Climate Consequences of Rebalancing Official Climate Finance: Analyzing Multilateral Development Banks’ Allocation Practices

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Abstract

The transition towards a low-carbon economy requires the fundamental reallocation of financial capital from current technologies towards green innovation. The role of public financing of green technological innovation by Multilateral Development Banks (MDB) is a largely unexplored area. In this paper, we provide novel evidence on the climate financing practices of MDBs and their long-term climate consequences. The majority of MDB climate finance is for mitigation projects and is concentrated in a small number of relatively wealthy countries. We show that MDBs’ climate financing is positively correlated with countries’ greenhouse gas emissions but not with their vulnerability to climate risks. Our numerical simulations show that moving towards more equal funding of innovative mitigation-adaptation projects can substantially lower global climate vulnerability. We also show that rebalancing MDB funding towards adaptation projects and technologies can reduce vulnerability significantly for an additional 2.5 billion people, without a significant change in the annualized growth rate of emissions.

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1. Introduction

The IPCC (2018) estimates that limiting rises in global mean temperatures to 1.5°C above pre-industrial levels will require investments in the range of USD 1.6 trillion to USD 3.8 trillion annually between 2016 and 2050 (see Owen, 2020 and Peñasco et al., 2021 for review of project and policy effectiveness). Several studies have examined the green innovation pathways that can achieve the global climate targets, but the role of financing is largely marginalized in the literature on green innovation (Geddes and Schmidt, 2020).

Financing climate adaptation and mitigation is challenging due to the required scale, global character, and the already high and rapidly increasing levels of public debt in developed and developing countries (Stern and Valero, 2021; IMF, 2021). Left to market forces alone, there will be underinvestment in climate change adaptation (projects for climate change resilient infrastructure) and mitigation projects (emission reduction and transition to a low-carbon economy). This underinvestment is driven by the fact that green financing innovation will likely cause structural change in the economic system with uncertain outcomes. These factors decrease the attractiveness of climate projects to private investors and corporations who are reluctant to bear the risks and have short planning horizons (Egli et al., 2018; Schmidt, 2014).

Therefore, the role of official climate financing by public financial institutions like the multilateral development banks (MDBs) is crucial (Ackerman, 2009; Brunner and Enting, 2014; Buchner et al., 2019; Cochran et al., 2014; Mazzucato and Penna, 2016). The literature

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1 MDBs were set up to address market failure and channel international funding to projects where private funding is not sufficient, such as climate financing (Dzebo and Stripple, 2015; Hochrainer-Stigler
acknowledges the important role of macroprudential policy in this regard (D’Orazio and Popoyan, 2019; Monasterolo et al., 2019; Baer et al., 2021; Chenet et al., 2021). Despite MDBs crucial role in financing low-carbon and climate-resilient projects, how efficiently they allocate climate finance funds based on relative climate risk priorities of countries remains an open question (Buchner et al., 2019; Roberts et al., 2021).

Against this backdrop, this paper has two objectives. First, we provide novel evidence on the country-wise funding of climate change mitigation (technology to reduce carbon emissions) and adaptation projects (innovation aimed at addressing vulnerability to climate risks) by MDBs based on the climatic priorities of the countries. We hypothesize that mitigation funds should be allocated in line with the country’s emissions reduction potential for optimal use of green innovation technology. In contrast, adaptation funds should be allocated in response to the country’s vulnerability (Michaelowa et al., 2020). Towards that end, we study the climate finance allocation practice of the six leading multilateral development banks: Asian Development Bank (ADB), African Development Bank (AfDB), European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), Inter-American Development Bank (IDB), and the World Bank (WB). We provide evidence on the efficiency of climate finance allocation of MDBs using granular project-level data. Second, there is very little evidence on the long-term climate consequences of the current MDB’s climate financing activities. We provide et al., 2014; Smallridge et al., 2012). They have a long history of providing investment loans for specific projects, such as clean energy technology innovation and climate-resilient capacity building in the climate change context (Steffen and Schmidt, 2017). Their lead is also a signal for the market and stimulates more climate investments from private sectors in climate change mitigation and adaptation. In December 2018, MDBs reinforced their commitments in the alignment of financial flows with the objectives of the Paris Agreement, which again emphasized their alignment with mitigation goals and adaptation and climate-resilient operations (MDBs, 2018).
estimates from numerical simulations based on official forecasts of carbon emissions and climate risks. Given the importance of public funding of green innovation, these issues are important and relevant for public policies on financing green innovation.

To investigate the efficiency and the long-term climate consequences of MDBs climate finance allocation, we first map the aggregate official climate finance provided by the MDBs for 136 countries. We examine how the MDB’s climate finance allocation relates to countries’ emissions and climate vulnerability. To account for country needs and preferences, we concentrate on their CO₂ emissions and their vulnerability regarding climate change. It is motivated by the fact that the majority of mitigation efforts and innovations target emissions, whereas adaptation efforts and innovations aim at improving resilience (Naess et al., 2015; Rafey and Sovacool, 2011; Roberts et al., 2021; Singh and Chudasama, 2021; Smallridge et al., 2012; Surana and Anadon, 2015). Considering that countries differ in their climate priorities and the lack of granular data on each country’s mitigation finance and adaptation finance, we estimate the efficiency of MDB climate finance allocation with data envelopment analysis (Adenle et al., 2017; Yuan and Gallagher, 2018). In this regard, we consider countries’ CO₂ emissions and vulnerability as inputs and climate finance investments by MDBs as outputs. Then, an efficient allocation refers to proportional MDB climate finance disbursed to countries with similar CO₂ emissions and vulnerability levels. Further, we use numerical simulations to predict how total CO₂ emissions and climate vulnerability change under different scenarios of climate finance allocations.

