sustainability

MDPI

Article

A Sectoral Approach of Adaptation Finance in Developing Countries: Does Climate Justice Apply?

Nadia Basty * and Dorsaf Azouz Ghachem

Higher Institute of Management of Tunis, LR GEF-2A, University of Tunis, Tunis 2000, Tunisia
* Correspondence: bastyndd@gmail.com

Abstract: In this study, we explore climate justice with specific reference to vulnerability at the level of different sectors in 90 developing countries in Asia, Africa and Europe, over a period from 2010 to 2019. The paper seeks to advance the discussion on the idea that adaptation financing is allocated according to the level of need in the recipient country and sector. By considering five crucial sectors (food, water, health, infrastructure and habitat), we explore the linear and quadratic effect of the vulnerability of each sector on the allocated endowment. The study is based on a dynamic panel regression method based on the Generalized Method of Moments (GMM) in the system model. Our findings reveal that vulnerability is an important consideration in funding allocation. The results suggest that the relationship between adaptation funding and vulnerability is sector-dependent. We also observe that this relationship is non-linear, providing further evidence of distributive justice in terms of allocating more funding to the most vulnerable sectors. Climate justice begins to emerge when vulnerability reaches a certain threshold. However, it appears that the infrastructure sector is dysfunctional in terms of adaptation financing needs and investments undertaken. Overall, the regulations put in place should further integrate climate risk parameters into technical and procedural standards to make projects more effective and climate justice more widespread.

Keywords: sectoral adaptation finance; vulnerability indicator; climate vulnerability; developing countries; readiness indices

Citation: Basty, N.; Azouz Ghachem, D. A Sectoral Approach of Adaptation Finance in Developing Countries: Does Climate Justice Apply? *Sustainability* **2022**, *14*, 10835. https://doi.org/10.3390/su141710835

Academic Editors: Sahbi Farhani and Mehdi Ben Jebli

Received: 26 June 2022
Accepted: 15 July 2022
Published: 31 August 2022

1. Introduction

Climate change is of the utmost concern to environmental authorities and governments around the world. According to the World Meteorological Organization, surface temperatures have increased by about 0.2 °C per decade over the past 50 years, reaching a temperature of 1.2 °C in 2020 compared to the pre-industrial era. Moreover, since 1950, the number of cold days and nights has been decreasing, and the number of warm days and nights has been rising. These various changes are widely recognized as a major threat to humanity and much of the natural world. Several governments and world bodies have therefore been focusing on the analysis of the causes of climate change as well as its economic and social consequences. The importance given by the international community to climate change in the world is growing from one year to another. Carbon dioxide is pointed out as the main cause of human-induced climate change. Recently in New York on 10 March 2021, more than twenty ministers from United Nations (UN) member states called for urgent action to ensure universal access to clean and affordable energy by 2030. These messages mark the beginning of deliberations by five technical working groups that together will prepare a global roadmap to achieve clean and affordable energy for all by 2030 and net zero emissions by 2050. The 2030 Agenda and associated Sustainable Development Goals emphasize the need to "leave no one behind." According to the Intergovernmental Panel on Climate Change, limiting global warming to 1.5 °C above pre-industrial levels and avoiding the worst effects of climate change would require that energy production and use be completely carbon-free by 2050. Indeed, since the signing of the Kyoto Protocol,

international negotiations have been taking place on the distribution of greenhouse gas mitigation efforts between developed countries, emerging countries and developing countries. In this context, it turns out that financing for climate change mitigation and adaptation is playing an increasingly important role in international climate change negotiations [1,2]. In fact, since COP Paris 2015, discussions have shifted towards a consensus on the need to diversify funding sources. The UN chief stated that building a sustainable economy based on renewable energy must be carried out by supporting developing countries so that the energy transition would be equitable, creates jobs, and ensures a cleaner and healthier environment and a resilient future. These trends underscore the urgent need to position adaptation as a top priority for climate finance, especially for developing countries that have limited resources to manage climate risks. The objective of this funding is to help countries build resilience and reduce vulnerability to the adverse effects of climate change, and to support efforts to build adaptive capacity in the most affected sectors.

Countries must focus their investments on green and resilient pathways that reflect the urgency of addressing climate change priorities. Ensuring equity and fairness in the deployment of climate finance is critical to balancing mitigation and adaptation outcomes. Globally, due to the high costs of renewable energy infrastructure, mitigation and adaptation goals are primarily achieved through public and private financing, which is referred to as climate finance. In 2014, the World Bank Group spent an average of USD 10.3 billion of its resources to help developing countries meet mitigation and adaptation goals. This support is critical to enabling developing countries to scale up transformational innovations and practices. Investments in key sectors such as agriculture, infrastructure development, energy, and urban transformation will help promote the technology leap in developing countries. Because of entrenched discrimination, adaptation in one sector may come at the cost of increased vulnerability in another [3]. Inequality influences climate change adaptation and funding may be ineffective or increase vulnerability in one sector. To ensure a balance between mitigation and adaptation outcomes, there is a critical need for equity and fairness in the deployment of climate finance. To distribute funds appropriately, vulnerability must be taken into account [4,5]. Indeed, each country is characterized by a degree of vulnerability [2,6]. Countries are thus differently exposed to climate change; their commitments and response strategies are affected by their degree of vulnerability [7,8]. In this regard, ref. [9] as well as [10] state that developing countries are the most vulnerable with higher Carbon dioxide (CO_2) intensity, larger carbon sinks, lower Gross domestic product (GDP), and good governance. They should therefore be the primary beneficiaries of the funds. Indeed, the adaptation allocation is intended for particularly vulnerable countries, namely the least developed countries, small developing states and African states. The African continent, which is among the most vulnerable to climate change, is already feeling the effects of rising temperatures, rising sea levels, and changing rainfall and weather patterns. Ref. [11] found that African countries have high levels of vulnerability and should receive a large amount of aid. However, the "Investments to End Poverty" report [12] and Oxfam International's "Climate Finance Shadow Report" [13] found that the most vulnerable countries do not receive the most funding for adaptation due to the difference and fragmentation in the construction of vulnerability indices. Vulnerability is a multidimensional construct that differs significantly across communities, sectors, and regions [14].

Therefore, our paper aims to explore whether the most vulnerable sectors receive the most financial assistance; and whether sector vulnerability has a significant impact on assistance allocation. We focus on adaptation funding because historically, funding in developed countries has focused more on mitigation than adaptation. This has led developing countries to negotiate more funding for adaptation. Indeed, poor developing countries, with a high degree of vulnerability, have historically been the lowest emitters of greenhouse gases, and at the same time the most affected by climate change. Adaptation to climate change, in the international context, is of crucial importance at the institutional and policy levels. Indeed, while mitigation is very important, it remains insufficient on its own

to help countries manage climate change and adaptation is therefore a more effective and sustainable policy [15]. The developing countries' sensitivity to climate change, from an environmental, economic and social perspective, has led the Organization for Economic Co-operation and Development (OCDE) to include adaptation in development programs and economic growth plans. Hence, we consider the allocation of adaptation aids to 90 OCDE developing countries in Europe, Asia, and Africa. To further analyze the relationship between adaptation finance and vulnerability, we consider the vulnerability from a sectoral point of view and not by country. Studying the relationship between financial adaptation and sectoral vulnerability allows stakeholders to better explore adaptation strategies by sector as well as limitations and challenges they may face depending on the involved sector. We retain five critical sectors (food, water, health, infrastructure, and shelter). These are drawn from the Notre Dame-Global Adaptation Index (ND-GAIN vulnerability index) in order to match each sector's vulnerability with its financing.

Our paper proposes to add to the existing literature by examining the dynamic effects of sectoral vulnerability on adaptation financing using panel regression methods covering a decade. Most previous studies have relied on static aggregate funding data over short periods, which calls into question the robustness of the results obtained. Moreover, we extend the existing literature on the topic, by considering sectoral and not aggregate country vulnerability. Moreover, our paper fills the gap regarding the degree of influence of a sector's vulnerability to climate change on donor allocation decisions, which remains little explored in the literature.

The paper is structured around four sections. In the second section, we critically explore previous research on climate finance and key contributions to factors impacting vulnerability to climate change. In Section 3, we present the sample, data, model, and variables used to highlight the link between sector vulnerability and adaptation finance. Section 4 presents the main results by analyzing the descriptive statistics for each sector, the correlation between the variables and their significance. The conclusion, limitations and recommendations are given in the Section 5.

