Investing in Green Futures: Climate Finance Effects on Environmental Performance in Developing Countries

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Abstract

This paper analyses the relationship between climate-related official development assistance (ODA) and the environmental performance of developing countries. To do so, we use the least square dummy variable method on a panel of 104 developing countries spanning 2008-2021. The results indicate that climate finance positively improves environmental performance in recipient countries. Moreover, this effect of climate finance is significant only for climate issues but does not influence ecosystem vitality and environmental health issues. The study also identifies variations in the effects based on vulnerability, development level, and institutional quality of recipient countries. This research contributes to the limited literature on the subject, shedding light on the critical role of climate finance in fostering sustainable development. Additionally, it offers essential implications for policymakers to better direct climate finance funds.

Keywords: • Climate finance • Environmental performance • Developing countries

JEL Classification: F35; O13; O44; Q56

1 Introduction

In recent decades, global recognition of the urgency to address climate change has led to the creation of climate finance mechanisms like Official Development Assistance (ODA) and international climate funds. Developing countries, vulnerable to climate challenges, require substantial financial support. Accessing climate finance involves countries identifying funding, developing strategies, and proposing projects for review and approval, aiming to effectively address climate challenges. However, climate finance, while offering opportunities for sustainable development, also poses challenges in ensuring effective environmental performance in developing countries. The commitment of developed countries to provide financial resources is crucial, given the diverse socio-economic challenges faced by these nations alongside climate issues.

The current climate finance has reached an all-time high, albeit constituting only approximately 1% of the global GDP. At the 15th Conference of the Parties (COP15) to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in 2009, developed countries pledged to mobilise a total of $100 billion per year by 2020 to support climate-related initiatives in developing countries. However, this target, reaffirmed at COP21 in Paris, has not been met. According to OECD data, total climate finance provided and mobilised by developed countries for developing countries has continued to rise, reaching USD 89.6 billion in 2021, a substantial 7.6% growth from 2020. Although substantial, the amount falls significantly short of the 2009 commitment. Moreover, it relies on accounting practices that do not accurately reflect the actual level of support provided (Carty and Kowalzig, 2022). Oxfam estimates that in 2020, the actual value of financial support for climate action was only between 21 and 24.5 billion dollars, much less than suggested by official figures (Carty and Kowalzig, 2022). This aid is received by developing countries in the form of grants or debt with different goals. Out of all climate-related ODA initiatives during 2020-21, 42% were dedicated to adaptation, 33% to mitigation, and 24% pursued both objectives. For example, between 2009 and 2019, Sub-Saharan Africa (SSA) received $43 billion in grants and $29 billion in concessional debt (Belianska et al., 2022). Mitigation funding accounts for most climate finance, with projects focused on energy and transport. In contrast, adaptation funding supports activities in the water supply and sanitation sector, as well as agriculture, forestry, and fisheries.

In terms of environmental performance, developing countries are at the very bottom of the scale according to the Environmental Performance Index (EPI). Indeed, environmental performance varies widely and is influenced by a range of factors such as economic development, governance systems, technological capabilities, and resource availability (Acemoglu et al., 2012; Rai and Funkhouser, 2015; Usman et al., 2020; Dkhili, 2018). Especially in developing countries, several difficulties limiting the effectiveness of environmental policies need to be highlighted, notably limited resources for adaptation, threats such as habitat loss, illegal wildlife trade, and air and water pollution. Also, the particular context of developing countries facing financing constraints manifested through the narrowness of their budgetary space, thus underlining the crucial need for external financing to support the fight against climate change.

Despite the abundant literature on climate finance issues (Kouwenberg and Zheng, 2023; Wang et al., 2022; Lee et al., 2022; Banga, 2019) very few papers study the effects of climate finance on environmental performance. This issue is all the more important as developing countries (DCs) face financial challenges that restrict their limited fiscal space. Constraints such as fragile economies and high levels of debt mean that these countries have little room to manoeuvre when it comes to financing essential development projects. Therefore, the importance of external financing, such as foreign aid and investment, is crucial in helping DCs overcome their financial limitations and progress towards sustainable development. In this context, this study contributes to the existing literature by examining the impact of climate-related ODA on environmental performance in developing countries.

First, we use the newly published Environmental Performance Index (EPI) as an indicator to measure the performance of developing countries. First established in 2006 by researchers at Yale and Columbia Universities, the Environmental Performance Database assesses the effectiveness of environmental policies relating to climate change, ecosystem vitality, and environmental health. This synthetic index assesses how countries align with internationally established sustainability targets for specific environmental issues. It is constructed based on climate change, ecosystem vitality, and environmental health indicators. It is a multidimensional indicator that differs from conventional measures such as CO_2 emissions (Lee et al., 2022).

This approach is crucial as it provides a more holistic view of a country's environmental standing. The significance of our research lies in shedding light on whether climate finance effectively contributes to sustainability targets in developing nations. If successful, such financial support should lead to improvements across various environmental dimensions. Using a panel of 104 countries over the period 2008-2021, our findings suggest that climate-related ODA significantly improves environmental performance and that the effects are robust and economically significant. A one percent increase in total climate finance results in a 0.114 unit increase in environmental performance, which corresponds to an increase of around 0.3 percentage points. Furthermore, climate finance improves climate-related aspects of environmental performance and does not have a spillover effect on issues of ecosystem vitality and environmental health. These results will not only inform policymakers and international organizations about the effectiveness of climate finance but also offer insights into the areas where interventions can yield the most significant positive outcomes. Ultimately, the results of this study encourage political decision-makers not to reduce their spending in other areas of the environment (fungibility of climate finance).

Secondly, the impact of climate finance is influenced by diverse socio-economic and institutional factors in recipient countries. These contextual nuances shape the outcomes and effectiveness of climate finance initiatives. Addressing these heterogeneities is crucial for tailoring strategies that can navigate the challenges specific to each socio-economic and institutional context, optimizing the positive impact on environmental performance.

The rest of the paper is organized as follows. The next section discusses the research background. The methodology is described in Section 3. Sections 4 and 5 present the data and our main findings. Sections 6 and 7 underline robustness and heterogeneity analyses. The last section concludes.

2 Research background

Subsections 2.1 and 2.2 briefly discuss climate finance in developing countries and review the empirical literature on the potential effects, respectively.

2.1 Climate finance: Definition, allocation, and effectiveness

According to the United Nations Framework Convention on Climate Change (UNFCCC), “Climate finance refers to local, national, or transnational financing—drawn from public, private, and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change”. While this definition may appear widely accepted today, it hasn’t been the historical norm. In their study, Caruso and Ellis (2013) identified various definitions employed by 24 key actors in climate finance. They observed that the definitions utilized to quantify the level of private climate finance mobilized by these entities vary significantly, posing a considerable risk of potential double-counting.

Who raises and to whom are climate-related funds allocated? These two notions - the ’raising’ and ’allocation’- refer to climate justice. Grasso (2010) asserts that, in defining a procedural and distributively just approach to international adaptation funding, three assumptions should be considered: (1) *the processes of raising and allocating funds should ensure the fair involvement of all parties*;(2) *the raising of adaptation funds should be carried out according to the responsibility for climate impacts*; (3) *the allocation of funds raised should put the most vulnerable first.* It is within this framework that Khan et al. (2020) evaluate the first 25 years of adaptation funding under the UNFCCC, exploring whether there has been an improvement in the equitable governance and delivery of adaptation funds over this period. They conclude that for adaptation finance, much remains to be done in terms of justice. Still, there are several scientific articles on the determinants of climate finance in developing countries (Halimanjaya, 2015; Doku et al., 2021; Weiler and Klöck, 2021; Weiler et al., 2018; Islam, 2022); These studies argue that climate finance is attracted by political, economic, institutional, socio-demographic characteristics and the vulnerability level of the recipient country.