Although MDBs aim for a 50:50 distribution between mitigation and adaptation needs (UNFCCC, 2015), they currently spend about 70% of the climate funds on mitigation projects (MDBs, 2019a). Therefore, assuming that MDBs’ climate financing in the future evolves in line with the
current annualized growth rate, we examine the influence of changes in their climate finance allocation on aggregate carbon emissions and vulnerability to climate risks. We show the real effects of these scenarios based on the number of people affected by rebalancing MDBs’ climate finance.

We first discuss the data and methods used to assess MDBs climate finance allocation efficiency and the scenarios and simulations for rebalancing their allocation. Then, we map climate finance provided by MDBs about countries’ emission levels and climate vulnerability. Next, we estimate the efficiency of MDBs climate finance allocation based on countries’ emissions and vulnerability. Further, we examine climate-risk changes and the impact on population when moving towards alternate climate-finance allocations. Lastly, we derive policy implications from our results to conclude the analysis.

2. Data and Methods

2.1 Data

We use MDB’s climate finance data, CO2 emissions, and proxies for vulnerability to climate change in our allocation efficiency analysis and numerical simulation.

2.1.1 Climate finance

The six MDBs in our research started to report their climate finance figure, which is based on a jointly developed MDB tracking methodology since 2011. They developed and agreed on sets of Common Principles for finance to mitigate and support adaptation to climate change, gradually updated and detailed year by year. “MDB climate finance”, as they defined, refers to
the financial resources committed by MDBs to development operations and components thereof, which enable activities that mitigate climate change and support adaptation to climate change in developing and emerging economies. It only includes the proportions of projects that directly contribute to or promote adaptation and/or mitigation (MDBs, 2019a).

The climate finance data we use in this research are from the 2018 Joint Report on Multilateral Development Banks’ Climate Finance (MDBs, 2019a). There are 172 countries (include territories) are covered and reported by the six MDBs in this report (see Appendix A). We initially obtained data on the climate finance of 147 countries from 2015 to 2018, for they have received climate finance from at least one MDB in this period. There are 11 countries without available data on total CO₂ emissions and vulnerability index. After excluding those 11 countries, we obtain data on 136 countries for mapping analysis and efficiency analysis. EIB also provides climate finance to some EU countries, including Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. However, EIB’s climate finance figures in the joint report are restricted to developing and emerging economies in transition and do not include the 18 EU mentioned above countries. Those 18 countries are out of the scope of our analysis.

There are 1,272 individual climate-related projects from 2016 to 2018 with detailed data on mitigation finance, adaptation finance and dual-benefit finance for every recipient country. This set of climate finance data is the aggregate amount that each country received from all six MDBs,
which does not differentiate between mitigation and adaptation purposes. For more detailed analyses about the correlation between mitigation finance and CO2 emissions and that between adaptation finance and vulnerability separately, we complement climate finance data with project-level information from three large MDBs (ADB, IDB, WB; the information went missing for the other three).

2.1.2 CO$_2$ emissions

We use total CO$_2$ emissions data as a proxy of the country’s mitigation need. Countries with higher CO$_2$ emissions, which have greater emission reduction potential, are expected to receive more climate investment for mitigation purposes. We rely on country-level CO$_2$ emissions data from the Global Carbon Project (GCP) for 2017 (Global Carbon Atlas, 2021), similar to data provided by other widely used sources, namely the World Bank and World Resources Institute. These three CO$_2$ emissions data sources all have worldwide coverage of countries and are positively correlated with each other. We adopt CO$_2$ emissions data from GCP in this analysis, for it provides the most recent emissions of countries (updated until 2018).

2.1.3 Vulnerability

Climate change vulnerability is the degree to which a social system is susceptible to, or unable to cope with, adverse effects of climate change (Field and Barros, 2014). Vulnerability should be the primary criterion when allocating adaptation finance as it can have the greatest impact on the most vulnerable countries. Here, we use the vulnerability measure from the Notre Dame-GLOBAL Adaptation Index (ND-GAIN) Country Index, which provides an annual estimate of
the vulnerability of 182 countries from 1995 to the present (Chen et al., 2015).
Figure 1. Geographic distribution of climate finance, CO2 emissions, and vulnerability.

This figure indicates the 136 sample countries’ climate finance received from MDBs, CO2 emissions and vulnerabilities. Countries that are not in the scope of this analysis are coloured in light grey. Panel A shows MDBs climate finance allocations. It includes the aggregate climate funding that MDBs provided in the period 2015-2018. The three intervals correspond to the 25th (US$ 67 million), 50th (US$ 334 million) and 75th (US$ 914 million) percentiles of climate finance commitments of 136 countries. Panel B showed the countries’ CO2 emissions in 2017. The three intervals correspond to the 25th (2.2 Mt), 50th (8.6 Mt) and 75th (41.5 Mt) percentiles of CO2 emissions of 136 countries. Panel C showed the countries’ vulnerability index in 2017. The three intervals correspond to the 25th (0.390), 50th (0.455) and 75th (0.543) percentiles of vulnerability indices of 136 countries.

Panel A Climate finance

Panel B CO2 emissions
Panel C Vulnerability

We use this vulnerability index to proxy the country’s requirement for funds to support adaptation actions (see also Haddad, 2005). ND-GAIN defines vulnerability as the propensity or predisposition of human societies to be negatively impacted by climate hazards. It 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 representing 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.

