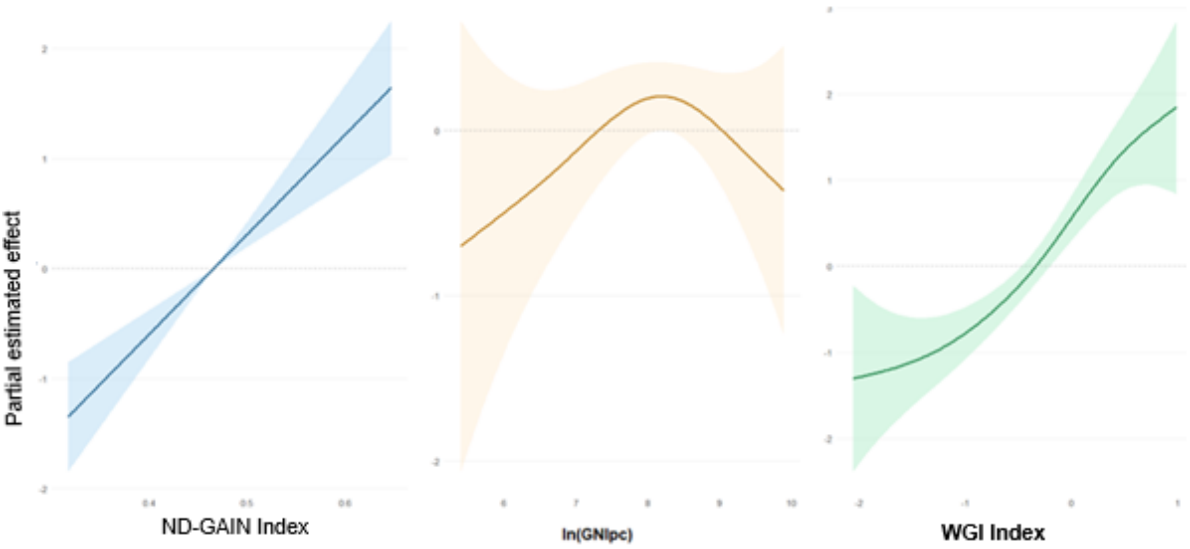


Table A3: GAM model estimations – All donors (2021-2023)

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 1.26, p = 0.296, edf = 2.35	F = 1.81, p = 0.213, edf = 1.56	F = 2.21, p = 0.169, edf = 1.48
s(ln GNIpc)	—	F = 3.25**, p = 0.042, edf = 1.72	F = 7.83***, p = 0.006, edf = 1.00
s(WGI)	—	—	F = 29.02***, p < 0.001, edf = 2.09
Constant	3.97*** (0.14)	3.97*** (0.14)	3.97*** (0.11)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Table A3bis: GAM model estimations – Multilateral donors (2021-2023)

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 0.80, p = 0.454, edf = 1.66	F = 1.88, p = 0.173, edf = 1.00	F = 2.53, p = 0.114, edf = 1.00
s(ln GNIpc)	—	F = 3.54**, p = 0.022, edf = 2.28	F = 6.34**, p = 0.013, edf = 1.00
s(WGI)	—	—	F = 32.75***, p < 0.001, edf = 1.77
Constant	3.61*** (0.15)	3.61*** (0.14)	3.61*** (0.11)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Table A3ter: GAM model estimations – Bilateral donors (2021-2023)

Explanatory variables	(1) PVCCI only	(2) + GNIpc	(3) + GNIpc and WGI
s(PVCCI)	F = 3.12**, p = 0.015, edf = 3.47	F = 3.15**, p = 0.014, edf = 3.53	F = 2.58*, p = 0.050, edf = 2.63
s(ln GNIpc)	—	F = 0.41, p = 0.676, edf = 1.56	F = 6.38***, p = 0.001, edf = 2.21
s(WGI)	—	—	F = 18.38***, p < 0.001, edf = 2.36
Constant	2.57*** (0.12)	2.57*** (0.12)	2.57*** (0.10)
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure A5: GAM model partial estimated effects – All donors (post-COVID period, 2021–2023)

