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Rebalancing climate finance: Analysing multilateral development banks' allocation practices

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ABSTRACT

This paper provides novel evidence on the climate financing practices of Multilateral Development Banks (MDBs) and their long-term social and climate consequences. We find that the majority of MDB climate finance is for mitigation projects, concentrated in a few relatively wealthy countries, and positively correlates with countries' greenhouse gas emissions but not with their vulnerability to climate risks. A transition towards a more equal allocation between mitigation and adaptation can substantially reduce global climate vulnerability for an additional 1.9 billion people without significant changes in the annualized growth rate of emissions. Our results contribute to the discussion on global equity in climate finance allocation and the societal impact of climate change.

1. Introduction

There is an urgent need to finance decarbonisation projects to limit global temperature rises to 1.5° and reduce losses and damages from climate risks [1,2]. The estimated additional annual mitigation (projects aimed at reducing carbon emissions) and adaptation (projects aimed at increasing climate-resilience of areas vulnerable to climate risks) investments are in the range of US$150–1700 billion and US$315–565 billion by 2050 [3,4]. The challenge of raising such a large amount of money is exacerbated by the rapidly increasing levels of public debt following the COVID-19 pandemic, resistance against policies addressing climate change, and fragmentation of global political views [5–7]. What distinguishes climate finance from conventional finance is that such funding is earmarked for long-term and risky investments in low-carbon energy and technologies, improving climate information systems, and strengthening the nation's capacity to integrate adaptation into policies and strategies [8–10].

In addition to the challenge of raising sufficient funding for adaptation and mitigation projects, there is also the distributional concern. Developing countries, which have contributed less to climate change but will bear more adverse impacts, have lower investment capacity to fund climate actions on their own. They often rely on funds mobilised by financial institutions from high-income countries [11]. At the 15th Conference of Parties (COP15) in 2009, the latter pledged to mobilize US $100 billion per year by 2020 for climate actions in developing countries, which has now been extended to 2025 [12].

Given their role in allocating capital across economic activities, financial institutions are central to policy discussions on financing climate change. Specifically, public financial institutions like the multilateral development banks (MDBs) are crucial in closing the climate finance gap and facilitating the redistribution of funds from wealthier to poorer countries [13–16]. These financial institutions were established with the mandate to finance projects that are unlikely to be attractive to profit-maximising agents in the capital market [17,18]. MDBs are significant climate finance providers and a major funding channel when it comes to the US$100 billion goal. The share of MDB climate finance as a percentage of total public climate finance has risen from 14 % (2011) to 23 % (2020) [19]. OECD data shows that 40 % of climate finance provided and mobilised between 2016 and 2020 was attributed to MDBs and multilateral climate funds [12] (See figures in Appendix A). MDBs fund risky mitigation and adaptation projects and have longer investment horizons than private investors [18,20]. Moreover, they often are catalysts to attract private financiers in mitigation and adaptation investments [15,16,18,21].

Despite MDBs' important role in financing global climate actions, there is little evidence regarding the allocation of their climate finance. We study the climate finance allocation practices of eight MDBs: Asian Development Bank (ADB), African Development Bank (AfDB), Asian Infrastructure

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Investment Bank (AIIB), European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), Inter-American Development Bank Group (IDBG), Islamic Development Bank (IsDB) and the World Bank Group (WBG). We provide evidence on the distribution of MDBs' climate finance across projects and countries and simulate the impact of their allocation practices for future climate outcomes.

The allocation of MDBs' climate financing is an important issue because climate action priorities vary widely across countries. The underlying theoretical construct of our analysis is that orthodox market mechanisms would not achieve the most economically efficient allocation of climate financing [22]. Moreover, economic efficiency may not be an optimal decision rule because that puts smaller, less developed countries at risk from adverse and potentially extreme effects of climate change [11].

The MDBs jointly developed a methodology of accounting and reporting climate finance provided to borrowing countries [8]. "MDB climate finance" refers to the financial resources committed by MDBs from their own accounts and external resources managed by them to development operations and components thereof, which enable activities that mitigate climate change and support adaptation.[2] The MDBs use a wide range of financial instruments like grants, loans, and equity, which can be drawn from both public and private entities to disburse climate finance funds [8]. The loan is the primary instrument that is most used by MDBs to provide climate finance; it accounts for a lion's share of 69.3 % in 2020, followed by policy-based financing (11.6 %) and grant (8.7 %).

We first map the aggregate climate finance provided by the MDBs for 143 emerging and developing countries between 2015 and 2020 (see Appendix B for the countries covered). The MDB climate finance exhibits highly skewed distribution towards mitigation needs, for which 90 % of climate funding is allocated to countries with high emissions and only 8 % goes to countries with high vulnerability and low emissions.

Then, we provide novel evidence on the needs-based efficiency of country-wise climate funding by MDBs based on the climate action needs of the recipient countries. In the context of climate finance allocation, an efficient allocation implies funding projects that have the greatest net benefit of mitigating and adapting to climate change. However, it is difficult to have an objective and comparable measure of costs and benefits in this context (see, for example, the case of the Adaptation Fund [23]). Our approach to estimating needs-based efficiency is based on examining the allocation of funding in relation to the recipient countries' mitigation and adaptation needs. We examine how the MDBs' climate finance allocation relates to countries' climate action needs by concentrating on their CO_2 emissions and their vulnerability to climate change. In that sense, our measure is an equity-focused measure of allocative efficiency instead of conventional cost-benefit analysis of climate investments [23–25]. We hypothesize that if the allocation is efficient, MDBs' mitigation funding to a country will be positively correlated with its emission reduction potential (proxied by CO_2 emissions), and adaptation funding will be positively correlated with the country's vulnerability to climate change. This is motivated by the fact that most mitigation efforts and innovations target emissions, whereas adaptation efforts and innovations aim to improve society's resilience [11,26–29].

We estimate the needs-based allocative efficiency of MDB climate finance with data envelopment analysis (DEA) by considering the mitigation and adaptation needs simultaneously.[3] In these models, we consider countries' CO_2 emissions and vulnerability as inputs and climate finance investments by MDBs as outputs. An efficient allocation refers to *proportional* MDB climate finance disbursed to countries with similar CO_2 emissions and vulnerability levels. Around 10 % of countries (14 out of 143) receive efficiency scores between 0.8 and 1, and each country was provided with US$922 million in climate finance every year on average between 2015 and 2020. In contrast, 49 countries are in the lowest efficiency score bracket (0 to 0.2) and receive only US$49 million in climate finance from MDBs on average. The majority of MDB climate finance is for mitigation and is concentrated in a small number of relatively wealthy countries. It appears that countries' vulnerability is not prioritised in MDBs' funding allocation.

Using hand-collected data from three MDBs who make project-level information available (ADB, EIB and IDBG for 2016–2020), we can also consider heterogeneity in country characteristics (such as income level, population size, etc. emission intensity and institutional capacity). Collectively we have information on 955 adaptation, 3145 mitigation and 673 dual-type (combined adaptation and mitigation) projects. Our linear regression models with the more granular financing data show similar patterns: mitigation financing has a strong positive association with the emission intensity of a country but higher vulnerability to climate risks is not associated with more adaptation projects being funded by MDBs.

Furthermore, we examine the potential long-term climate consequences of MDBs' climate finance allocations. We estimate future carbon emissions and climate risks using numerical simulations under different allocation scenarios. The issue of a balance between "mitigation" and "adaptation" was raised and emphasized in the international negotiations to enhance fairness. Paris Agreement (Article 9, Paragraph 4) states that the *provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation, …, especially those that are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints* [30]. COP27 promoted significant progress on adaptation with a breakthrough agreement to provide "loss and damage" funding for vulnerable countries. Starting from the present 70 % share of mitigation finance, we examine the climate and social outcomes if MDBs' climate finance allocation progressively aligns with the Paris Agreement objectives [31]. We use numerical simulations to predict how total CO_2 emissions and climate vulnerability change under different scenarios of climate finance allocations. When the mitigation-adaptation finance split shifts from 70:30 to 40:60 by 2050, the annual growth rate of emissions and average vulnerability will be 1.87 % and − 0.34 % (compared to 1.84 % and − 0.18 % from 2011 to 2019), and the vulnerability index of around 1.9 billion people will be reduced below the global average (0.465 in 2019).

Our study makes several contributions to the climate finance literature. First, we contribute to the literature on climate financing activities of financial institutions. Several studies have focused on the role of private financial intermediaries such as banks, insurers and institutional investors role in facilitating decarbonisation [32–35]. A major step towards bridging the climate finance gap highlighted by the United Nations Framework Convention on Climate Change (UNFCCC) is to first create an inventory of all potential funding sources and the scope of their operations. Therefore, it is important to examine the climate financing activities of both public and private financial intermediaries. Our paper contributes towards that goal by investigating a set of understudied financial institutions which play a pivotal role in financing climate actions.

Second, our results contribute to the discussion on the allocative efficiency of climate financing around the world. While the need for providing climate financing to less developed and more vulnerable countries is well established in recent policy discussions, there is a raging debate about the allocative mechanisms of such financing, particularly if these funds reach the most vulnerable countries [36]. For example, Garschagen and Doshi [27] track and analyse the adaptation funds allocation of the Green Climate Fund (GCF). They find that the most vulnerable countries with weak institutional governance are not

[2] It includes the proportions of project funds that directly contribute to or promote adaptation and/or mitigation.

[3] DEA is widely used in economic studies to assess the productivity (efficiency) of decision-making units with multiple inputs and outputs. Traditionally, it is related to the cost-effectiveness analysis. However, in our analysis, the efficiency scores produced by DEA do not relate to economic efficiency but aim to help us understand whether climate finance is allocated in proportion to the recipient countries' mitigation and adaptation needs.

able to access GCF funding. Michaelowa et al. [28] find that the mitigation trust funds allocate their funding according to recipients' certified emission reductions (a market-based indicator), while the adaptation trust funds do not prioritise the most vulnerable countries. Our paper contributes to these studies by showing that climate finance funds from MDBs are more likely to prioritise mitigation over adaptation projects, and that countries most vulnerable to climate risks receive relatively little adaptation funding.[4]

Finally, several studies investigate the effect of financial intermediation on the climate actions of firms and their consequent effects on corporate profits and competitiveness [37–39]. A major challenge in addressing climate change is that it suffers from a collective action problem – positive climate action of a specific company and industry is often offset by heavy polluters elsewhere. Therefore, it is important to understand if financial intermediation can affect future societal outcomes. For example, it is of academic and policy relevance to examine how many people could be affected if MDBs employ an alternative distribution of adaptation and mitigation financing. Our study highlights that moving towards prioritising adaptation funding can substantially reduce climate vulnerability for nearly 1.9 billion people without a significant change in the annualized growth rate of emissions. This result links our paper to the debate on climate justice [40–42].

In the remainder of this study, we first discuss the methods and data used in our analysis. Then, we map climate finance provided by MDBs about countries' emission levels and climate vulnerability. Next, we estimate the allocative efficiency of MDB climate finance based on countries' emissions and vulnerability. Further, we examine climate-risk changes and the impact on the population when moving towards alternate climate finance allocations. Lastly, we derive policy implications from our results to conclude the analysis.

2. Materials and methods

2.1. Methods

To assess the allocation of MDB climate finance, we connect country-level climate finance with countries' emissions and vulnerability and assess allocative efficiency using data envelopment analysis. We use numerical simulation of countries' emissions and climate vulnerability to calibrate the scenarios for rebalancing mitigation and adaptation finance.

