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DISCUSSION PAPER

// CLAIRE GAVARD AND NIKLAS SCHOCH

Climate Finance and Emission Reductions: What Do the Last Twenty Years Tell Us?

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Climate Finance and Emission Reductions: What Do the Last Twenty Years Tell Us?

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*Claire Gavard and Niklas Schoch**

Abstract: In the framework of the Paris Agreement implementation, financial transfers remain a major point of negotiation for addressing equity concerns raised by the ambitious climate objectives. In complement to the theoretical, experimental and numerical studies that have examined the role of transfers in facilitating coalitions, we conduct the first empirical analysis of their impact on national carbon emission reductions. We build on the existing literature to develop a conceptual framework which models continuous national emission choices in the presence of financial transfers. We infer an equation of the impact of mitigation and adaptation finance on national emissions of recipient countries. We test the derived hypothesis using carbon emissions data of non-OECD countries in the last 20 years. We find that public adaptation and mitigation finance tend to increase emissions. Private mitigation finance seems to reduce them only after five years following the transfers.

Keywords: International environmental agreements; public goods; transfers; climate finance; emission reductions; adaptation; climate policy
JEL classification: C23, C70, D02, K33, Q54, Q58

*Gavard: ZEW Mannheim (claire.gavard@zew.de); Schoch: ZEW Mannheim, University of Mannheim (nschoch@mail.uni-mannheim.de); Corresponding author: claire.gavard@zew.de.

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1 Introduction

Within the Paris Agreement, countries have agreed to set the objective to limit global warming to a maximum of 2°C above preindustrial levels. Reaching this goal requires significant global emission reduction efforts involving all major carbon emitting nations. Addressing equity concerns related to the distribution of these abatement efforts is a major requirement for successful international climate cooperation. The United Nations Framework Convention on Climate Change (UNFCCC) acknowledges the necessity of a fair burden sharing accounting for "common but differentiated responsibilities and respective capabilities" (UNFCCC, 1992). With international climate action moving forward, financial transfers remain a key point of negotiation for moderating these equity concerns and, in particular, assisting developing countries in facilitating mitigation and adaptation, as stated in Article 9 of the Paris Agreement (United Nations, 2015). It urges developed countries "to provide financial resources to assist developing country Parties" for both climate change mitigation and adaptation, and recognizes relevant capacity constraints of developing countries for national climate policies. It also rules that financial transfers are to be incorporated in the global stockdate process specified in Article 14 of the agreement. At the 26^{th} Conference of the Parties (COP 26), the decision was taken to initiate new goals in climate finance mobilisation from a floor of $100billion.[1,2] Such negotiations call for empirical evidence of the impact of financial transfers in emission reductions, evidence on which to set appropriate financing targets. An improved understanding of the historical impact of climate finance transfers will help inform the future steps in the Paris Agreement implementation, and in particular the global stocktake exercise planned in 2023.

While many theoretical and experimental studies have focused on the topic, little empirical analysis has been conducted so far. This paper takes advantage of the historical experience since the RIO Earth Summit in 1992 in order to draw lessons for the current negotiations about how financial transfers can adequately support reaching long term climate objectives.

To do so, we build on the existing literature to develop a conceptual framework analyzing the continuous emissions choice by non-cooperative agents in the presence of international financial transfers. The model gives rise to the implication that transfer payments can help incentivize emission reductions.

To test this hypothesis, we utilize a panel of country-level emission data and estimate the impact of public mitigation and adaptation finance as well as private mitigation investment on emissions.

[1]Decision 14 of COP 24 serving as the first meeting of the Parties to the Paris Agreement (CMA1) in Katowice 2018.

[2]Due to the COVID-19 pandemic, COP 26, initially planned in Glasgow at the end of the year 2020, will not take place before 2021.

We estimate the model with a generalized least squares estimator in first-differences (FDGLS), accounting for potential with-in country autocorrelation of the residuals. We thereby allow for feedback from current emissions to future transfers and avoid this to compromise the consistency of our estimates. Assuming contemporaneous exogeneity, we employ lagged transfer variables to account for the fact that the effect of transfers may take time to fully develop. This requires using a correctly specified lag-dynamic of our independent variable.