In the current global architecture of climate finance, several national and international parties are involved. Financial resources move through various channels, both within and beyond the UNFCCC Financial Mechanism, encompassing multilateral, bilateral, and regional initiatives like The Global Environment Facility(GEF), the Green Climate Fund (GCF), the Special Climate Change Fund (SCCF), the Least Developed Countries Fund (LDCF) or the Adaptation Fund (AF). Additionally, an increasing number of recipient nations are establishing domestic climate change funds. These funds gather contributions from multiple donor countries, aiming to synchronize and align donor interests with the recipient country's national priorities. There are also various financial instruments including green bonds, debt swaps, guarantees, concessional loans, and grants/donations. Grant finance dominates approvals from multilateral climate funds. In developing countries, particularly in Sub-Saharan Africa, governments remain the primary providers of financial resources. The contribution from banks and the private sector remains relatively low. This may be due to information asymmetry leading to credit rationing. Indeed, Reuters discovered substantial funds being directed towards projects such as a coal plant, a hotel, and chocolate shops in developing countries [1].

The effectiveness of climate finance can be defined as the extent to which an activity achieves its intended objectives. The ever-increasing level of climate finance flows is leading researchers and politicians alike to question its effectiveness (Chaum et al., 2011; Wagner et al., 2011). Analysing the effectiveness of climate finance requires a specific framework. Nakhooda et al. (2013) and Trujillo et al. (2013) have proposed an analysis of the effectiveness of multilateral climate funds, highlighting ten interconnected dimensions that play a central role in understanding the effectiveness of spending and the results that flow from it. For Ellis et al. (2013), diverse viewpoints exist regarding the definition of "effective" climate finance and the methodologies applied to evaluate its efficacy. In their publication, they seek to address the following inquiries: What constitutes the effectiveness of climate finance? At which stage is effectiveness evaluated? And how do the assessments of climate finance outcomes compare across the climate community, the development community, and the private sector?

According to Ellis et al. (2013), the first two questions will depend on the objective,

[1] https://www.reuters.com/investigates/special-report/climate-change-finance/

source, and channel used. For the last question, Ellis et al. (2013) agrees with Nakhooda et al. (2013) by highlighting points such as the funding context, the time horizon, and the scale that can influence effectiveness. The effectiveness of climate finance can be influenced by several variables. It is in this sense that Cichocka and Mitchel (2022) identifie some challenges to the effectiveness of climate finance. First, there is uncertainty about the extent to which finance reaches its intended beneficiaries when low disbursement rates are observed. Secondly, the use of debt instruments, including concessional and non-concessional loans, can create debt sustainability problems for recipient countries. But for lower-income countries, loans are the mean instrument due to the high risk of debt distress. Thirdly, the increase in the number of providers and the decrease in the size of projects has led to a proliferation of sources of climate finance and a reduction in the scale of individual projects. Fourth, the data used by the author shows that an increasing proportion of climate change mitigation funding remains unallocated, due to a lack of beneficiaries or specific projects to support, and that institutions in beneficiary countries are not integrated into the fund implementation process. Finally, the authors confirm the existence of a significant "evaluation deficit" when it comes to assessing climate interventions. Bird et al. (2013) propose a method for evaluating the effectiveness of national systems involved in providing climate finance. This method includes the policy environment that facilitates climate change spending, the institutional architecture that determines roles and responsibilities, and the public financial system that manages climate change spending.

2.2 The effect of climate finance

In this subsection 2.2, we review the climate finance effects on renewable energy and carbon emissions in developing countries.

2.2.1 On renewable energy

The objective of climate finance is to support developing countries in their transition to a low-carbon economy (Pickering et al., 2017; Lohani et al., 2016; Iacobuţă et al., 2021). Even though the amounts invested are still low compared with the needs, climate finance remains a reliable tool for developing countries (Lohani et al., 2016). In the context of international environmental agreements, Iacobuţă et al. (2022) show how climate finance can be an important element in achieving the commitments made by countries. Romano et al. (2018) show how climate finance can significantly contribute to green growth in developing countries. Most studies on climate finance address the question of the use of renewable energies, and they do not directly talk about environmental performance. However, a direct link can be made between the use of renewable energy and environmental performance (Iqbal et al., 2021). Lee et al. (2023), analyzing provincial data from 2001 to 2019 in China with a focus on the effects of green finance find that green finance has a direct positive impact on promoting renewable energy, and it also indirectly drives research and development efforts, enhances market openness, and contributes to overall economic growth. They argue also that a robust economy and strong government support are crucial factors for maximizing the effectiveness of green finance in promoting renewable energy. Carfora and Scandurra (2019) use the propensity score matching to evaluate the effectiveness of the introduction of policies implementing the use of climate funds in developing countries. Their results show that the policy measures implementing the use of climate funds have contributed to a reduction in greenhouse gas (GHG) emissions and have facilitated the transition in energy generation systems by supporting the shift from fossil fuels to renewable energy sources. Focusing on the countries of the Congo Basin, Aquilas and Atemnkeng (2022) present, using a panel over the period 2002-2020, an analysis of the effects on GHG emissions of climate-related development mitigation financing and renewable energy consumption. Their findings, in line with those of Mahalik et al. (2021), Kang and Jung (2016), Li et al. (2021), indicate that as climate-related financing increases, there is a corresponding surge in the consumption of non-renewable energy sources. This trend is linked to the fact that countries in the Congo Basin have yet to reach their peak in terms of pollution caused by the utilization of these non-renewable energy sources. Consequently, this delay in reaching the pollution peak may diminish the motivation to prioritize investments in climate-resilient development initiatives. However, the interaction between climate finance and renewable energy consumption decreases the amount of GHG emissions.

2.2.2 On carbon dioxide emission

Research on the impact of climate finance in developing countries is few and provides mixed insights into its effects on environmental performance. Lee et al. (2022) assess the effectiveness of multilateral climate finance flow in reducing GHG emissions in developing countries. Using the OECD database on climate-related ODA, they find that climate finance plays a role in reducing carbon emissions, with the impact of mitigation finance appearing to be more significant than that of adaptation finance. Additionally, the reduction of GHG emissions due to climate finance is particularly noteworthy in small island developing states and countries with higher levels of economic development. Using the quantile regression method, Carfora et al. (2017) analyse the relationship between the funds destined for "energy generation and supply" and "general environmental protection" and GHG emission. The results of their study conclude that climate financing positively affects GHG emissions but with a strong heterogeneity in the disbursement of funds between countries. With a two-stage generalized method of moments (GMM) to explore the link between green ODA, institutions, and carbon emissions, Li et al. (2021) find that green ODA does not affect carbon emissions in recipient countries. However, it becomes effective when it is directed to countries with greater economic freedom and lower levels of corruption. This result takes us back to the work of Collier and Dollar (2004), Chauvet and Collier (2004), Jacquet 2 (2006) on the effectiveness of ODA. Han and Jun (2023) employ mitigation aid as a proxy to evaluate the impact of international support on reducing CO2 emissions in developing countries. Their findings indicate that mitigation aid does not reduce CO2 emissions across the entire sample, with variations observed based on income levels. Notably, a beneficial effect is evident in low-income countries, while a detrimental impact is observed in lower-middle-income countries. Furthermore, distinct regional patterns emerge, with the East Asia and Pacific (EAP) and Europe and Central Asia (ECA) showing a diminishing significance, while the Middle East and North Africa (MENA) exhibit positive effects.

Due to these nuanced results, there is a need for research to better understand the effectiveness of international support for climate action. This analysis should consider climate finance in line with its specific objectives, such as mitigation and adaptation, while also incorporating a more comprehensive measure of environmental performance.

2.3 Research question

According to the literature review presented above, the impact of climate finance on environmental outcomes in developing countries is not clear. On the one hand, climate finance may lead to increased utilization of non-renewable energy sources when countries have not reached their pollution peak. That potentially undermines environmental sustainability. On the other hand, climate finance has the potential to foster the adoption of renewable energy technologies and other sustainable practices, thereby positively impacting environmental performance.

This article aims to contribute to this debate and analyze the efficiency of climate finance in developing countries. The results will inform policymakers, practitioners, and donors on how to optimize the allocation of resources to meet the challenge of combating climate change in these countries.