2.1.1. Assessing climate finance allocation

We assess the needs-based allocative efficiency assuming that climate finance allocation is in proportion with the country's CO_2 emissions and vulnerability level. Since we do not have granular data on country-wise mitigation finance and adaptation finance, we assess the allocative efficiency by considering the country's mitigation and adaptation needs simultaneously. Data envelopment analysis (DEA) provides a solution in this regard. DEA is a non-parametric method used to estimate optimal combinations of inputs and outputs [43,44]. In our DEA analysis, each country is a unit of analysis. We take a country's total CO_2 emissions and vulnerability index as inputs and climate finance from MDBs as an output. DEA analysis yields a set of efficiency scores for all countries: the higher the ratio of the output (climate finance) over the weighted inputs (country's total CO_2 emissions and vulnerability index), the higher the efficiency score is. We rely on an output-oriented constant returns-to-scale model, and the efficiency scores are calculated by solving the following linear program.

$$\max_{\eta,\mu} \eta \tag{1}$$

$$s.t.$$

$$\boldsymbol{x_0} - \boldsymbol{X\mu} \geq 0 \tag{2}$$

$$\eta \boldsymbol{y_0} - \boldsymbol{Y\mu} \leq 0 \tag{3}$$

$$\boldsymbol{\mu} \geq 0 \tag{4}$$

Here, $\boldsymbol{X}$ and $\boldsymbol{Y}$ are the input data matrix and output data matrix of all analysis units, $\boldsymbol{x_0}$ and $\boldsymbol{y_0}$ are input vector and output vector of an analysis unit, η is a real variable, and $\boldsymbol{\mu}$ is a non-negative vector. We obtain a set of efficiency scores (η) for each analysis unit which is denoted by $\eta \in [0, 1]$. The efficiency score is high when climate finance provided by MDBs is maximised while the total CO_2 emissions and vulnerability are held constant (countries' efficiency scores are calculated using DEAP software, see [45]).

An efficiency score of 1 is the benchmark, indicating specific country (countries) received the highest volume of climate finance from MDBs with a given level of CO_2 emissions and vulnerability. Countries with efficiency scores lower than one (which are enveloped by the benchmark) received less climate finance with the same CO_2 emissions and vulnerability. For example, DEA grades an efficiency score of 1 for Ethiopia, which received US$506 million in climate finance with 15.27 million tons of emissions and a vulnerability index of 0.565. Yemen had a similar level of emissions (13.78 million tons) and vulnerability (0.562), but received US$77.3 million climate finance (15.3 % of Ethiopia's). This yields an efficiency score for Yemen of 0.159 in the DEA.

Our DEA models are useful to assess the allocative efficiency of MDBs' climate finance based on the country's climate action needs in mitigation and adaptation, namely whether countries with the same level of emissions and vulnerability receive similar amounts of climate finance. Factors such as political circumstances or institutional capacity are not explicitly included in this framework. Therefore, we conduct additional regression analyses that controls for the countries' income level, population size, emission intensity and institutional capacity [46–51]. For these analyses, we use the project-level climate finance data from ADB, EIB and IDBG. For mitigation finance, we estimate the model as:

$$Mitigation_{c,t} = \alpha + \beta_1 Emissions_{c,t-1} + \theta X_{c,t-1} + \delta_c + \varepsilon_{c,t} \tag{5}$$

Where $Mitigation_{c,t}$ is the mitigation finance that country c received from the MDB (i.e., ADB) in year t. For example, investments in a wind farm in Indonesia or a smart and electric transport system in China. $Emissions_{c,t-1}$ is the country's total CO_2 emissions, with one-year lag. $X_{c,t-1}$ is a vector of country characteristics as control variables. We include the country's GDP per capita, readiness, emission intensity and dynamics. The country's readiness is used to proxy the institutional capacity, which informs the country's ability to make effective use of investments for climate actions thanks to a safe and efficient business environment. We use the changing rate of emission intensity as a proxy of the country's effort in addressing climate change.

For adaptation finance allocation, we estimate the model as:

$$Adaptation_{c,t} = \alpha + \beta_1 Vulnerability_{c,t-1} + \theta X_{c,t-1} + \delta_c + \varepsilon_{c,t} \tag{6}$$

Where $Adaptation_{c,t}$ is the adaptation finance that country c received from ADB in year t, such as investments to an integrated water man-

[4] This imbalance is also visible in bilateral climate financing. According to data from OECD, only 25 % of public climate finance channelled by bilateral institutions went to adaptation between 2016 and 2020, and 32 % of public climate finance channelled by multilateral institutions and funds went to adaptation in this period, which were similar or lower to the MDBs adaptation finance share (30 %).

agement program in Bolivia or a tropical storms warning and response project in Vietnam. $Vulnerability_{c,t-1}$ is the country's vulnerability index, with one-year lag. $X_{c,t-1}$ is a vector of country characteristics as control variables, including the country's GDP per capita, readiness, and population size.[5]

2.1.2. Numerical simulation of countries' emissions and climate vulnerability

In our numerical simulation, we first establish the association between countries' emissions and received mitigation finance and the association between vulnerability index and received adaptation finance based on historical data. Then we predict the future emissions and vulnerability based on those associations and simulate the emissions and vulnerability changes when MDBs would rebalance their mitigation and adaptation finance allocation.

To establish the associations stated above, we first construct an MDB-year panel dataset of mitigation finance and adaptation finance, with the average vulnerability index and average CO_2 emissions of countries covered by each MDB[6] between 2011 and 2019. The MDBs are ADB, AfDB, EBRD, EIB and IDBG in this dataset, given they have available data on mitigation and adaptation finance and specific operating countries. We use this data to regress the average vulnerability index on adaptation finance with an MDB fixed effect. The adaptation finance is one-year lagged in the regression. From this, we predict the future average vulnerability index using assumptions of future MDBs' adaptation finance under four different scenarios (discussed in Section 2.1.3). Next, for the simulation of emissions, we regress CO_2 emissions on mitigation finance and GDP (as a proxy for national wealth) with an MDB fixed effect. We then predict the future total CO_2 emissions using assumptions of the mitigation finance under the four scenarios and estimates of the future GDP growth [52].

The vulnerability simulation only captures the direct effects of the increase in adaptation finance. If total climate finance is constant, an increase in adaptation finance implies a reduction in mitigation finance. The reduction in mitigation finance can increase CO_2 emissions, which may also affect the future vulnerability of countries. When the CO_2 concentration in the atmosphere increases, the projected change in warm periods, flood hazards, etc., may change too. These indicators also are part of the vulnerability index. In our analyses, we do not consider such spillover effects but leave this for further research. Predictions are based on the average marginal effect of adaptation finance on vulnerability in the past, and this effect may decrease over time as adaptation investment accumulates.

2.1.3. Scenarios of mitigation and adaptation finance until 2050

We consider four scenarios of MDBs' mitigation/adaptation finance allocation: the baseline scenario (current 70:30), the transition scenario (to a 50:50 split), and two ambitious scenarios (with the dominance of adaptation over mitigation finance). We assume total climate finance and obtain the amount of mitigation and adaptation finance under the four scenarios.

The assumption of total climate finance is based on the High-Level MDB Statement that the MDB group published on 22nd September 2019 [53]. The MDBs committed that their collective climate finance would at least reach US$65 billion annually by 2025, with US$50 billion for low- and middle-income countries. It indicates an annual growth rate of 2.1 % from 2018 to 2025.[7] We assume the MDBs' climate finance will keep growing at this constant rate until 2050. Then, the MDBs' total climate finance will reach US$85 billion in 2050. We investigate four scenarios of MDBs' mitigation/adaptation allocation:

A. Baseline scenario: MDBs keep the current 70:30 mitigation/adaptation allocation until 2050.
B. Transition scenario: MDBs' mitigation/adaptation allocation will change gradually from the current 70:30 to 50:50 in 2050, with intermediate steps of 65:35 in 2025, 60:40 in 2030 and 55:45 in 2040.
C. Ambitious adaptation scenario 1: MDBs will change their mitigation/adaptation allocation from the current 70:30 to 50:50 in 2035 and remain so thereafter.
D. Ambitious adaptation scenario 2: MDBs will change their mitigation/adaptation allocation from the current 70:30 to 50:50 in 2035 and then keep raising the share of adaptation funding and reach 40:60 mitigation/adaptation allocation in 2050.

The baseline scenario had a mitigation/adaptation allocation of 70:30 in 2018, and we set this as the basic scenario, which will last until 2050. The transition and ambitious adaptation scenario 1 are based on a balanced mitigation/adaptation allocation goal. Therefore, in these two scenarios, the mitigation and adaptation finance distribution will reach 50:50 in 2050. In the transition scenario, it will shift gradually and reach 50:50 in 2050, with 65:35 in 2025, 60:40 in 2030 and 55:45 in 2040. In ambitious scenario 1, the mitigation/adaptation finance allocation will reach 50:50 earlier in 2035 and remain so after that.

Since adaptation finance is mainly provided by public financial institutions and MDBs are crucial investors in this regard, we assume that MDBs prioritise adaptation investments in their portfolio to support countries that are vulnerable to climate risks. Therefore, in the ambitious adaptation scenario 2, we assume the MDBs' mitigation/adaptation finance allocation will reach 40:60 in 2050.

With a constant annual growth rate of 2.1 % (extrapolate using the committed growth rate between 2018 and 2025), MDBs' total climate finance will reach US$50 billion by 2025 and increase to 56 billion, 62 billion, 69 billion and 85 billion in 2030, 2035, 2040 and 2050. Under the baseline model, mitigation finance and adaptation finance will reach 59.5 and 25.5 billion by 2050, respectively. An equal allocation of mitigation and adaptation finance indicates US$42.5 billion for each. Under the ambitious adaptation scenario 2, adaptation finance will reach US$51 billion in 2050 (See appendix C).

2.2. Data

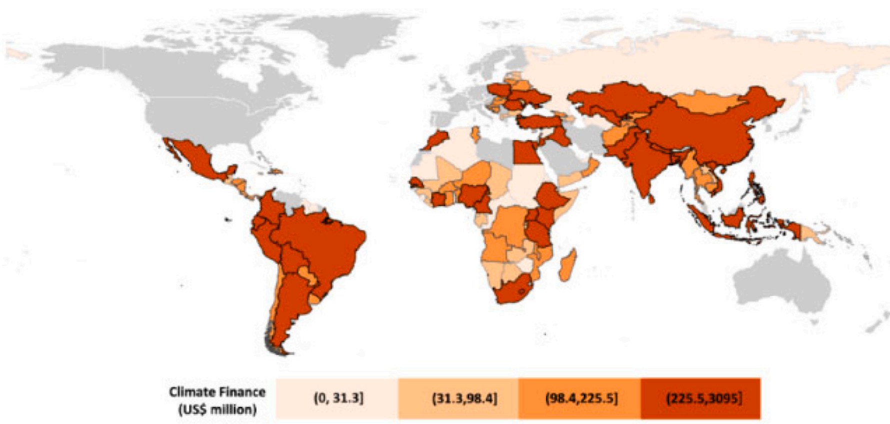
We use three sets of climate finance data in our study. Firstly, we use country-level climate finance provided by the MDBs group from 2015 to 2020. This data is drawn from the *2020 Joint Report on Multilateral Development Banks' Climate Finance* [8]. The MDBs cover 183 countries and territories (hereinafter referred to as countries), the majority being developing and emerging countries (see Appendix B). We will focus on the allocation of climate finance across developing and emerging countries; the 18 European developed countries eligible to obtain climate finance from EIB are not included in the analysis.