2. Literature Review

2.1. Financing the Green Climate Fund (GCF)

In 2010, the Green Climate Fund (GCF) was founded as one of the operational arms of the United Nations Framework Convention on Climate Change (UNFCCC) [16] financial mechanism. It is charged with a key role in delivering new and additional funding to recipient countries [17]. Its main purpose is to promote the diffusion of clean technologies in developing countries and to support all initiatives such as projects, programs, and any other activities related to climate mitigation and adaptation in these regions [18,19]. Since then, the literature review, looking at GCF, has focused on how GCF should raise funds [20–22]; the distribution of GCF among the many developing countries [4,11,23]; and the balance of GCF use between mitigation and adaptation activities [10,24,25]. Regarding the issue of financing, different thoughts were addressed in several articles in order to ensure the effectiveness of GCF financing which represents a key to the future and fate of the GCF [21,26,27]. Despite the fact that a variety of financial instruments were proposed to lift the GCF [22,28,29], the appropriate financial instruments remain undetermined [30]. Most of the financial instruments proposed are simple conceptual analyses, with no empirical aspects. In addition, the various fundraising efforts of the Global Climate Change Fund have not been very successful so far in addressing the climate change needs of developing countries [26,31]. Since its inception, the GCF received strong support from civil society organizations (CSOs). However, there is a growing sense among many CSOs today that their expectations are not being met [32]. Ref. [33] reports that the GCF faces the issue of insufficient funding, and that developed countries do not have clear guidelines for increasing their contributions to climate finance.

There are three international ongoing funding mechanisms: UN membership fees, official development assistance (ODA), and the Global Environment Facility (GEF) [30].

Nevertheless, the mechanisms used to collect the funding for the GCF are still under research and most of the researchers focus on two perspectives: historical responsibility for emissions (HR) and the ability to pay (AP). The HR principle is based on the theory and notions of the ''Polluters Pay Principle'', which means that polluters should pay for damage caused to the natural environment. It was first proposed by the OCDE in the 1970s [34,35]. The most greenhouse gas-intensive country is considered to be the most responsible for the climate decline and hence has to contribute the most to GFC financing [36,37]. The ability to pay (AP) is initially suggested by Adam Smith; the contribution of each part of the community must depend on its capacities. In this sense, each country must contribute an amount to the GCF proportionally to its economic capacity. Thus, countries that represent greater economic capacity must provide considerable funding to the GCF. According to [38,39], there is a fair international burden-sharing by deploying HR and AP. For [30], who based their study on two perspectives (HR) and (AP), the United States (USA) and the European Union (EU) must be the major donors to the GCF.

Despite these several financial sources proposed by multiple researchers, the appropriate ones remain undetermined and establishing a clear method of distributing financial responsibilities among developed countries can help stabilize financial contributions [30]. To reduce the insufficient financing of the GCF, some mechanisms are used to share the burden and specify the contribution of each country, especially for developed countries which contribute the most to GCF financing. [23] focused on the effects of degrees of international coordination on the equity of global financing. They found that the level of adequacy or equity improves proportionally less than the number of contributors; unless it can converge on credible measures of accountability and capacity. In general, although many scholars discuss the issue of how the GCF should raise funds, the proposed schemes or methods remain under study. While lessons learned from existing international funding mechanisms have not been summarized, they could provide a valuable reference for raising the level of the GCF. Ref. [40] proposed to use the pilot to detect whether the privately financed projects can succeed to respect the climate adaptation targets or not before their accomplishment. However, the barriers to effective climate finance are multiple. Ref. [24] mention that the barriers lie primarily in democratic structures, economic power, and domestic drivers. On one hand, the domestic drivers include economic ability, public opinion, and government intention. On the other hand, Ref. [41] argue that political orientation cannot explain all climate finance variability. Moreover, Ref. [10] studied the relation between the donor country's characteristics and the aid dedicated to climate investments. Their results mentioned that wealthier countries contribute less than developing countries in the climate investments funds. Adaptation strategies aim to reduce the negative effects of climate change and take advantage of opportunities, while climate change mitigation strategies seek to minimize the potential impacts of these changes. Ref. [42] claimed that while adaptation improves the resilience of developing economies in the face of increasing weather and climate uncertainty, mitigation activities can often complement adaptation.

2.2. Vulnerability

Financial aid is based on three theoretical foundations. The first issue is the altruistic nature of the financial support which aims to provide positive transfers of developing help to poor countries. The second one focuses on the donor's self-interest that would be in line with the provided aid. Finally, the third and last underpinning states that donations depend on the recipient countries' characteristics, which impact the effectiveness of the aid provided donors consider recipient characteristics that could impact the efficiency of the provided aid [43–45]. Therefore, more financial support is provided to poorer countries (5). Low GDP per capita countries perceive the highest financial aid [46,47]. The link between the distribution of adaptation finance and vulnerability still remains a controversial topic in the literature. According to [48], the vulnerability does not impact the number of adaptation projects. Otherwise, Ref. [27] claimed that despite the vulnerability disparities, the distribution of adaptation finance is equal. Refs. [49–51] found that the

distribution of adaptation assistance is also unequal among countries facing similar climatic challenges. While poverty is considered a criterion to distribute adaptation assistance, adaptation capacity is not taken into account in allocation aid decisions [51]. Hence, it would seem necessary to have data that would make it possible to evaluate the relevance of projects by country in terms of climate change, and thus evaluate the corresponding funding. Moreover, the bilateral donors are more engaged in the allocation of the funding. Ref. [7] defined climate change vulnerability as the degree to which a country is at risk of being negatively impacted by climate change. Climate change vulnerability is also described by the Intergovernmental Panel on Climate Change (IPCC) as a "**function of exposure, sensitivity and adaptive capacity**" [52]. However, it seems that the relationship between provided funding and recipient country vulnerability is not linear. Beyond a certain level of vulnerability, donors would begin to allocate less funding on average to recipients [13,27].

Globally, vulnerability is a crucial factor to determine the appropriate distribution of funding for Least developed countries (LDCs). The level of innovation and R&D is usually a variable that helps to cope with the vulnerability so it is dependent on each country's degree of innovation [53]. While the developed countries are less vulnerable thanks to their high GDP per capita and high Foreign Direct Investment (FDI), they are emitting a big amount of CO_2 as stated by [54].

Developing countries, on the other side, face the worst impact of climate change caused by Greenhouse gas (GHG) emissions and consequently become more and more vulnerable [7,55,56] further conferred that the vulnerability to environmental change was not only driven by physical factors but also by governance-related factors. Moreover, Ref. [7] claimed that the vulnerability is not related only to GHG emissions but also can be explained by demographic, social and political issues which can aggravate the coping capacity. While, the institutional capacity, the country's degree of innovation, the financial resources, the awareness, the infrastructure and the policies can improve the coping capacity, the LDCs countries still suffer from a lack of institutional capacity which explains the failure to attract or implement the Clean Development Mechanism (CDM) projects according to United Nations Environment Programme (UNEP) in 2010. In fact, two key criteria are crucial to attracting CDM projects according to the Kyoto protocol (1997) which are good institutional frameworks and infrastructure.

Furthermore, the strength of the institutional system that characterizes developed countries has led to the rapid implementation of new energy efficiency policies [57]. The OECD is now focusing on creating the right conditions for a transition to a low-emissions economy so that financial flows are distributed fairly across sectors and regions. Thus, selecting the weakest as well as the best-governed countries is the rational criterion for this transition, as indicated by the Overseas Development Institute (2016). Moreover, [58] pointed out that climate finance governance seems to be crucial to ensuring climate resilience and reducing vulnerability.