Contrary to expectations, we find that public mitigation and adaptation finance tend to induce a rise in emissions: one additional billion dollars of adaptation finance per million tons of national carbon emissions would increase them by 1.74%, one additional billion dollars of public mitigation finance per million tons of national emissions by 1.05%. This might be due to associated construction activities and enhanced economic activities. We do not observe a significant impact of CDM investment (proxy for private mitigation finance) on emissions in the five years following the transfers but a negative effect in the sixth year.

The current academic literature has recognized the importance of equity and fairness in international climate negotiations, but it has mainly approached this topic through the lens of coalition formation in public good games. It applies these game-theoretic approaches to the formation and stability of international environmental agreements (IEAs). Acknowledging the Westphalian sovereignty of states, the literature emphasizes the necessity of self-enforcing agreements, since a country's decision to enter any international contract must be voluntary (Treaty of Vienna, 1969; Nordhaus, 2015). An issue of international cooperation in climate policy is to address the inherently strong free-riding incentives (Nordhaus, 2015). Models rooted in non-cooperative game theory have produced rather pessimistic results about the formation of international environmental cooperation with a large number of participating agents (Barrett, 1994). Many studies have subsequently incorporated a range of measures into the game theoretic literature on coalition formation and investigated their effectiveness in managing these free-riding incentives to ensure the stability of international cooperation on climate change. Proposed instruments to negotiate self-enforcing IEAs other than transfers vary from punishments for deviations (Mason et al., 2017), the formation of 'climate clubs' where the participation in a trade-agreement is conditional on emission reduction efforts (Nordhaus, 2015) to technology transfer and investment into climate change adaptation (Yang and Nordhaus, 2006; Li and Rus, 2019; Rubio, 2018). Other studies incorporate heterogeneity amongst players (Pavlova and de Zeeuw, 2013) or inequality averse preferences (Vogt, 2016) and find only small stable coalitions amongst heterogenous players in the global climate game.

The most widely discussed way to reduce free-riding incentives and facilitate stable coalition formation amongst the players is by sharing the cost of emission reductions via financial transfers. There are two common means to model financial transfers in international coalition formation, either as a surplus sharing amongst coalition members or as direct incentive payments. We consider the two possibilities in the conceptual framework we develop below. Studies of surplus sharing in global climate coalitions find that an appropriate design of transfer schemes can stabilize IEAs in global climate policy (Weikard et al., 2006; Nagashima et al., 2009; Finus et al., 2006; Carraro et al., 2006; Lessmann et al., 2015; Tulkens and Chander, 1998). Direct transfer payments bribing other agents into coalition participation can also constitute optimal behavior for some agents and thereby help reduce global emissions below non-cooperative levels (Ansink et al., 2018; Carraro et al., 2006; Fuentes-Albero and Rubio, 2010). Especially strong asymmetry among players can result in an equilibrium, where side-payment from richer to poorer countries to form a stable coalition emerge as an equilibrium outcome (Barrett, 2001). This literature typically combines theoretical results with numerical simulations using data from well-established integrated assessment models, and countries usually face a dichotomous choice of entering a coalition or unilaterally choosing its optimal emissions.

Our work contributes to the literature on global climate policy and financial transfers in two ways. It is the first empirical analysis of the impact of financial transfers on emission reductions. Relying on historical data rather than on numerical simulations enables us to complement the current literature and provide evidence-based insights for the Paris Agreement implementation. To derive the econometric model, we extend the current theoretical literature by relaxing the focus on coalition formation and modelling a continuous choice of emissions by each country in the presence of transfers. We wish to thereby better reflect the current negotiations, in particular in the framework of the Paris Agreement, where nationally determined contributions (NDCs) are negotiated amongst membership parties.

In the following section, we develop the model for the global emissions game and consider two approaches to integrate financial transfers into it. In Section 3, we explain our empirical strategy to test the theoretically derived hypotheses. We present the data employed as well as discuss the estimation results. In Section 4, we conclude and discuss the policy implications of our analysis.

2 Conceptual Framework

2.1 The global emissions game

We proceed by modeling the global emissions game and incorporate financial transfers following two approaches supported by the current literature. We develop the latter by assuming that there is no international coalition and countries behave as individual utility maximizers. The reader may raise the concern that there are existing international environmental agreements in place. However, following Nordhaus (2007) or Murdoch and Sandler (1997), one can consider that these agreements simply codify the emission levels observed in a non-cooperative Nash-equilibrium, i.e. under the assumption of individual utility maximization.