2.2 Methods

We rely on data envelopment analysis (DEA) to assess the efficiency of MDBs climate finance allocation. We engage with numerical simulation of countries’ emissions and climate vulnerability to calibrate the scenarios for rebalancing mitigation and adaptation finance.
2.2.1 Data envelopment analysis

Data envelopment analysis (DEA) is used to estimate optimal combinations of inputs and outputs. The DEA method compares feasible input and output combinations based on the available data only. It informs about the efficiency of decision-making units (DMUs) and helps benchmark the performance of organizations, relative to their peers (Coelli et al., 2005). When used for benchmarking, DEA results in a ‘best-practice frontier’ (Charnes et al., 1978). This method has an enveloping property of the dataset’s efficient DMUs: the observed, most efficient DMUs constitute the production frontier, and all DMUs are compared to this frontier (Coelli et al., 2005).

In our DEA analysis, each country is a unit of analysis. This analysis evaluates MDBs’ decisions of allocating climate finance to different countries. It takes the country’s total CO$_2$ emissions and vulnerability index as inputs and climate finance received from MDBs as an output. This analysis yields a set of efficiency scores for all countries; the higher the ratio of the weighted output (climate finance) over the weighted inputs (country’s total CO$_2$ emissions and vulnerability index), the higher the efficiency score is. We aim to investigate how MDBs allocate climate finance to a group of countries with a given level of total CO$_2$ emissions and vulnerability. We rely on an output-oriented constant returns-to-scale model. This model identifies the most efficient analysis unit by maximizing the climate finance (output) while the total CO$_2$ emissions and vulnerability (inputs) are held constant. Further, as our analysis assumes that MDBs provide climate finance in proportion to a country’s total CO$_2$ emissions and vulnerability, the variation of inputs is associated with the variation in outputs. The efficiency scores are calculated by solving the following linear program.
\[
\begin{align*}
\max_{\eta, \mu} & \quad \eta, \\
\text{s.t.} & \quad x_0 - X\mu \geq 0, \\
& \quad \eta y_0 - Y\mu \leq 0, \\
& \quad \mu \geq 0.
\end{align*}
\]

Here, \(X\) and \(Y\) are input data matrix and output data matrix of all analysis units, \(x_0\) and \(y_0\) are input vector and output vector of an analysis unit, \(\eta\) is a real variable, and \(\mu\) is a non-negative vector. We obtain a set of efficiency scores \(\eta\) for each analysis unit denoted by \(\eta \in [0,1]\). The efficiency score is high when climate finance provided by MDBs is maximized. At the same time, the total \(CO_2\) emissions and vulnerability are held constant (countries’ efficiency scores are calculated using DEAP software, see Coelli, 2016).

### 2.2.2 Numerical simulation with vulnerability index and total \(CO_2\) emissions

The numerical simulation and prediction of vulnerability index are based on the association between vulnerability and adaptation finance; total \(CO_2\) emissions is based on the association between emissions and mitigation finance, taking into account the Gross Domestic Product (GDP) as a proxy for countries’ wealth. As we aim to simulate the vulnerability and emissions changes when MDBs rebalance their mitigation and adaptation finance allocation, MDBs are observations in our numerical simulation rather than each country. Total \(CO_2\) emissions, average vulnerability index and GDP data in regressions and predictions are on an MDB-level (aggregate/average figure for all countries that each MDB covers).
We use a panel dataset of the adaptation finance of ADB, AfDB, EBRD, EIB and IDB (we lack this information for the WB) and the average vulnerability indices of their covered countries from 2011 to 2017. We use this data to regress the average vulnerability index on adaptation finance by ordinary least squares regression. Then we use the regression results to predict the future average vulnerability index and future MDB adaptation finance under four different scenarios (discussed below). Next, for the simulation of total CO$_2$ emissions, we use the panel data of the mitigation finance of ADB, AfDB, EBRD, EIB and IDB and the aggregate CO$_2$ emissions (and GDP) of their covered countries from 2014 to 2018. We regress the aggregate CO$_2$ emissions on mitigation finance, and GDP with an MDB fixed effect. We then predict the future total CO$_2$ emissions of MDBs’ covered countries and the mitigation finance under the four scenarios. We use an estimate of the future GDP growth of countries from the OECD(2018). The average annual GDP growth estimates are 4% until 2030, 3% between 2030 and 2040, and 2.3% between 2040 and 2050.

In the numerical simulation, we estimate two models: one is regressing the average vulnerability on adaptation finance (for predicting the future vulnerability with the changing adaptation finance); the other one is regressing the aggregate CO$_2$ emissions on mitigation finance and GDP (for predicting the aggregate CO$_2$ emissions with the changing GDP and mitigation finance). The vulnerability simulation only captures the direct effects of the increase of adaptation finance. If total climate finance holds constant, a rise 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 CO₂ concentration in the atmosphere increases, the projected change in warm periods, flood hazards, etc., may change too. These indicators also are parts of the vulnerability index. In our analyses, we do not consider such spillover effects, and as such, our estimates should be taken as a lower bound of the true effects. We also check the robustness of the predictions of our numerical simulation using aggregate data on adaptation and mitigation financing.

