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Article

A study on the allocation of financial aid from OECD/DAC donors focusing on climate change adaptation using the Panel Double Hurdle Model

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Abstract: This study scrutinizes the allocation of financial aid for climate change adaptation from OECD/DAC donors, focusing on its effectiveness in supporting developing countries. With growing concerns over climate risks, the emphasis on green development as a means of adaptation is increasing. The research explores whether climate adaptation finance is efficiently allocated and what factors influence OECD/DAC donor decisions. It examines bilateral official development assistance in the climate sector from 2010 to 2021, incorporating climate vulnerability and adaptation indices from the ND-GAIN Country Index and the IMF Climate Risk Index. A panel double hurdle model is used to analyze the factors influencing the financial allocations of 41,400 samples across 115 recipient countries from 30 donors, distinguishing between the decision to select a country and the determination of the aid amount. The study unveils four critical findings. Firstly, donors weigh a more comprehensive range of factors when deciding on aid amounts than when selecting recipient countries. Secondly, climate vulnerability is significantly relevant in the allocation stage, but climate aid distribution does not consistently match countries with high vulnerability. Thirdly, discerning the impact of socio-economic vulnerabilities on resource allocation, apart from climate vulnerability, is challenging. Lastly, donor countries' economic and diplomatic interests play a significant role in climate development cooperation. As a policy implication, OECD/DAC donor countries should consider establishing differentiated allocation mechanisms in climate-oriented development cooperation to achieve the objectives of climate-resilient development.

Keywords: climate change; climate adaptation; finance allocation; climate-related development finance; panel double hurdle model

1. Introduction

The purpose of this study is to analyze what factors are driving the allocation of climate change adaptation aid by OECD/DAC donors, which significantly impacts green development in developing countries. Climate change aid has different underlying motivations from general development aid. While a few industrialized countries cause climate change, it's devastating consequences are felt through natural disasters across the planet, including the developing world (Doshi and Garschagen, 2020; Mikhaylov et al., 2020). While development assistance is humanitarian and therefore justified in considering donor countries' interests to some extent, climate assistance is financially obligatory for donor countries, most of which are industrialized countries (Gorelick and Walmsley, 2020). Therefore, it is necessary to consider the determinants from a perspective different from general development cooperation assistance (Guillaumont, 2008).

It also serves the purpose of highlighting inequalities in the allocation of climate-

related development finance. There is an expanding chorus of voices from developing countries, mainly from small island developing states, that not only are the impacts of climate change inadequate but so is the allocation of climate-related development finance, with the Alliance of Small Island States (AOSIS) arguing that climate change creates double inequalities. This raises the question of whether the allocation of the finance is similar to the pattern of development finance, which means that there is a need to empirically analyze whether climate-related development finance is being prioritized for countries most affected by climate change.

Thus, it is necessary to emphasize 'climate vulnerability' as a criterion for allocating climate aid. Factors such as hazard, sensitivity, and adaptive capacity are generally considered when determining vulnerability (Smit and Wandel, 2006). By focusing on the climate aid allocation standards of OECD/DAC donors, this study aims to understand what factors are at play in the allocation of climate aid and whether there are any irrationalities in the allocation standards (Pierson and Skocpol, 2002). If climate aid allocations do not reflect climate vulnerability, they may increase climate inequality between developed and developing countries and between developing and developing countries (Newell et al., 2021). Given that most recipient countries are still in the economic development stage, they are likely to depend on foreign sources of climate change finance (Catalano et al., 2020).

Responses to climate change are broadly divided into mitigation and adaptation (IPCC, 2014), where mitigation refers to responding to climate change by reducing greenhouse gas emissions, and adaptation refers to responding to the adverse effects of climate change that have already been realized (IPCC, 2014). Although climate change mitigation and adaptation are complementary, adaptation has received relatively little attention compared to mitigation (Hardee and Mutunga, 2010; IPCC, 2014; Birchall and Bonnett, 2021). Policies have focused on GHG mitigation when it was thought that the problem of climate change could be solved by controlling the greenhouse effect, which is responsible for rapid climate change (Kim and Oh, 2018; Sung, 2019). However, global surface temperatures have already risen by 1.1 ℃ from 1850–1900 to the present (2011–2020), and adaptation is becoming increasingly important as climate change is becoming an unstoppable phenomenon (IPCC, 2021).

The research question of the study is what factors influence the allocation of climate-related development finance, both in terms of the selection of recipient countries and the amount of finance allocated. Using the Panel Hurdle Double Model is also academically significant in this study. Initially, climate aid from OECD/DAC donors is characterized by a large number of samples with a zero value for the dependent variable, "aid commitment," because the timing of initial aid varies widely across recipient countries, and there are many years with no recipient record (Birchall and Bonnett, 2021). Previous studies have either ignored zeros or used Tobit or Heckman models, which have certain limitations. However, this study uses the Panel Hurdle Double Model, optimized for panel data analysis with many samples with zero dependent variable values. This model has the advantage of analyzing separately the criteria by which donor countries select recipient countries and the criteria by which they allocate resources, revealing their differences (Jones, 1989; Wooldridge, 2009).

In particular, compared to the analysis of existing studies that use the two-stage modeling method, this study is different in that it focuses on the gap between the two

stages, i.e., how the factors affecting the selection of countries to receive climate-related development finance differ from those affecting the allocation stage, which determines the amount of finance to be allocated. Existing studies either focus on physical vulnerability or differ from this study's analysis of factors affecting the selection and allocation stages (Saunders, 2019; Weiler et al., 2018).

Therefore, in this study, we describe the current status of climate-related development finance and climate vulnerability, extend the huddle model to include potential recipient countries ($y \geq 0$), and conduct a more sophisticated analysis using the Panel Double Huddle Model of Dong and Kaiser (2009), and then present the results to draw implications.

2. Theoretical background and hypothesis construction

2.1. Financial aids on climate change

As climate change has intensified in recent years, discussions on climate finance have rapidly progressed in the international community (Lee et al., 2022). Although major global climate agreements have been underway for many years, the implementation of the agreements has not appropriately progressed due to differences in interests and opinions among countries, and the issue of supporting developing countries for climate change issues has always been a critical issue and has been fiercely contested (Höhne et al., 2017; Nawaz et al., 2021).

Over the past few decades, international aid has tended to be guided by the view that environment and development are mutually opposed, but there is a growing movement to reconcile them (Elder and Olsen, 2019; OECD, 2019). Since adopting the Paris Climate Agreement, awareness of the climate crisis and the importance of the capacity to respond has spread, and donors are attempting to mainstream climate change into development cooperation. The Paris Agreement, the first universal climate action framework in which all 195 industrialized and developing countries agreed to reduce greenhouse gas emissions in 2015, prioritizes keeping the global average temperature increase to well below 2 ℃ above pre-industrial levels, with a limit of 1.5 ℃. It also set greenhouse gas mitigation, climate change adaptation, loss and damage, climate finance, technology development and transfer, capacity building, and transparency on climate action and financing as the core agenda and specified guidelines related to them. In particular, Article 7 of the agreement, which deals with climate change adaptation, aims to strengthen the capacity of developing countries to respond to climate change, enhance resilience, and address vulnerability.