3 Methodology

The objective of this study is to examine whether climate finance influences the environmental performance of recipient countries. To do so, we employ a dynamic specification enriched by the incorporation of the lag of the dependent variable, a strategic choice stemming from the recognized inertia effect of the Environmental Performance Index (EPI) (see 3). The forthcoming section will discuss the choice of estimator, considering the intricacies introduced by both lag effects and potential biases inherent in our modeling decisions.

3.1 Model specification

To build a good model, we have to identify the factors that affect the environmental performance index of a country. Following Wolf et al. (2022) and the existing literature on environmental performance, we specify our model as follows:

$$EPI_{i,t} = \alpha + EPI_{i,t-1} + \beta CF_{i,t-k} + \eta X_{i,t} + \upsilon_i + \delta_t + \epsilon_{i,t} \tag{1}$$

here, i = 1, . . . , N denotes the recipient countries, while t = 1, . . . , T represents the time period. In equation 1, EPI_{it} serves as our dependent variable, representing the environmental performance score of country i in year t. $EPI_{i,t-1}$ is a one-year lag of the EPI. $CF_{i,t-k}$ measures the total amount of climate-related funds allocated to country i in year t-k with k={0,1}. In the context of climate finance, we employ three categories of climate funds—specifically, total climate, climate mitigation, and climate adaptation funds. To address a potential endogeneity issue and recognize the time lag between interventions and their impacts, we introduce a lag to our variable of interest (Ellis et al., 2013; Aquilas and Atemnkeng, 2022; Lee et al., 2022). α is a constant, and $X_{i,t}$ represents a set of control variables related to economic (GDP per capita, trade, FDI, manufacturing, natural resources) demographic (population), and institutional (corruption) factors that play a significant role in explaining environmental performance.

The use of *GDP per capita* as a control variable is justified by the environmental Kuznets curve (EKC). The EKC is a hypothesis that various indicators of environmental degradation first increase and then decrease as gross domestic product (GDP) per capita increases (Stern, 2018). The impact of *international trade* on the environment is a complex question addressed in the literature, where three major effects have been identified: the size effect, the technological effect, and the composition effect (Copeland and Taylor, 2004). These effects are likely to vary across countries (Le et al., 2016; Managi et al., 2009). Following Demena and Afesorgbor (2020), *FDI* is introduced as a control variable to take into account the technology spillovers from other sources of investment (Lee et al., 2022) and the pollution haven hypothesis (Su et al., 2022; Zhang et al., 2021). We account for *industry value added*, considering that industrialization typically leads to increased carbon emissions (Li and Lin, 2015). The use of *natural resources* can have dual impacts on the environment. While sustainable practices can support ecosystem health and biodiversity, the improper utilization of resources, often linked to the resource curse hypothesis, can lead to environmental harm (Li et al., 2020; Shittu et al., 2021). Countries with abundant natural resources may face challenges due to inefficient use and mismanagement, particularly influenced by governance issues (Niknamian, 2019). The potential effect of *population* size on the environment is well-studied in the literature. Alam et al. (2016) and Cropper and Griffiths (1994) show that a larger population can be harmful to the environment through greater economic activity and accelerated urbanisation. About the role of *institutional quality*, several models and empirical results corroborate the fact that the level of corruption can affect both the formulation and the effectiveness of strict environmental policies (Damania et al., 2003; Pellegrini and Pellegrini, 2011; Wilson and Damania, 2005).

The unobserved characteristics of countries are captured by υ_i and a time-fixed effect (δ_t) to account for unobserved time-specific factors that may affect the dependent variable. $\epsilon_{i,t}$ denotes the idiosyncratic errors.

3.2 Estimation method

The dynamic panel data model resolves the challenge of simultaneously incorporating dynamics and unobserved individual heterogeneity in the phenomena under consideration. Estimating equation 1 using common econometric techniques such as Fixed-Effect (FE) creates endogeneity problems due to a negative correlation between the lagged dependent variable and the error term. This negative correlation of the fixed effects estimator is known as Nickell's bias (Nickell, 1981). Due to this situation, a range of new estimators notably the Instrumental Variable and Generalized Method of Moments Estimators methods (Anderson and Hsiao, 1982, Arellano and Bond, 1991, Blundell and Bond, 1998) have been proposed in the econometric literature. However, these methods can show significant bias and imprecision in panel data with a limited number of cross-sectional units, whether the samples have finite time and cross-sections or long time and finite cross-sections, as underlined by Bruno (2005a).

Based on the earlier points, a recent trend in econometric literature highlights an alternative approach gaining popularity. This approach focuses on the bias correction of least-squares dummy variable (LSDV) in unbalanced dynamic panel-data models. This method calculates bias-corrected LSDV estimators for the standard autoregressive panel data model, employing bias approximations as outlined in Bruno (2005a). Indeed, the work of Bruno (2005a) follows that of Bun and Kiviet (2003), Kiviet (1995), and Kiviet (1998) to obtain approximations of bias of the LSDV estimator. In practice, that correction is done in two steps (Bruno, 2005b). The first step is to approximate the bias and in the second step the bias-corrected LSDV estimators could be obtained by subtracting the approximate bias from LSDV. There are three different biases presented in the literature:

$B_1 = c_1(\overline{T}^{-1})$

$B_2 = B_1 + c_2(N^{-1}\overline{T}^{-1})$

$B_3 = B_2 + c_3(N^{-1}\overline{T}^{-2})$

with N the number of study units and $\overline{T} = \frac{1}{N}\sum_1^N T$.

The bias B_1 is less complex, so less stringent than the bias B_3, which is the most complex. For the first step, the Anderson and Hsiao (1982) estimator, Arellano and Bond (1991) difference estimator, or Blundell and Bond (1998) system estimator can be applied to approximate the bias. In our main regressions, we use the Blundell-Bond estimator to estimate the bias B_3 (Bruno, 2005b). The other estimators and biases are used for robustness. Let's note that the Nickell bias-corrected least squares method employs GMM estimators to estimate Nickell's bias.

4 Data

Subsection 4.1 describes the main variables used in the study. Then, subsection 4.2 provides some descriptive statistics.

4.1 Variables description

This study focuses on a set of 104 developing countries over the period 2008-2021. The choice of this study period is motivated by the emergence of the question of financing climate action in developing countries starting from the Kyoto Protocol and COP15 (Copenhagen). These events were crucial as they facilitated the establishment of financing mechanisms to support climate initiatives in these countries. Starting in 2008, the flow of climate finance to developing countries became significant in terms of volume. Our explained variable is the environmental performance index (EPI). As explained by Wolf et al. (2022), the EPI is a composite index derived from 40 performance indicators distributed across 11 categories and aligned with 3 environmental policy objectives. It gauges a country's advancements in enhancing environmental health, addressing climate change, and safeguarding ecosystem vitality (refer to figure 1). The index assigns weights to various components, producing an EPI ranging from 0 (the worst environmental performance score) to 100 (the best environmental performance score).

For the core explanatory variable, we use the logarithm of the climate-related ODA. The data is compiled by the OECD Development Assistance Committee (DAC), which aggregates statistics on ODA and other various sources, such as non-ODA bilateral flows, multilateral development finance, philanthropic support, and private finance. This database contains information on mitigation and adaptation finance and captures both bilateral and multilateral climate finance flows (Guillaume et al., 2018). Data collection on climate finance was based on the objectives of the Rio Earth Summit Conventions in 1992 (biodiversity, climate change, and desertification). As explained by Donner et al. (2016), the tracking of these financial flows was done thanks to the "Rio markers". The statistical framework of the Development Assistance Committee (DAC) offers the opportunity to examine development finance flows from two distinct viewpoints: the recipient and the provider perspective. For our study, we will use data from the recipient perspective, as it encompasses development finance directed towards developing nations from both bilateral and multilateral sources. This dataset incorporates bilateral activities aimed at climate change objectives, identified through the Rio markers, as well as climate-related multilateral activities (outflows) sourced from multilateral providers engaged in the climate domain, identified through the Rio markers or Climate Components methodologies (i.e., identifying climate components within projects). The "Rio markers" were set up to track aid flows that support the implementation of the Convention. Climate finance from a variety of sources is tracked by similar methodologies used by multilateral development banks. Although the approaches vary, the definitions of climate change mitigation and adaptation remain linked (OECD, 2022). To mobilise $100 billion, climate finance figures are based on data reported directly to the UNFCCC, different from the bilateral data in the Rio markers. Between 2000 and 2010, the data collected concerned only mitigation. It was in December 2009 that the DAC approved a new marker designed also to track aid intended to support adaptation to climate change.