2.2.3 Scenarios of mitigation and adaptation finance until 2050

We will consider four scenarios in our simulation models: basic (current) scenario, transition scenario (to a 50:50 split), and two ambitious scenarios (dominance of adaptation over mitigation finance). We need to predict the future total climate finance and the mitigation/adaptation split for these scenarios. We base our calculation on the future total climate finance on the High-Level MDB Statement that the MDB group published on 22nd September 2019 (MDBs, 2019b). The MDBs committed that their collective climate finance would at least reach US$65 billion annually by 2025. It indicates an annual growth rate of 2.1% from 2018 to 2025. If the MDBs’ climate finance keep growing at this constant rate until 2050, then the MDBs’ total climate finance will reach US$ 85 billion in 2050. Our baseline scenario is the 70:30 split in the mitigation-adaptation financing in 2018, and we set this distribution as the basic scenario, which will last until 2050.

The transition and ambitious scenario 1 are based on their long-term goal of reaching an equal distribution of climate finance funds between mitigation and adaptation needs. Therefore, in
these two scenarios, the mitigation/adaptation finance distribution will shift to 50:50. In the transition scenario, it will shift gradually and reach 50:50 at 2050, with 65:35 in 2025 (close to MDBs’ commitments in 2025, which mitigation finance and adaptation finance will be US$32 billion and US$18 billion), 60:40 in 2030 and 55:45 in 2040. In the ambitious scenario 1, the mitigation/adaptation finance distribution will reach 50:50 earlier and remain so after that. Since adaptation finance is mainly provided by public sources such as national, bilateral, and multilateral development financial institutions and mitigation projects also can attract funding from private sources, we assume that MDBs distribute more adaptation finance from their investment portfolio than mitigation finance to support countries that are vulnerable to climate risks. Therefore, in ambitious scenario 2, we assume the mitigation/adaptation finance distribution will reach 40:60 in 2050.

3. Results

3.1 Mapping climate finance with countries’ emissions and vulnerability

Understanding the allocation of climate finance by MDBs requires analysis of the mitigation and adaptation investments with respect to the country-level priorities of carbon emissions and vulnerability to climate risks. The six internationally leading MDBs collectively report their aggregate climate finance commitments on the country-level during 2015-2018. The geographic distribution of MDBs’ climate finance is highly skewed: the five largest recipients (India, Turkey, China, Poland, and Argentina) received 30% of MDBs’ climate finance investments. Another 112 countries received the same proportion (see Appendix B).
Using the data for carbon emissions and country vulnerability as explained in the previous section, we categorize 136 countries into four groups: (A) countries with high CO\textsubscript{2} emissions and low vulnerability (HeLv); (B) countries with high CO\textsubscript{2} emissions and high vulnerability (HeHv); (C) countries with low CO\textsubscript{2} emissions and low vulnerability (LeLv); (D) countries with low CO\textsubscript{2} emissions and high vulnerability (LeHv). We use medians of CO\textsubscript{2} emissions (8.6 million tons) and vulnerability index (0.445) to classify high/low CO\textsubscript{2} emissions and high/low vulnerability. Figure 2 maps these four groups, and Table 1 reports the key characteristics of each group. Table 1 shows that countries in the HeLv group received more official climate finance than those in HeHv; the LeHv countries received the least. About 90% of MDBs climate finance goes to countries with high emissions, irrespective of their vulnerability. In contrast, only 6% of the official climate finance allocation goes to countries with high vulnerability with low emissions (LeHv). This skewed distribution of MDBs’ climate finance towards mitigation needs brings us to analyze the efficiency of allocating these funds.

**Fig. 2. Mapping climate finance commitments with countries’ CO\textsubscript{2} emissions and vulnerabilities.**
This figure includes the collective climate finance commitments from the six MDBs during 2015-2018 to 136 countries. Colours indicate the amount of climate finance commitments. The three intervals correspond to the 25th (US$ 67 million), 50th (US$ 334 million) and 75th (US$ 914 million) percentiles of climate finance commitments of 136 countries. Panel A includes 44 HeLv countries; panel B includes 24 HeHv countries; panel C includes 24 LeLv countries; panel D includes 44 LeHv countries.
Table 1. Climate finance received by four groups of countries (US$ million).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of countries</th>
<th>% total MDBs climate financing</th>
<th>Group mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) HeLv</td>
<td>44</td>
<td>59.3%</td>
<td>1653.0</td>
<td>803</td>
<td>1943.1</td>
<td>1</td>
<td>7957</td>
</tr>
<tr>
<td>(B) HeHv</td>
<td>24</td>
<td>30.6%</td>
<td>1562.5</td>
<td>975</td>
<td>2370.5</td>
<td>54</td>
<td>11346</td>
</tr>
<tr>
<td>(C) LeLv</td>
<td>24</td>
<td>4.1%</td>
<td>208.1</td>
<td>151</td>
<td>186.0</td>
<td>6</td>
<td>607</td>
</tr>
<tr>
<td>(D) LeHv</td>
<td>44</td>
<td>6.1%</td>
<td>169.2</td>
<td>81</td>
<td>210.2</td>
<td>7</td>
<td>926</td>
</tr>
<tr>
<td>Total</td>
<td>136</td>
<td>100%</td>
<td>902.0</td>
<td>334</td>
<td>1643.7</td>
<td>1</td>
<td>11346</td>
</tr>
</tbody>
</table>

3.2 The efficiency of climate finance allocation

To investigate the efficiency of MDBs climate finance allocation, we employ data envelopment analysis (see section 2.2). It allows us to calculate relative ratios of climate finance over the weighted mitigation and adaptation needs of different countries. An efficient allocation implies that two countries with identical carbon emissions and vulnerability receive the same amount of climate finance. When total CO₂ emissions and vulnerability are held constant, the more climate finance MDBs provide, the higher the efficiency score is and the closer the country to the efficient frontier. In our sample, six countries (Kenya, Morocco, Nepal, Rwanda, Turkey and
Vanuatu) have the same level of climate finance in relation to their emissions and vulnerability, and, therefore, they constitute the efficiency frontier (this is graphically shown in Appendix C, where the area between the origin and the frontier envelops the other 130 countries).