In 2021, the OECD/DAC, which has provided guidance and policies for integrating climate change and development cooperation since the early 2000s, published Guidance for Governments and Development Cooperation on Strengthening Climate Resilience to emphasize the need to build climate resilience into all development cooperation activities, rather than just focusing on climate change adaptation. The guiding principles are country ownership, inclusive approaches, and environmental and social sustainability (OECD, 2021). 'Country ownership' is defined in the context of development cooperation as a country determining its development priorities, choosing a development model based on those priorities, and taking the lead in implementing development' (OECD, 2016). International

discussions on climate change have emphasized recipient country ownership, as development cooperation based on recipient country ownership is closely related to development effectiveness (Booth, 2012). The second guiding principle, 'inclusive approaches,' is intended to reflect the slogan of the Sustainable Development Goals, 'No One is Left Behind,' in terms of climate resilience (Leal Filho et al., 2021). Socially vulnerable groups, such as least developed countries, ethnic minorities, and women, are more likely to be vulnerable to climate change, and the OECD/DAC believes that there is a close relationship between climate vulnerability and climate resilience and that the pursuit of an inclusive approach has implications for strengthening climate resilience. Finally, environmental and social sustainability focuses on how climate resilience can be strengthened by ensuring the sustainability of ecosystems and social stability.

2.2. Climate vulnerability and related indexes

Vulnerability is defined and measured differently by different disciplines, sectors, and institutions (Brooks, 2003). However, it is defined as a condition that makes a person or space susceptible to risk. The concept has been transformed and expanded into several different concepts in various fields, including natural hazards, impact assessment, food security, health, climate change, and sustainability (Zarowsky et al., 2013). It is often used interchangeably with the term 'poverty,' but in fact, vulnerability can be interpreted in different ways depending on the socio-scientific, normative, and cultural background, and it also has a social, economic, and political context (Aven, 2011; Füssel, 2007).

The concept of climate change vulnerability is supposed to have been formally introduced in the IPCC's Second Assessment Report. The IPCC defines climate vulnerability as "the sensitivity of a system to, or inability to respond to, the impacts of climate change, including climate variability and extreme weather events." The emphasis of the definition has shifted slightly with each Assessment Report. The most recent definition, from 2022, focuses more on socio-structural vulnerability than natural vulnerability. While the external stimulus is 'climate change,' it is interpreted to mean that social structural imbalances lead to existing socially vulnerable groups becoming climate vulnerable.

Table 1. Climate change-related indexes.

Index	**WRI**	**INFORM**	**ND**	**CRI**
Conceptual design and components	$R = E \times V$	$R = E \times V \times (1 - C)$	$ND = (RE - V + 1) \times 50$	$R = F + EL$
	$V = SU + (1 - C) + (1 - A)$	-	$V = E \times SE \times (1 - A)$	-
Number of indexes	27	54	45	2
Measured countries	171	191	175	181

Source: Made by based on Garschangen et al. (2021). (R)Risk, (E)Exposure, (V)Vulnerability, (C)Coping Capacity, (A)Adaptive Capacity, (SU)Susceptibility, (SE)Sensitivity, (RE)Readiness, (F)Fatalities, EL(Economic Losses).

As climate change has received increasing attention and discussion, an ongoing effort has been made to index its various impacts. Commonly used climate change-related indices include the World Risk Index (WRI), the INFORM Climate Change

Risk Index (INFORM), the Notre Dame Global Adaptation Index (ND), and the Climate Risk Index (CRI). WRI, INFORM, and ND have similar indicator composition and calculation methods, such as vulnerability, hazard/exposure, and adaptation/response. At the same time, CRI focuses on the scale of physical losses, such as capital, population, and economy, which is somewhat different from the rest of the indexes (**Table 1**).

2.3. Literature review

The determinants of development resource allocation are typically categorized into two models in aid research: Donor Interest and Recipient Need (Berthélemy, 2006). This study adds the Recipient Merit studies. The donor interest model refers to the pattern of emphasizing donor countries' political, economic, diplomatic, and security interests in aid allocation (Ali et al., 2015; Bermeo, 2017; Maizels and Nissanke, 1984). Based on realist theory, which views donors as rational actors who tend to prioritize their survival and interests, the allocation of development resources to the international community is assumed to fulfill donors' interests, and the donor interest model is the most commonly used model of allocation in development assistance research (Neumayer, 2005). Donor interests include trade with the recipient country, foreign direct investment (FDI), distance from the recipient country, former colonization, and military spending (**Table 2**).

The recipient needs model views development cooperation as motivated by the recipient's economic and social development support and humanitarian needs rather than the donor's economic, diplomatic, and political objectives and was conceptualized as a recipient need model in the study of the determinants of aid allocation (Park et al., 2013). Relevant variables include per capita income (GNI), poverty rate, GINI Index, health expenditure, life expectancy, primary school enrollment rate, and under-five mortality rate (Bandyopadhyay and Vermann, 2013; Fuchs and Vadlamannati, 2013; Nielsen, 2010).

The recipient merit model prioritizes recipient countries with favorable conditions for effectiveness in aid allocation to maximize the outcomes of development cooperation activities (Berthélemy, 2006). However, based on the judgment that the performance of aid is based on the perspective of the donor country, it has recently expanded to focus on development effectiveness, which means maximizing the performance of development activities for the growth and welfare of the people of the recipient country (Kim and Lee, 2013). Variables related to aid effectiveness include government corruption, government control, government quality, government stability, civil war, democracy index, and inflation in recipient countries (Bickenbach et al., 2019; Civelli et al., 2016; Fuchs and Vadlamannati, 2013).

Before the 1990s, the mainstream of environmental aid research included climate as part of the environment. However, as the issue of climate change rose to the top of the agenda, climate aid research expanded. In particular, as with climate finance, a growing body of research on innovative development finance proposed by the OECD recognizes the limitations of current public finance (De Nevers, 2011; Steckel et al., 2017). Steckel et al. (2017) highlighted the need for large-scale investments to decarbonize the international energy system and the importance of international

climate finance institutions in mobilizing private finance to complement the current lack of public climate finance and achieve sustainable development goals. Similarly, De Nevers (2011) argues for the need to use public climate finance as a catalyst for mobilizing private finance to support climate change mitigation and adaptation further.

Table 2. Literature.