The control variables introduced into our basic model measure the socio-economic

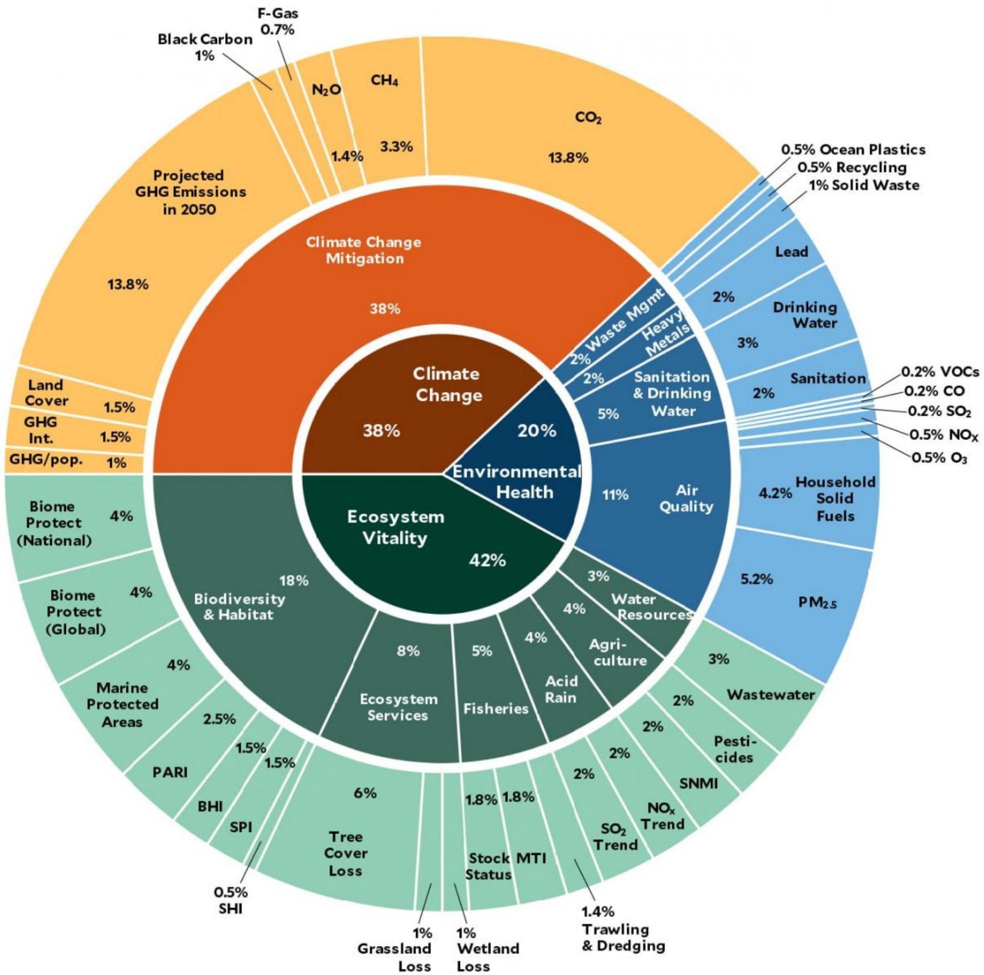


Figure 1: EPI framework from (Wolf et al., 2022)

Notes: The 2022 EPI framework. 40 performance indicators fall into 11 issue categories, which are aggregated into three policy objectives. Weights show the percentage of the total EPI score. (Wolf et al., 2022)

Table 1: Descriptive statistics of the main variables

Variable	Obs	Mean	Std. dev.	Min	Max
Environmental Performance	1,441	33.174	7.723	11.898	55.791
Climate Finance	1,441	375793.1	785630.2	17.13205	1.10E+07
Mitigation Fund	1,441	253989.4	586356.8	0	8014522
Adaptation Fund	1,441	154467	298281	0	3341044
Manufacturing	1,360	27.782	11.175	2.759	78.064
Trade	1,290	71.314	30.466	4.127	186.468
Population	1,415	5.74E+07	1.89E+08	17794	1.41E+09
GDP per capita	1,362	3669.004	3392.273	263.361	17437.86
Foreign Direct Investment	1,241	4.062	5.141	-37.173	43.912
Natural Resources	1,367	8.128	9.493	0	56.966
Corruption	1,144	-0.547	0.604	-1.815	1.648

Notes: The amount of climate finance are in USD thousand

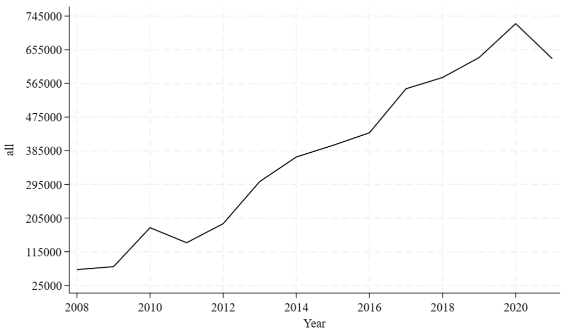
and institutional conditions of the countries receiving the climate funds. These variables can influence the countries' environmental performance, as explained in section 3.1.

4.2 Descriptive statistics

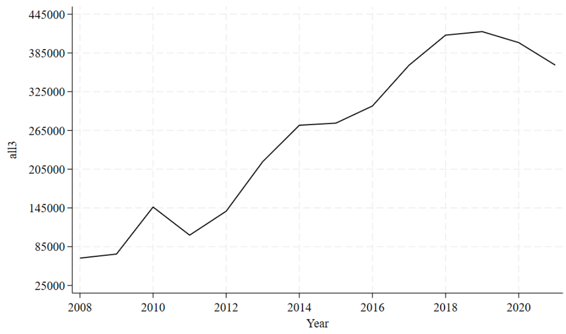
Figure 2 displays the average evolution of total climate finance in the countries in our sample, over the period 2008-2021. As highlighted in section 4.1, data collection before 2010 was not accurate due to the lack of a well-defined framework defining and tracking climate finance funds. As you can see on graph 2a of figure 2, the amount of total climate finance increases constantly and rapidly. Within our sample, the average total amount of climate finance is $ 375,793,100 with a high standard deviation, suggesting a reasonable dispersion around the sample mean. Regarding the EPI, we report an average value of 33,17 and a standard deviation of about 7,7.

Over the entire 2008-2021 period, there has been a steady but fairly small increase in the level of environmental performance in the countries in our sample. The level of environmental performance rose from 31.91 in 2008 to 34.63 in 2021, corresponding to an average annual increase of around 0.58% (refer to Figure 3).