Table 2. The number of four types of countries in each efficiency score interval.

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, 1], and categorize countries of each group according to their efficiency scores. The last row shows the average of MDBs climate finance for each efficiency group of countries. The table shows that more than 40% of countries cluster in the lowest efficiency score interval, and those countries received very limited climate finance on average.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Efficiency score</th>
<th>Total (number of countries)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[0, 0.2]</td>
<td>(0.2, 0.4]</td>
</tr>
<tr>
<td>(A) HeLv</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>(B) HeHv</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>(C) LeLv</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>(D) LeHv</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Total (number of countries)</td>
<td>56</td>
<td>37</td>
</tr>
<tr>
<td>% share of all countries</td>
<td>41.2%</td>
<td>27.2%</td>
</tr>
<tr>
<td>Group average of MDBs climate finance (US$ million)</td>
<td>135.6</td>
<td>591.3</td>
</tr>
</tbody>
</table>

Table 2 reports the distribution of the four groups of countries (see Figure 2) across five efficiency groups. This table shows that a substantial proportion of high vulnerability countries are in the two lowest efficiency brackets, namely 50% of the HeHv and 77% of the LeHv countries. The highly skewed distributed efficiency scores also reflect the uneven distribution of MDBs climate finance, which do not correspond to the expectation that climate finance allocation is in line with countries’ mitigation and adaptation requirements, especially for countries with urgent adaptation needs.
The rank correlations between the aggregated climate finance of the MDBs group and the country’s total CO$_2$ emissions, carbon intensity, vulnerability index, GDP and GDP per capita (Table 3, Panel A) show that official climate finance is positively associated with the country’s CO$_2$ emissions, but negatively so with its vulnerability. It also suggests that MDBs prioritize mitigation needs.

### Table 3. Spearman’s rank correlation coefficient matrices.

Panel A illustrates the correlation coefficients between the aggregated climate finance of the MDBs group and the country’s total CO$_2$ emissions, carbon intensity, vulnerability index, GDP and GDP per capita. Carbon intensity is the CO$_2$ emissions scaled by a country’s GDP at current prices as of 2017. The GDP and GDP per capita data are drawn from the World Bank Open Data (2020a, 2020b). Both are in current U.S. dollars as of 2017.

Panel B illustrates the correlation coefficients between the collective mitigation finance and adaptation finance provided by the ADB, the IDB and the WB and the country’s total CO$_2$ emissions, vulnerability index, GDP, and GDP per capita. The ADB, the IDB and the WB collectively provided US$ 23.8 billion and US$ 12.9 billion of mitigation finance and adaptation finance. * indicates correlation coefficients significant at the 5 per cent level or better.

#### Panel A Correlation coefficient matrices of the aggregate MDB group’s climate finance

<table>
<thead>
<tr>
<th></th>
<th>Climate finance</th>
<th>CO$_2$ emissions</th>
<th>Carbon intensity</th>
<th>Vulnerability index</th>
<th>GDP</th>
<th>GDP per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate finance</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$ emissions</td>
<td>0.719$^*$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon intensity</td>
<td>0.179$^*$</td>
<td>0.473$^*$</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability index</td>
<td>-0.246$^*$</td>
<td>-0.491$^*$</td>
<td>-0.291$^*$</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td>0.740$^*$</td>
<td>0.939$^*$</td>
<td>0.186$^*$</td>
<td>-0.433$^*$</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>GDP per capita</td>
<td>0.054</td>
<td>0.323$^*$</td>
<td>0.065</td>
<td>-0.814$^*$</td>
<td>0.329$^*$</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Panel B Correlation coefficient matrices of the collective mitigation finance and adaptation finance from the ADB, the IDB and the WB

<table>
<thead>
<tr>
<th></th>
<th>Mitigation finance</th>
<th>CO$_2$ emissions</th>
<th>Adaptation finance</th>
<th>Vulnerability index</th>
<th>GDP</th>
<th>GDP per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitigation finance</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO$_2$ emissions</td>
<td>0.654$^*$</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptation finance</td>
<td>0.542$^*$</td>
<td>0.436$^*$</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vulnerability index</td>
<td>-0.227$^*$</td>
<td>-0.487$^*$</td>
<td>-0.067</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Information on 1,272 individual climate-related projects of three large MDBs (ADB, IDB, WB; the information went missing for the other three) enables us to investigate the correlation between mitigation finance and CO₂ emissions and that between adaptation finance and vulnerability separately. Table 3 (Panel B) shows that their combined mitigation funding strongly correlates with the countries’ CO₂ emissions. In contrast, there is no significant association between adaptation finance with vulnerability. However, the significant positive association between adaptation finance and GDP suggests that MDBs allocate more adaptation funds to wealthier countries with more capacities to address climate vulnerability.