Category	Name	Research method or message
Allocating development funding by donor country	Lebovic(2005)	Analyze the determinants of development finance allocation for 101 recipient countries from four donors, the United States, Japan, Germany, and the United Kingdom, 1970–1994.
	Berthélemy and Tichit (2004)	Analysis of the determinants of development finance allocation for 137 recipient countries from 22 donors, 1980–1999 (focusing on economic and political objectives).
	Hoeffler and Outram (2011)	The determinants of donor aid allocation are centered on the interests of the donor country, with some countries, such as the UK and Japan, considering growth rates and levels of democracy.
	Szent-Iványi (2012)	Analyze differences in determinants between traditional and emerging European donors (Czech Republic, Hungary, Poland, Slovakia) in 2001–2008.
Allocate development resources by domain	Neumayer (2005)	An analysis of the determinants of development finance allocation to food aid shows that conventional donors are driven by donor interests centered on geographic proximity. At the same time, the recipient country needs to influence NGOs and European countries.
	Kim (2019)	Analyzing the Determinants of Development Finance Allocations for Energy Assistance Funds 1996–2013.
	Davis and Swiss (2020)	Factor analysis of NGO development funding allocation drivers based on a distributional model.
Climate sector development finance allocation	Steckel et al. (2017)	Discuss the scarcity of public climate finance and the role of international climate finance institutions in achieving sustainable development goals.
	De Nevers (2011)	Discuss the role of public climate finance as a catalyst for mobilizing private finance to support climate change mitigation and adaptation further.
	Islam (2022)	Analyze how the climate vulnerability of recipient countries affects the allocation of climate development finance.
	Weiler et al. (2018)	Analyzing the relationship between recipient country climate vulnerability and climate development finance allocation.
	Iacobuță et al. (2022)	Demonstrated the need to quantify the contribution of climate development cooperation to the Sustainable Development Goal (SDG) targets.
Climate development finance allocation to particular region	Robertsen et al. (2015)	Analyzing the factors affecting climate adaptation finance for sub-Saharan African countries.
	Keeley (2017)	A survey-based analysis from the perspective of donor countries to emphasize the importance of renewable energy adoption in Pacific Island countries.
	Scandurra et al. (2020)	Analyzing relationship between climate finance and vulnerability in 33 small island developing states using a PCSE model.

On the other hand, as an extension of development finance allocation, the allocation of climate finance has been discussed. Since adaptive development finance aims to strengthen the capacity of climate-vulnerable countries to cope with climate change, the literature has been critical of the allocation of adaptation finance and whether it is being implemented justly (Barrett, 2013; Betzold and Weiler, 2017; Duus-Otterström, 2016; Saunders, 2019; Weiler et al., 2018).

Islam (2022) conducts a panel analysis of climate development finance approvals from 2000–2018 to examine the impact of recipient countries' climate vulnerability on the allocation of climate development finance. He finds that adaptation aid considers climate vulnerability more than mitigation aid. However, aid allocation is not significantly related to vulnerability, suggesting that distributive climate justice is

undermined. Weiler et al. (2018) and Saunders (2019) also studied the relationship between the climate vulnerability of recipient countries and the allocation of climate development finance. They found that it considers not only climate vulnerability but also the interests of donor countries, just like general development aid.

The studies have focused on allocation of climate-related development finance from climate justice perspective, particularly in vulnerable regions such as sub-Saharan Africa and Small Island Developing States (Keeley, 2017; Robertsen et al., 2015; Scandurra et al., 2020).

Robertsen et al. (2015) analyzed the factors affecting climate adaptation finance for sub-Saharan African countries. They found that it is not the vulnerability of the recipient country but the donor-recipient relationship that has an impact. Keeley (2017) surveyed from the perspective of donor countries to emphasize the importance of renewable energy adoption in Pacific Island countries and discussed the critical factors for renewable energy adoption. The results showed that effective regulatory institutions are needed for renewable energy adoption and that the financial aspects of infrastructure are more important than the technical aspects of renewable energy for getting donor support. Moreover, Scandurra et al. (2020) estimated the relationship between climate finance and vulnerability in 33 small island developing states using a PCSE model. The results show that social development variables affect the balance of climate development finance allocation, confirming that external finance is crucial to reducing climate vulnerability.

Research has also been conducted on the share of mitigation and adaptation finance in climate development finance. Iacobuță et al. (2022) argue that the close linkages between climate change and development make it necessary to quantify the contribution of climate development cooperation to each of the SDGs in order to ensure efficient use of resources and suggest that in recent years, more aid has been channeled to adaptation than mitigation and that the mismatch with source country NDCs focusing on adaptation has been reduced.

Studies on allocating climate-related development finance to reflect climate vulnerability include Weiler et al. (2018), Saunders (2019), and Islam (2022). Weiler et al. (2018) and Saunders (2019) used Cragg's huddle model to analyze adaptation finance alone, with different inputs. In Islam's (2022) study, climate-related development funding was divided into mitigation, adaptation, and overlapping finance. The Generalized Method of Moments (GMM) model was used to estimate the factors affecting funding allocation.

Among the studies that used the two-stage method, Weiler et al. (2018) focused on physical vulnerability, so their analysis centers on determining the target and scale of financial allocation to physically vulnerable countries. However, there are cases where physical vulnerability indicators such as disasters are higher in donor countries such as the United States and Japan. Also, it is unlike social vulnerability, which can be improved through development assistance. On the other hand, Saunders (2019), as a result of a working paper, used a vulnerability indicator that considers both physical and social, and the dependent variable is the share of adaptation resources, which is different from this study. In addition, studies using the two-stage method focus only on adaptation finance and use Cragg's huddle model, which determines the size of finance only for those countries selected as recipients ($y > 0$), so the results may be

limited. On the other hand, this study considers the overlap between mitigation and adaptation finance. It uses total climate-related development finance and adaptation finance as the dependent variable. The results would differ from previous studies because of using the Panel Double Huddle Model from Dong and Kaiser, which considers potential recipient countries to measure the scale of finance. In addition, unlike previous studies (Betzold and Weiler, 2017; Saunders, 2019; Weiler et al., 2018) that covered a short, 4-6-year funding period, which was not amenable to robust econometric methods, this study considered 2010–2021 as the analysis period to use a large amount of data for a more sophisticated analysis.

3. Research methods

3.1. Panel double hurdle model

In the case of development finance data, there are a significant number of cases with a value of zero, given that it is composed of the relationship between one donor and multiple recipient countries. This is partly due to the development assistance guidelines, which aim to reduce the dispersion of resources and improve aid effectiveness by providing focused assistance to priority partner countries. However, it is also because DAC donors allocate their development assistance budgets on a slightly different basis each year depending on the situation and conditions in various social, economic, environmental, political, diplomatic, and security areas. When analyzing the factors that determine the size of aid under this mechanism of development assistance, it is essential to choose a suitable model for handling zero values of the dependent variable.

In regular Ordinary Least Squares (OSL) regression, the explanatory power of the difference between zero and non-zero values are reduced, potentially biasing the results. Traditionally, the Tobit model is used, but it has the problem of estimating the zero value of the dependent variable as a corner solution, and nonzero variables can raise the mean of the dependent variable (Greene, 1993). Also, since the Tobit model requires the same explanatory variables for both participation and outcome, there is a constraint that the marginal effects of the explanatory variables on participation and outcome are in the same direction (Min and Choi, 2021). The Heckman Sample Selection model could be utilized. However, this model has the logical disadvantage of assuming that a dependent variable with a zero value is simply a “non-participation” behavior and is considered an incomplete sample. Therefore, a double hurdle model that allows for the existence of “potentially eligible recipient countries” is appropriate.