We can note that climate finance funds and the environmental performance index have a similar evolution. Nonetheless, these observed patterns offer correlation but cannot establish a causal relationship. They do not enable an assessment of the extent to



(a) Total Finance climatique



(b) Mitigation

(c) Adaptation

Figure 2: Climate finance Evolution (2020 USD thousand)

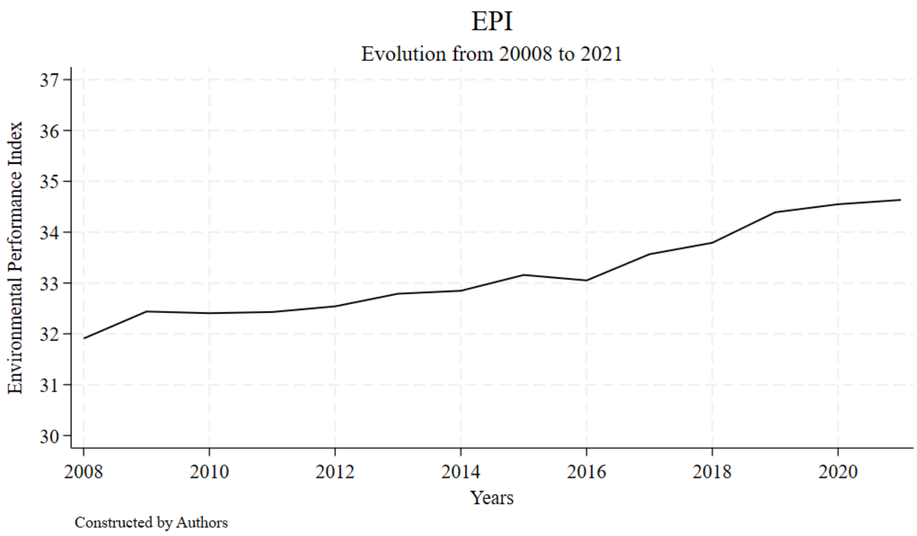


Figure 3: EPI Evolution over the period 2008-2021

which climate finance influences the environmental performance of the recipient country. Therefore, the remainder of the study employs an econometric approach to identify a causal relationship.

5 Main results

In this section, we present the results of our different models. From columns (1) to (3) of table 2, we regress the log of the total of climate finance, mitigation, and adaptation funds on the environmental performance index without any lags. The results show that the total of climate finance, mitigation, and adaptation funds positively contribute to the improvement of the environmental performance of the recipient country. In value terms, a one percent increase in total climate finance results in a 0.114 unit increase in environmental performance, all else being equal. Within our sample, the average environmental performance score stands at 33.17 (see table 1). Consequently, we proceed to quantify the economic implications of our findings. With an average environmental performance of 33.17, a country would experience an approximate 0.35 point increase in environmental performance for each 1% rise in climate finance flow. As a result, we can reasonably deduce that the effects observed hold substantial statistical and economic significance.

To address a potential endogeneity issue and recognize the time lag between interventions and their impacts, we run the same regression using the lag of Total Climate Funds. The results are presented in table 2. We notice that the coefficients of the total climate finance and mitigation funds are still positive and significant, but not climate adaptation funds. This means that there is a time lag in the effect of mitigation funds. The results remain similar, with a lag of 2 and 3 years. While mitigation and adaptation both play crucial roles in addressing climate change, they exhibit distinct characteristics in their impact on environmental performance. The positive and significant coefficients for total climate finance and mitigation funds in the lagged regression suggest a temporal delay in the effectiveness of mitigation efforts. This delay can be attributed to the nature of mitigation projects. This observed pattern may be attributed to several potential mechanisms and transmission channels. Firstly, climate finance towards mitigation often involves investments in cutting-edge technologies and sustainable infrastructure, directly contributing to reduced emissions and environmental harm. Mitigation projects,

Table 2: Effects of climate finance on EPI

Dependent variable	no lag			one year lag		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.959***	0.963***	0.942***	0.956***	0.954***	0.953***
	(0.019)	(0.018)	(0.021)	(0.018)	(0.019)	(0.020)
Total Climate Finance	0.114**			0.035		
	(0.050)			(0.037)		
Climate Mitigation Funds		0.146***			0.086***	
		(0.039)			(0.030)	
Climate Adaptation Funds			0.077*			-0.004
			(0.042)			(0.044)
Manufacturing	0.022	0.018	0.022	0.023	0.017	0.027
	(0.016)	(0.020)	(0.020)	(0.017)	(0.016)	(0.023)
Trade	-0.021***	-0.021***	-0.018***	-0.022***	-0.021***	-0.019***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)
Population	-1.673	-1.381	0.868	-1.620	-1.475	3.226**
	(1.130)	(1.291)	(1.436)	(1.139)	(1.140)	(1.494)
GDP per capita	0.336	0.203	0.089	0.247	0.161	0.439
	(0.593)	(0.637)	(0.718)	(0.594)	(0.590)	(0.830)
Foreign Direct Investment	-0.014	-0.016	-0.014	-0.013	-0.014	-0.014
	(0.016)	(0.014)	(0.016)	(0.016)	(0.016)	(0.014)
Natural Resources	0.011	0.011	-0.009	0.009	0.011	-0.002
	(0.017)	(0.019)	(0.017)	(0.017)	(0.017)	(0.020)
Corruption	-0.828***	-0.869**	-0.914**	-0.807**	-0.845***	-1.254***
	(0.321)	(0.353)	(0.381)	(0.320)	(0.321)	(0.354)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

such as those focused on renewable energy or afforestation, may yield immediate and tangible benefits, enhancing overall environmental performance. The coefficient associated with our climate adaptation funds variable is no longer significant. In other words, within our sample, the allocation of climate adaptation funds is associated with observable changes in the environmental performance index during the same year. Adaptation projects supported by climate finance often focus on building climate-resilient infrastructure, implementing sustainable agricultural practices, and enhancing water resource management, among other measures. These initiatives contribute to the overall environmental performance by fostering ecosystems that can withstand climate-related stresses and ensuring the sustainable use of natural resources.

6 Robustness

This section focuses on the robustness of our results. Initially, we employ the Arellano-Bond estimators for bias estimation, substituting the Blundell-Bond estimator. Subsequently, we explore alternative, less stringent bias corrections. Finally, we introduce an alternative estimator, namely the GMM method.

6.1 The Arellano-Bond estimator and bias types

The command developed by Bruno (2005b) enables the use of multiple estimators for estimating Nickell's bias in correcting the Ordinary Least Square estimator. In our primary model, the Blundell-Bond estimator is employed, and for robustness, the Arellano-Bond estimator is used, as shown in panel A of table 3. These results uphold our findings.

We further assess the robustness by employing different levels of bias for estimating our results. As outlined earlier, Nickell's bias can be corrected using three potential bias estimates. The most restrictive one is applied in our primary model, while panels B and C of table 3 present results for the other two bias estimates. Once again, our results are affirmed, with coefficients largely consistent with those in our primary findings.

6.2 Generalized Method of Moments (GMM)

In this section, we re-evaluate our primary model using the GMM. GMM is frequently employed for estimating dynamic models as it addresses the issue of endogeneity, particularly stemming from the presence of lagged explained variables. The results of this alternative method, presented in panel D of table 4, once again confirm the robustness of our findings.

7 Heterogeneity

In this section, we delve into the analysis of result heterogeneity. Initially, we will shed light on additional aspects of environmental performance, including environmental

Table 3: Robustness: Alternative estimation method

Panel A: AB estimator	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.921***	0.927***	0.899***	0.920***	0.922***	0.906***
	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)	(0.025)
Total Climate Finance	0.102**			0.031		
	(0.050)			(0.037)		
Climate Mitigation Funds		0.137***			0.081***	
		(0.038)			(0.030)	
Climate Adaptation Funds			0.084**			0.007
			(0.040)			(0.043)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Biais type 1	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.958***	0.962***	0.940***	0.954***	0.953***	0.952***
	(0.019)	(0.018)	(0.021)	(0.019)	(0.020)	(0.020)
Total Climate Finance	0.113**			0.035		
	(0.050)			(0.037)		
Climate Mitigation Funds		0.146***			0.086***	
		(0.039)			(0.030)	
Climate Adaptation Funds			0.077*			-0.004
			(0.042)			(0.044)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: Biais type 2	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.956***	0.960***	0.938***	0.952***	0.951***	0.949***
	(0.019)	(0.018)	(0.020)	(0.019)	(0.019)	(0.020)
Total Climate Finance	0.113**			0.035		
	(0.050)			(0.037)		
Climate Mitigation Funds		0.146***			0.086***	
		(0.039)			(0.030)	
Climate Adaptation Funds			0.077*			-0.003
			(0.042)			(0.044)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

health, ecosystem vitality, and climate change (see 7.1). Subsections 7.2, 7.3, and 7.4 will explore vulnerability, institutional quality, and development level, respectively.