This set of climate finance data is the aggregate amount that each country received from all MDBs, which does not differentiate between

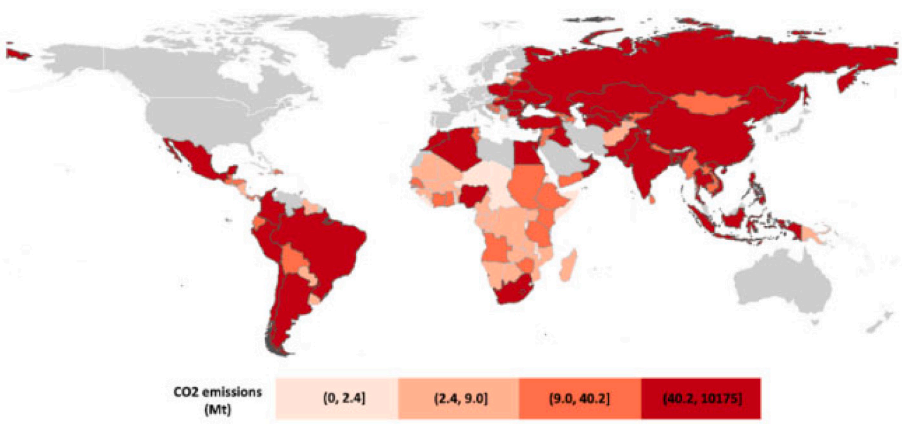
[5] These regressions are run on small samples of projects for each MDBs separately. Therefore, it is likely that the models have explanatory power close to zero, which sometimes leads to a negative adjusted R^2.

[6] The country coverage of each MDB is from its official website.

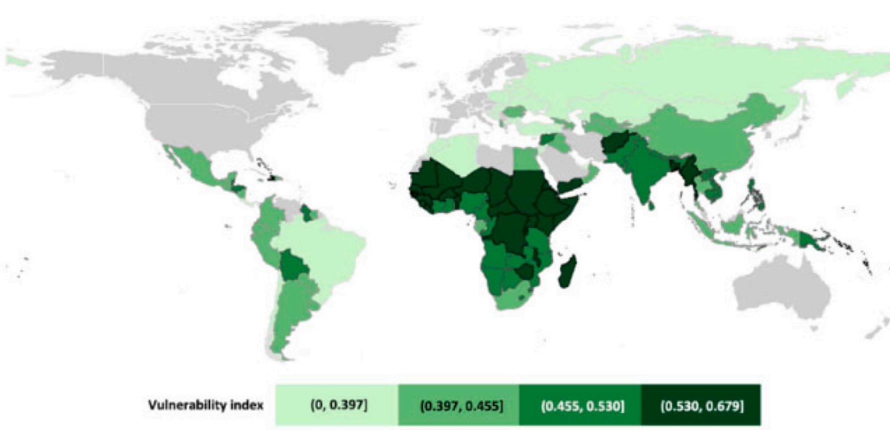
[7] Since the MDBs' statement was announced in 2019, we use 2018 as the baseline year to calculate the annual growth rate of climate finance in the period between 2018 and 2025. Although MDBs' total climate finance commitments kept increasing in 2019 and 2020, the actual climate finance commitments that MDBs provided to low- and middle-income countries in these two years did not reach the 2.1 % annual growth rate goal. Specifically, the climate finance provided to low- and middle-income countries shrank in 2020 and more climate finance flew to high-income countries under the shock of COVID-19.



(a) MDBs' climate finance



(b) Countries' CO2 emissions



(c) **Countries' vulnerability**

Fig. 1. Geographic distribution of climate finance, CO_2 emissions, and vulnerability.
This figure depicts climate finance, CO_2 emissions and vulnerability index of 143 countries covered by MDBs. Countries that are not in the scope of this analysis are coloured in light grey. Panel (a) presents the yearly average climate finance commitments that MDBs provided to countries between 2015 and 2020. The three intervals correspond to the 25th (US$31.3 million), 50th (US$98.4 million) and 75th (US$225.5 million) percentiles of climate finance commitments of 143 countries. Panel (b) and panel (c) present the countries' CO_2 emissions and vulnerability indices lagging one year, indicating each country's annual average emissions and vulnerability index between 2014 and 2019. The three intervals in panel (b) correspond to the 25th (2.4 Mt), 50th (9.0 Mt) and 75th (40.2 Mt) percentiles of CO_2 emissions. The three intervals in panel (c) correspond to the 25th (0.397), 50th (0.455) and 75th (0.530) percentiles of vulnerability indices.

mitigation and adaptation purposes. Further, we use hand-collected data on MDBs' mitigation and adaptation projects. This data is only available for three MDBs - ADB, EIB and IDBG for the period 2016–2020. This allows us to have more granular information on mitigation, adaptation finance and dual-benefit finance for each borrowing country covered by these three MDBs. The third set of climate finance data is used for numerical simulation (see Section 2.1.2). We collect the aggregate mitigation finance and adaptation finance provided by ADB, AfDB, EIB, EBRD and IDBG between 2011 and 2020 for regressions.

Countries with higher CO_2 emissions have greater emission reduction potential. Mitigation investments in these countries may more easily achieve economies of scale. Therefore, a country's total CO_2 emissions can be a proxy of its mitigation needs and, hence, direct mitigation finance. We rely on country-level CO_2 emissions data from the World Bank Development Indicators.

The level of recipient countries' vulnerability is an important consideration in adaptation finance allocation. Countries that are more vulnerable to climate change are expected to receive more climate funds. This is consistent with the emphases on vulnerability in achieving energy justice and climate finance distributive equity and the statement in the Paris Agreement [26,27,36,54]. Climate change vulnerability is the degree to which a social system is susceptible to or unable to cope with the adverse effects of climate change [55]. Here, we use the vulnerability measure from the Notre Dame-Global Adaptation Index (ND-GAIN) Country Index to proxy the country's requirement for funds to support adaptation actions [56]. ND-GAIN breaks the vulnerability measures into exposure, sensitivity, and adaptive capacity. It assesses a country's vulnerability by considering six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Each sector is represented by six indicators with three cross-cutting components: the exposure of the sector to climate-related or climate-exacerbated hazards, the sensitivity of that sector to the impacts of the hazard, and the adaptive capacity of the sector to cope or adapt to these impacts. ND-GAIN provides an annual estimate of the vulnerability of 182 countries from 1995 to the present, and it is widely used [27,28,36,51,57].

After excluding countries that did not receive climate finance from MDBs between 2015 and 2020 and those that lack data on CO_2 emissions and vulnerability index, we obtained data for 143 developing and emerging countries for the mapping and allocative efficiency analysis. Fig. 1 presents the countries' annual average level of climate finance, CO_2 emissions and vulnerability. It shows that the geographic distribution of climate finance is close to the country's total emissions (see Panel a and b), especially in Asia and Latin America. However, the most vulnerable countries, especially those in Sub-Saharan Africa, did not receive much climate finance between 2015 and 2020 (see Panel c).

3. Results

3.1. Mapping climate finance with countries' emissions and vulnerability

We investigate whether the allocation of MDB climate finance is based on the climate action needs of recipient countries. Instead of an economically oriented cost-benefit analysis of climate investments, our analysis connects the mitigation and adaptation investments with country-specific needs in the reduction of emissions and abatement of vulnerability to climate risks and relates to the human dimension [40,41].

The total climate finance commitment by MDBs between 2015 and 2020 was more than US$308.1 billion. The geographic distribution of MDBs' climate finance is highly skewed (see Appendix D). One-third of the climate finance was provided by EIB to 18 European developed countries (not included in our analysis). India, China, Turkey, and Poland (the top 4 developing and emerging recipient countries) received more than US$10 billion each. Using the data of country-specific CO_2 emissions and vulnerability, we categorize the 143 developing and emerging countries into four groups: (A) countries with high CO_2 emissions and low vulnerability (*HeLv*); (B) countries with high CO_2 emissions and high vulnerability (*HeHv*); (C) countries with low CO_2 emissions and low vulnerability (*LeLv*); (D) countries with low CO_2 emissions and high vulnerability (*LeHv*). We use medians of CO_2 emissions (9.0 million tons) and vulnerability index (0.455) to classify high/low CO_2 emissions and high/low vulnerability. Fig. 2 maps these four groups, and Table 1 reports the key characteristics of each group. Most

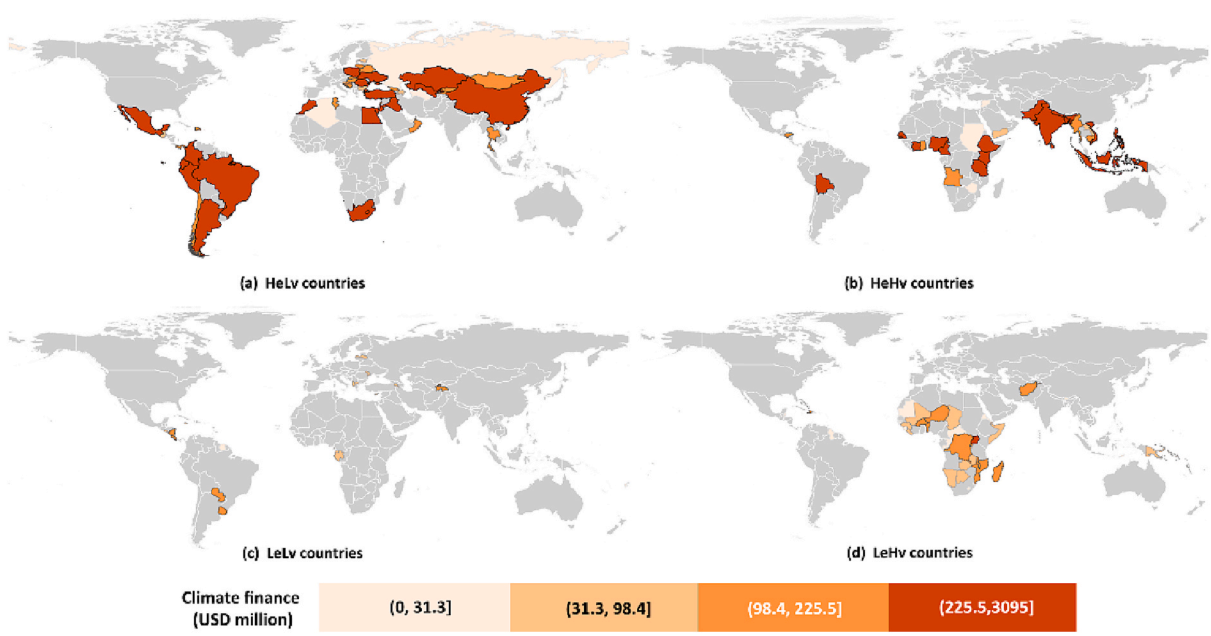


Fig. 2. Mapping climate finance with countries' CO_2 emissions and vulnerabilities
This figure presents MDBs' annual average climate finance commitments between 2015 and 2020 provided to countries in different groups. Those orange colours indicate the amount of climate finance. The three intervals correspond to the 25^{th} (US$31.3 million), 50^{th} (US$98.4 million) and 75^{th} (US$225.5 million) percentiles of climate finance commitments of 143 countries. Panel (a) includes 46 *HeLv* countries; Panel (b) includes 26 *HeHv* countries; Panel (c) includes 25 *LeLv* countries; and Panel (d) includes 46 *LeHv* countries.

Table 1
Climate finance received by four country groups (annual average, USD million).

Groups	Number of countries	Share of total climate finance	Group mean	Median	Std. Dev.	Min	Max
(A) *HeLv*	46	53.1 %	401.6	193.0	505.1	1	2092
(B) *HeHv*	26	34.1 %	456.0	267.6	623.0	0.5	3094
(C) *LeLv*	25	4.8 %	66.8	51.4	51.2	1	191
(D) *LeHv*	46	8.1 %	60.9	35.1	58.1	8	267
Total	143	100 %	243.4	98.3	428.2	0.5	3094

HeLv countries are in East Asia, Central Asia and East Europe, and Latin America and the Caribbean, and they receive the largest amount of climate finance. The *HeHv* countries are mainly in South Asia and Sub-Saharan Africa, and most of them received above-median amounts of climate finance. The *LeHv* group mainly includes Sub-Saharan African countries, which receive the below-median amount of climate finance.