Jones (1989) proposed the double hurdle model, which is an extension of Cragg’s (1971) hurdle model. It is a model that analyzes a limited dependent variable and separates the process into two stages: a participation decision and a quantity decision. However, it can provide a more sophisticated interpretation than the Tobit model because the influence of explanatory variables can be different (Wooldridge, 2009). A two-part model can be utilized similarly, but with the crucial difference that the outcome is unconditionally positive once participation is determined. The decision process for selecting an appropriate model for a restricted dependent variable can be schematized, as shown in **Figure 1**.

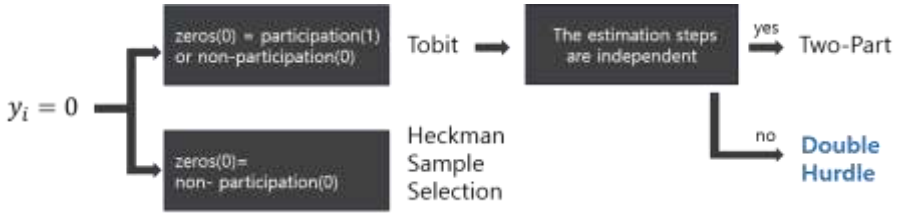

Figure 1. Model selection decision process for limited dependent variables (y_i = 0).

Since this study utilizes panel data, we use the panel double hurdle model proposed by Dong and Kaiser (2008). The model consists of a probit model for the participation decision and a panel Tobit model for the performance decision. Two hurdles must be crossed for the climate aid observation to have a non-zero value. The first hurdle is the decision on the target recipient country to which the donor provides climate aid, and the second hurdle is the decision on the amount of climate development finance to the selected recipient country. The double-hurdle model is appropriate when the decisions to cross the two hurdles are made at different points in time, as in the case of development finance allocation decisions, there is a significant time lag between the decision to target source countries and the decision to select and allocate funds to aid projects (Weiler et al., 2018). For this study, the participation and performance models will be replaced and divided into the selection and allocation stages. The analytical model is as follows:

- Selection stage (the first hurdle): Determine recipient countries for climate development finance allocations

$$selection*_i = \alpha_1 + \beta_1 z_i + \epsilon_{1i} \quad (1)$$

$$selection_i = \begin{cases} 1(selection*_i > 0) \\ 0(selection*_i \leq 0), \epsilon_{1i} \sim N(0,1) \end{cases} \quad (2)$$

- Allocation stage (second huddle): Determining the size of climate development financing

$$allocation**_{it} = \alpha_2 + \beta_2 x_{it} + \mu_i + \epsilon_{2it}, \mu_i \sim \mathrm{N}(0, \sigma^{2\sigma} \quad (3)$$

$$allocation*_{it} = \begin{cases} allocation**_{it} \ (allocation**_{it} > 0) \\ 0 \ (allocaton**_{it} \leq 0, selection*_i > 0 \ or \ selection*_i \leq 0) \end{cases} \quad (4)$$

- Final climate development finance allocation decision

$$allocation_{it} = selection_i allocation*_{it} \quad (5)$$

The selection stage models (1) and (2) are equations with a vector of determinants (z_i), a vector of z_i coefficients (β_1), a constant term (α_1), and an error term (ϵ_{1i}) that follows a standard normal distribution with mean zero and variance 1 for each potential donor country ($selection*_i$). In the first huddle of the panel-double-huddle model, time (t) is not included because it utilizes a time-invariant probit model, which assumes that participation remains constant at all time points. Therefore, we must include a time-invariant covariate (TIC) as a determinant. If it is a time-varying covariate (TVC), we need to use the average value of the observations or a single observation.

Equation (3) is a decision-stage model in which donor countries (i) determine the potential amount of climate finance ($allocation*_{it}$) at a time (t). The equation consists of a vector of determinants of climate finance (x_{it}), a constant term (α_2), a vector of x_{it} coefficients (β_2), and an error term (ϵ_{it}) that follows a normal distribution

with mean zero and variance σ^2. It follows a similar form to the panel Tobit model. However, its main feature is that it assumes unobserved group heterogeneity (μ) as a random effect, compensating for additional sampling bias by reflecting the correlation between the two levels of the deterministic model. The probability distributions for the three error terms in (2), (3), and (4) are assumed to be multivariate normal, which is equivalent to (6).

$$\begin{pmatrix} \epsilon_{1i} \\ \mu_i \\ \epsilon_{2it} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho\sigma_\mu & 0 \\ \rho\sigma_\mu & 1 & 0 \\ 0 & 0 & \sigma^{2_\epsilon} \end{pmatrix} \right] \quad (6)$$

The final amount of climate development finance can be defined as in (6), i.e., recipient countries ($selection_i = 0$) that do not receive any aid from the donor will have a final amount of climate development finance of zero ($allocation_{it} = 0$). In contrast, recipient countries ($selection_i = 1$) that the donor selects as potential targets for aid will receive climate development finance of zero ($allocation_{it}$ = 0) or climate development finance of the determinants ($allocation_{it} = allocation **_{it}$), depending on the determination of the potential amount of climate development finance ($allocation **_{it}$) in the allocation phase (**Figure 2**).

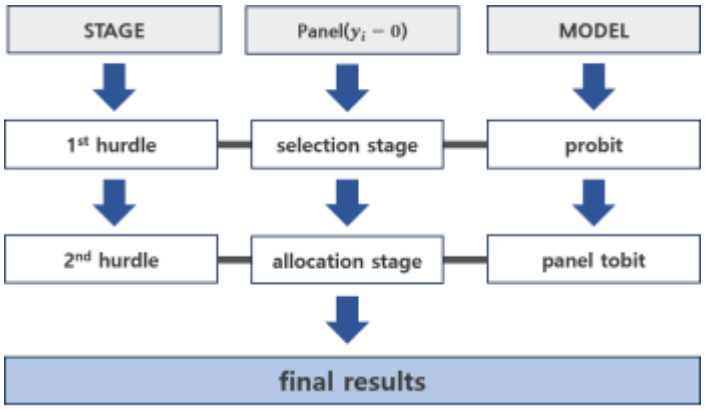

Figure 2. Analysis frame of the panel double huddle model.