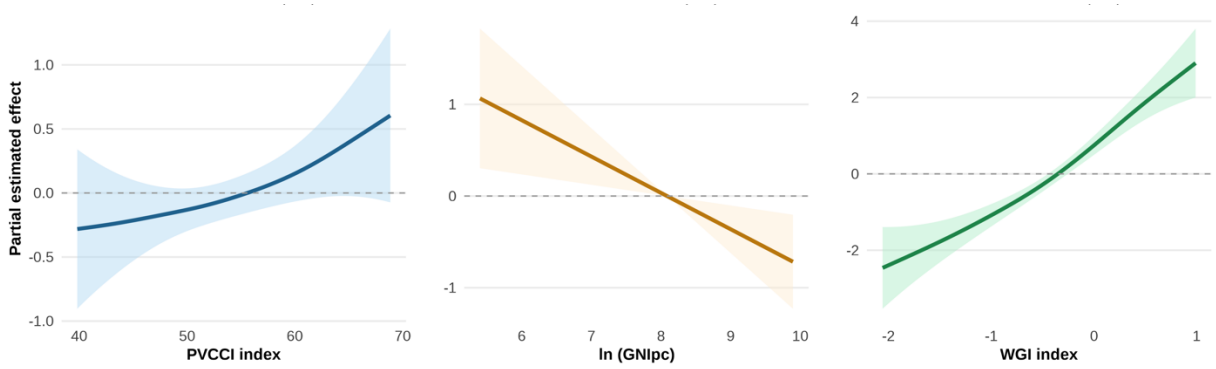


Figure A5bis: GAM model partial estimated effects – Multilateral donors (post-COVID period, 2021–2023)

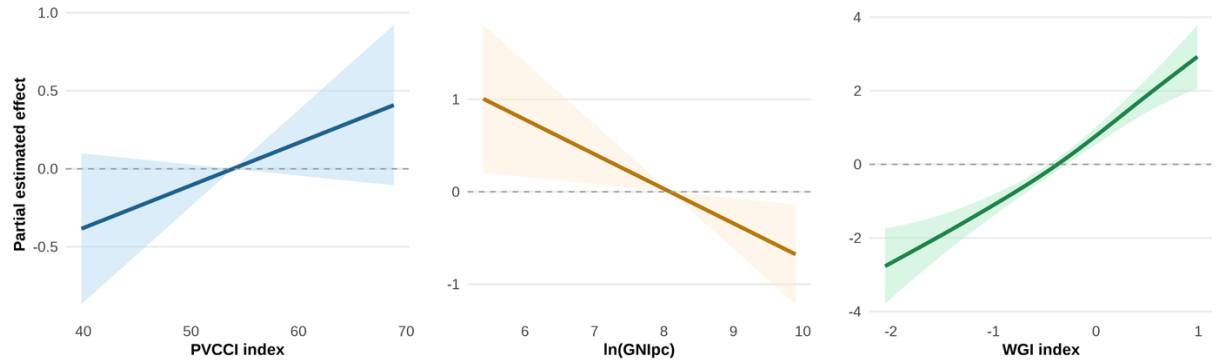


Figure A5ter: GAM model partial estimated effects – Bilateral donors (post-COVID period, 2021–2023)

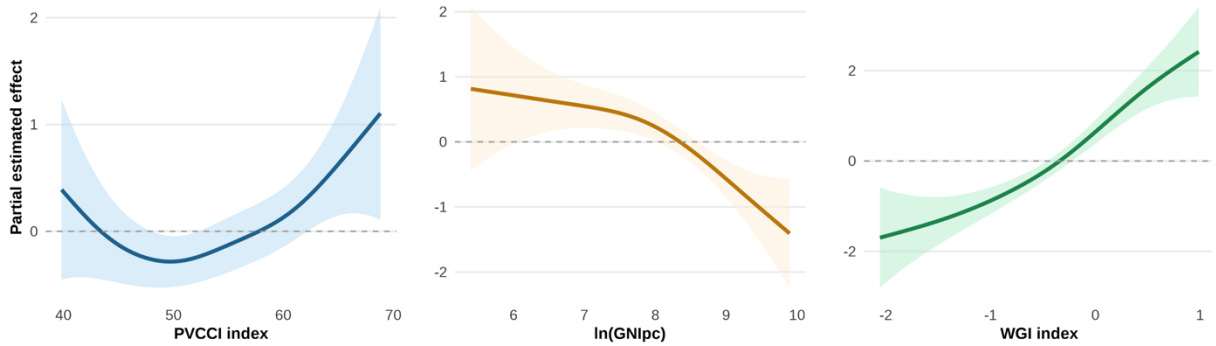


Table A4: GAM model estimations – All donors (with LDC and SIDS dummies)