Table 1 shows that about 90 % of climate finance is to countries with high emissions, and *HeHv* countries received, on average, 13 % more climate finance than *HeLv* countries. In contrast, only 8 % of MDB climate finance went to countries with high vulnerability and low emissions (*LeHv*). The *LeLv* countries received, on average, 10 % more climate finance than *LeHv* countries. This skewed distribution of MDB climate finance towards mitigation needs brings us to analyse the efficiency of allocating these funds.

3.2. The allocative efficiency of MDBs' climate finance

We employ DEA to investigate the needs-based allocative efficiency of MDBs' climate finance. We calculate the efficiency scores using climate finance in a year as the output and CO_2 emissions and vulnerability lagging for one year as inputs. Then, we obtain countries' efficiency scores each year between 2015 and 2020. We further calculate the efficiency scores using average climate finance between 2015 and 2020 and average CO_2 emissions and vulnerability between 2014 and 2020 to assess the allocative efficiency in this period. We do not aim to conduct a cost-effective economic analysis of climate-related investments. Instead, we analyse the allocative efficiency by connecting the climate finance amount with recipient countries' climate action needs in emissions reduction and abatement of vulnerability. Efficiency scores generated from the DEA analysis inform whether MDBs' climate finance allocation is in proportion to countries' emissions and vulnerability levels and does not relate to the economic efficiency of climate investment in different countries.

In our study, an efficient allocation implies that two countries with identical carbon emissions and vulnerability receive the same amount of climate finance. In the DEA, the more climate finance MDBs provide when CO_2 emissions and vulnerability are held constant, the higher the efficiency score is. An efficiency score of one indicates the country received the highest volume of finance compared to its peers with similar mitigation and adaptation needs. The score of one is to be regarded as the benchmark. A score close to zero implies the country receives much less climate finance from MDBs, even though it has a similar level of emissions and vulnerabilities as the benchmark.

Fig. 3 (panels (a) to (f)) shows the evolution of the allocative efficiency of MDBs' climate finance. In 2015, MDBs' climate finance was concentrated in a small number of countries, and their peer countries received very limited climate finance. In the post-Paris Agreement period, the number of countries that were prioritised by MDBs in climate finance allocation increased, and the geographic focus shifted over the years. For example, many countries in Latin America were prioritised in 2018, and some countries in Africa were done so in 2019. Panel (g) shows efficiency scores generated by using annual average data between 2015 and 2020. Countries in East and South Asia, like Bangladesh, India, Nepal, China and Vanuatu, are graded with efficiency scores higher than 0.8, indicating they received higher climate finance than their peer countries with similar emissions and vulnerability. Some Sub-Saharan African countries with high vulnerability are also prioritised by MDBs, such as Ethiopia, Malawi, Rwanda, Kenya and Uganda (efficiency scores higher than 0.8). In contrast, seventeen highly vulnerable Sub-Saharan African countries have efficiency scores lower than 0.2, such as Zimbabwe, Sudan, Seychelles, and Mauritania.

Table 2 reports the distribution of the four groups of countries across five efficiency score groups (using the annual average data, same as Fig. 3 panel g). This table shows that a substantial proportion of high-vulnerability countries are in the two lowest efficiency brackets, namely 50 % of the *HeHv* and 59 % of the *LeHv*. With high-emission countries, 65 % of *HeLv* are in the two lowest efficiency brackets. These highly skewed efficiency scores also reflect the uneven distribution of MDB climate finance. The distribution does not correspond with the expectation that climate finance allocation would be in line with countries' mitigation and adaptation requirements.

3.3. MDBs' climate finance allocation and the country characteristics

Table 3 reports the correlation coefficients between countries' MDB climate finance and their characteristics. It shows that climate finance is positively correlated with the country's CO_2 emissions but negatively so with its vulnerability. This suggests that MDBs prioritise mitigation needs when allocating climate finance. The allocation of climate finance is also positively correlated with the country's population size, economic size (GDP), development level (GDP per capita), emission per capita, and the ability to make efficient use of climate finance (readiness). However, countries with better performance in those aspects generally have better access to climate finance and are less vulnerable.

Furthermore, we investigate different determinants when MDBs allocate mitigation finance and adaptation finance using project-level data of ADB, EIB and IDBG. For each bank, we regress mitigation finance on the recipient country's emission and control variables, including the country's readiness, emission intensity and the change in emission intensity. Regarding adaptation, we regress adaptation finance on the recipient country's vulnerability and control the country's readiness, GDP per capita and population. The results show that mitigation finance is positively associated with the country's CO_2 emissions when ADB and IDBG allocate mitigation funds. EIB considers emission intensity when allocating mitigation funds and most of its recipients are European developed countries. Regarding adaptation finance, the allocation of EIB and IDBG's funds is not associated with any characteristics we investigate in the regressions, including the country's vulnerability, GDP per capita, population and readiness. Moreover, adaptation finance is negatively associated with the country's vulnerability level in ADB's allocation. (See Appendix E).

Given the purpose of MDB climate finance, we would have expected that the allocative efficiency thereof is highest when countries with high emissions receive more mitigation finance and countries that are more vulnerable to climate risks receive more adaptation finance. However, it shows that the distribution prioritises mitigation over adaptation needs. Therefore, we also investigate the impact of relating official climate finance closer to countries' adaptation needs, i.e., rebalancing the allocation of climate finance.

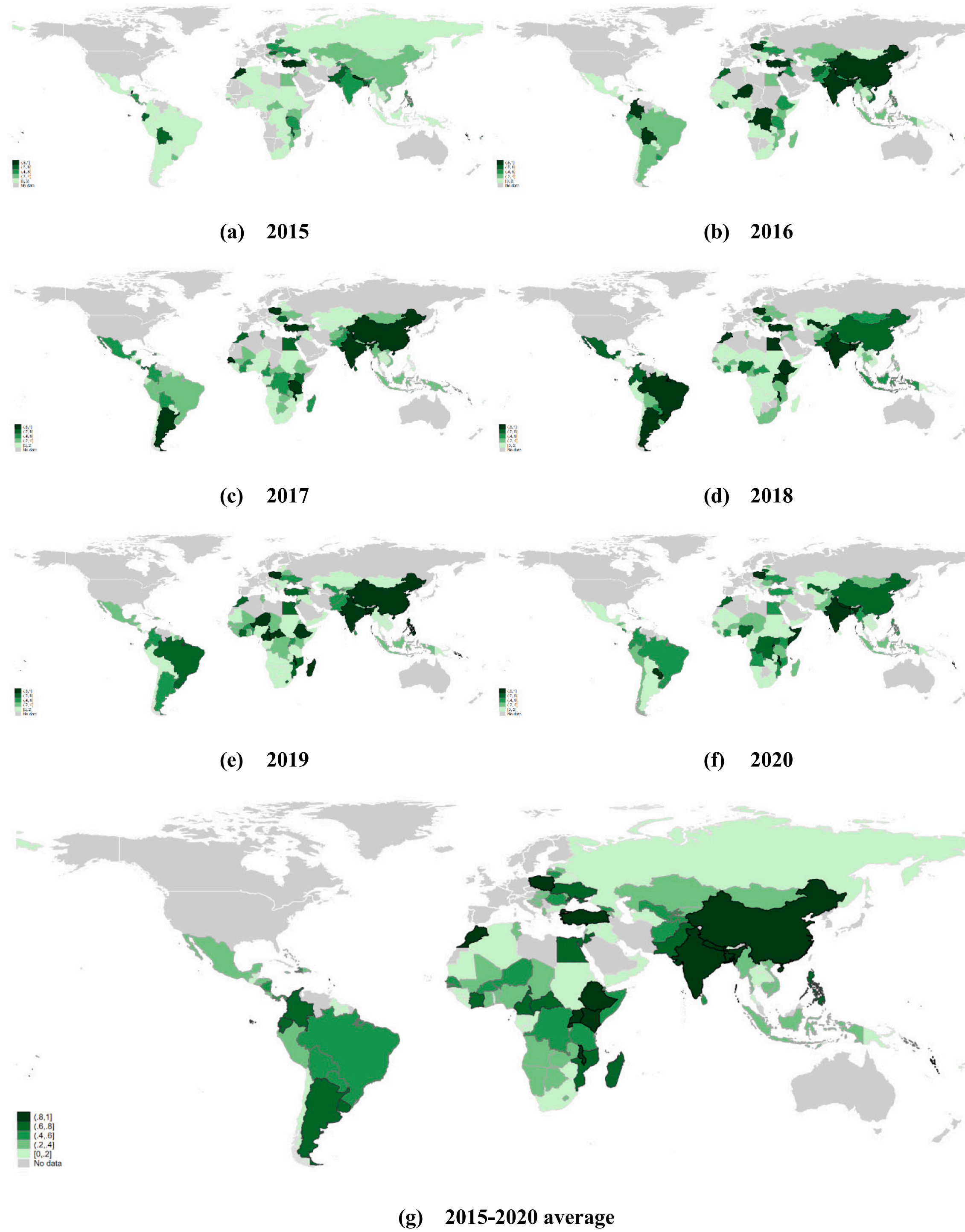


Fig. 3. Allocative efficiency of MDBs' climate finance.
This figure presents the allocative efficiency scores of countries from 2015 to 2020. For panel (a) to panel (f), we calculate the efficiency scores by using the climate finance in that year as the output and the CO_2 emissions and vulnerability index lagged one year as inputs. Because MDB climate finance data is not a balanced panel, some countries' efficiency scores in some years are not available. In panel (g) we use the average climate finance between 2015 and 2020 as the output and the average CO_2 emissions and vulnerability index between 2014 and 2019 as inputs to calculate the efficiency scores.

Table 2
The level of emissions and vulnerability and the country's efficiency score.
This table presents the efficiency scores calculated by the annual average climate finance between 2015 and 2020 and the annual average CO_2 emissions and vulnerability index between 2014 and 2019. Each country is graded with an efficiency score between 0 and 1. We construct five intervals for the efficiency score, which are [0, 0.2], (0.2, 0.4], (0.4, 0.6], (0.6, 0.8] and (0.8, 0.1], and categorize countries of each group according to their efficiency scores. The last row shows the average of MDB climate finance for each efficiency group of countries.

Groups	Efficiency score					Total (number of countries)
	[0, 0.2]	(0.2, 0.4]	(0.4, 0.6]	(0.6, 0.8]	(0.8, 0.1]	
(A) *HeLv*	17	13	6	6	4	46
(B) *HeHv*	5	8	4	4	5	26
(C) *LeLv*	11	8	4	1	1	25
(D) *LeHv*	16	11	11	4	4	46
Total (number of countries)	49	40	25	15	14	143
% share of all countries	34.3 %	28.0 %	17.5 %	10.5 %	9.8 %	100.0 %
Group average of climate finance (US$ million)	49.4	171.4	203.5	501.9	922.1	243.4

3.4. Rebalancing mitigation and adaptation finance

To examine the long-term climate consequences of rebalancing the distribution of MDBs' mitigation and adaptation finance, we perform numerical simulations. With a panel data regression, we establish the negative association between the average vulnerability index and adaptation finance with data between 2011 and 2019. An increase of US $1 million in adaptation finance per country is associated with a 0.0002 decrease in their vulnerability index. The negative association between CO_2 emissions and mitigation finance is established with data between 2014 and 2019. An increase of US$1 million in mitigation finance per country is associated with 4.7 thousand tonnes of CO_2 emissions decrease. Total CO_2 emissions increase with GDP growth. Next, we predict the aggregate CO_2 emissions and vulnerability index until 2050 based on those associations, the assumption of MDBs' total climate finance growth rate (a constant rate of 2.1 % until 2050) and annual GDP growth rate (4 % until 2030, 3 % between 2030 and 2040, and 2.3 % between 2040 and 2050), and four difference scenarios of mitigation/adaptation allocation (see Section 2.1.3).