Further, Table 3 (Panel A and B) shows positive associations of GDP and GDP per capita with emissions and negative ones with vulnerability. Therefore, we also construct a measure of carbon intensity by scaling CO₂ emissions to a country’s GDP at current prices as of 2017. We then use carbon intensity and the vulnerability index as inputs of the DEA. The resulting efficiency score is even more skewed compared to when we used CO₂ emissions and vulnerability as inputs: 76 per cent of the countries are in the lowest efficiency band compared to 41 per cent in the previous calculations (see Appendix D). It implies that countries’ GDP disproportionately affects MDB climate financing. As a further robustness check, we estimate DEA models with individual constituents of the vulnerability index (exposure, sensitivity, and capability) and CO₂ emissions as inputs (see Appendix E). Here, the results are qualitatively similar to what we find for the aggregate vulnerability score and CO₂ emissions.

Given the purpose of MDB climate finance, we would have expected that the allocative efficiency of official climate finance is highest when countries with high emissions receive more mitigation finance, and countries with more vulnerability to climate risks receive more adaptation finance. However, the current allocation clearly prioritizes mitigation over adaptation needs. Therefore, we will investigate the impact of relating official climate finance closer to countries’ adaptation needs, i.e., rebalancing the allocation of this climate finance.
3.3 Rebalancing mitigation and adaptation finance

To examine the long-term consequences of the mitigation-adaptation split in MDBs climate finance, we perform numerical simulations. In particular, we forecast the aggregate CO$_2$ emissions and vulnerability index in 2050 for four different scenarios (see section 2.2):

A. Basic scenario: the mitigation-adaptation split keeps at 70:30 until 2050;
B. Transition scenario: mitigation-adaptation split will change gradually from 70:30 in 2018 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: the mitigation-adaptation split will change from 70:30 in 2018 to 50:50 in 2035 and remain so thereafter;
D. Ambitious adaptation scenario 2: the mitigation-adaptation split will change from 70:30 in 2018 to 50:50 in 2035 and 40:60 in 2050.

For all four scenarios, we assume that official climate finance will grow at a constant rate until 2050. The growth rate of such climate finance is 2.1%, calculated from the annualized growth rate of MDB climate financing in the 2018-2025 period (MDBs, 2019b). At this rate, total climate financing by MDBs will reach US$ 85 billion in 2050 (the forecasted growth in mitigation and adaptation finance is depicted in Appendix F).

Figure 3 shows the evolution of aggregate CO$_2$ emissions and the average vulnerability index for the four scenarios. The initial conditions are the values of aggregate emissions and the average vulnerability index of all countries covered by MDBs in 2017. The outcomes from the scenarios are benchmarked to the values of CO$_2$ emissions in 2018 and the vulnerability index in 2017.

Fig. 3. The predicted average vulnerability index and total CO$_2$ emissions under different scenarios.
This figure shows the predicted average vulnerability index and total CO\textsubscript{2} emissions under different scenarios until 2050. The Vulnerability index is the blue line drawn on the left Y-axis, and the total CO\textsubscript{2} emissions is the navy line drawn on the right Y-axis. In 2017, the average vulnerability index of MDB covered countries was 0.463, and 67 countries were above the average (0.463). In 2018, the total emissions of those countries were 23.3 Gt. Panel A indicates the changing average vulnerability index and total emissions if mitigation/adaptation finance split keeps 70:30 until 2050. Under a basic scenario, the average vulnerability index will decrease by 3.6\% and total emissions will increase by 63.3\% until 2050. Panel B and C indicate the changes when mitigation/adaptation finance split shift to 50:50 until 2050. The average vulnerability index will decrease by 7.0\% in these two scenarios, and total emissions will increase by 66.9\% until 2050. Panel B shows a gradual change process, while panel C shows the change will be faster before 2035. Panel D indicates the changing of the average vulnerability index and total emissions in a more ambitious scenario. If mitigation/adaptation finance split shifts to 60:40 until 2050, the average vulnerability index will decrease by 8.6\%, and total emissions will increase by 68.6\%.
In the basic scenario, the MDB covered countries’ emissions and vulnerability index in 2050 will be 38 Gt in total and 0.447 on average, respectively. It represents an annualized growth rate of 1.54% and -0.11% for aggregate emissions and average vulnerability index, respectively. In scenarios (B) and (C), total emissions increase to 38.9 Gt (annualized growth rate of 1.61%), and the average vulnerability index decreases to 0.431 (annualized growth rate of -0.22%). Finally, in scenario (D), the annualized growth rate of aggregate emissions is 1.65%, and the average vulnerability is -0.27%. To put these percentage changes in perspective, the average annualized growth rate of CO₂ emissions and vulnerability index in the 2014-2017 period was 1.70% and -0.15%, respectively. Hence, all four scenarios show lower growth of aggregate emissions, and in three of the four scenarios, there are improvements regarding country vulnerability.

To 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 2017. The U.S. Energy Information Agency (EIA, 2019) predicts that global energy-related CO₂ emissions will be 43.1 Gt in 2050. When we connect this to scenario (C), the rebalancing will imply 2.1% higher total emissions than the current projections.

In the base year, the vulnerability indices of 83 countries were lower than the global average (0.463). The countries with below (above) average vulnerability indices are marked as the orange (red) in Figure 4. In this figure, panel A showed the distribution in 2017. In the basic scenario (scenario A), we observe that nine countries move from above-average vulnerability to below-average vulnerability (i.e., from the red to the orange zone, depicted in Panel B in Figure 4). It concerns an additional 2% of the global population.