The log-likelihood function can be constructed from the selection and allocation models, similar to the Tobit likelihood function assuming random effects (Eagle and Moffatt, 2014). For $selection *_i = 1$ ($cov(\mu_i, \epsilon_{1i}) = \rho = 0$), the likelihood function of the donor country is given by (7).

$$L_i|(selection_i = 1, \mu_i) = \prod_{t=1}^{T} \left\{1 - \Phi\left(\frac{\beta_2 x_{it} + \mu_i}{\sigma}\right)\right\}^{I(allocation_{it}=0)} \left\{\frac{1}{\sigma}\Phi\left(\frac{allocation_{it} - \beta_2 x_{it} - \mu_i}{\sigma}\right)\right\}^{I(allocation_{it}>0)} \quad (7)$$

If a country is not selected as an aid recipient, then the value of $allocation_{it}$ has a dominant value if and only if it is zero at all points in time (Min and Choi, 2021). Therefore, the dominance value for the phosphorus donor country i with $selection_i = 0$ can be expressed as (8), (9).

$$(L_i|selection_i = 0) = 0, if \sum_{t=1}^{T} allocation_{it} > 0 \quad (8)$$

$$(L_i|selection_i = 0) = 1, if \sum_{t=1}^{T} allocation_{it} = 0 \quad (9)$$

The first hurdle equation (selection stage) allows donor i to be either selected ($selection_i = 1$) or not selected ($selection_i = 0$), and the likelihood value is derived through a weighted average of (7), (8), and (9). The marginal likelihood of donor country i can be estimated using the resulting conditional likelihood over μ_i where $f(\mu)$ is a normal density function $(0, \sigma_\mu^2)$ over μ_i.

$$(L_i|\mu_i) = \Phi(\beta_1 z_i)(L_i|selection_i = 1, \mu_i) + \{1 - \Phi(\beta_1 z_i)\}(L_i|selction_i = 0) \quad (10)$$

$$L_i = \int_{-\infty}^{\infty} (L_i|\mu_i) f(\mu) selection\, \mu \quad (11)$$

Finally, the likelihood function of donor country i for the panel double huddle model estimation is given by (12).

$$LogL = \sum_{i=1}^{30} lnL_i \quad (12)$$

3.2. Dependent variable and its data source

The dependent variables used in analyzing the determinants of climate development finance allocation by OECD/DAC donors are CCMA, which refers to climate development finance commitments with mitigation and adaptation markers, and CCA, which refers to adaptation finance commitments with only adaptation markers. While this study focuses on the allocation of climate adaptation finance, the size of total climate-related development finance was also added as a dependent variable to account for the overlapping nature of the finance between climate mitigation and climate adaptation. We use only the bilateral aid data and use constant prices in 2021 US dollars. To account for the asymmetry of the data, both variables are naturalized and used as lnCCMA and lnCCA. Covering aid from 30 donor countries in the OECD/DAC to 115 recipient countries, this study collected 41,400 observations on climate development finance from the OECD/CRS for the 12 years from 2010 to 2021. The final 115 recipient countries were selected by excluding countries with missing data. To examine the distribution of climate change adaptation finance aimed at supporting developing countries' capacity to adapt to climate change separately, we used data from 2010 onwards, when adaptation aid began to be officially reported. The aid includes both grants and loans. Since climate development finance provided by the OECD/CRS includes Official Development Assistance (ODA), Other Official Flows (OOF), private funds, and private gifts, it is necessary to process the raw data separately for each year (see Supplementary 1).

A notable problem with measuring climate aid through climate markers is marker 'overlap'. This is because a single development cooperation project may be assigned multiple markers. The causes, responses, and solutions to environmental problems such as climate change are often intertwined with other environmental problems. A single development cooperation project may be assigned multiple markers due to its inclusive environmental objectives, including addressing climate change, and this should be taken into account when calculating the size of climate development finance to avoid double counting. Mitigation and adaptation markers are also aggregated

separately, so duplicate figures should be excluded when aggregating them into climate development finance to avoid double counting.

This study aggregates the commitments of projects with both mitigation and adaptation markers for project purposes: Principal (Direct Purpose) and Significant (Indirect Purpose). Significant is a vague criterion often subject to arbitrary and subjective judgment by DAC donors, so studies typically use only half of the indirect purpose commitments as valid amounts (AdaptationWatch, 2015; Weiler et al., 2018), and this study follows this standard.

3.3. Independent variables and their data sources

3.3.1. Climate variables: Vulnerability indicators and adaptation indicators

This study extracts and utilizes the Lack of Adaptive Capacity indicator and the Vulnerability indicator from the Notre Dame Global Adaptation Index (ND), which is relatively common in the climate development finance allocation literature. Adaptive capacity is a concept similar to resilience, emphasized in climate development cooperation (Giddens, 2009). In addition, the adaptive capacity indicator is one of the sub-indicators of vulnerability. However, the multicollinearity test between ND indicators by Garschangen et al. (2021) showed that no multicollinearity was found, and there are similar previous studies, so this study decided to utilize both indicators. The indicators are scaled from 0 to 1, with higher values indicating higher climate vulnerability and lower climate adaptation.

The vulnerability indicator uses an average of measures of exposure, sensitivity, and lack of adaptive capacity for six sectors: food, water, health, ecosystems, local environment, and infrastructure, each of which is equally weighted. As with vulnerability, the study averages the corresponding indicators for each dimension, which are equally weighted.

3.3.2. Donor interest variables

Donor interests can be broadly categorized into economic, security, and diplomatic. The prioritized donor interest is the trade volume between DAC donors and recipient countries. Trade-related indices and indicators are the most commonly used variables representing donor interests (Berthélemy, 2006; Martínez-Zarzoso et al., 2014). While the Nordic countries tend to focus on areas with solid humanitarian objectives, such as poverty, human rights, and climate, and seek to comply with the DAC Code, most other donors have a mix of commercial, security, political, and diplomatic realist and humanitarian motives (Gates and Hoeffler, 2004; Karahan, 2022). Trade volumes were calculated as the sum of exports and imports between donor and recipient countries, sourced from UNComtrade. They were set to constant 2021 U.S. dollars, and logarithmic values were used.

It also utilizes the recipient country's military spending as a percentage of GDP. After the September 11 attacks in 2001, when the United States declared the so-called "War on Terror," aid securitization began to reemerge as a significant objective among donors (Ascher, 2016; Spear, 2016). To measure the military factor, this study utilizes data on military expenditure as a share of GDP in recipient countries provided by the Stockholm International Peace Research Institute (SPIRI). This study also considers the diplomatic objectives of donor countries. Diplomacy has been a significant

motivator and purpose of aid throughout the history of international development cooperation, often referred to as "aid diplomacy. (Lancaster, 2008). In this context, we use distance (distance) and former colonial ties (dummy) as explanatory variables for realizing diplomatic benefits by donor countries, and each variable is obtained from CEPII and Harvard Dataverse.

3.3.3. Recipient needs variables

From traditional aid to the Millennium Development Goals (MDGs) to the SDGs, the ultimate goal of aid is poverty alleviation and welfare enhancement in developing countries, and all the factors that make up this goal are the needs of the recipient country. In terms of economic development, GDP per capita (constant 2015, US$), GNI per capita, FDI, etc., are representative, and in terms of shared growth through economic cooperation with donor countries, the volume of trade (export) of the recipient country can also be included as a need. Social development factors include infant mortality rate, child mortality rate under the age of 5, poverty level, maternal and child health, life expectancy, and primary education enrollment rate, which are more humanitarian than economic development factors because they can check the essential quality of life and human rights of people in developing countries. In particular, child mortality rates are often used in development cooperation studies because they are among the most sensitive indicators of social vulnerability (Barman and Talukdar, 2014).