Fig. 4 shows the evolution of aggregate CO_2 emissions and the average vulnerability index under four scenarios. We predict the aggregate emissions and the average vulnerability index of 154 developing and emerging countries that received climate finance from MDBs under different scenarios between 2020 and 2050. The vulnerability index is the blue line drawn on the left Y-axis, and the total CO_2 emissions is the navy line drawn on the right Y-axis. In 2019, the average vulnerability index of MDB-covered countries was 0.465, and 65 countries were above this average. The total emissions of those countries were 22.4 Gt.

In the baseline scenario (panel a), the MDB covered countries' emissions and vulnerability index in 2050 will be 39.1 Gt in total and 0.449 on average, respectively. This represents an annualized growth rate of 1.77 % and − 0.11 % for aggregate emissions and average vulnerability index, respectively. In transition scenario and ambitious scenario 1 (panel b and c), total emissions increase to 39.4 Gt (annualized growth rate of 1.84 %), and the average vulnerability index decreases to 0.429 (annualized growth rate of −0.26 %). Finally, in ambitious scenario 2 (panel d), the growth of emissions is 1.87 % per year, and the average vulnerability is −0.34 %. To put these percentage changes in perspective, one needs to realize that the average annualized growth rate of CO_2 emissions and vulnerability index in the 2011–2019 period was 1.84 % and − 0.18 %, respectively. Hence, ambitious scenario 2 shows a higher growth rate of aggregate emissions than in the recent past as well as in the transition scenario. In the transition and ambitious scenarios, there are much faster improvements in the abatement of country vulnerability. We note that those improvements are based on the implicit assumption that all recipients have sufficient institutional capacity to make effective use of those funds to reduce their emissions or vulnerabilities.

To specifically account for the human dimension, we benchmark the magnitude of the percentage changes in emissions and vulnerability in terms of the number of people living in the countries affected by these changes compared to 2019. In the base year (2019), the vulnerability indices of 78 countries were lower than the global average (0.465). The countries with below (above) average vulnerability indices are marked as the orange (red) in Fig. 5. In this figure, panel (a) shows the distribution in 2019. In the basic scenario, we observe that seven countries move from above-average vulnerability to below average vulnerability (i.e., from the red to the orange zone, depicted in panel (b) in Fig. 5). This concerns an additional 1.3 % of the global population.

Next, we investigate the implications at the country level assuming that adaptation finance is distributed in line with countries' vulnerability and efficiently used for improving their resilience. In the transition scenario, 13 countries move out of the red (above-average vulnerability) to the orange (below-average vulnerability) zone, which accounts for 5.2 % of the 2019 global population. The transition scenario and ambitious scenario 1 result in the same emissions and vulnerability in 2050 (panel c); the difference between these two scenarios is the speed of reaching this point. Finally, panel (d) shows the effect of ambitious scenario 2. Here, 18 countries, concerning 24.4 % of the global population (1.87 billion), move out of the red zone.

Table 3
Correlation coefficient matrix of climate finance and country characteristics.
This table illustrates the correlation coefficients between MDBs' climate finance and the country's total CO_2 emissions, vulnerability index, GDP and GDP per capita, population, emission per capita, carbon intensity (emission per dollar), and readiness. The GDP, GDP per capita, population, emission per capita and carbon intensity data are drawn from the World Bank Development Indicators. The data on the country's readiness is drawn from ND-GAIN, indicating the country's ability to make effective use of investments for climate actions thanks to a safe and efficient business environment. ***, **, and * indicate significance at the 1%, 5%, and 10% statistical level, respectively.

	Climate finance	CO_2 emissions	Vulnerability	GDP	GDP per capita	Population	CO_2 per capita	CO_2 per dollar	Readiness
Climate finance	1								
CO_2 emissions	0.37***	1							
Vulnerability	−0.28***	−0.09***	1						
GDP	0.54***	0.93***	−0.21***	1					
GDP per capita	0.22***	0.01	−0.64***	0.16***	1				
Population	0.50***	0.84***	0.02	0.77***	−0.07**	1			
CO_2 per capita	0.13***	0.11***	−0.54***	0.13***	0.58***	−0.01	1		
CO_2 per dollar	−0.02	0.15***	−0.152***	0.04	−0.24***	0.14***	0.33***	1	
Readiness	0.25***	0.07**	−0.75***	0.20***	0.76***	−0.05	0.47***	−0.13***	1

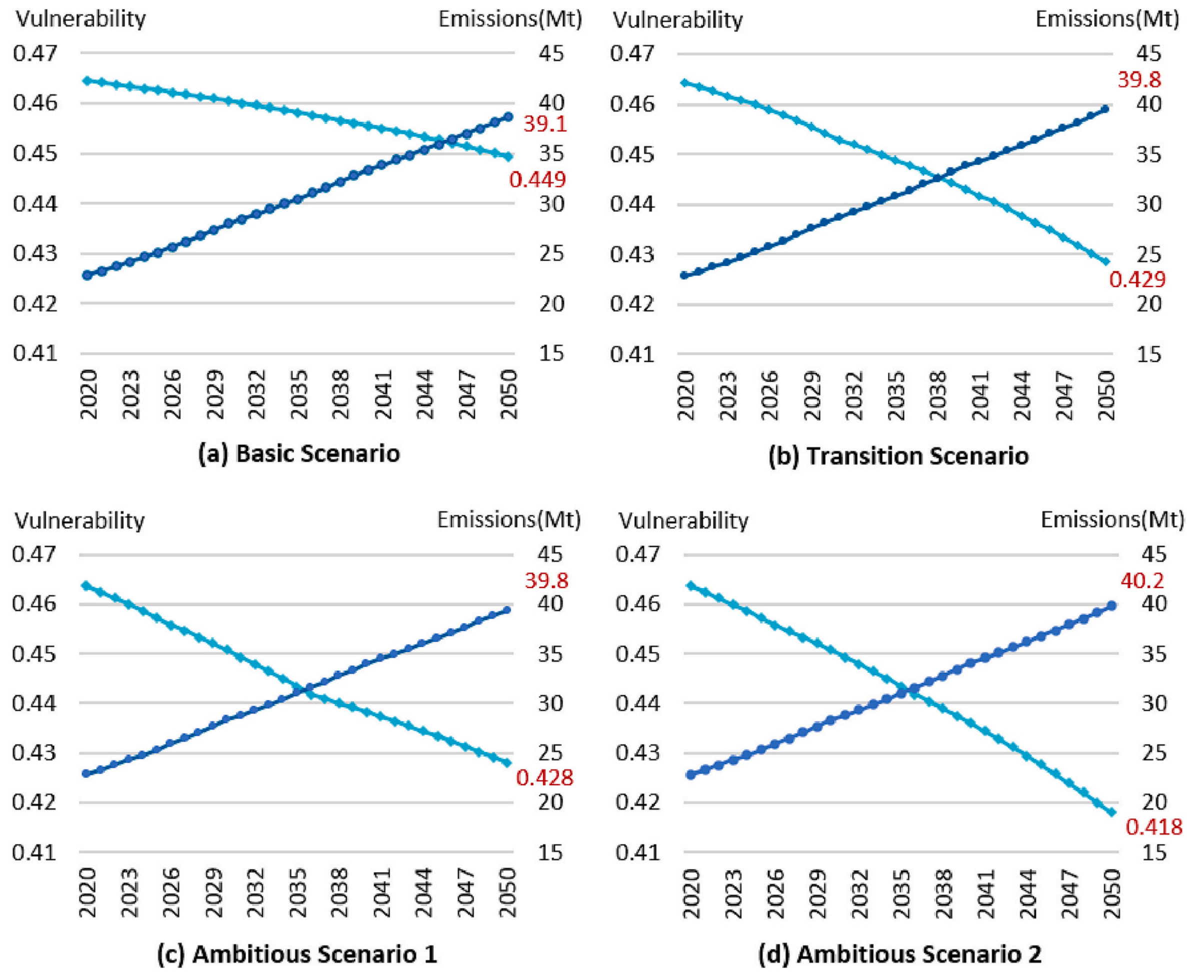


Fig. 4. The predicted average vulnerability index and total CO_2 emissions under four scenarios.
Panel (a) indicates the changing average vulnerability index and total emissions if the mitigation/adaptation finance split remains 70:30 until 2050. Under the baseline scenario, the average vulnerability index will decrease by 3.3 % and total emissions will increase by 72.4 % by 2050. Panel (b) and (c) indicate the changes when mitigation/adaptation finance split shift to 50:50 by 2050. In this case, the average vulnerability index will decrease by 7.8 %, and total emissions will increase by 75.8 %. Panel (b) shows a gradual change, while panel (c) shows the change will be faster before 2035. Panel (d) indicates the change of the average vulnerability index and total emissions in the most ambitious scenario. If the mitigation/adaptation finance split shifts to 40:60 until 2050, the average vulnerability index will decrease by 10.1 %, and total emissions will increase by 77.5 %.

4. Conclusion

Addressing the predicted risks of climate change to human lives and livelihoods requires collective actions from multiple economic agents. It also requires large-scale funding to adopt green technologies and build the climate resilience of vulnerable communities. The private sector alone is unlikely to meet such large-scale and risky funding requirements. Therefore, significant participation of the public sector financial institutions, particularly multilateral development banks (MDBs), in climate financing is required. In this paper, we provide the first evidence on the climate finance allocation practices of MDBs, focusing on the flow of mitigation and adaptation funding to countries with high emission intensity and high vulnerability to climate risks, respectively.

We map the aggregate climate finance provided by the MDBs between 2015 and 2020 and investigate the allocative efficiency based on countries' climate action needs. We find MDBs' climate finance is highly skewed towards a small number of upper-middle-income countries and biased towards mitigation. More funding is allocated to mitigation needs than adaptation needs: 90 % of MDBs climate funds are allocated to high-emission countries, whereas only 8 % goes to countries with high vulnerability to climate risks. We also detect this mitigation preference in climate financing by analysing granular project-level data available for three MDBs.

This current distribution pattern of MDB climate financing significantly differs from the Paris Agreement goals of a 50:50 split between mitigation and adaptation finance. Therefore, in numerical simulation models, we examine the potential consequences for human lives of transitioning from the current allocation to the Paris Agreement goals by 2050. In our estimates, such a transition could substantially reduce vulnerability to climate change for around 1.9 billion people without significantly increasing emissions levels compared to the current projections.