Thus, we formulate the following hypothesis:

Hypothesis 1 (H1). *There is a positive relationship between the level of sectoral vulnerability in a recipient country and the financial assistance it gets.*

Hypothesis 2 (H2). *There is a non-linear positive relationship between the level of sectoral vulnerability in a recipient country and the financial assistance it gets.*

3. Empirical Methodology

3.1. Data

We consider 5 pillar economic sectors extracted from the ND-GAIN vulnerability index: food, water, health, human habitat, and infrastructure. Our model matches each sector's vulnerability to the adaptation finance level. According to ND-GAIN Country Index, a country's food vulnerability is related to its agricultural capacity as well as food demand and production. The health score, which reflects a country's public health vulnerability,

represents the provision of health services, the spread of communicable diseases, medical personnel, and access to improved health facilities. From its side, the score of Human habitat mirrors a country's vulnerability of human living conditions to climate change, considering weather extremes, urban development, demography, and quality of transport and trade infrastructure, and paved roads. Refs. [59,60] claimed that Transportation infrastructure is crucial to guarantee the development and implementation of green investment. The infrastructure score represents the vulnerability of coastal and energy infrastructure to climate change, primarily general preparedness for climate-related natural disasters, coastal hazards, and energy supply challenges. Indicators include projected change of hydropower generation capacity, projected change of sea level rise impacts, and dependency on imported energy. The Water score captures a country's vulnerability of fresh water supplies to climate change. Indicators include projected change of annual runoff, and projected change of annual groundwater recharge access to reliable drinking water. Moreover, the adaptation finance data for each sector are extracted from the OECD Creditor Reporting System, the 90 considered developing countries are taken from Asia, Europe, and Africa. The financial aid is based on the endowment of the Official development assistance (ODA) which is well-known as an international aid flow. It is defined as a multilateral institution whose members are governments. Its objective is to collect voluntary and mandatory aid in order to build up financial assets used for adaptation purposes.

3.2. Variables

3.2.1. Dependent Variable

Adaptation finance: Like [28], the adaptation finance variable is measured as the official development assistance in terms of grants. Data for each sector are collected from the OECD Creditor Reporting System; project-level data are considered for each sector separately.

3.2.2. Independent Variables

Vulnerability: The IPCC Third Assessment Report (TAR) describes vulnerability as "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC, 2001, p. 995) (IPCC Def. 1). Despite this definition, multiple types of research were founded to study the main effects that could impact the vulnerability and that find the appropriate distribution of climate finance. Refs. [61–63] established an appropriate metric for calculating key vulnerability indicators, with special consideration of human and environmental issues, through a holistic socio-ecological system framework. In the continuity of these works, the University of Notre Dame, 2015, constructed a vulnerability index that takes into consideration the social and environmental dimensions. Nevertheless, setting a quantitative model requires the fragmented vulnerability indices aggregation into a single index. The Notre Dame vulnerability index considers six normalized sectoral vulnerability indices, the sectors are equally weighted, which makes it suitable for all nations as stated by [64]. The score of the vulnerability of Health, infrastructure, habitat, and food are taken separately to isolate each sector study.

GDP per capita: The economic variables taken into consideration includes per capita Gross Domestic Product (GDP per capita based on purchasing power parity). It is a country's core indicator of economic performance, which reflects the country's wealth and economic well-being. According to [65,66], the GDP per capita has a negative impact on vulnerability which means that higher GDP per capita induces lower vulnerability.

Governance readiness, Social readiness, and Economic readiness: The ND-GAIN Index also includes a readiness sub-index that measures the readiness of recipients to set up green investments. The readiness sub-index reflects the nature of the in-country business environment [67]. The readiness can be divided into 3 components: governance, social

and economic readiness scores. First, governance readiness indicators reflect the social stability and the institutional factors that enhance the climate investments, such as political stability, corruption control, regulatory quality, and the rule of law [68]. Second, social readiness indicators represent social conditions, such as social inequality, education, and innovation [69]. Third, economic readiness indicators are primarily concerned with the deployment of private sector financing for green climate implementation [67,69,70].

3.2.3. Controls Variables

Population: This variable is positively linked to financial aid as stated by [71,72] and it is considered a tool to control the large populous nations such as India and China and avoid having a large impact on the vulnerability coefficients [73]. Population data are sourced from the World Bank Databank (2019).

3.3. Model

Our study aims to identify vulnerable sectors and to test whether adaptation funding is allocated according to the level of vulnerability of countries and their benefiting sectors. Our panel data combines 7 variables covering 90 countries, from Asia, Africa and Europe. The study period extends 10 years, going from 2010 to 2019. As a baseline, we estimate (Model 1) whether funding allocation is a function of vulnerability, governance readiness, social readiness, economic readiness, control variables, time-specific effects, unobserved country-specific fixed effects, and errors. Second, we include in the first model a quadratic function with the variable of vulnerability, which permits us to confirm the nonlinear relationship between vulnerability and adaptation finance (model 2). Hence, our two models are as follows:

$$\begin{aligned}\text{Ln } a_{i,t} = \alpha_0 + \alpha_1 \text{Ln } a_{i,t-1} + \alpha_2 V_{i,t-1} + \alpha_3 GOV_{i,t-1} + \alpha_4 SOC_{i,t-1} + \alpha_5 ECO_{i,t-1} + \alpha_6 GDP_{i,t-1} + \alpha_7 POP_{i,t-1} \\ + \nu_i + \mu_{t-1} + \epsilon_{it} \text{ (model 1)}\end{aligned} \quad (1)$$

$$\begin{aligned}\text{Ln } a_{i,t} = \alpha_0 + \alpha_1 \text{Ln } a_{i,t-1} + \alpha_2 V_{i,t-1} + \alpha_3 (V_{i,t-1})^2 + \alpha_4 GOV_{i,t-1} + \alpha_5 SOC_{i,t-1} + \alpha_6 ECO_{i,t-1} + \alpha_7 GDP_{i,t-1} + \alpha_8 POP_{i,t-1} \\ + \nu_i + \mu_{t-1} + \epsilon_{it} \text{ (model 2)}\end{aligned} \quad (2)$$

With:
Ln $a_{i,t}$: the log-transformed value of provided adaptation finance to a country i at time t.
Ln $a_{i,t-1}$: the lagged dependent variable.
$V_{i,t-1}$: the sector vulnerability of the recipient country i at $t-1$.
$GOV_{i,t-1}$: the governance readiness index of the recipient country i at time $t-1$.
$SOC_{i,t-1}$: the social readiness index of the recipient country i at time $t-1$.
$ECO_{i,t-1}$: the economic readiness index of the recipient country i at time $t-1$.
$GDP_{i,t-1}$: the GDP per capita of the recipient country i at time $t-1$.
$POP_{i,t-1}$: the total population of the recipient country i at time $t-1$.
α_0: the term of fixed individual heterogeneity.
μ_{t-1}: represents time-specific effects,
ν_i: unobserved country-specific fixed effects,
ϵ_{it}: the error term $\epsilon_{it} \rightarrow i.i.d.(0, \sigma_\varepsilon^2)$

Modeling this relationship between funding allocation, vulnerability, governance readiness, social readiness and economic readiness, may suffer from two issues. First, vulnerability was considered as time-varying which may simultaneously affect, governance readiness, social readiness and economic readiness which entails endogenous correlations resulting from simultaneity biases and reverse causality. Second, we note that the process of funding approval would take some time since a country's vulnerability and its funding approval cannot occur at the same time. Countries must first submit an application, which will be reviewed by the relevant donor before an allocation is made, which leads us to consider the underlying dynamics of the relationship under study. To alleviate these two concerns, first, we use a dynamic model in the panel data framework (model 1), which allows for taking into account the dynamic structure of the dependent variable as well as

its relationship with the independent variables. In line with others [51,74], the proposed analysis considers one of the exogenous variables as the lagged endogenous variable of a period; which raises the endogeneity problem between the independent variable at time $t-1$ and the dependent variable at time. We consider also one-year lagged values of all time-varying regressors. Second, we use the GMM in system technique as proposed by [75] over to ensure the robustness of the results. It is considered the most efficient of GMM techniques [76,77] to address endogeneity problems of the lagged dependent variable "Ln $a_{i,t-1}$", the potential endogeneity issues with different other regressors and problems of heteroscedasticity, omitted variables, and missing values in data. Finally, we perform a two-pronged test to assess the consistency of the system's GMM estimator. The first test is deployed to examine the validity of the instruments (i.e., the problem of weak and excessively numerous instruments). The Hansen J-test, therefore, examines the null hypothesis that the overidentifying restrictions used in the regressions are valid. The second test seeks to validate the system GMM identification assumptions by testing for serial autocorrelation (AR2). It applies a second-order serial correlation test for the residuals, with the null hypothesis that the model errors do not have serial autocorrelation. As expected, the test results confirm the robustness of the models. We find that the Hansen J-test result indicates the validity of internal instruments used in the dynamic model and that there is high first-order autocorrelation (AR1), but no evidence for significant second-order autocorrelation (AR2).