In this study, we use the GDP per capita of the recipient country as a variable for economic status and the under-five child mortality rate as a variable for social vulnerability, each based on data from the World Development Indicators (WDI). We also added a dummy variable for whether a country is a Least Developed Country (LDC) as an indicator that combines social and economic vulnerability. LDCs are categorized by an index that comprehensively reflects GNI per capita, child mortality rate, nutritional intake level, literacy rate, and share of manufacturing in GDP (Kawamura, 2014). It is a variable often used in empirical studies on climate change adaptation, and there are slight differences in the criteria for classifying least-developed countries among international organizations. This study utilizes the OECD/DAC classification system.

3.3.4. Recipient merit variables and other control variables

Improving aid effectiveness has long been a significant challenge for donors (Dietrich, 2016) and a key factor influencing donors' allocation of development resources. Traditional donors have a long history of implementing aid and have begun to recognize that good governance is a prerequisite for aid to be effective, including factors such as institutional soundness, low corruption, stability, and stable laws and institutions in recipient countries (Bourguignon and Sundberg, 2007; Neumayer, 2003). We use the Worldwide Governance Indicators (WGIs) to measure recipient governments' quality. The WGIs have six indicators: Regulatory Quality, Rule of Law, Control of Corruption, Voice and Accountability, Government Effectiveness, and Political Stability and Absence of Violence. The second factor that can be considered is the level of education in the recipient country. The higher the level of education, the more responsive and receptive the recipient country, and the more efficient and effective the aid implementation (Thorbecke, 2000; Adelman, 2000; Arndt, 2000;

Lopes and Theisohn, 2004). We add tertiary education completion rates in recipient countries as a variable related to aid effectiveness, utilizing data from the WDI.

In addition to vulnerability, donor interests, recipient needs, and aid effectiveness, we control for two other variables that may affect the allocation of climate aid. The first is population size, a general characteristic of recipient countries, which is considered in many studies of development finance allocation because countries with larger populations are likely to receive more geopolitical attention (Moon, Seungmin, 2022). Therefore, we add the population size of the recipient country as a control variable in this study. The following is the amount of climate aid from DAC donors in the previous year. Aid can be closely correlated with the previous year's allocation, which can be attributed to aid behavior that gradually increases or decreases the amount of aid from year to year.

3.3.5. Hurdle variables

Table 3. Variables and data sources.

Variables			**Reference**	**Data sources**
Dependent variable		$lnCCMA$	Logarithm of climate aid	OECD/CRS
		$lnCCA$	Logarithm of adaptation aid	
Independent variables	Climate vulnerability	VUL	Notre Dame Global Adaptation Index-Vulnerability	Univ. of Notre Dame
		$\overline{H-VUL}^*$	Notre Dame Global Adaptation Index-Average of vulnerabilities	
	Climate adaptability	CAP	Notre Dame Global Adaptation Index-Climate adaptability	
		$\overline{H-CAP}^*$	Notre Dame Global Adaptation Index-Average of Climate adaptability	
	Donor interests	$lnTRADE$	Logarithm of bilateral trade (imports+exports)	UN Comtrade
		$\overline{H-lnTRADE}^*$	The logarithm of the average value of bilateral trade volume	
		MIL	Military spending as a percentage of the recipient country's GDP (%)	SPIRI
		$\overline{H-MIL}^*$	The average value of military spending as a percentage of GDP in the recipient country (%)	
		$DIST$	The logarithm of the distance between the two countries	CEPII
		$COL(D)$	Whether it was colonized in the past (dummy)	Harvard dataverse
	Recipient needs	$lnGDPP$	The logarithm of the recipient country's GDP per capita (constant 2015, US$)	WDI
		$\overline{H-lnGDPP}^*$	Logarithm of the average value of GDP per capita in the recipient country	
		MOT	Under-5 child mortality rate in recipient country (%)	
		$\overline{H-MOT}^*$	Average under-five child mortality rate in recipient country (%)	
		$LDC(D)$	Least developed country (dummy)	OECD
	Recipient merits	WGI	Quality of government in the recipient country: World Governance Index	WB
		$\overline{H-WGI}^*$	The average value of the recipient country's Global Governance Index	
		EDU	Higher education attainment rate in the recipient country (%)	WDI
		$\overline{H-EDU}^*$	Average value of higher education attainment in the recipient country (%)	
Control variables		$lnPOP$	The logarithm of the population size of the recipient country	
		$L.lnCCMA$	The logarithm of previous year's climate aid	OECD/CRS
		$L.lnCCA$	The logarithm of previous year's adaptation aid	

Note 1. AST (*) is a variable used as a hurdle variable.

The panelized double-hurdle model combines a probit and a Tobit model. The variable entered at the allocation stage, or the first hurdle is called the hurdle variable, and since we are utilizing a probit model, we need time-invariant variables. Therefore, the following time-varying variables were calculated and entered as hurdle variables: vulnerability and adaptive capacity (VUL and CAP), trade volume (lnTRADE), military expenditure (MIL), under-five mortality rate (MOT), tertiary education attainment rate (EDU), and governance quality (WGI), each averaged over the 12 years of 2020–2021. The original time-invariant variables, distance from the source country (DIST) and colonization status (COL(D)), were used without further processing (**Table 3**).

4. Results

4.1. The first hurdle: Selection stage

For the dependent variables lnCCMA and lnCCA, we constructed an all-period (2010–2021) model and a pre-2015 (2010–2014) model. At the selection stage, DAC donors do not consider climate vulnerability and adaptation capacity for both climate aid and adaptation assistance. This does not appear to have changed significantly compared to the pre-Paris Agreement period. According to Weiler et al. (2018), climate aid still tends to follow a pattern similar to development aid allocations. This is further confirmed by the impact of trade volumes and former colonization (**Table 4**).

Table 4. Results of the selection stage analysis.

Model	**DV: $lnCCMA$**		**DV: $nCCA$**	
	ALL-period	**Pre-2015**	**ALL-period**	**Pre-2015**
$\overline{H-VUL}$	1.370	0.444	1.392	0.455
	(0.971)	(0.946)	(0.961)	(0.969)
$\overline{H-CAP}$	−0.309	−0.116	−0.166	−0.0905
	(0.552)	(0.520)	(0.538)	(0.530)
$\overline{H-lnTRADE}$	0.181***	0.193***	0.189***	0.210***
	(0.0102)	(0.0104)	(0.0103)	(0.0110)
$\overline{H-MIL}$	−3.282	−7.503***	−1.243	−4.430
	(2.694)	(2.617)	(2.700)	(2.708)
$DIST$	0.00391	0.168***	0.0606	0.202***
	(0.0480)	(0.0461)	(0.0473)	(0.0481)
$COL(D)$	0.913***	1.167***	0.806***	0.924***
	(0.273)	(0.260)	(0.231)	(0.222)
$\overline{H-lnGDPP}$	−0.693***	−0.702***	−0.760***	−0.842***
	(0.131)	(0.128)	(0.130)	(0.132)
$\overline{H-MOT}$	−0.00478**	−0.000863	−0.00466**	−0.00297
	(0.00233)	(0.00227)	(0.00231)	(0.00231)
$LDC(D)$	−0.0609	−0.0194	−0.116	−0.0477
	(0.111)	(0.106)	(0.110)	(0.108)

Table 4. (*Continued*).