Our analysis adds an important dimension that has so far been missing in the climate finance literature, namely the trade-off between mitigation and adaptation. From a pure climate perspective, one would want to reduce all emissions as much and as quickly as possible. As such, one would prioritise climate mitigation. However, because of the long duration of mitigation measures to take effect, this implies that many people have to face increasing climate risks for a prolonged time. It is a

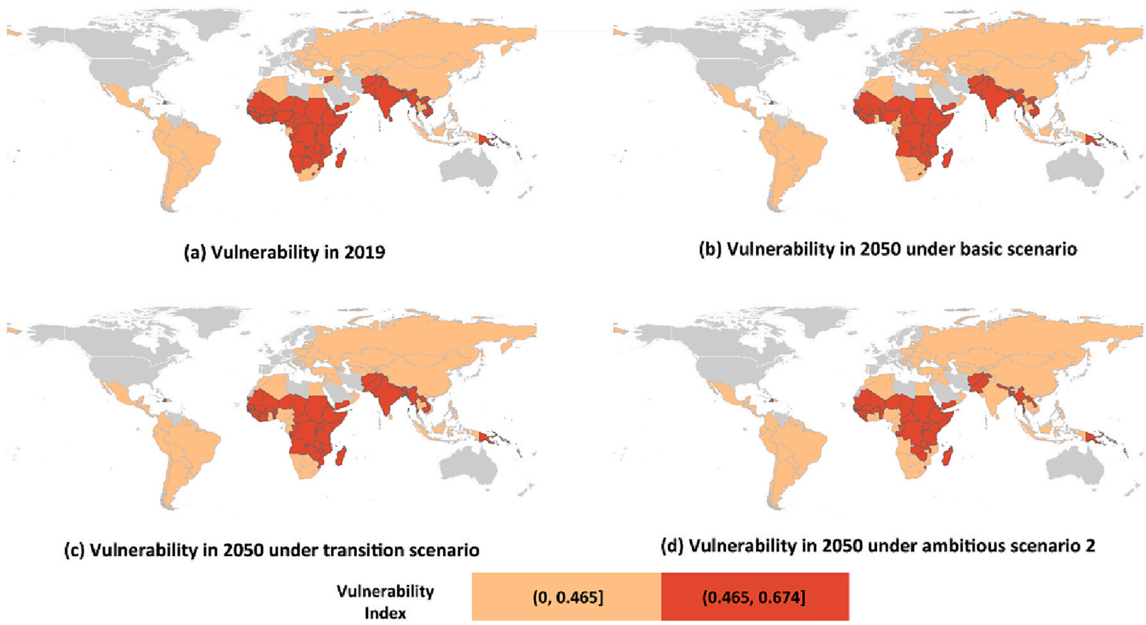


Fig. 5. Vulnerability index changes under different scenarios.
This figure indicates the vulnerability index of 143 developing and emerging countries in 2019 and 2050 under different scenarios. We use the average vulnerability index in 2019 (0.465) as the benchmark. Countries with a vulnerability index higher than 0.465 are coloured in red, and those with a lower vulnerability index lower than 0.465 (include) are coloured in orange. In 2019, there were 78 countries with vulnerability indices below 0.465 (panel a). Panel (b) indicates 7 countries will move to the orange zone under the basic scenario. These countries are Cameroon, Sri Lanka, Namibia, Ghana, Seychelles, Botswana and Syrian Arab Republic. Panel (c) shows another 6 countries will have vulnerability indices below 0.465 in 2050 under transition scenario compared to panel (b), including Timor-Leste, Nigeria, Samoa, Lesotho, Vietnam and Djibouti. Panel (d) shows an additional 5 countries will have vulnerability indices below 0.465 if the mitigation/adaptation finance split reaches 40:60 in 2050 compared to 50:50, including Mozambique, Cote d'Ivoire, Cambodia, India and Angola. In total, when climate finance allocation shifts to 60:40 with a dominance of adaptation over mitigation finance, the vulnerability will reduce for 1.87 billion people. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

particularly salient point because many communities facing heightened climate risks are in developing countries that rely more on development funds to build climate resilience. Our analysis shows that even without a significant upscaling, rebalancing MDBs' climate finance portfolios can have a material impact on the vulnerability to climate change for countries where a large part of the global population lives. The focus of MDBs on emission reduction in the disbursal of climate funds is essential to meet climate goals as set in the Paris Agreement. However, in the short run, underfunding adaptation projects can increase the risk that countries with high vulnerability to climate change face significant economic damage from climate change-related incidents.

This paradox reflects the real nature of the climate crisis: the urgent need to protect vulnerable societies and ecosystems and the pressure to cut emissions simultaneously. It is not only a simple trade-off between short- and long-run climatic priorities. Instead, it highlights the need for a more balanced distribution of scarce funds and adaptation and mitigation priorities. An unbalanced allocation of climate funds may exacerbate the existing inequalities for the most vulnerable societies rather than ameliorate them [26,42]. Adaptation is not only required to protect against negative climate events, but it is also necessary to avoid long-term damage to society and to provide lasting support for climate policies. Similarly, mitigation is important to achieve the objectives of the Paris Agreement, but it is also a matter of urgency as all emissions add up to the increasing concentration of greenhouse gases in the atmosphere and in turn, increase vulnerabilities of communities as well as ecosystems. The urgency of increasing the provision of adaptation finance and balancing between mitigation and adaptation are also acknowledged by MDBs and COP26: COP26 requests developed country parties to consider doubling adaptation finance to achieve a balance between mitigation and adaptation [58]. MDBs expect to double their collective level of adaptation finance by 2025 to support climate resilience-improving projects [53].

Our paper opens up a number of avenues for future research. Climate outcomes are likely to be affected by collective actions of both public and private climate financing. This paper maps the financing activities of only one type of public financial institution. An extension of this paper will be to investigate the projects funded by other public financial institutions. Further, our paper does not explore the possible complementarities in MDBs and private-sector climate financing. An important question for future research can be the extent to which public climate finance augments or crowds out private funding for decarbonisation projects. Finally, our numerical simulation models attempt to connect earth systems with social systems. As the standards of climate disclosure among corporations and financial institutions evolve, a more fine-grained approach can identify the financing needs of communities for more granular geographic regions.

Abbreviations

ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
DEA	Data Envelopment Analysis
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
IDBG	Inter-American Development Bank Group
IsDB	Islamic Development Bank
GCF	Green Climate Fund
GDP	Gross Domestic Product
MDBs	Multilateral Development Banks

OECD Organisation for Economic Co-operation and Development
UN United Nations
UNFCCC United Nations Framework Convention on Climate Change
WBG World Bank Group

Declaration of competing interest

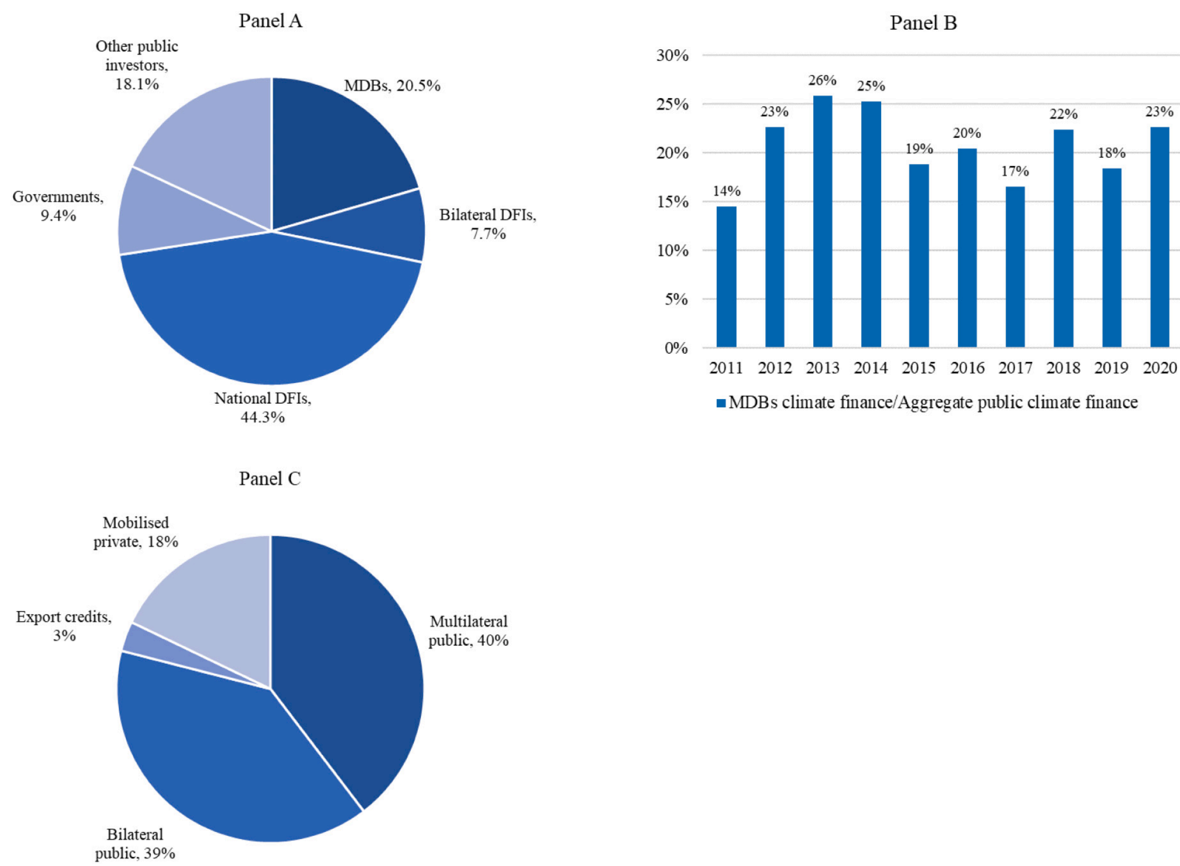
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Share of MDB climate finance in global public climate finance and US$100 billion pledge

Panel A illustrates the average share of MDB climate finance in global public climate finance between 2011 and 2020 with data drawn from Climate Policy Initiative. The aggregate yearly public climate finance in this period is US$240.9 billion, and MDBs provide US$49.4 billion every year. Panel B shows the changes of the share of MDB climate finance in global public climate finance between 2011 and 2020. Panel C illustrates climate finance that provided and mobilised by developed countries between 2016 and 2020 with data drawn from OECD. The multilateral public indicates climate finance provided by MDBs and multilateral climate funds which are attributed to developed countries. The total climate finance provided and mobilised in this period is US$74.7 billion (annual average) and US$29.6 billion is attributed to MDBs and multilateral climate funds.



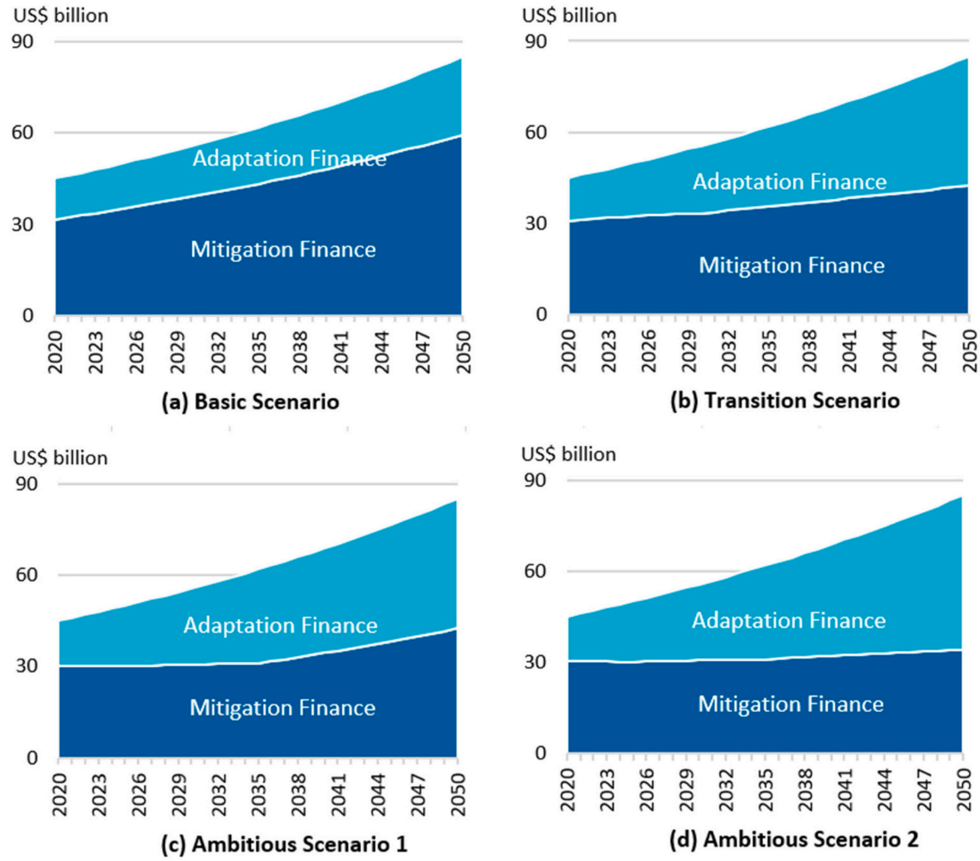
Appendix B. List of countries covered by MDBs

This list comes from Table A.F.1 of the Joint Report on Multilateral Development Banks' Climate Finance (2020). There are 183 countries covered and reported in the joint report by the eight MDBs. There are 18 European developed countries eligible to obtain climate finance from EIB (in column (4)-1). There are 11 countries covered by those MDBs but without valid or positive climate finance data (in column (4)-2). In addition, the data on vulnerability index of 11 countries, namely Kiribati, Marshall Islands, New Caledonia, Nauru, Palau, West Bank and Gaza, South Sudan, Sint Maarten, Tuvalu, Saint Vincent and the Grenadines, and Kosovo, are not available. After excluding those 22 countries without fully available data on climate finance, CO_2 emissions and vulnerability and 18 European developed countries, we obtain 143 countries for our analysis.