4. Founded Results

4.1. Descriptive Statistics and Correlation Analysis

Table 1 provides a descriptive overview of the five studied sectors (vulnerability and allocated financial aid). Overall, it appears that the most important adaptation funding concerns the housing sector, with an average of 2.8, followed by the health and food sectors with averages of 2.108 and 2.059, respectively.

Table 1. Descriptive statistics.

Variable	Obs	Mean	Std.dev	Min	Max
Sector 1: Water					
LLa1	776	1.9316	2.2584	−6.9077	10.2233
V1	776	0.3678	0.1157	0.0219	0.7197
$V1^2$	776	0.0015	0.0009	4.83×10^{-6}	0.0051
Sector 2: Health					
LLa2	776	2.10801	2.07338	−5.80914	5.63081
V2	776	0.562384	0.157306	0.321415	0.842008
$V2^2$	776	0.340989	0.186106	0.103307	0.708978
Sector 3: Infrastructure					
LLa3	776	0.383681	2.70211	−6.90775	6.17758
V3	776	0.36441	0.111633	0.130225	0.796966
$V3^2$	776	0.145241	0.095353	0.016958	0.6351561
Sector 4: Food					
LLa4	776	2.0593	2.20360	−5.80914	6.38024
V4	776	0.525249	0.118834	0.17214	0.82573
$V4^2$	776	0.28999	0.12221	0.029634	0.681837

Table 1. *Cont.*

Variable	Obs	Mean	Std.dev	Min	Max
Sector 5: Habitat					
LLa5	776	2.8585	2.4340	−6.9077	7.9035
V5	776	0.54356	0.09629	0.32806	0.81589
$V5^2$	776	0.30472	0.10401	0.10762	0.66568
Common Variables					
Govread	776	0.3996	0.1183	0.0804	0.7557
Socialread	776	0.2719	0.0910	0.10622	0.6868
Economicread	776	0.3519	0.1276	0.00223	0.70753
Lgdp-cap	776	7.8702	1.0579	5.4563	9.9855
Lpop	776	16.2238	1.7058	11.3854	21.0253

The least funded sectors are the water supply with an average of 1.93 and the energy infrastructure with the lowest average of 0.38. In addition, the vulnerability is high for the health and housing sectors (0.56 and 0.54, respectively) followed by the food sector with an average of 0.52. Water and energy infrastructure have the lowest vulnerability exposure, with averages of 0.367 and 0.364 accordingly. Nevertheless, the adaptation finance variable appears to be the most volatile for all five sectors (2.258). Regarding exogenous variables, the housing sector has the lowest variability in vulnerability at 0.09 while the health sector has the highest level of volatility for vulnerability at 0.157 which could be explained by the diseases' spread.

Based on correlation matrices (Tables 2–6), there is a weak correlation between the adaptation finance and the vulnerability for all sectors, except the health one (0.526). Moreover, the readiness scores are negatively correlated with the adaptation finance. Hence, the correlation is negative between preparedness scores and the vulnerability variable, except for habitat sectors. GDP and Population have, respectively, strong negative and positive correlations with the endogenous variable across the five sectors.

Table 2. Matrix of correlation of the water sector.

	1	2	3	4	5	6	7
(1) Lndisb	1000						
(2) v1	0.3388	1000					
(3) LNGDP	−0.0532	−0.2839	1000				
(4) GOVREAD	−0.1273	−0.0163	0.2771	1000			
(5) SOCIREAD	−0.0121	−0.1908	0.6215	0.3533	1000		
(6) ECOREAD	−0.3934	−0.2696	0.5466	0.4464	0.586	1000	
(7) LNPOP	0.5481	0.4791	−0.3012	−0.1519	−0.2459	−0.293	1000

Table 3. Matrix of correlation of the health sector.

	1	2	3	4	5	6	7
(1) Lndisb	1.000						
(2) v1	0.5261	1.000					
(3) LNGDP	−0.3266	−0.4409	1.000				
(4) GOVREAD	−0.4316	−0.6060	0.2832	1.000			
(5) SOCIREAD	−0.4435	−0.5687	0.6316	0.3585	1.000		
(6) ECOREAD	−0.6561	−0.7720	0.4793	0.4511	0.5301	1.000	
(7) LNPOP	0.6228	0.1438	−0.2923	−0.1326	−0.2561	−0.2925	1000

Table 4. Matrix of correlation of the infrastructure sector.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) lndisb	1.000						
(2) v1	0.004	1.000					
(3) LNGDP	−0.116	−0.430	1.000				
(4) GOVREAD	0.050	−0.037	0.551	1.000			
(5) SOCIREAD	−0.030	−0.168	0.510	0.265	1.000		
(6) ECOREAD	0.087	−0.063	0.532	0.579	0.314	1.000	
(7) LNPOP	0.430	−0.224	−0.274	−0.328	−0.218	−0.264	1000

Table 5. Matrix of correlation of the food sector.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) lndisb	1.000						
(2) v1	0.266	1.000					
(3) LNGDP	−0.539	−0.682	1.000				
(4) GOVREAD	−0.183	−0.395	0.532	1.000			
(5) SOCIREAD	−0.298	−0.471	0.445	0.270	1.000		
(6) ECOREAD	−0.266	−0.526	0.573	0.619	0.343	1.000	
(7) LNPOP	0.588	−0.035	−0.289	−0.316	−0.147	−0.264	1000

Table 6. Matrix of correlation of the habitat sector.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) lndisb	1.000						
(2) v1	−0.172	1.000					
(3) LNGDP	−0.148	−0.293	1.000				
(4) GOVREAD	0.074	−0.194	0.511	1.000			
(5) SOCIREAD	0.044	−0.414	0.440	0.255	1.000		
(6) ECOREAD	0.120	−0.503	0.569	0.610	0.341	1.000	
(7) LNPOP	0.600	0.018	−0.283	−0.297	−0.131	−0.260	1000

4.2. Empirical Results

Results of the linear model 1 regressions are displayed in Table 7 below. It should be noted that we found that the lagged endogenous variable shows a statistically significant impact on all sectors, which confirms the dynamic process. Adaptation finance depends on its past value. Furthermore, other exogenous variables have different effects on adaptation finance according to sectors.

First, it seems that the relationship between vulnerability and adaptation funding depends on the receiving sectors. In fact, the vulnerability variable is not significant for the water sector. This finding corroborates [78] who showed the insignificant effect of vulnerability on adaptation finance. Our result could be explained by the insufficient levels of investment for maintaining aquatic ecosystems and water infrastructure as well as the inefficiencies of existing water management systems [79,80]. Climate change negatively impacts damage to water storage, transportation, distribution, and thus inevitably its quality. Therefore, it seems imperative to focus on parameters that address climate risks and present resilience opportunities in water-related investments, while giving priority to the most vulnerable countries in terms of funding. Otherwise, vulnerability positively impacts climate financial aid for the health and infrastructure sectors; while it has a negative effect on provided aid for food and habitat sectors. This ambiguous vulnerability effect is consistent with previous studies [4]. Previous researchers showed that donors allocate the adaptation finance to the countries and sectors expected to be the most vulnerable [51]. Regarding health and infrastructure sectors, it is important to mention that they represent a high level of vulnerability to climate change, and future promising technologies are needed

to avoid maladaptation. Low health system capacity makes developing countries highly vulnerable to novel pandemics which explains the high financial aid allocated to this sector. Moreover, the infrastructure sector's vulnerability could be explained by the lack of water for hydro-energy. For example, Ref. [81] stated that the demand and the supply side of energy are impacted directly by climate change. However, access to modern energy is a necessity for the needs of households, companies, and institutions, as traditional energy sources are inefficient, costly and damage health. Therefore, an increasing vulnerability in these sectors leads to enhance provided financial aid. Conversely, the food and habitat sectors' vulnerability has a negative impact on adaptation finance. This could be explained by the effectiveness of the projects undertaken in these sectors, which motivates their funding and mitigates their vulnerabilities. In fact, the agriculture sector, which supports the food sector, is one of the sectors prioritized in adaptation finance. Agriculture is a crucial sector in the COP negotiations, it employs over 1.1 billion people worldwide and is extremely vulnerable to climate change [82]. Therefore, over 90% of countries' NDCs incorporate agriculture targets [83]. Indeed, every African country has proposed an NDC that incorporates agricultural adaptation objectives. Alongside their NDCs, many countries have developed National Adaptation Plans (NAPs) which highlights their medium- and long-term adaptation needs, and growingly focus on the agriculture sector [84]. In 2015 and 2016, an average of USD 5 billion were spent on agriculture, forestry and land use, which represents 21% of adaptation funding [85]. Despite the disparity in food and habitat needs, depending on the level of economic development and existing infrastructure, developing countries remain the most vulnerable and should be considered first in financing adaptation. However, developed countries also have to ensure their food security and replace and maintain their existing infrastructure which explains the negative relationship between vulnerability and finance adaptation in these sectors.