7.1 Different type of EPI

In this section, we perform a decomposition based on constructing the environmental performance index. The interest of this decomposition is to be able to examine the impact of climate finance on diverse dimensions of environmental performance. Indeed, as

Table 4: Robustness using GMM

Dependent variable	no lag			one year lag		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.946***	1.119***	1.244***	0.982***	1.103***	1.061***
	(0.308)	(0.357)	(0.096)	(0.323)	(0.241)	(0.156)
Total Climate Finance	0.561			-0.783		
	(0.529)			(0.575)		
Climate Mitigation Funds		1.678**			1.174*	
		(0.725)			(0.653)	
Climate Adaptation Funds			0.096			-0.215
			(0.283)			(0.346)
Observations	1104	1102	880	1104	1102	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
AR(1)	0.002	0.009	0.016	0.016	0.012	0.026
AR(2)	0.118	0.463	0.260	0.638	0.202	0.930
Hansen Test	0.257	0.711	0.068	0.527	0.311	0.117

Notes: Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

Lee et al. (2022) mentioned, environmental sustainability is a multifaceted concept that encompasses various aspects, including human health, ecosystem vitality, and resource efficiency. The Environmental Performance Index includes three indicators: the climate, the vitality of the ecosystem, and the environmental health.

The results of these regressions are presented in panels A, B, and C of the table 5. We can see that the Total Climate finance flow and climate mitigation flows improve only the climate composition of EPI. Ecosystem vitality and environmental health are found to be not influenced by climate finance. These results confirm the ability of climate finance to improve domestic climate-related environmental policy in recipient countries, without having spillover effects on other areas of environmental protection. This is in line with Mahalik et al. (2021) in the case of India.

These results emphasize the effectiveness of climate finance in developing and improving domestic environmental policies, with a particular focus on climate-related aspects in beneficiary countries. This effectiveness implies a deliberate and successful intervention, showing climate finance as a potent catalyst for positive change in the domain of climate-centric environmental protection. The targeted improvements observed in climate-related policies indicate a strategic alignment of climate finance with the priorities and needs of recipient nations in addressing climate challenges (Iacobuţă et al., 2022).

Conversely, the lack of observable impact on dimensions such as ecosystem vitality and environmental health raises questions about the broader impact and reach of climate finance in the realm of environmental protection. This suggests that while climate finance excels in addressing climate-related policy gaps, its influence may be more limited when it comes to broader environmental indicators. Remember that the climate finance data we have is based on the Rio Markers, which are biodiversity, climate change, and desertification. As Iacobuţă et al. (2022) mention, on the role of finance climate in implementing the Paris Agreement, SDG7 (energy) and SDG11 (cities) are highly supported, indicating a strong commitment and investment in achieving their respective sustainable development goals. It should be noted that the flow of climate finance depending on the sector remains uneven. According to the 2023 report from the Climate Policy Initiative (CPI) [2], the majority of funding for mitigation is directed towards the energy and transport sectors, with 44% allocated to energy and 29% to transport, highlighting the dominant role of private finance in these crucial domains. This choice can be explained by insufficient financial resources. These outcomes encourage political decision-makers not to reduce their spending in other areas of the environment (fungibility of climate finance). Indeed, the availability of these funds can indirectly support broader environmental initiatives by alleviating budgetary pressures and enabling governments to sustain or enhance investments in other environmental priorities. As a result, decision-makers may opt to maintain funding levels in areas such as biodiversity conservation, ecosystem restoration, and pollution control.

7.2 Vulnerability level

In this section, we consider each country's vulnerability level using the ND-GAIN (Notre Dame Global Adaptation Index) indicator. Going from 0 (most vulnerable) to 100 (less vulnerable), this indicator measures a country's current vulnerability to climate disruptions and its readiness to take adaptation actions. Vulnerability is segmented into exposure, sensitivity, and adaptive capacity, whereas readiness encompasses economic,

[2] https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2023/

Table 5: EPI decomposition

Panel A: EPI Climate	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI_climate	0.952***	0.958***	0.928***	0.949***	0.950***	0.929***
	(0.019)	(0.020)	(0.024)	(0.019)	(0.019)	(0.024)
Total Climate Finance	0.219**			0.064		
	(0.105)			(0.078)		
Climate Mitigation Funds		0.282***			0.179***	
		(0.082)			(0.065)	
Climate Adaptation Funds			0.199**			0.022
			(0.088)			(0.091)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: EPI Eco Vitality	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI_eco_vit	0.959***	0.995***	0.963***	0.991***	0.992***	1.009***
	(0.020)	(0.023)	(0.016)	(0.024)	(0.024)	(0.020)
Total Climate Finance	0.072			0.046		
	(0.054)			(0.063)		
Climate Mitigation Funds		0.094*			0.057	
		(0.056)			(0.046)	
Climate Adaptation Funds			0.006			-0.025
			(0.048)			(0.050)
Observations	1030	800	880	801	799	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: EPI Environmental health	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI_env_health	0.955***	0.955***	0.929***	0.956***	0.956***	0.893***
	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.014)
Total Climate Finance	-0.003			0.004		
	(0.011)			(0.008)		
Climate Mitigation Funds		0.002			0.005	
		(0.009)			(0.007)	
Climate Adaptation Funds			-0.001			-0.001
			(0.010)			(0.011)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

governance, and social aspects. Indeed, all countries are facing the effects of climate change. However, some countries are more vulnerable than others because of their geographical position or socio-economic conditions. There is a large literature on how a country's vulnerability can affect ODA (Guillaumont and Wagner, 2012; Guillaumont and Chauvet, 2019; Chauvet and Guillaumont, 2004). This literature compares two opposite visions: aids are effective only if domestic policies are appropriate, and aid effectiveness depends on the external and climatic environment. Most of the studies on this question endorsed the last vision. In the case of climate finance, Islam (2022) addressed the issue of distributive justice in global climate finance. Scandurra et al. (2020) and Lee et al. (2022) argue that climate finance enables a reduction of the country's vulnerability.

In our case, we divide our sample into 3 different vulnerability levels (low, medium, and high). We decided to use the splitting sample method because, in the case of the vulnerability level, the standard deviation is very important, and the results with a crossed variable are not significant.

Results are presented in table 6. In countries with lower vulnerability levels, where the capacity to adapt may be relatively higher, the positive and significant impact of climate finance on environmental performance is evident. This implies that targeted financial support and initiatives can effectively contribute to improved environmental outcomes in nations that are better equipped to address the challenges posed by climate change. Conversely, in countries characterized by higher vulnerability levels—indicating potentially lower adaptive capacity—the observed impact of climate finance on environmental performance becomes less prominent. This could suggest that, in highly vulnerable nations, the challenges posed by climate change may outweigh the mitigating effects of financial assistance, underlining the complexity and multi-faceted nature of the relationship between vulnerability, climate finance, and environmental outcomes.

This result highlights the importance of tailoring climate finance strategies to the specific needs and circumstances of countries based on their vulnerability levels. It also emphasizes the need for a comprehensive approach that considers not only financial assistance but also factors related to exposure, sensitivity, and adaptive capacity when addressing the environmental impacts of climate change.