Explanatory variables	(1) Without controls	(2) + GNIpc	(3) + GNIpc and WGI
LDC_dummy	0.243 (0.230), p = 0.292	0.798 (0.339)**, p = 0.020	0.562 (0.302)*, p = 0.065
SIDS_dummy	2.379 (0.246)***, p < 0.001	2.188 (0.257)***, p < 0.001	1.707 (0.240)***, p < 0.001
s(ln GNIpc)	—	F = 4.83*, p = 0.030, edf = 1.00	F = 0.65, p = 0.423, edf = 1.00
s(WGI)	—	—	F = 37.15***, p < 0.001, edf = 1.00
Constant	3.83 (0.14)***, p < 0.001	3.72 (0.15)***, p < 0.001	3.90 (0.13)***, p < 0.001
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Table A4bis: GAM model estimations – Bilateral donors (with LDC and SIDS dummies)

Explanatory variables	(1) Without controls	(2) + GNIpc	(3) + GNIpc and WGI
LDC_dummy	0.450 (0.250)*, p = 0.074	0.792 (0.390)**, p = 0.044	0.728 (0.355)**, p = 0.043
SIDS_dummy	1.833 (0.270)***, p < 0.001	1.771 (0.284)***, p < 0.001	1.123 (0.281)***, p < 0.001
s(ln GNIpc)	—	F = 0.89, p = 0.468, edf = 2.77	F = 2.28*, p = 0.068, edf = 3.36
s(WGI)	—	—	F = 8.33***, p < 0.001, edf = 3.88
Constant	2.42 (0.15)***, p < 0.001	2.33 (0.17)***, p < 0.001	2.50 (0.15)***, p < 0.001
Estimation method	REML	REML	REML

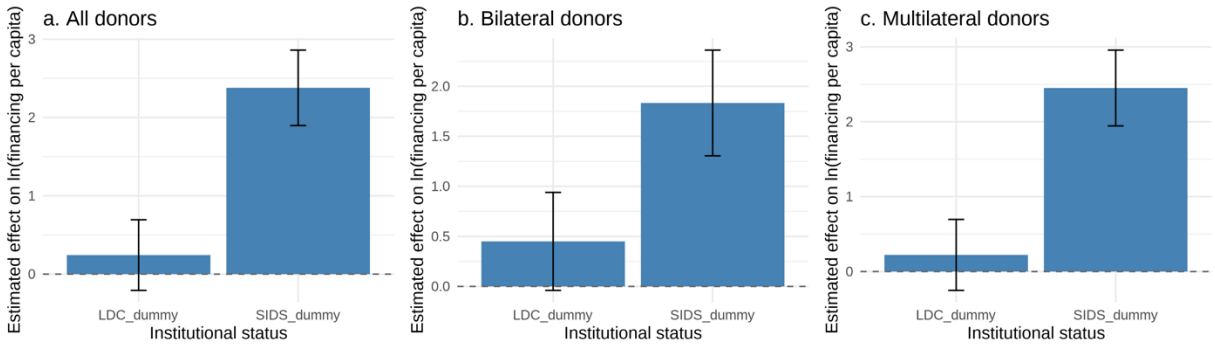
*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Tableau A4ter: GAM model estimations – Multilateral donors (with LDC and SIDS dummies)

Explanatory variables	(1) Without controls	(2) + GNIpc	(3) + GNIpc and WGI
LDC_dummy	0.222 (0.242), p = 0.361	0.852 (0.355)**, p = 0.018	0.607 (0.317)*, p = 0.058
SIDS_dummy	2.451 (0.258)***, p < 0.001	2.234 (0.269)***, p < 0.001	1.732 (0.252)***, p < 0.001
s(ln GNIpc)	—	F = 5.68**, p = 0.019, edf = 1.00	F = 0.37, p = 0.545, edf = 1.00
s(WGI)	—	—	F = 36.74***, p < 0.001, edf = 1.00
Constant	3.48 (0.15)***, p < 0.001	3.35 (0.15)***, p < 0.001	3.54 (0.14)***, p < 0.001
Estimation method	REML	REML	REML

*Note: The symbols ***, **, * indicate statistical significance at the 1%, 5% and 10% thresholds respectively.*

Figure A6: Estimated effects of LCS and SIDS status according to donors' type



Note: Vertical bars represent the 95% confidence interval.

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