Table 7. Regression results of model 1.

	Sector 1	**Sector 2**	**Sector 3**	**Sector 4**	**Sector 5**
Variables					
Ln $a_{i,t-1}$	0.6329 *** (0.000)	0.569777 *** (0.000)	0.950555 *** (0.000)	0.738148 *** (0.000)	0.714664 *** (0.000)
$V_{i,t-1}$	0.595801 (0.285)	0.897703 ** (0.010)	0.445047 * (0.100)	−0.569182 *** (0.008)	−0.712911 ** (0.042)
GOV	1.74765 ** (0.042)	1.08790 *** (0.001)	0.52688 ** (0.020)	1.37207 *** (0.000)	1.82259 *** (0.000)
SOC	0.450813 (0.561)	−0.80185 ** (0.031)	1.47399 *** (0.000)	−0.84477 *** (0.002)	0.734559 ** (0.024)
ECO	1.5693 ** (0.043)	−0.65669 *** (0.006)	1.20711 *** (0.000)	−0.079529 (0.583)	0.867544 *** (0.004)
GDP	−0.40529 *** (0.000)	−0.30130 *** (0.000)	−0.336229 *** (0.000)	−0.356656 *** (0.000)	−0.202816 *** (0.000)
POP	0.259670 *** (0.000)	0.237522 *** (0.000)	0.078347 *** (0.000)	0.193487 *** (0.000)	0.262348 *** (0.000)
Const.	−1.92277 ** (0.019)	−1.01896 (0.198)	0.168748 (0.744)	0.169361 (0.616)	−2.62310 *** (0.000)
Wald chi 2	3256.38 *** (0.000)	12,812.64 *** (0.000)	208,096.92 *** (0.000)	61,137.09 *** (0.000)	47,654.60 *** (0.000)
Nb.Observations	776	77	776	776	776

Note. ***, ** and * denote significance at 1%, 5% and 10%.

Second, readiness indexes are in line with previous research [42] and seem to have significant effects on adaptation finance, which could be both positive and negative. Good

governance readiness ensures the undertaken projects' effectiveness and therefore provides a greater incentive for adaptation finance for all sectors. Moreover, one of the most important barriers to climate change mitigation programs is the lack of institutional capacity which engender unfavorable politics. Furthermore, the vulnerability decreases if the country is well-governed, which explains once again the positive effect of governance readiness on climate-provided funds. Social and economic readiness reflects the socio-economic indicators of the recipient country and its ability to make the project effective. Results show an alignment of coefficients' signs (positive or negative) for each sector. They are positive for water, infrastructure and habitat sectors and negative for health and food. For the first sectors, the positive significant effect is explained by the effectiveness and recipient merit theory, i.e., the greater the social and economic preparedness is, the more effective and efficient the project will be, which strengthens adaptation funding [67]. For health and food, which are considered sectors of primary importance, a decline in social and economic indices increases the country's vulnerability to climate change, which requires the provision of funds from donor countries [69]. Climate change is threatening the overall supply of food which can cause hunger in several regions all over the world, especially for small farmers depending on rainfed agriculture in developing countries [86]. Countries in Africa are particularly vulnerable to these changes, as one-fifth of Africans were undernourished in 2017 [84] and 70% of the African workforce is employed in the agriculture sector [87]. Underlying the significance of agriculture in climate action, over 90% of countries' NDCs incorporate agriculture targets [83]. According to the report of the Climate Policy Initiative, 22% of the climate-related disasters in developing countries between 2003 and 2013 are damaging the agriculture sector so higher financial aid must be allocated to the agriculture sector.

In accordance with established assumptions, GDP per capita has a significant negative effect on financial aid. In conformity with the adaptation finance literature [43,45,66], the sectors of the recipient countries with a low GDP per capita are selected to obtain more financial aid than those with high GDP per capita. Conversely, the population is positively associated with adaptation funding, across all sectors. This result corroborates the findings of [88], which suggest that the more popular nations have greater levels of need and thus apply for more funding. Overall, the Wald statistic indicates that the estimated coefficients are significantly close to the true value of the parameter.

Table 8 below presents the results of the quadratic regressions of model 2. Again, the dynamic process of the model is confirmed, which means that climate finance depends positively on its prior values. Readiness as well as GDP and Population coefficients remain unchanged as well as the globally significant model; this confirms the robustness of the results found in model 1.

The contribution of model 2 is to add the quadratic vulnerability term that permits testing if the most vulnerable countries are prioritized in adaptation finance. The most notable result is that the linear and quadratic vulnerability terms are significant for all sectors except for the infrastructure sector. The linear vulnerability term is negative while the quadratic one is positive; which indicates a convex relationship between vulnerability and adaptation finance. Hence, there is an inflection point in the vulnerability variable after which a further increase in vulnerability will enhance climatic provided funding. These results are consistent with the findings of [89] and show that there is a limit beyond which vulnerability could disadvantage a recipient country. Hence it seems that beyond a certain threshold of vulnerability, the most vulnerable countries could be allocated the most adaptation finance. In most sectors, the relationship between financing and vulnerability is not linear [74]; climate justice seems to be applied to the most vulnerable sectors, but does not appear to apply to moderately vulnerable sectors. Up to a certain point of vulnerability, a sector may be penalized for funding until it reaches a very high level of vulnerability to receive it. Ref. [90] showed that adaptation curves are more convex in developed countries than in developing ones. They also highlighted the convexity of climate damage in temperature, which makes reactive adaptation the primary option in the long term.

However, our results could be refined by taking into account the involved sector and they show that this convexity does not apply to the infrastructure sector and that both linear and quadratic vulnerability terms are not significant. While appropriate infrastructure enables adaptation and resilience to climate change, poor choices in infrastructure such as roads, energy, water and sanitation services can increase vulnerability. Thus, many national and international efforts were made to increase adaptive financing for this sector in developing countries [91]. Nevertheless, these efforts have often been dissociated from the actual investments that were made in physical infrastructure. The current practice of adaptive financing for the infrastructure sector is confusing the costs of climate change impacts with the real costs of adaptation measures. This does not make donations affected by the level of vulnerability of the sector.

Table 8. Regression results of model 2.

	Sector 1	**Sector 2**	**Sector 3**	**Sector 4**	**Sector 5**
Variables					
L n $a_{i,t-1}$	0.738119 *** (0.000)	0.474644 *** (0.000)	0.939975 *** (0.000)	0.746848 *** (0.000)	0.446492 *** (0.000)
$V_{i,t-1}$	−18.10423 *** (0.000)	−65.0251 * (0.095)	−5.8723 (0.246)	−16.30275 *** (0.000)	−287.1269 *** (0.006)
$(V_{i,t-1})^2$	24.02736 *** (0.000)	53.7983 * (0.093)	7.5011 (0.209)	15.60499 *** (0.000)	266.9905 *** (0.006)
GOV	2.727939 *** (0.000)	2.15016 * (0.072)	0.872625 ** (0.029)	0.922569 *** (0.000)	9.181009 *** (0.002)
SOC	1.200755 ** (0.027)	−8.133168 ** (0.041)	1.36438 *** (0.003)	−1.62633 *** (0.000)	−4.718213 * (0.087)
ECO	0.2334466 (0.477)	−3.558727 ** (0.029)	1.54891 *** (0.000)	0.045252 (0.807)	3.484595 * (0.10)
GDP	−0.40529 *** (0.000)	−0.241608 (0.290)	−0.373931 *** (0.000)	−0.230305 *** (0.000)	−0.646459 ** (0.011)
POP	0.2324113 *** (0.000)	0.259178 * (0.010)	0.093449 *** (0.001)	0.195218 *** (0.000)	0.858979 *** (0.001)
Const.	0.8538838 (0.313)	19.6294 (0.011)	1.21509 (0.148)	3.20189 *** (0.000)	63.85564 (0.011)
Wald chi 2	11,270.36 *** (0.000)	535.90 *** (0.000)	174,450.68 *** (0.000)	47,531.11 *** (0.000)	519.62 (0.000)
Nb.Observations	776	776	776	776	776

Note. ***, ** and * denote significance at 1%, 5% and 10%.