Model	DV: $\boldsymbol{lnCCMA}$		DV: $\boldsymbol{nCCA}$	
	ALL-period	**Pre-2015**	**ALL-period**	**Pre-2015**
$\overline{H-WGI}$	0.000842	0.00137	0.00150	0.00122
	(0.00167)	(0.00165)	(0.00166)	(0.00169)
$\overline{H-EDU}$	−0.00541***	−0.00409**	−0.00629***	−0.00636***
	(0.00204)	(0.00202)	(0.00204)	(0.00211)
Constant	−0.562	−2.371***	−1.205*	−2.551***
	(0.717)	(0.694)	(0.713)	(0.727)
VIF	Max: 3.46	Max: 3.35	Max: 3.41	Max: 3.31
	Mean: 2.07	Mean: 2.00	Mean: 2.06	Mean: 2.05

Note 1. *** is significant at 1% significance, ** is significant at 5% significance, and * is significant at 10% significance. Note 2. Parentheses indicate the standard error.

When allocating climate aid, donor countries are more likely to favor source countries with open markets and active trade in goods and services. High trade volumes imply well-established relationships of mutual benefit and cooperation, so it is natural for donor countries to direct their altruistic aid towards them. However, when climate vulnerability and adaptive capacity are not prioritized, the imbalance in climate aid allocation is bound to arise, and donor countries with former colonies tend to prioritize their former colonized recipients.

Regarding impact, the All-period model has fewer significant variables than the pre-2015 model, but the differences do not appear significant. Donors with colonial experience are mainly developed European countries such as France, Germany, the United Kingdom, Portugal, and Spain, and their former colonies are mainly concentrated in Africa. As most of Africa is highly climate-vulnerable, it seems unproblematic that colonial status should be the main criterion for climate aid allocation, regardless of donor intentions. Nevertheless, the lack of significance of climate vulnerability and climate adaptation raises questions about how climate development finance is targeted to countries with relatively low climate change sensitivity.

4.2. The second hurdle: Allocation stage

The second hurdle is the application of the Panel Tobit model, and even at this stage, there are source countries with zero climate aid received, all of which are considered potential recipients of climate development finance (**Table 5**).

At the allocation stage, a more comprehensive range of factors are considered. Climate vulnerability has a statistically significant relationship with climate aid and adaptation aid for 2010–2021, influencing the allocation levels of DAC donors. However, it cannot be concluded that recipient countries' climate adaptation is still considered. In particular, the neglect of the importance of climate adaptation in selecting adaptation aid recipients and determining allocation amounts suggests that the allocation strategy should be reviewed when considering the Military strength and geographic accessibility tended to be considered more than in the selection stage. The share of military expenditure was found to have a significant negative effect, which

can be interpreted in two ways based on the literature. There are two possible interpretations based on the literature: the recipient's willingness to strengthen its defense capabilities as a security threat or the recipient's support for defense capabilities as a form of development assistance.

Table 5. Results of the allocation stage analysis.

Model	DV: $lnCCMA$		DV: $nCCA$	
	ALL-period	**Pre-2015**	**ALL-period**	**Pre-2015**
VUL	12.18*	10.67	18.00**	24.85**
	(7.333)	(8.768)	(7.894)	(10.12)
CAP	0.207	1.282	−0.228	0.812
	(4.109)	(4.624)	(4.495)	(5.509)
$lnTRADE$	1.113***	0.903***	1.135***	0.875***
	(0.0796)	(0.0987)	(0.0885)	(0.111)
MIL	−26.32**	−32.14*	−30.20**	−42.46**
	(13.03)	(18.66)	(14.22)	(20.93)
$DIST$	1.772***	1.490***	1.849***	1.633***
	(0.384)	(0.453)	(0.401)	(0.515)
$COL(D)$	6.072***	3.945***	6.159***	3.637***
	(1.000)	(1.017)	(1.016)	(1.126)
$lnGDPP$	−9.260***	−8.937***	−8.803***	−7.362***
	(1.048)	(1.260)	(1.112)	(1.410)
MOT	−0.137***	−0.110***	−0.157***	−0.111***
	(0.0168)	(0.0198)	(0.0180)	(0.0227)
$LDC(D)$	1.209	−0.779	2.160**	−0.561
	(0.821)	(0.946)	(0.867)	(1.057)
WGI	0.0655***	0.0672***	0.0601***	0.0752***
	(0.0110)	(0.0147)	(0.0119)	(0.0165)
EDU	−0.0140*	−0.0217	−0.0193**	−0.0330**
	(0.00810)	(0.0144)	(0.00907)	(0.0168)
$lnPOP$	2.396***	2.631***	2.543***	2.809***
	(0.431)	(0.504)	(0.459)	(0.562)
$L.lnCCMA$	0.469***	0.385***	-	-
	(0.0157)	(0.0313)	-	-
$L.lnCCA$	-	-	0.504***	0.382***
	-	-	(0.0170)	(0.0334)
Constant	−26.41***	−19.28***	−33.67***	−34.59***
	(5.830)	(6.939)	(6.198)	(7.968)
Obs.	20,568	7,384	19,158	6,701
VIF	Max: 4.02	Max: 4.19	Max: 4.00	Max: 4.15
	Mean: 2.39	Mean: 2.40	Mean: 2.38	Mean: 2.35
Log-likelihood	−50,967.141	−22,241.05	−46,308.929	−19,781.463

Note 1. *** is significant at 1% significance, ** is significant at 5% significance, and * is significant at 10% significance. Note 2. Parentheses indicate the standard error.

In both cases, the share of military expenditure is negatively related to distance.

On the other hand, in the case of distance, the more geographically distant the recipient country, the more significant the amount of climate aid. This means that donors are less likely to be influenced by their spheres of influence or the geopolitical location of the recipient country when allocating climate aid. Colonial status is also significant after the selection stage, with former colonies receiving more climate aid.

However, the determinants of the recipient country's needs are less clear. The GDP per capita variables are all significant, indicating that donor countries consider recipient countries' economic vulnerability in climate development cooperation. However, for the under-five mortality rate, which is a good proxy for the sensitivity of social vulnerability, we find that climate and adaptation aid decreases as the mortality rate increases. However, being a least-developed country has a positive effect on adaptation aid only.

What do these seemingly contradictory results mean? Why is economic vulnerability considered in the allocation of climate development finance, but the impact of social vulnerability is unclear? There are two possible explanations: first, countries with high social vulnerability are more likely to implement social infrastructure projects, such as primary healthcare and essential services or humanitarian aid, than climate change projects (CCFAH, 2023), and second, climate development finance tends to be more significant for LMICs-UMICs than for LDCs (ICRC, 2021).