7.3 Institutional quality

In this section, we try to capture a potential effect linked to institutional quality. The institutional quality may affect the effectiveness of climate-related ODA and environmental performance. Focusing on EU countries, Usman et al. (2020) examine the role of institutional quality on environmental performance. Applying a dynamic panel data

Table 6: Heterogeneity by Vulnerability level

Panel A: High Vulnerability	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.925***	0.928***	0.863***	0.920***	0.925***	0.928***
	(0.057)	(0.057)	(0.071)	(0.055)	(0.055)	(0.076)
Total Climate Finance	0.021			-0.080		
	(0.134)			(0.096)		
Climate Mitigation Funds		0.053			0.032	
		(0.093)			(0.066)	
Climate Adaptation Funds			0.055			-0.065
			(0.155)			(0.146)
Observations	225	225	188	225	225	168
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Medium Vulnerability	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.978***	0.980***	0.956***	0.978***	0.978***	0.968***
	(0.032)	(0.034)	(0.031)	(0.032)	(0.032)	(0.039)
Total Climate Finance	0.137			0.040		
	(0.085)			(0.071)		
Climate Mitigation Funds		0.143**			0.062	
		(0.058)			(0.058)	
Climate Adaptation Funds			0.095			-0.002
			(0.083)			(0.079)
Observations	490	488	412	490	488	372
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: Low Vulnerability	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.963***	0.978***	0.913***	0.960***	0.959***	1.023***
	(0.039)	(0.023)	(0.027)	(0.040)	(0.042)	(0.043)
Total Climate Finance	0.090			0.120		
	(0.085)			(0.085)		
Climate Mitigation Funds		0.125***			0.197**	
		(0.045)			(0.080)	
Climate Adaptation Funds			0.098*			-0.069
			(0.056)			(0.077)
Observations	315	713	600	315	315	261
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** p < 0.01, ** p < 0.05, and * p < 0.1

analysis spanning from 2002 to 2014, the findings indicate that improved institutional quality leads to enhanced environmental performance. Mavragani et al. (2016) confirm this result using a more large sample of 75 developed countries.

In our case, we cross our climate finance variable with the institutional quality variable. We measure the level of institutional quality using the World Bank's Worldwide Governance Indicators, control of corruption index. Results are presented in table 7 from column (1) to column (3). Results show that the crossed variable is positive and significant, meaning that the level of institutional quality influences the effect of climate

Table 7: Heterogeneity by Institutional quality

Dependent Variable	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.957***	0.961***	0.941***	0.951***	0.951***	0.952***
	(0.019)	(0.018)	(0.020)	(0.018)	(0.019)	(0.020)
Total Climate Finance	0.158***			0.109**		
	(0.057)			(0.046)		
Inst*TotalCF	0.074			0.121***		
	(0.048)			(0.042)		
Climate Mitigation Funds		0.197***			0.162***	
		(0.045)			(0.041)	
Inst*Mitigation		0.079			0.116***	
		(0.048)			(0.043)	
Climate Adaptation Funds			0.112**			0.028
			(0.045)			(0.054)
Inst*Adaptation			0.072			0.061
			(0.045)			(0.056)
Institutional quality	-1.694***	-1.733***	-1.662***	-2.201***	-2.119***	-1.879***
	(0.582)	(0.621)	(0.583)	(0.561)	(0.567)	(0.660)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

finance on environmental performance. Better institutions help have a better effect of climate finance on environmental performance.

Institutions with transparency, accountability, and effective governance structures are better equipped to utilize climate finance efficiently and allocate resources judiciously toward environmental initiatives. However, in environments characterized by hidden information and hidden actions within institutions, often associated with poorer institutional quality, the positive impact of climate finance on environmental performance is compromised. This result underscores the broader implications of institutional quality on the efficacy of climate finance interventions. It aligns with the economic theory of information asymmetry, where the presence of hidden information and actions can hinder the optimal utilization of resources, potentially impeding the desired positive outcomes of climate finance in countries with suboptimal institutional frameworks (Leitner and Wall, 2021).

7.4 Income groups

In this section, we use the World Bank's new countries' classification The World Bank has ranged countries according to different income groups in that classification. In our study, we have three different income groups: Lower income countries, Lower middle-income countries, and Upper middle-income countries. Results are presented in table 8. The total climate finance and climate mitigation funds are significant only for upper-middle countries. In less developed countries, the effect is non-significant. These results corroborate those of Lee et al. (2022). Indeed, in their article, Lee et al. (2022) made a heterogeneity according to the economic and financial development of the recipient country. They find that the more developed the recipient country, the more effective climate finance is. A possible explanation is that upper-middle-income countries may have more robust infrastructure and institutional capacity to effectively utilize and implement climate finance, leading to measurable impacts on environmental performance. In contrast, less developed countries might face challenges such as limited institutional capacity, governance issues, or barriers to project implementation, which could diminish the significance of climate finance in influencing environmental outcomes. Additionally, differences in the nature and scale of projects funded in these countries could contribute to the varying levels of significance.

7.5 Is the amount of climate finance matter ?

In this section, we examine the potential effect of the size of climate finance flows on the environmental performance of countries. To better understand this relationship, we introduce the square of our variable of interest, thus exploring possible non-linear effects. This approach allows us to identify thresholds or critical points where variations in climate finance flows could have disproportionate impacts on environmental performance. This term denotes a higher level of climate-related ODA.

The results of the regressions are presented in table 9. We observe a positive and significant effect of our squared climate finance variable. This suggests a non-linear relationship between the size of climate finance flows and environmental performance. These findings underscore the importance of considering non-linear relationships in the

Table 8: Heterogeneity by income group

Panel A: Low inc. countries	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.916***	0.925***	0.801***	0.870***	0.877***	0.885***
	(0.056)	(0.057)	(0.071)	(0.074)	(0.079)	(0.071)
Total Climate Finance	0.052			-0.009		
	(0.175)			(0.192)		
Climate Mitigation Funds		0.095			0.099	
		(0.090)			(0.099)	
Climate Adaptation Funds			0.096			0.063
			(0.195)			(0.179)
Observations	179	179	153	139	139	139
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Lower middle countries	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.957***	0.956***	0.933***	0.960***	0.957***	0.944***
	(0.028)	(0.028)	(0.033)	(0.029)	(0.029)	(0.038)
Total Climate Finance	0.028			-0.079		
	(0.070)			(0.061)		
Climate Mitigation Funds		0.056			-0.009	
		(0.061)			(0.050)	
Climate Adaptation Funds			-0.011			-0.075
			(0.078)			(0.070)
Observations	458	458	390	458	458	355
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Panel C: Upper middle countries	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.960***	0.970***	0.971***	0.959***	0.961***	0.961***
	(0.029)	(0.029)	(0.036)	(0.029)	(0.029)	(0.039)
Total Climate Finance	0.221***			0.180**		
	(0.074)			(0.076)		
Climate Mitigation Funds		0.281***			0.216***	
		(0.066)			(0.075)	
Climate Adaptation Funds			0.116*			0.042
			(0.069)			(0.067)
Observations	363	361	313	363	361	285
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

analysis of the impacts of climate finance.

8 Conclusion and Discussion

The objective of this paper is to study the effect of climate finance on environmental performance in developing countries over the period 2008-2021. The first contribution of our study is to be able to use a comprehensive measure of environmental performance.

Table 9: Quadratic effect of climate finance

	no lag			one year lag period		
	(1)	(2)	(3)	(4)	(5)	(6)
L.EPI	0.961***	0.964***	0.948***	0.956***	0.953***	0.957***
	(0.019)	(0.018)	(0.020)	(0.019)	(0.020)	(0.020)
Total Climate Finance	-0.220			-0.124		
	(0.214)			(0.141)		
Total CF square	0.018*			0.009		
	(0.010)			(0.007)		
Climate Mitigation Funds		-0.211			-0.141	
		(0.174)			(0.122)	
Climate MF square		0.020**			0.013**	
		(0.009)			(0.007)	
Climate Adaptation Funds			0.442**			0.443**
			(0.179)			(0.179)
Climate AF square			-0.020**			-0.025***
			(0.009)			(0.009)
Observations	1030	1028	880	1030	1028	801
Time and country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: All the controls of the baseline model as well as the constant are included, but not reported for the sake of space. Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.1$

We use the Environmental Performance Index which better captures all the dimensions of environmental performance. The selection of the EPI is crucial for this study as it allows for the consideration of environmental health, ecosystem vitality, and climate change. The 2nd contribution was to show the various heterogeneities that may exist, taking into account the objective of climate finance which is adaptation or mitigation, and the economic, institutional, and structural aspects of the countries receiving the flows of climate finance.