Regarding readiness indexes, results seem to be once again sector-dependent. For all studied sectors, the governance index has a positive effect on adaptation funding. Conversely, sectors with high social readiness are considered less vulnerable with a low need for adaptation allowances [67]. Moreover, sectors with good economic readiness receive the most funding. For their part, the poorest countries with high populations are selected for adaptation financing. These results confirm once again that donors select the most vulnerable sectors but with good governance and economic readiness which ensures the effectiveness of considered projects.

The results on this topic could be subject to many criticisms. First, this study considered all forms of adaptation funding regardless of donor type (bilateral or multilateral donors). As an illustration, the multilateral donors take more into account the readiness scores than bilateral ones [74]. Moreover, unlike previous studies, it focuses on the relationship between sectoral vulnerability and not the country's vulnerability. In this sense, the vulnerability perception differs between sectors which leads to inconsistent findings. The positive effect

of population on adaptation finance is important and supports the distributive justice hypothesis on climate finance.

Globally, the results of the model 1 and 2 regressions allow us to accept the four assumptions contained in the paper, except hypothesis 1 which could be partially accepted, as the relationship between adaptation finance and vulnerability seems to be sector-dependent. Moreover, despite the disparity of the need for infrastructure according to the level of economic development and the existing infrastructure, the developing countries remain the most vulnerable and must be considered the first in the adaptation finance. However, even developed countries are also under an obligation to replace and maintain existing infrastructure. Nevertheless, if the infrastructure can resist the climate impacts, the economic activity will be insane and the crucial services accessible which means a higher subsistence as the climate resilience is taken into consideration. Transportation infrastructure is very vulnerable due to extreme weather conditions and weak physical infrastructure in developing countries. For example, paved roads in most African countries are still below the global average. The Overseas Development Institute, 2016 confirms that the most expected investment in African countries is dedicated to transportation infrastructure. Asian countries are also highly vulnerable to natural disasters. Therefore, they need to maintain transport infrastructure to ensure resilience to climate change risks.

5. Conclusions

In this paper, we explored how donors distribute the adaptation finance between the five sectors taken from the Notre Dame vulnerability index: water, health, infrastructure, food and habitat. We specifically aimed to test if a sector's vulnerability impacts the financial aid allocated for the recipients. We use a dynamic model in the panel data framework, which combines seven variables covering 90 countries, from Asia, Africa and Europe. The study period extends 10 years, going from 2010 to 2019. Our data are extracted from the OECD database and the ND-GAIN Index. We consider first a GMM in a system linear model which regresses the financial aid on its past value, vulnerability, governance, social and economic readiness indexes, GDP and population. Second, we test the quadratic model by adding to the first model the squared vulnerability term.

Our results suggest that the relationship between adaptation finance and vulnerability depends on the sector. Some vital sectors should be given greater consideration and more effective investments, such as the water sector. Moreover, climate justice begins to be established when the vulnerability reaches a certain threshold. However, it seems that the infrastructure sector is dysfunctional in terms of adaptive financing needs and undertaken investments. That is why climate policy-makers should play a crucial role in planning and implementing adaptive financing for climate-resilient infrastructure. Moreover, the regulations put in place should further integrate climate risk parameters into technical and procedural standards, to make projects more effective and climate justice more widespread.

Our paper makes contributions at several levels. From the research literature perspective, our paper examines both the linear and quadratic relationship between adaptive finance and climate vulnerability across sectors. The results show that climate justice begins to be established when vulnerability reaches a certain threshold and for certain sectors. However, this relationship is sector dependent and there are barriers to climate-vulnerable sectors accessing funding in proportion to their needs. That is why, in terms of managerial implications, some vital sectors vulnerable to climate change should be prioritized and studied in depth as to the types of adaptive investments to be undertaken, such as the water sector. Thus, climate policy-makers should establish the priorities according to the altered sectors independently of the countries. Finally, the results of our paper highlight a lack of concerted national and international efforts in adaptive financing decisions, which affects the effectiveness of the undertaken projects. In terms of research implications, our paper provides a path forward to two lines of research. The first concerns the effectiveness of adaptation projects to be funded. Indeed, if this research highlights the implementation of certain climate justice for the sectors that present suitable governance and economic

readiness scores, it would be interesting to verify whether adaptation funds are destined for the most efficient projects of vulnerable sectors. The second involves designing a holistic sectoral vulnerability index, which takes into account not only climate change but also social justice and good governance. Indeed, until now, little attention has been paid to the environmental and social justice aspects of climate change adaptation. The issue of environment and social justice frequently becomes the main concern, especially in sectors that confront environmental degradation and the widening inequalities between individuals. Our study could be further extended by investigating the effect of donor types on the relationship between sector climate vulnerability and adaptive finance.

Author Contributions: Conceptualization and methodology N.B. and D.A.G.; software N.B.; validation, N.B. and D.A.G.; data curation, D.A.G.; writing—original draft preparation, N.B. and D.A.G.; writing—review and editing, N.B. and D.A.G. All authors have read and agreed to the published version of the manuscript.

Funding: The APC was funded by [LR GEF-2A is "Laboratoire de recherche gouvernance d'entreprise finance appliquée et audit"].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Abdelzaher, D.M.; Abdelzaher, A. Beyond Environmental Regulations: Exploring the Potential of "Eco-Islam" in Boosting Environmental Ethics within SMEs in Arab Markets. *J. Bus. Ethics* **2017**, *145*, 357–371. [CrossRef]
2. Kasdan, M.; Kuhl, L.; Kurukulasuriya, P. The evolution of transformational change in multilateral funds dedicated to financing adaptation to climate change. *Clim. Dev.* **2021**, *13*, 427–442. [CrossRef]
3. Eriksen, S.; Schipper, E.L.F.; Scoville-Simonds, M.; Vincent, K.; Adam, H.N.; Brooks, N.; West, J.J. Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Dev.* **2021**, *141*, 105383. [CrossRef]
4. Garschagen, M.; Doshi, D. Does funds-based adaptation finance reach the most vulnerable countries? *Glob. Environ. Chang.* **2022**, *73*, 102450. [CrossRef]
5. Grasso, M. *Justice in Funding Adaptation under the International Climate Change Regime*; Springer: Dordrecht, The Netherlands, 2010. [CrossRef]
6. O'Brien, K.; Eriksen, S.; Nygaard, L.P.; Schjolden, A. Why different interpretations of vulnerability matter in climate change discourses. *Clim. Policy* **2007**, *7*, 73–88. [CrossRef]
7. Busby, J.W.; Cook, K.H.; Vizy, E.K.; Smith, T.G.; Bekalo, M. Identifying hot spots of security vulnerability associated with climate change in Africa. *Clim. Chang.* **2014**, *124*, 717–731. [CrossRef]
8. Hao, F.; Liu, X.; Michaels, J.L. Social Capital, carbon dependency, and public response to climate change in 22 European countries. *Environ. Sci. Policy* **2020**, *114*, 64–72. [CrossRef]
9. Dai, H.; Mamkhezri, J.; Arshed, N.; Javaid, A.; Salem, S.; Khan, Y.A. Role of Energy Mix in Determining Climate Change Vulnerability in G7 Countries. *Sustainability* **2022**, *14*, 2161. [CrossRef]
10. Halimanjaya, A.; Papyrakis, E. Donor characteristics and the allocation of aid to climate mitigation finance. *Clim. Chang. Econ.* **2015**, *6*, 1550014. [CrossRef]
11. Cui, D.W.; Liu, B.; Zhang, K. Relative effects of human activities and climate change on the river runoff in an arid basin in northwest China. *Hydrol. Process.* **2014**, *28*, 4854–4864.
12. Development Initiatives. *Investments to end Poverty*; Development Initiatives: Bristol, UK, 2015.
13. Shadow, F. *Climate Finance Shadow Report*; OXFAM: Nairobi, Kenya, 2020.
14. Klöck, C.; Molenaers, N.; Weiler, F. Responsibility, capacity, greenness or vulnerability? What explains the levels of climate aid provided by bilateral donors? *Environ. Politics* **2018**, *27*, 892–916. [CrossRef]
15. EC. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 'A Clean Air Programme For Europe'*; COM(2013) 918 Final; EC: Brusells, Belgium, 2013.
16. UNCC. *Cancún Climate Change Conference-November 2010*; UNCC: Charlotte, NC, USA, 2010.
17. Fund, G.C. *Governing Instrument for the Green Climate Fund*; GCF: Songdo City, China, 2011.
18. Costantini, V.; Sforna, G. Do bilateral trade relationships influence the distribution of CDM projects? *Clim. Policy* **2014**, *14*, 559–580. [CrossRef]
19. Suman, A. Role of renewable energy technologies in climate change adaptation and mitigation: A brief review from Nepal. *Renew. Sustain. Energy Rev.* **2021**, *151*, 111524. [CrossRef]