**Fig. 4. Vulnerability index changes under different scenarios.**
This figure indicates the vulnerability index of 150 countries in 2017 and 2050 under different scenarios. We use the average vulnerability index in 2017 (0.463) as the benchmark. Countries with a vulnerability index higher than 0.463 are coloured in red, and those with a lower vulnerability index lower than 0.463 (inclusive) are coloured in orange. In 2017, there were 83 countries with vulnerability indices below 0.463 (Panel A). Panel B indicates an additional 9 countries will move to the orange zone under the basic scenario. These countries are Ghana, Sri Lanka, Botswana, Seychelles, Belize, Viet Nam, Sao Tome and Principe, Comoros and Equatorial Guinea. Panel C shows another 22 countries will have vulnerability indices below 0.463 in 2050 under transition scenario, including south Asian countries with a great population. Panel D shows an additional 22 countries will have vulnerability indices below 0.463 if the mitigation/adaptation finance split reaches 60:40 in 2050 compared to 50:50, including countries in South Asia and Sub-Saharan and SIDS like the Maldives.

We now concentrate on what the simulations imply at the country level based on the assumptions that adaptation finance is distributed in line with countries’ vulnerability and fully efficiently used in resilience improvement. In the transition scenario (scenario B), an additional 22 countries move out of the red (above-average vulnerability) to the orange (below-average vulnerability) zone. These countries, including India, Pakistan, Nigeria and Cameroon, have a combined population of 1.87 billion people or 24% of the 2017 world population (for 2050, this
would be 2.53 billion people or 26% of the 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 (scenario D). Then, another 22 countries, concerning an additional 7.5% of the global population, move out of the red zone.

4. Discussion and conclusion

Our analysis adds key results that have so far been missing in the literature on financing green innovations. We show that the allocation of MDBs’ climate finance has important short-term and long-term climate consequences. The focus on emissions 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 damages from climate change-related incidents. This seeming 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 the funds and adaptation and mitigation priorities. Adaptation is not only required to protect against negative climate events, but it is also necessary to avoid long-term damage to communities and ecosystems 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 and ecosystems.

The climate crisis requires climate-resilient development, embracing innovative green mitigation and adaptation technologies, and inclusive, sustainable development to advance both human and planetary health and well-being (Buchner et al., 2019; Owen, 2020b; Folke et al., 2021; Singh and Chudasama, 2021). Such large-scale and risky funding of green innovation needs significant participation from the public sector financial institutions such as the MDBs. To
begin with, there is a ‘gap’ between what is required and what is provided is estimated at US$1.6-3.8 trillion (IPCC, 2018). MDBs and their sponsors may not be able to bridge the gap on their own. However, we find that even without scaling up, 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.

We show that the distribution of official climate finance has significant climate-risk consequences. For example, one of our four scenarios suggests that a more evenly balanced allocation between adaptation and mitigation finance could substantially reduce vulnerability to climate change for more than 2.5 billion people. As such, our forecasts also show the partial effects of MDB climate financing on future outcomes. These outcomes are likely to be affected by both official and private sector climate financing. In this regard, it is important to realize that both conventional official and private financing practices have supported an economic system that inadequately addresses climate externalities. We do not comment on the possible complementary in MDB and private-sector climate financing but leave this for further research.

We suggest that in addition to raising the standards of climate-disclosure among corporations and financial institutions, such as suggested by the Taskforce on Climate-related Financial Disclosures (TCFD, 2017), public policies should aim at a coherent public-private collaboration that prioritizes climate financing based on both mitigation and adaptation needs and connects earth systems and social systems.
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### Appendix A

#### List of countries covered by the six multilateral development banks

This list comes from Table A.G.4 of the Joint Report on Multilateral Development Banks’ Climate Finance (2018). There are 172 countries covered and reported in the joint report by the six MDBs. There are 25 countries covered by the six MDBs but without valid or positive climate finance data (marked by a single star). In addition, the data on CO₂ emissions of Kosovo and Madagascar (marked by double stars) and the data on vulnerability index of Cape Verde, Cook Islands, Kiribati, Marshall Islands, Nauru, Palau, South Sudan, Tuvalu, West Bank and Gaza (marked by triple stars) are not available. After excluding those 36 countries without fully available data on climate finance, CO₂ emissions and vulnerability, we obtain 136 countries for analyzing the allocation of climate finance of six major MDBs.

<table>
<thead>
<tr>
<th>Afghanistan</th>
<th>Congo, Dem. Rep.</th>
<th>India</th>
<th>Myanmar</th>
<th>South Sudan***</th>
<th>Anguilla*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>Congo, Rep.</td>
<td>Indonesia</td>
<td>Namibia</td>
<td>Sri Lanka</td>
<td>Antigua and Barbuda*</td>
</tr>
<tr>
<td>Algeria</td>
<td>Cook Islands***</td>
<td>Iraq</td>
<td>Nauru***</td>
<td>St. Lucia</td>
<td>Bahrain*</td>
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<tr>
<td>Angola</td>
<td>Costa Rica</td>
<td>Israel</td>
<td>Nepal</td>
<td>St. Vincent and the Grenadines</td>
<td>Bonaire, Sint Eustatius and Saba*</td>
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<td>Argentina</td>
<td>Côte d’Ivoire</td>
<td>Jamaica</td>
<td>Nicaragua</td>
<td>Sudan</td>
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<td>Niger</td>
<td>Suriname</td>
<td>Guadeloupe*</td>
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<tr>
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<td>Nigeria</td>
<td>Tajikistan</td>
<td>Iran*</td>
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<td>Kenya</td>
<td>North Macedonia</td>
<td>Tanzania</td>
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<td>Dominica</td>
<td>Kiribati***</td>
<td>Pakistan</td>
<td>Thailand</td>
<td>Libya*</td>
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<td>Barbados</td>
<td>Dominican Republic</td>
<td>Kosovo**</td>
<td>Palau***</td>
<td>Timor-Leste</td>
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<td>Togo</td>
<td>Mayotte*</td>
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<td>El Salvador</td>
<td>Latvia</td>
<td>Paraguay</td>
<td>Trinidad and Tobago Montserrat*</td>
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<td>Cape Verde***</td>
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<td>Mauritius</td>
<td>Seychelles</td>
<td>West Bank and Gaza***</td>
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<td>South Africa</td>
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</table>
Appendix B