After regressing the total of climate finance on the environmental performance of recipient countries, the results, first, indicate that climate finance directed toward developing countries only affects the climate change aspect of environmental performance. These findings suggest that countries receiving financing in the fight against climate change engage in effective climate-related activities. However, our results should, on the one hand, reassure donors about the effectiveness of these funds in improving the climate environment and on the other hand, encourage them to mobilize more funds which can be used in other areas of environmental performance such as environmental health and ecosystem vitality.

Secondly, our results show that different mitigation and adaptation objectives enhance environmental performance. These observations also suggest an opportunity for institutions to realign their efforts, aiming for a balance between mitigation (emission reduction) and adaptation (adjustment to climate change), with the ideal goal of achieving a 50% balance for each aspect according to the Green Climate Fund (GCF). It is crucial to note that most developing countries face greater challenges in adapting to climate change, emphasizing the importance of strengthening initiatives to enhance their adaptive capacity. Our findings underline that the combined approach of mitigation and adaptation goals significantly contributes to improving overall environmental performance.

Thirdly, we demonstrate that better economic and institutional conditions enhance the performance of countries receiving climate finance. Indeed, when a country has sufficient economic resources and good governance, it can mobilize the necessary infrastructure and technologies to implement climate initiatives, ensuring transparent management and efficacy of funds. This does not imply excluding vulnerable countries but rather allocating a portion of the funds to strengthen their capacity to absorb these financial flows effectively, investing in training, governance, and regulatory frameworks. On the other hand, countries receiving assistance, by reducing their expenditures in the targeted sector, can reinvest these funds in other areas, thereby improving governance.

Finally, this study emphasizes the urgent need for addressing climate change through sustained and effective climate finance. Despite the challenges and disparities in funding, the commitment of developed countries remains crucial. This reaffirms the urgency of mobilizing resources to meet the financial commitments made at international forums like COP15 and COP21. Moreover, the results of our study demonstrate the positive impact of climate-related ODA on environmental performance in developing countries. Policymakers and international organizations should take note of these findings, as they provide valuable insights into the areas where interventions can yield the most significant positive outcomes. This study calls for continued and increased efforts to mobilize climate finance effectively, fostering genuine environmental progress in the developing world.

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Annexes

A Sources of variables

Variables	Definition	Sources
EPI	Environmental Performance Index (ranging from 0 to 100)	https://epi.yale.edu/epi-results/2022/component/epi
Climate finance	logarithm of climate-related ODA	OECD
Adaptation finance	logarithm of climate-related ODA for adaptation	OECD
Mitigation finance	logarithm of climate-related ODA for mitigation	OECD
Manufacturing	Manufacturing, value added (% of GDP)	World Development Indicators (WDI)
Trade	The sum of exports and imports of goods and services (%GDP)	World Development Indicators (WDI)
Population	Total Population	World Development Indicators (WDI)
GDP per capita	Gross Domestic Product per capita	World Development Indicators (WDI)
Foreign Direct Investment	Foreign direct investment, net inflows (% of GDP)	World Development Indicators (WDI)
Natural resources	Total natural resources rents (% of GDP)	World Development Indicators (WDI)
Institutional quality	Control of Corruption	World Development Indicators (WDI)

B Sample

Table 10: Sample

Afghanistan	Albania	Algeria	Angola	Argentina
Armenia	Azerbaijan	Bangladesh	Benin	Bhutan
Bolivia	Bosnia and Herzegovina	Botswana	Brazil	Burkina Faso
Burundi	Cabo Verde	Cambodia	Cameroon	Central African Republic
Chad	Chile	China	Colombia	Cook Islands
Costa Rica	Cote d'Ivoire	Cuba	Dem. Rep. Congo	Ecuador
Egypt	El Salvador	Equatorial Guinea	Eritrea	Eswatini
Ethiopia	Gabon	Gambia	Georgia	Ghana
Guatemala	Guinea	Honduras	India	Indonesia
Iran	Iraq	Jordan	Kazakhstan	Kenya
Kiribati	Kyrgyzstan	Laos	Lebanon	Lesotho
Madagascar	Malawi	Malaysia	Mali	Mauritania
Mexico	Micronesia	Moldova	Mongolia	Morocco
Mozambique	Myanmar	Namibia	Nepal	Nicaragua
Niger	Nigeria	Niue	North Macedonia	Pakistan
Palau	Panama	Paraguay	Peru	Philippines
Republic of Congo	Rwanda	Sao Tome and Principe	Senegal	Serbia
Sierra Leone	South Africa	Sri Lanka	Sudan	Tajikistan
Tanzania	Thailand	Togo	Tunisia	Turkmenistan
Uganda	Ukraine	Uruguay	Uzbekistan	Venezuela
Vietnam	Yemen	Zambia	Zimbabwe	

C Environmental performance around the world

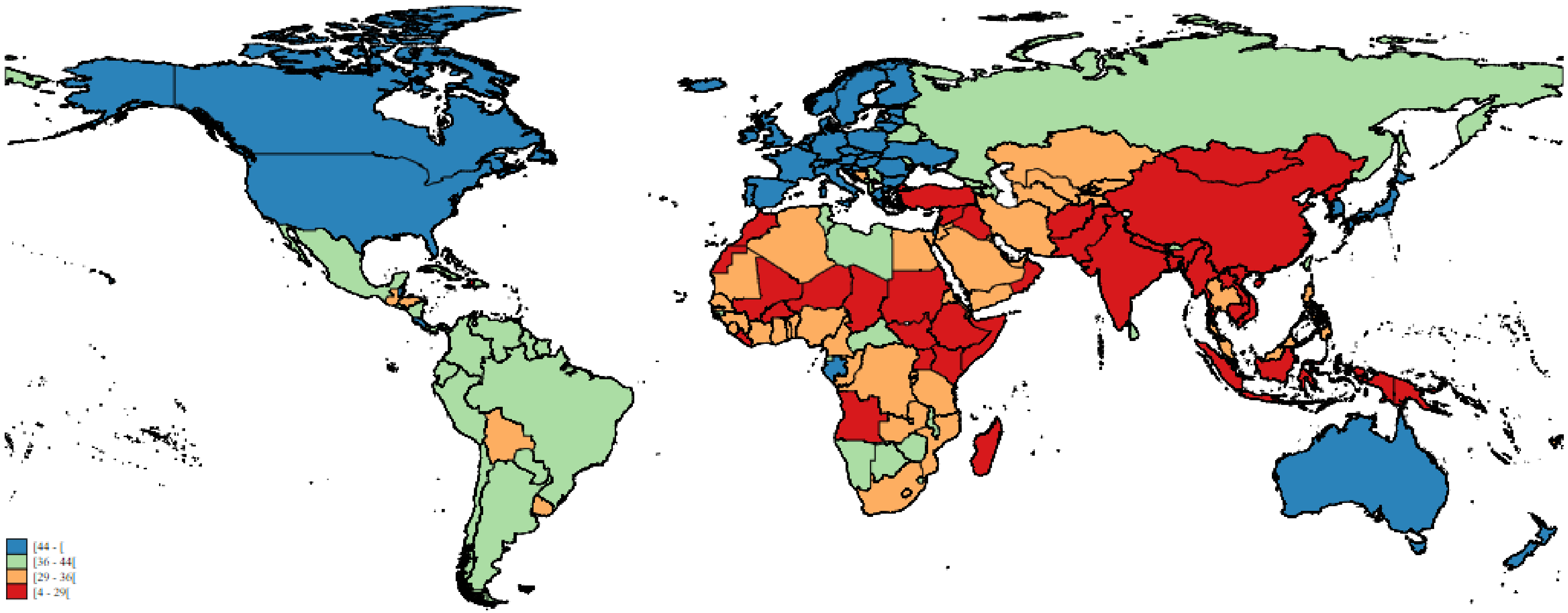

Figure 4 1: Distribution of the environmental performance index (EPI) around the world (2008-2021)

Notes: This map displays the average distribution of the environmental performance index (EPI) around the world, over our study period (2008-2021.) The index can range from 0 to 100, where higher values indicate better performance.