2.1.1 No financial transfers

We start with the optimal emission choice of country i in the absence of financial transfers. Following Li and Rus (2019), the welfare of country i can be expressed as the benefits received from emissions minus climate-induced damages

$$W_i = B_i(e_i) - D_i\left(\sum_{j=1}^{N} e_j\right), \tag{1}$$

with $B_i(e_i)$ denoting the benefits country i receives from emitting e_i and $D_j\left(\sum_{j=1}^{N} e_j\right)$ the damages caused by global emissions $\sum_{j=1}^{N} e_j$ to country i.

Country i chooses its optimal emission level maximising its welfare with respect to emissions. Its maximisation reads as

$$\max_{e_i} W_i(e_i) = B_i(e_i) - D_i\left(\sum_{j=1}^{N} e_j\right). \tag{2}$$

The first-order condition (FOC) of this maximisation problem is given by

$$\frac{\partial W_i(e_i)}{\partial e_i} = \frac{\partial B_i(e_i)}{\partial e_i} - \frac{\partial D_i\left(\sum_{j=1}^{N} e_j\right)}{\partial e_i} \stackrel{!}{=} 0. \tag{3}$$

The subsequent optimality condition is

$$\frac{\partial B_i(e_i)}{\partial e_i} = \frac{\partial D_i\left(\sum_{j=1}^{N} e_j\right)}{\partial e_i} \quad \forall i \in N. \tag{4}$$

As a country does not internalize the damages its emissions impose on other countries, the resulting emission level from individual maximization is too high and a reduction of emissions increases global welfare (Samuelson, 1954).

2.1.2 Transfers as surplus sharing

A large body of the literature on global emission reductions focuses on the implementation of international cooperation as a means to fix this problem. International coalition formation in emission reduction can result in the internalization of external damages from emissions. Countries engaging in international cooperation take into account the damage of their emissions on other coalition members and reduce their emissions (Vogt, 2016). This yields a global welfare surplus compared to the situation of individual maximization. One can distribute this surplus amongst coalition members such that the new allocation achieves a Pareto-improvement as compared to the non-cooperative emission behavior.

In the existing coalition formation literature, countries usually face a dichotomous choice between joining an international coalition, or remaining non-signatory (Weikard et al., 2006; Carraro et al., 2006; Finus et al., 2006; Vogt, 2016; Tulkens and Chander, 1998). Transfers are then modelled as a redistribution of coalition surpluses in the emissions game. In contrast, we want to establish a surplus sharing scheme for a continuous emission choice. Our model describes a global emissions game with a pre-agreed transfer scheme redistributing the welfare surpluses obtained from unilateral continuous emission reductions. To better see how the theoretical model reflects real negotiations, one can think of this transfer scheme as negotiating parties making further emission reductions conditional on extended financial commitments from the international community. As a result, the amount of transfer received is a function of the emission reductions of the recipient country.

We propose the following structure of the game to model this negotiation behavior: There exists an exogenously given transfer scheme, granting each country a share of the welfare surplus resulting from its emission reduction. Countries then choose their optimal emission level knowing the transfer scheme will be enforced.

From the Samuelson rule (Samuelson, 1954), we know that a reduction of emission below the non-cooperative level will yield a global welfare increase. The increase arises since, for any emissions above the globally optimal emission level,[3] the foregone benefits for country i when reducing its emissions are outweighed by the relieved damages to the other countries. The surplus of emission reduction is defined as the increase in global welfare arising from this emission reduction.

Mathematically, the global surplus induced by the reduction in emissions of country i from the non-cooperative level $e_i^{'}$ to e_i can be expressed as

$$SU = B_i(e_i) - B_i(e_i^{'}) - \sum_{j=1}^{N} \left(D_j \left(e_i, \sum_{k \neq i}^{N} e_k \right) - D_j \left(e_i^{'}, \sum_{k \neq i}^{N} e_k \right) \right). \tag{5}$$

It holds that

$$SU > 0 \quad \forall \ e_i^{'} > e_i > e_i^*, \tag{6}$$

with e_i^* denoting the global optimum.