(1)	(2)	(3)	(4)-1
Afghanistan	Guatemala	Philippines	Austria
Angola	Guyana	Palau	Belgium
Albania	Honduras	Papua New Guinea	Switzerland
United Arab Emirates	Croatia	Poland	Czech Republic
Argentina	Haiti	Paraguay	Germany
Armenia	Hungary	West Bank and Gaza	Denmark
Azerbaijan	Indonesia	Romania	Spain
Burundi	India	Russian Federation	Finland
Benin	Iraq	Rwanda	France
Burkina Faso	Israel	Sudan	United Kingdom
Bangladesh	Jamaica	Senegal	Greece
Bulgaria	Jordan	Solomon Islands	Ireland
Bahamas, The	Kazakhstan	Sierra Leone	Iceland
Bosnia and Herzegovina	Kenya	El Salvador	Italy
Belarus	Kyrgyz Republic	Somalia	Luxembourg
Belize	Cambodia	Serbia	Netherlands
Bolivia	Kiribati	South Sudan	Norway
Brazil	Lao PDR	Sao Tome and Principe	Sweden
Barbados	Lebanon	Suriname	
Bhutan	Liberia	Slovak Republic	**(4)-2**
Botswana	St. Lucia	Slovenia	Antigua and Barbuda
Central African Republic	Sri Lanka	Eswatini	Bahrain
Chile	Lesotho	Sint Maarten (Dutch part)	Iran, Islamic Rep.
China	Lithuania	Seychelles	St. Kitts and Nevis
Cote d'Ivoire	Latvia	Syrian Arab Republic	Kuwait
Cameroon	Morocco	Chad	Libya
Congo, Dem. Rep.	Moldova	Togo	Malaysia
Congo, Rep.	Madagascar	Thailand	Puerto Rico
Colombia	Maldives	Tajikistan	Qatar
Comoros	Mexico	Turkmenistan	Saudi Arabia
Cabo Verde	Marshall Islands	Timor-Leste	Venezuela, RB
Costa Rica	North Macedonia	Tonga	
Cyprus	Mali	Trinidad and Tobago	
Djibouti	Malta	Tunisia	
Dominica	Myanmar	Turkey	
Dominican Republic	Montenegro	Tuvalu	
Algeria	Mongolia	Tanzania	
Ecuador	Mozambique	Uganda	
Egypt, Arab Rep.	Mauritania	Ukraine	
Eritrea	Mauritius	Uruguay	
Estonia	Malawi	Uzbekistan	
Ethiopia	Namibia	St. Vincent and the Grenadines	
Fiji	New Caledonia	Vietnam	
Micronesia, Fed. Sts.	Niger	Vanuatu	
Gabon	Nigeria	Samoa	
Georgia	Nicaragua	Kosovo	
Ghana	Nepal	Yemen, Rep.	
Guinea	Nauru	South Africa	
Gambia, The	Oman	Zambia	
Guinea-Bissau	Pakistan	Zimbabwe	
Equatorial Guinea	Panama		
Grenada	Peru		

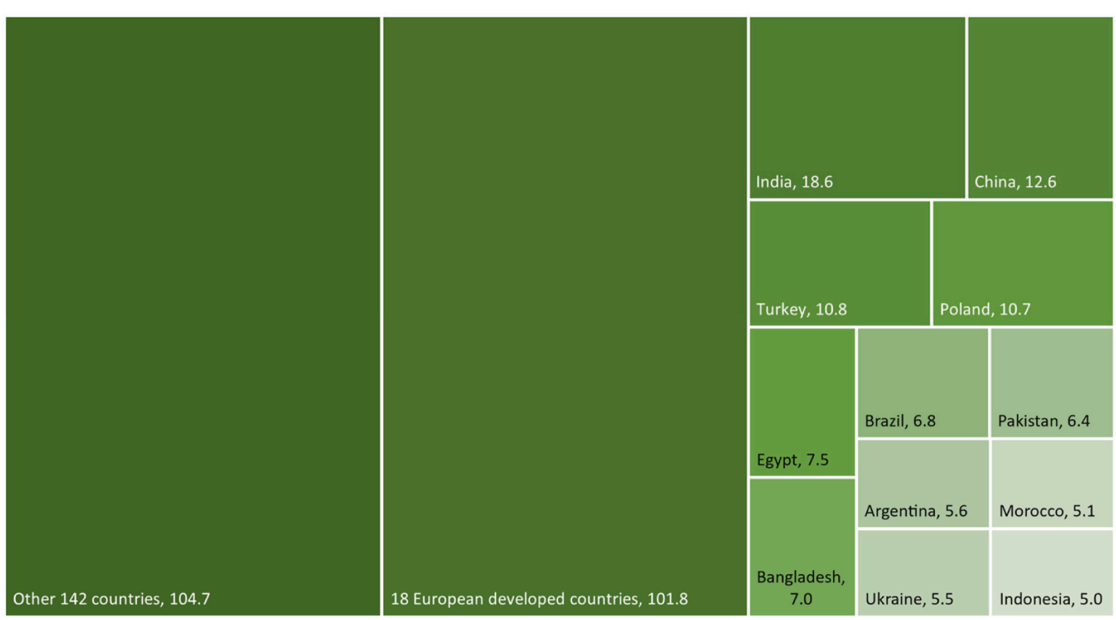
Appendix C. Assumptions of adaptation finance and mitigation finance under four scenarios

We assume that MDBs' collective climate finance will grow at a constant rate of 2.1 % and reach USD 85 billion in 2050. Each Panel shows the adaptation finance and mitigation finance distribution under different scenarios. Panel (a) shows that both mitigation finance and adaptation finance will grow at 2.1 % annually until 2050. The mitigation finance and adaptation finance will reach USD 59.5 billion and USD 25.5 billion in 2050 under the basic scenario (70:30 mitigation/adaptation split). Panel (b) and (c) show that both mitigation finance and adaptation finance will reach USD 42.5 billion in 2050, given the equal distribution of climate finance. Under the transition scenario, mitigation finance's average annual growth rate from 2020 to 2050 will be 1.1 %, and that of adaptation finance will be 3.7 %. Under ambitious scenario 1, the growth of adaptation finance will be faster than under the transition scenario before 2035, with an annual growth rate of 5.0 % between 2010 and 2035. Under ambitious scenario 2 (40:60 mitigation/adaptation split, see panel (d)), the adaptation finance will keep growing faster than mitigation finance. From 2035 to 2050, adaptation and mitigation finance's average annual growth rate will be 3.4 % and 0.6 %, respectively.

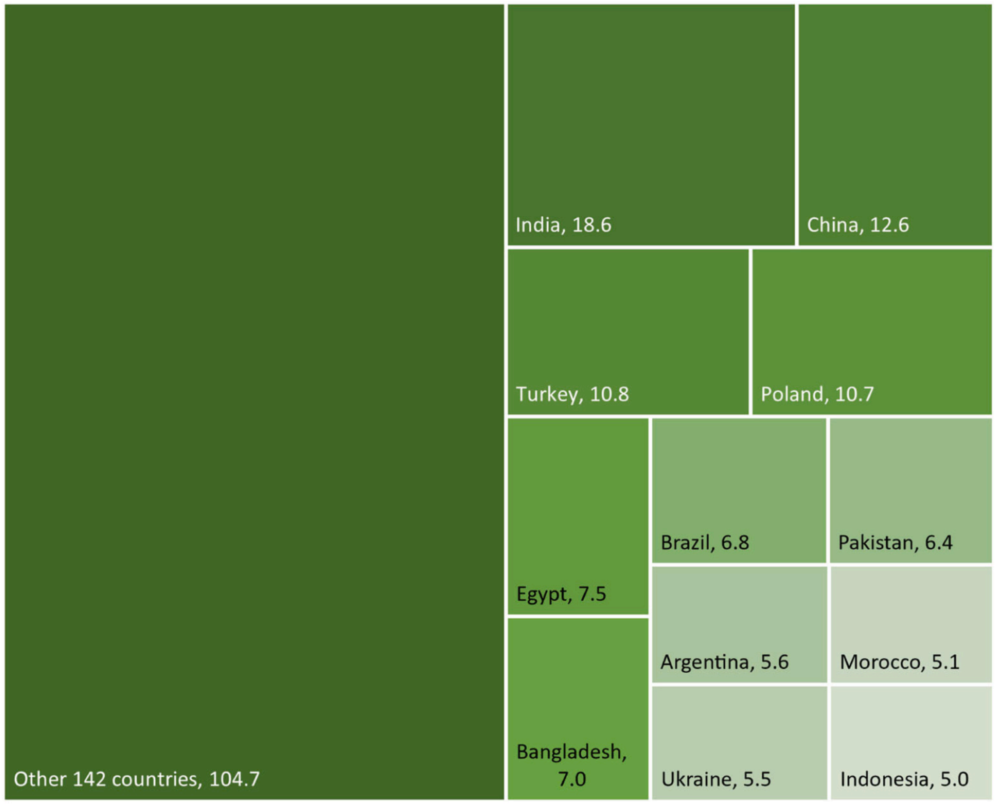


Appendix D. MDBs' climate finance commitments allocation across countries

This figure includes the aggregate climate finance commitments from the eight MDBs between 2015 and 2020 to 172 countries. Numbers and the areas of boxes indicate the accumulated climate finance commitments (US$ billion) provided by MDBs between 2015 and 2020. Panel (a) include all countries that are covered by MDBs. Panel (b) exclude the 18 European developed countries and include only developing and emerging countries in transition.



Panel (a) Climate finance commitments to all MDBs covered countries.



Panel (b) Climate finance commitments to all MDBs covered developing and emerging countries.

Appendix E. Determinants of climate finance allocation of individual MDBs

We collect climate finance data with project-level information from three MDBs (ADB, EIB and IDBG) between 2016 and 2020 which includes detailed data on mitigation finance, adaptation finance and dual-benefit finance for each borrowing country of those MDBs. Then we investigate the correlations of their mitigation finance and adaptation finance with countries' characteristics and examine determinants of climate finance allocation with regression analysis on individual MDB level.

E.1. ADB's mitigation and adaptation finance allocation

Table AE-1 shows ADB's mitigation finance allocation is positively correlated with the recipient country's total CO_2 emissions, GDP and Population which are all indicators about economic size. Meanwhile, mitigation finance is not significantly correlated with the emission intensity indicators (CO_2 per capita and CO_2 per dollar). The adaptation finance is also significantly correlated with the economic size indicators (GDP and population). Contrary to our expectation, adaptation finance is not significantly correlated with the country's vulnerability, and is negatively correlated with GDP per capita and the readiness of the country.

We further investigate those possible determinants of ADB's allocation using regression analysis introduced in Section 2.1.1. The panel includes data of 38 countries covered by ADB from 2016 to 2020. Table AE-2 shows that ADB allocates more mitigation finance to countries with larger CO_2 emissions regardless of the country's readiness, emission intensity and its dynamics. Table AE-3 shows that ADB allocates more adaptation finance to poorer countries (negative coefficient of GDP per capita) but less vulnerable countries (negative coefficient of vulnerability).

Table AE-1
Correlation coefficient matrix of ADB's mitigation finance, adaptation finance, CO_2 emissions, vulnerability and other country characteristics (variables are in natural logarithm (except vulnerability, readiness, ΔCO_2 per capita and ΔCO_2 per dollar)).