20. Fonta, W.M.; Ayuk, E.T.; Van Huysen, T. Africa and the Green Climate Fund: Current challenges and future opportunities. *Clim. Policy* **2018**, *18*, 1210–1225. [CrossRef]
21. Hannam, P.M.; Liao, Z.; Davis, S.J.; Oppenheimer, M. Developing country finance in a post-2020 global climate agreement. *Nat. Clim. Chang.* **2015**, *5*, 983–987. [CrossRef]
22. Horsch, A.; Richter, S. Climate change driving financial innovation: The case of green bonds. *J. Struct. Financ.* **2017**, *23*, 79–90. [CrossRef]
23. Pickering, J.; Jotzo, F.; Wood, P.J. Sharing the global climate finance effort fairly with limited coordination. *Glob. Environ. Politics* **2015**, *15*, 39–62. [CrossRef]
24. Bailer, S.; Weiler, F. A political economy of positions in climate change negotiations: Economic, structural, domestic, and strategic explanations. *Rev. Int. Organ.* **2015**, *10*, 43–66. [CrossRef]
25. Harrison, K.; Sundstrom, L.M. The comparative politics of climate change. *Glob. Environ. Politics* **2007**, *7*, 1–18. [CrossRef]
26. Cui, L.; Sun, Y.; Song, M.; Zhu, L. Co-financing in the green climate fund: Lessons from the global environment facility. *Clim. Policy* **2020**, *20*, 95–108. [CrossRef]
27. Donner, L.J.; Wyman, B.L.; Hemler, R.S.; Horowitz, L.W.; Ming, Y.; Zhao, M.; Zeng, F. The dynamical core, physical parameterizations, and basic simulation characteristics of the atmospheric component AM3 of the GFDL global coupled model CM3. *J. Clim.* **2011**, *24*, 3484–3519. [CrossRef]
28. Bhandary, R.R. National climate funds: A new dataset on national financing vehicles for climate change. *Clim. Policy* **2022**, *22*, 1–10. [CrossRef]
29. Amighini, A.; Giudici, P.; Ruet, J. Green finance: An empirical analysis of the Green Climate Fund portfolio structure. *J. Clean. Prod.* **2022**, *350*, 131383. [CrossRef]
30. Cui, L.; Huang, Y. Exploring the schemes for green climate fund financing: International lessons. *World Dev.* **2018**, *101*, 173–187. [CrossRef]
31. Bhatnagar, S.; Sharma, D. Evolution of green finance and its enablers: A bibliometric analysis. *Renew. Sustain. Energy Rev.* **2022**, *162*, 112405. [CrossRef]
32. Bruun, J. Governing Climate Finance: Paradigms, Participation and Power in the Green Climate Fund. Ph.D. Dissertation, University of Manchester, Manchester, UK, 2017.
33. Kumar, S. Green Climate Fund faces slew of criticism. *Nat. News* **2015**, *527*, 419. [CrossRef]
34. Luppi, B.; Parisi, F.; Rajagopalan, S. The rise and fall of the polluter-pays principle in developing countries. *Int. Rev. Law Econ.* **2012**, *32*, 135–144. [CrossRef]
35. OCDE. *Politique Commerciale et Relations Économiques Internationales*; Perspectives: Paris, France, 1972; p. 123.
36. Hansen, J.; Sato, M. Regional climate change and national responsibilities. *Environ. Res. Lett.* **2016**, *11*, 034009. [CrossRef]
37. Müller, A. *Benefits of Organic Agriculture as a Climate Change Adaptation and Mitigation Strategy in Developing Countries*; EFD: Geneva, Switzerland, 2009.
38. Dellink, R.; Den Elzen, M.; Aiking, H.; Bergsma, E.; Berkhout, F.; Dekker, T.; Gupta, J. Sharing the burden of financing adaptation to climate change. *Glob. Environ. Chang.* **2019**, *19*, 411–421. [CrossRef]
39. Wang, Q.; Guo, J.; Li, R. Official development assistance and carbon emissions of recipient countries: A dynamic panel threshold analysis for low-and lower-middle-income countries. *Sustain. Prod. Consum.* **2022**, *29*, 158–170. [CrossRef]
40. Kotchen, M.J. On the scope of climate finance to facilitate international agreement on climate change. *Econ. Lett.* **2020**, *190*, 109070. [CrossRef]
41. Pickering, J.; Mitchell, P. What drives national support for multilateral climate finance? International and domestic influences on Australia's shifting stance. *Int. Environ. Agreem. Politics Law Econ.* **2017**, *17*, 107–125. [CrossRef]
42. Adenle, A.A.; Manning, D.T.; Arbiol, J. Mitigating Climate Change in Africa: Barriers to Financing Low-Carbon Development. *World Dev.* **2017**, *100*, 123–132. [CrossRef]
43. Alesina, A.; Dollar, D. Who gives foreign aid to whom and why? *J. Econ. Growth* **2000**, *5*, 33–63. [CrossRef]
44. Berthélemy, J.C.; Tichit, A. Bilateral donors' aid allocation decisions—A three-dimensional panel analysis. *Int. Rev. Econ. Financ.* **2004**, *13*, 253–274. [CrossRef]
45. Younas, J. Motivation for bilateral aid allocation: Altruism or trade benefits. *Eur. J. Political Econ.* **2008**, *24*, 661–674. [CrossRef]
46. Halimanjaya, A. Climate mitigation finance across developing countries: What are the major determinants? *Clim. Policy* **2015**, *15*, 223–252. [CrossRef]
47. Robinson, S.A.; Dornan, M. International financing for climate change adaptation in small island developing states. *Reg. Environ. Chang.* **2017**, *17*, 1103–1115. [CrossRef]
48. Bunce, A.; Ford, J. How is adaptation, resilience, and vulnerability research engaging with gender? *Environ. Res. Lett.* **2015**, *10*, 123003. [CrossRef]
49. Barrett, S. Subnational climate justice? Adaptation finance distribution and climate vulnerability. *World Dev.* **2014**, *58*, 130–142. [CrossRef]
50. Remling, E.; Persson, Å. Who is adaptation for? Vulnerability and adaptation benefits in proposals approved by the UNFCCC Adaptation Fund. *Clim. Dev.* **2015**, *7*, 16–34. [CrossRef]
51. Weiler, F.; Klöck, C.; Dornan, M. Vulnerability, good governance, or donor interests? The allocation of aid for climate change adaptation. *World Dev.* **2018**, *104*, 65–77. [CrossRef]