MDBs’ climate finance commitments allocation among 136 countries

This figure includes the climate finance commitments from the six MDBs during 2015-2018 to 136 countries. Numbers and the areas of boxes indicate the accumulated climate finance commitments (US$ million) provided by the six MDBs from 2015 to 2018.
Appendix C
Efficient frontier constituted by Kenya, Morocco, Nepal, Rwanda, Turkey and Vanuatu

Given the efficiency score is graded according to the relative ratio of climate finance (output of DEA) over the weighted sum of total CO₂ emissions and vulnerability index (two inputs in DEA), the efficiency frontier should be an envelopment surface in a three-dimensional space (the X-axis and Y-axis are CO₂ emissions and vulnerability index, and the Z-axis is climate finance). Here we show a reduced form of the efficient frontier. We divide climate finance by CO₂ emissions and vulnerability index respectively for each country and plot those values for 136 countries in this two-dimensional plane. With the same CO₂ emissions and vulnerability index level, the most efficient countries received the highest amount of climate finance from MDBs. The points of the six most efficient countries locate furthest from the origin and constitute the efficient frontier (the orange points and line). The other 130 countries are enveloped between the origin and the frontier—the closer to the origin, the lower the efficiency score.
Appendix D

Country frequency as per efficiency score interval with carbon intensity

Among our 136 sample countries, the GDP data on Somalia and Eritrea is not available. Therefore, we cannot obtain the carbon intensity for them. We categorize the remaining 134 countries in four groups according to their carbon intensity and vulnerability: (1) countries with high carbon intensity and high vulnerability (HiHiV); (2) countries with high carbon intensity and low vulnerability (HiLlV); (3) countries with low carbon intensity and high vulnerability (LlHiV); (4) countries with low carbon intensity and low vulnerability (LlLlV). We use the median of carbon intensity (0.357 tons/thousand US$) and vulnerability index (0.453) to classify high/low carbon intensity and high/low vulnerability. Each country is assigned 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, 1], and then categorize countries according to their efficiency scores. The table shows that more than 76% of countries cluster in the lowest efficiency score interval.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Efficiency score</th>
<th>Total (number of countries)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[0, 0.2]</td>
<td>(0.2, 0.4]</td>
</tr>
<tr>
<td>(1) HiHiV</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>(2) HiLlV</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>(3) LlHiV</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>(4) LlLlV</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>Total (number of countries)</td>
<td>102</td>
<td>20</td>
</tr>
<tr>
<td>% share of all countries</td>
<td>76.1%</td>
<td>14.9%</td>
</tr>
</tbody>
</table>
Appendix E
Efficient frontier of running DEA with sub-indices of the vulnerability index

As the vulnerability index consists of three components, namely 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. Here, we estimate the DEA models with those constituents and CO$_2$ emissions. The results are qualitatively similar to what we show for the aggregate vulnerability score and CO$_2$ emissions. The allocation of climate finance is uneven, no matter in relation to countries’ exposure index, sensitivity index or capability index. The majority of vulnerable countries received very limited support from MDBs, no matter their vulnerability originated from exposure, sensitivity or capability.

In panel A, we replace the vulnerability index with the exposure index and run DEA and give a reduced form of the efficient frontier. We divide climate finance by CO$_2$ emissions and exposure index respectively for each country and plot those countries in this two-dimensional plane. India, Kenya, Morocco, Nepal, Nauru, Rwanda, Turkey, Tuvalu are the most efficient countries in this model. In panel B, we replace the vulnerability index with the sensitivity index and run DEA and give a reduced form of the efficient frontier. We divide climate finance by CO$_2$ emissions and sensitivity index respectively for each country and plot those countries in this two-dimensional plane. India, Kenya, Morocco, Nepal, Rwanda, Turkey, and Vanuatu are the most efficient countries in this model. In panel C, we replace the vulnerability index with the capability index and run DEA and give a reduced form of the efficient frontier. We divide climate finance by CO$_2$ emissions and capability index respectively for each country and plot those countries in this two-dimensional plane. Kenya, Morocco, Nepal, Rwanda, Turkey, and Vanuatu are the most efficient countries in this model.
Panel C
We assume that MDBs' collective climate finance will grow at a constant rate of 2.1% and reach US$ 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 US$ 59.5 billion and US$ 25.5 billion in 2050 under the basic scenario. Panel B and C shows that both mitigation finance and adaptation finance will reach US$ 42.5 billion in 2050, given the equal distribution of climate finance. Under the transition scenario, mitigation finance’s average annual growth rate from 2019 to 2050 will be 1.1%, and that of adaptation finance will be 3.8%. Under ambitious scenario 1, the average annual growth rate of adaptation finance will be 5.3%.

Under ambitious scenario 2, 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. In comparison, mitigation finance will grow at only 0.1% annually from 2018 to 2035 to reach the equal distribution of climate finance.