	Mitigation finance	CO_2	Adaptation finance	Vulnerability	GDP	GDP per capita	Population	CO_2 per capita	CO_2 per dollar	ΔCO2 per capita	ΔCO2 per dollar	Readiness
Mitigation finance	1											
CO_2	0.62***	1										
Adaptation finance	0.51***	0.51***	1									
Vulnerability	−0.09	−0.46***	−0.04	1								
GDP	0.65***	0.98***	0.51***	−0.35***	1							
GDP per capita	−0.09	−0.02	−0.21***	−0.4144***	−0.06	1						
Population	0.65***	0.95***	0.54***	−0.24***	0.97***	−0.30***	1					
CO_2 per capita	0.01	0.24***	−0.11	−0.68***	0.12*	0.84***	−0.09	1				
CO_2 per dollar	0.14	0.48***	0.15*	−0.67***	0.31***	0.20***	0.26***	0.69***	1			
ΔCO2 per capita	−0.15	0.01	−0.06	0.17**	0.00	−0.18**	0.05	−0.13*	0.02	1		
ΔCO2 per dollar	−0.18*	0.00	−0.11	0.03	−0.02	−0.13*	0.02	−0.07	0.11	0.77***	1	
Readiness	−0.13	−0.26***	−0.18**	−0.43***	−0.25***	0.57***	−0.38***	0.38***	−0.05	−0.18**	−0.16**	1

Table AE-2
Determinants of ADB's mitigation finance allocation.

	(1)	(2)	(3)	(4)	(5)
	Ln (mitigation finance)				
L. ln (CO_2)	1.832*	1.211	1.262	0.626	7.061
	(1.024)	(1.138)	(1.451)	(1.344)	(7.880)
L. readiness		0.141		0.146	0.116
		(0.112)		(0.0993)	(0.106)
L. ln (GDP per capita)			1.912		
			(3.394)		
L. ln (CO_2 per dollar)				0.933	
				(1.257)	
L. ΔCO2 per dollar				−0.0145	
				(1.367)	
L. ln (CO_2 per capita)					−6.306
					(8.630)
L. ΔCO2 per capita					1.216
					(1.134)
Constant	−14.41	−14.04	−24.32	−8.202	−64.77
	(9.541)	(9.311)	(19.54)	(11.67)	(68.82)
N	155	155	155	155	155
adj. R^2	0.023	0.032	0.019	0.022	0.032

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

Table AE-3
Determinants of ADB's adaptation finance allocation.

	(1)	(2)	(3)	(4)
	Ln (adaptation finance)			
L. vulnerability	−0.486**	−0.710***	−0.675***	−0.732***
	(0.184)	(0.159)	(0.200)	(0.201)
L. ln (GDP per capita)		−3.557*	−4.382*	−6.194**
		(1.820)	(2.295)	(2.931)
L. ln (population)			3.421	2.770
			(6.426)	(6.375)
L. readiness				0.105
				(0.0887)
Constant	25.79***	64.71***	13.40	37.25
	(8.852)	(18.72)	(102.7)	(105.0)
N	139	139	139	139
adj. R^2	0.029	0.046	0.042	0.043

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

Table AE-6
Determinants of EIB's adaptation finance allocation.

	(1)	(2)	(3)	(4)
	Ln (adaptation finance)			
L. vulnerability	−0.160	−0.210	−0.0941	0.0800
	(0.436)	(0.378)	(0.314)	(0.387)
L. ln (GDP per capita)		3.135	2.201	2.138
		(2.812)	(3.192)	(3.160)
L. ln (population)			11.46	13.43
			(7.635)	(8.361)
L. readiness				0.150
				(0.0940)
Constant	8.983	−18.44	−202.9*	−248.9*
	(16.50)	(25.44)	(117.5)	(132.8)
N	138	138	138	138
adj. R^2	−0.005	0.003	0.014	0.027

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

E.2. EIB's mitigation and adaptation finance allocation

We do the same analysis with the data of EIB. In EIB's allocation, mitigation finance is positively correlated with total CO_2 emissions, GDP and Population, and negatively correlated with the changing rate of emission intensity (emissions per dollar). Adaptation finance is not significantly correlated with vulnerability, but positively correlated to GDP and population. It is negatively correlated with GDP per capita and the country's readiness. (See Table AE-4).

In the regression analysis, Table AE-5 shows that EIB's mitigation finance is negatively associated with the country's total CO_2 emissions in columns (1) to (4). Specifically, mitigation is negatively associated with GDP but positively associated with its quadratic term in column (4). Those relationships disappear when including emission intensity and its changes (column 5). Their coefficients imply that EIB allocates more mitigation finance to countries with higher emission intensity and lag in the emission reduction process. We cannot find any significant associations between EIB's adaptation finance and the country's vulnerability, population size, economic development and readiness. (See Table AE-6).

Table AE-4
Correlation coefficient matrix of EIB's mitigation finance, adaptation finance, CO_2 emissions, vulnerability and other country characteristics (variables are in natural logarithm (except vulnerability, readiness, ΔCO_2 per capita and ΔCO_2 per dollar)).

	Mitigation finance	CO_2	Adaptation finance	Vulnerability	GDP	GDP per capita	Population	CO_2 per capita	CO_2 per dollar	ΔCO2 per capita	ΔCO2 per dollar	Readiness
Mitigation finance	1											
CO_2	0.59***	1										
Adaptation finance	0.52***	0.48***	1									
Vulnerability	−0.37***	−0.4***	−0.29***	1								
GDP	0.71***	0.94***	0.53***	−0.51***	1							
GDP per capita	0.43***	0.37***	0.29***	−0.8612***	0.51***	1						
Population	0.50***	0.80***	0.42***	0.0813**	0.76***	−0.18***	1					
CO_2 per capita	0.25***	0.51***	0.31***	−0.85***	0.48***	0.85***	−0.11***	1				
CO_2 per dollar	−0.33***	0.17***	−0.22**	0.2***	−0.19***	−0.45***	0.14***	0.08*	1			
ΔCO2 per capita	−0.12*	−0.14***	−0.00	0.30***	−0.20***	−0.29***	0.00	−0.23***	0.17***	1		
ΔCO2 per dollar	−0.01	−0.04	0.041	0.16***	−0.10**	−0.18***	0.05	−0.15***	0.144***	0.62***	1	
Readiness	0.40***	0.24***	0.29***	−0.82***	0.40***	0.87***	−0.21***	0.71***	−0.45***	−0.25***	−0.17***	1

Table AE-8
Determinants of IDBG's mitigation finance allocation.

	(1)	(2)	(3)	(4)	(5)
	Ln (mitigation finance)				
L. ln (CO_2)	3.228	3.287*	1.349	6.260*	2.552
	(1.913)	(1.914)	(2.209)	(3.176)	(9.390)
L. readiness		−0.0562		−0.0214	−0.0640
		(0.187)		(0.198)	(0.186)
L. ln (GDP per capita)			10.11		
			(6.623)		
L. ln (CO_2 per dollar)				−2.853	
				(3.089)	
L. ΔCO2 per dollar				−0.826	
				(1.350)	
L. ln (CO_2 per capita)					1.386
					(9.934)
L. ΔCO2 per capita					−1.069
					(1.805)
Constant	−28.33	−26.86	−99.60*	−59.46*	−20.62
	(18.44)	(19.14)	(56.95)	(33.17)	(81.49)
N	130	130	125	125	130
adj. R^2	0.013	0.006	0.032	0.016	−0.008

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

Table AE-5
Determinants of EIB's mitigation finance allocation.

	(1)	(2)	(3)	(4)	(5)	(6)
	Ln (mitigation finance)					
L. ln (CO_2)	−4.241***	−3.903***	−2.991**	−3.526***	−1.475	−4.832
	(1.168)	(1.126)	(1.321)	(1.186)	(2.984)	(4.183)
L. readiness		−0.0789				
		(0.0871)				
L. ln (GDP per capita)			−29.61*			
			(17.45)			
L. ln (GDP per capita) square			1.495			
			(0.932)			
L. ln (GDP)				−11.42***	−5.441	−11.13***
				(4.000)	(5.386)	(4.013)
L. ln (GDP) square				0.472***	0.232	0.454**
				(0.171)	(0.235)	(0.173)
L. ln (CO_2 per dollar)					7.482**	
					(3.136)	
L. ΔCO2 per dollar					−2.019**	
					(0.999)	
L. ln (CO_2 per capita)						2.991
						(4.319)
L. ΔCO2 per capita						−2.966*
						(1.493)
Constant	49.03***	49.40***	179.5**	108.8***	47.23	117.9***
	(12.43)	(12.58)	(78.37)	(23.57)	(37.39)	(44.75)
N	276	276	276	276	220	276
adj. R^2	0.033	0.034	0.046	0.048	0.029	0.056

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

E.3. IDBG's mitigation and adaptation finance allocation

In IDBG's allocation, the correlation coefficient matrix is similar to the other two MDBs. The difference is that IDB's adaptation finance is not significantly correlated with GDP per capita (See Table AE-7). In regression analysis, only the mitigation finance is positively associated with the country's total CO_2 emissions. The other variables are not statistically significant in IDBG's analysis (see Tables AE-8 and AE-9).

Table AE-9
Determinants of IDBG's adaptation finance allocation.

	(1)	(2)	(3)	(4)
	Ln (adaptation finance)			
L. vulnerability	−0.177	0.249	0.410	0.423
	(0.767)	(0.875)	(0.926)	(0.930)
L. ln (GDP per capita)		6.646	5.535	5.572
		(5.510)	(6.043)	(6.111)
L. ln (population)			6.226	6.425
			(9.540)	(9.799)

(*continued on next page*)

Table AE-9 (*continued*)

	(1)	(2)	(3)	(4)
	Ln (adaptation finance)			
L. readiness				0.0422
				(0.149)
Constant	9.575	−67.34	−161.9	−167.5
	(32.50)	(69.00)	(158.6)	(164.8)
N	130	125	125	125
adj. R^2	−0.007	−0.004	−0.008	−0.016

Standard errors in parentheses. ***, **, and * indicate significance at the 1, 5, and 10 % statistical level, respectively.

Table AE-7

Correlation coefficient matrix of IDBG's mitigation finance, adaptation finance, CO_2 emissions, vulnerability and other country characteristics (variables are in natural logarithm (except vulnerability, readiness, ΔCO_2 per capita and ΔCO_2 per dollar)).

	Mitigation finance	CO_2	Adaptation finance	Vulnerability	GDP	GDP per capita	Population	CO_2 per capita	CO_2 per dollar	ΔCO2 per capita	ΔCO2 per dollar	Readiness
Mitigation finance	1											
CO_2	0.54***	1										
Adaptation finance	0.4740***	0.23**	1									
Vulnerability	−0.0642	−0.37***	0.12	1								
GDP	0.58***	0.96***	0.24***	−0.36***	1							
GDP per capita	0.01	0.13	0.01	−0.70***	0.19**	1						
Population	0.49***	0.90***	0.19**	−0.09	0.91***	−0.23***	1					
CO_2 per capita	−0.16	0.21***	−0.15	−0.63***	0.08	0.81***	−0.23***	1				
CO_2 per dollar	−0.15	0.04	−0.03	0.10	−0.24***	−0.24***	−0.12	0.36***	1			
ΔCO2 per capita	−0.08	−0.22**	0.08	0.13	−0.14*	−0.08	−0.17*	−0.11	−0.01	1		
ΔCO2 per dollar	−0.05	0.00	−0.05	−0.02	−0.03	−0.02	−0.01	0.02	0.11	0.66***	1	
Readiness	0.12	−0.05	0.02	−0.59***	0.16**	0.75***	−0.20***	0.35***	−0.44***	0.07	−0.0472	1

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