52. Tol, R.S.; Yohe, G.W. The weakest link hypothesis for adaptive capacity: An empirical test. *Glob. Environ. Chang.* **2007**, *17*, 218–227. [CrossRef]
53. Kim, H.; Woosnam, K.M.; Kim, H.; Lim, C.H. Green infrastructure and energy justice in health adaptation: Leveraging climate policy innovation and vulnerability-readiness nexus. *J. Environ. Policy Plan.* **2022**, *24*, 21–38. [CrossRef]
54. Twerefou, D.K.; Danso-Mensah, K.; Bokpin, G.A. The environmental effects of economic growth and globalization in Sub-Saharan Africa: A panel general method of moments approach. *Res. Int. Bus. Financ.* **2017**, *42*, 939–949. [CrossRef]
55. Jurgilevich, A. Governance modes and epistemologies of future-oriented vulnerability assessments: Example of a mixed-methods approach. *Futures* **2021**, *128*, 102717. [CrossRef]
56. Kasperson, J.X.; Kasperson, R.E.; Turner, B.L.; Hsieh, W.; Schiller, A. Vulnerability to global environmental change. In *The Social Contours of Risk*; Routledge: Milton Park, UK, 2022; pp. 245–285.
57. Khan, P.A.; Johl, S.K.; Akhtar, S.; Asif, M.; Salameh, A.A.; Kanesan, T. Open Innovation of Institutional Investors and Higher Education System in Creating Open Approach for SDG-4 Quality Education: A Conceptual Review. *J. Open Innov. Technol. Mark. Complex.* **2022**, *8*, 49. [CrossRef]
58. Sarker, M.; Islam, N.; Peng, Y.; Khatun, M.; Alam, G.M.; Shouse, R.C.; Amin, M. Climate finance governance in hazard prone riverine islands in Bangladesh: Pathway for promoting climate resilience. *Nat. Hazards* **2021**, *110*, 1–18. [CrossRef]
59. Jayachandran, S. Selling labor low: Wage responses to productivity shocks in developing countries. *J. Political Econ.* **2006**, *114*, 538–575. [CrossRef]
60. Malik, A.; Temple, J.R. The geography of output volatility. *J. Dev. Econ.* **2019**, *90*, 163–178. [CrossRef]
61. Adger, W.N. Vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 268–281. [CrossRef]
62. Eakin, H.; Luers, A.L. Assessing the Vulnerability of Social-Environmental Systems. *Annu. Rev. Environ. Resour.* **2006**, *31*, 365–394. [CrossRef]
63. Gallopín, G.C. Linkages between vulnerability, resilience, and adaptive capacity. *Glob. Environ. Chang.* **2006**, *16*, 293–303. [CrossRef]
64. Edmonds, H.K.; Lovell, J.E.; Lovell, C.A.K. A new composite climate change vulnerability index. *Ecol. Indic.* **2020**, *117*, 106529. [CrossRef]
65. Guillaumont, P. Assessing the economic vulnerability of small island developing states and the least developed countries. *J. Dev. Stud.* **2010**, *46*, 828–854. [CrossRef]
66. Kling, G.; Volz, U.; Murinde, V.; Ayas, S. The impact of climate vulnerability on firms' cost of capital and access to finance. *World Dev.* **2021**, *137*, 105131. [CrossRef]
67. Chen, C.; Noble, I.; Hellmann, J.; Coffee, J.; Murillo, M.; Chawla, N. *University of Notre Dame Global Adaptation Index Country Index Technical Report*; ND-GAIN: South Bend, IN, USA, 2015.
68. Kim, B.J.; Jeong, S.; Chung, J.B. Research trends in vulnerability studies from 2000 to 2019: Findings from a bibliometric analysis. *Int. J. Disaster Risk Reduct.* **2021**, *56*, 102141. [CrossRef]
69. Sarkodie, S.A.; Strezov, V. A review on environmental Kuznets curve hypothesis using bibliometric and meta-analysis. *Sci. Total Environ.* **2019**, *649*, 128–145. [CrossRef]
70. Amegavi, G.B.; Langnel, Z.; Ofori, J.J.Y.; Ofori, D.R. The impact of adaptation on climate vulnerability: Is readiness relevant? *Sustain. Cities Soc.* **2021**, *75*, 103325. [CrossRef]
71. Tezanos Vázquez, S. Aiding middle-income countries? *The case of Spain. Oxf. Dev. Stud.* **2008**, *36*, 409–438. [CrossRef]
72. Trumbull, W.N.; Wall, H.J. Estimating aid-allocation criteria with panel data. *Econ. J.* **1994**, *104*, 876–882. [CrossRef]
73. Wing, O.E.; Lehman, W.; Bates, P.D.; Sampson, C.C.; Quinn, N.; Smith, A.M.; Kousky, C. Inequitable patterns of US flood risk in the Anthropocene. *Nat. Clim. Chang.* **2022**, *12*, 156–162. [CrossRef]
74. Islam, M.M. Distributive justice in global climate finance–Recipients' climate vulnerability and the allocation of climate funds. *Glob. Environ. Chang.* **2022**, *73*, 102475. [CrossRef]
75. Blundell, R.; Bond, S. Initial conditions and moment restrictions in dynamic panel data models. *J. Econom.* **1998**, *87*, 115–143. [CrossRef]
76. Das, P. *Econometrics in Theory and Practice*; Springer: Singapore, 2019; Volume 10, pp. 978–981.
77. Roodman, D. A note on the theme of too many instruments. *Oxf. Bull. Econ. Stat.* **2009**, *71*, 135–158. [CrossRef]
78. Doshi, D.; Garschagen, M. Understanding Adaptation Finance Allocation: Which Factors Enable or Constrain Vulnerable Countries to Access Funding? *Sustainability* **2020**, *12*, 4308. [CrossRef]
79. Ludwig, F.; van Slobbe, E.; Cofino, W. Climate change adaptation and Integrated Water Resource Management in the water sector. *J. Hydrol.* **2014**, *518*, 235–242. [CrossRef]
80. WWAP (United Nations World Water Assessment Programme). *The United Nations World Water Development Report 2015: Water for a Sustainable World*; UNESCO: Paris, France, 2015.
81. Williamson, C.E.; Saros, J.E.; Vincent, W.F.; Smol, J.P. Lakes and reservoirs as sentinels, integrators, and regulators of climate change. *Limnol. Oceanogr.* **2009**, *54*, 2273–2282. [CrossRef]
82. Kalfagianni, A. 'Just food'. The normative obligations of private agrifood governance. *Glob. Environ. Chang.* **2015**, *31*, 174–186. [CrossRef]

83. Strohmaier, R.; Rioux, J.; Seggel, A.; Meybeck, A.; Bernoux, M.; Salvatore, M.; Agostini, A. *The Agriculture Sectors in the Intended Nationally Determined Contributions: Analysis*; Environment and Natural Resources Management Working Paper; FAO: Rome, Italy, 2016; p. 62.
84. FAO; GDP. *Climate Change and The Global Dairy Cattle Sector—The Role of the Dairy Sector in a Low-Carbon Future*; Licence: CC BY-NC-SA-3.0 IGO; FAO: Rome, Italy, 2018; p. 36.
85. Micale, V.; Tonkonogy, B.; Mazza, F. *Understanding and Increasing Finance for Climate Adaptation in Developing Countries*; Climate Policy Initiative: Cologne, Germany, 2018.
86. Harvey, C.A.; Saborio-Rodríguez, M.; Martinez-Rodríguez, M.R.; Viguera, B.; Chain-Guadarrama, A.; Vignola, R.; Alpizar, F. Climate change impacts and adaptation among smallholder farmers in Central America. *Agric. Food Secur.* **2018**, *7*, 1–20. [CrossRef]
87. Gatune Kariuki, J. *The Future of Agriculture in Africa*; Boston University: Boston, MA, USA, 2011.
88. Saunders, N. *Climate Change Adaptation Finance: Are the Most Vulnerable Nations Prioritized?* SEI: Stockholm, Sweden, 2019.
89. Houser, T. Climate Convexity: The Inequality of a Warming World. 2020. Available online: https://www.economicstrategygroup.org/wp-content/uploads/2020/12/8.-Houser.pdf (accessed on 12 May 2022).
90. Agrawala, S.; Bosello, F.; Carraro, C.; De Cian, E. *Adaptation, Mitigation and Innovation: A Comprehensive Approach to Climate Policy*; Research Paper Series No. 25_09; University Ca' Foscari of Venice, Deptartment of Economics: Venice, Italy, 2009. Available online: https://ssrn.com/abstract=1511501 (accessed on 23 November 2009). [CrossRef]
91. Nakhooda, S.; Watson, C. *Adaptation Finance and the Infrastructure Agenda*; Overseas Development Institute: London, UK, 2016.