On the other hand, unlike the selection stage, the quality of the recipient country's government impacts the allocation stage significantly. All of them are positive at the 1% significance level, suggesting that donors first determine potential recipients and then consider aid effectiveness. In other words, donors believe that the higher the level of integrity, political stability, norms, and legal order of the recipient government, the more efficiently and transparently the resources will be utilized.

The results from both phases of the two-stage analysis show some differences from previous studies. Islam (2022) showed that climate vulnerability only affects mitigation finance and not adaptation finance and overlap finance, which may not be easily comparable to studies that analyze the selection and allocation process separately, and the variables used are also limited by structural limitations of panel data that exclude the interests of donor countries (DI). In the study of Weiler et al. (2018), the physical vulnerability of the recipient country affects both the selection and allocation stages, with more physically vulnerable countries being more likely to be selected as recipients and receiving larger amounts of aid. On the other hand, Saunders (2019), using both physical and social climate vulnerability, found that the more vulnerable a country is, the less likely it is to be selected as a recipient and the larger the amount of aid. This study indicates that climate vulnerability does not affect the selection stage. However, it does affect the allocation size, which means the affection of climate vulnerability in each stage is different.

5. Conclusion and discussion

This study analyses the determinants of climate development finance allocation in OECD/DAC donor countries using a panel double hurdle model, and the results are divided into the selection and allocation stages. Overall, the results show that donor

countries consider more factors in the allocation phase than in the selection phase, which determines the size of climate development finance. Aid effectiveness has become increasingly important, and most donors operate a 'Country Partnership Strategy', which is selecting and managing "priority countries", to implement selective and targeted aid. Therefore, it would be difficult to change the number of source countries targeted for allocations significantly. On the other hand, the size of climate development finance is relatively volatile due to various internal and external conditions, so it is expected to be influenced by many factors at the allocation stage.

Next, among climate vulnerability and climate adaptive capacity, only climate vulnerability at the allocation stage showed a significant relationship. This suggests that countries with high climate vulnerability may not be the same countries that receive climate finance allocations or countries with large climate finance allocations. Furthermore, for social and economic vulnerability, while economic vulnerability is generally significant, the opposite is true for social vulnerability. Higher social vulnerability tended to be associated with a lower likelihood of being included in the allocation or receiving less funding.

Economic and diplomatic interests, which correspond to the interests of donor countries, remain a significant factor, confirming existing strategic aid practices such as mercantilist aid, commercial aid, and aid diplomacy. It is also worth noting that the significant differences in the determinants of allocation between overall climate aid and adaptation aid are challenging to explain.

A comprehensive analysis of the selection stage, where potential recipients are identified, and the allocation stage, where the amount of funding is determined, can be summarised by three features. First, donors consider more factors in determining the size of development finance than in selecting recipient countries. With the emphasis on selection and focus on improving aid effectiveness, most donors operate a system of priority partner countries, and in this context, the targeting of resources is not expected to change significantly from year to year. However, funding sources are subject to unpredictable fluctuations in tax revenues and economic, political, and social conditions so that funding can increase and decrease frequently. Due to these characteristics, it is estimated that the influence of more factors can be identified at the allocation stage than at the selection stage.

Second, climate vulnerability is only significant at the allocation stage, suggesting that the distribution of recipient countries may not match the distribution of countries with high climate vulnerability in other words, climate vulnerability is considered less in selecting adaptation finance recipients than in determining the scale of climate-related development finance.

Climate adaptation is not significant at either the selection or the allocation stage.

Third, while economic vulnerability is significant at all stages, higher social vulnerability tends to be associated with a lower likelihood of inclusion and smaller allocations. Furthermore, being a least developed country, which includes both social and economic vulnerability, is largely unrelated to the allocation of development finance. This is related to the second characteristic, which is that donors tend to allocate more resources to middle-income countries (LMICs-UMICs) than to the least socially vulnerable countries (LDCs). This trend also appears to apply to the climate sector.

We note that the allocation of climate development finance is similar to the pattern of the development finance allocation. We find that factors such as Donor Interests, Recipient Needs, and Recipient Merit also significantly impact the allocation of climate-related development finance, providing the theoretical implication that the allocation of finance follows the path dependence theory. And based on our findings of empirical analysis, we offer three policy implications. First, OECD/DAC donors should consider establishing differential allocation mechanisms in the climate sector of development cooperation to achieve the climate-resilient development goal. The current international debate on climate issues is essentially a matter of financing, with climate development cooperation centered on middle-income countries. The implication emerges from the analysis in this study, where the impact of climate vulnerability was not identified at the selection stage. Amidst the prolonged global recession, many donor governments are reducing the size of their development funds, and there are concerns about the amount of funds flowing to the climate sector within the limited development funds. In other words, it is argued that development funds for essential social services such as medical care, health care, food, and humanitarian aid to socioeconomically vulnerable countries are being pushed aside in favor of climate development funds. While there is a need to increase the scale of development and climate finance, this is not always easy to realize.

However, given the trend toward mainstreaming climate change in all areas of development cooperation, it is possible to propose a solution that considers separating the climate-related development assistance system rather than implementing economic decoupling in climate-related development budgets. This may be worth considering as a partial mitigation strategy to apply the donors' development finance allocation patterns revealed in this study to climate development finance allocation.

Second, in promoting aid effectiveness through 'selection and focus', OECD/DAC donors should consider selecting priority partner countries in the climate sector based on their level of climate vulnerability, climate-resilience, and climate-readiness. Currently, most donor countries' development cooperation policies adopt the priority partner system and use it to select target countries when allocating development resources. The question is, what are the criteria for selecting priority countries? The criteria for selecting priority partners vary from donor to donor, and the exact methodology is unclear. But in some countries, colonial linkage or distance, which is one of the key variables used in this study, has a significant impact on the selection of priority countries. As mentioned, France selects its former colonies as priority partners regardless of their social, economic, and climate vulnerability. In the case of South Korea and Japan, the selection process tends to focus on ASEAN, but it is unclear what exactly the criteria are. If the controversial Priority Partner system is applied to climate development cooperation, it could have an impact on widening the climate gap between developing countries.

Finally, a discussion of the climate-related development indicator would be required for the effectiveness of cooperation for climate change. For the proper allocation of climate-related development finance, a new climate index comprising climate vulnerability, climate hazard, and climate adaptive capacity, which the IPCC's Assessment Reports (ARs) have continued to emphasize, should be developed and provided. In this study, we used ND-GAIN from the University of Notre-Dame, and

as mentioned earlier, there are other climate vulnerability indices such as WRI, INFORM, and CRI. However, the results could be different due to different criteria and indicators, so the results may vary depending on which indicator is used. Therefore, our finding suggests that developing standardized climate indicators improves the reliability of research on climate-related development cooperation and climate-related development finance.

However, this study is limited in scope because it focuses only on bilateral climate development finance when the discussion on mobilizing innovative development finance is expanding due to the lack of climate finance. As climate finance inevitably overlaps (Ko, 2021), we hope to contribute to the effective mobilization of climate finance by expanding the scope of the study to include a broader range of funding sources.

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