[3]The global optimum are the emissions resulting for all countries incorporating all damages of their emissions on all other countries.

It follows that the surplus arises due to the prevented damages to all other countries. We define these global prevented damages (GPD) as

$$GPD = \sum_{j=1}^{N} \left(D_j \left(e_i^{'}, \sum_{k \neq i}^{N} e_k \right) - D_j \left(e_i, \sum_{k \neq i}^{N} e_k \right) \right). \tag{7}$$

When choosing their optimal emission level, countries now take into account the transfer payment they receive for reducing their emissions. The magnitude of this transfer depends on the share of surplus λ each country receives. The simplest choice for λ is a Nash-bargaining solution, as described by Carraro et al. (2006). It implies equal shares for all. Other mechanisms are also possible (Sheriff, 2019). Our analysis below is valid for any arbitrary choice of the sharing vector $\lambda = (\lambda_1, ..., \lambda_N)$, assigning each country i an individual λ_i.

Knowing about its individual share λ_i, which it will receive when reducing its emission below the non-cooperative level, the maximisation problem of country i reads as

$$\max_{e_i} W_i = B_i(e_i) - D_i \left(\sum_{j=1}^{N} e_j \right) + \lambda_i GPD. \tag{8}$$

The resulting FOC

$$\frac{\partial W_i(e_i)}{\partial e_i} = \frac{\partial B_i(e_i)}{\partial e_i} - \frac{\partial D_i \left(\sum_{j=1}^{N} e_j \right)}{\partial e_i} + \lambda_i \left(\frac{\partial GPD}{\partial e_i} \right) \stackrel{!}{=} 0 \; \forall i \in N \tag{9}$$

yields the optimality condition

$$\frac{\partial B_i(e_i)}{\partial e_i} = \frac{\partial D_i \left(\sum_{j=1}^{N} e_j \right)}{\partial e_i} + \lambda_i \sum_{j=1}^{N} \left(\frac{\partial D_j \left(\sum_{k=1}^{N} e_k \right)}{\partial e_i} \right) \; \forall i \in N. \tag{10}$$

We define the marginal transfer as the increase in transfer per unit of emission reduction and obtain

$$-\frac{\partial tr_{j,i}(e_i)}{\partial e_i} = -\lambda_i \left(\frac{\partial GPD}{\partial e_i} \right) = -\lambda_i \sum_{j=1}^{N} \left(\frac{\partial D_j \left(\sum_{k=1}^{N} e_k \right)}{\partial e_i} \right). \tag{11}$$

Equation 10 can thus be expressed as

$$\frac{\partial B_i(e_i)}{\partial e_i} = \frac{\partial D_i \left(\sum_{j=1}^{N} e_j \right)}{\partial e_i} - \frac{\partial tr_{j,i}(e_i)}{\partial e_i} \; \forall i \in N. \tag{12}$$

In (4), the benefits for country i to emit an additional unit must only compensate the resulting damage to itself. In contrast, in (10), the additional benefits must also compensate for the damages to all other countries, represented by the transfer received. Equation (12) shows that this means it also accounts for the reduced transfer when emitting an additional unit. The second term on the right-hand side shows by how much the transfer increases with an additional unit of emission reduction, which is how we defined the marginal transfer in (11). The marginal benefit in optimum in (10) or (12) is then higher than in (4).

Assuming concave benefit and convex damage functions is a standard assumption in the literature, e.g. in Li and Rus (2019). This means transfers decrease the amount of emissions. Intuitively, when receiving a larger share of the surplus (meaning a larger transfer), a country incorporates a larger share of the avoided damages caused by its emissions to other countries into its maximization. This results in a reduction of the optimal emission level. We examine the optimality condition (9) further when deriving analytic expressions for a country's optimal emission choice.

2.1.3 Transfers as direct incentive payments

We now present direct incentive payments as an alternative way to consider financial transfers. We develop an emissions game with donor and recipient countries. The donor countries choose to pay recipient countries transfers, where the transfer amount depends on the recipient's emission choice. This approach is inspired by Ansink et al. (2018), where donor countries incentivize recipient countries to join a coalition. They show that there exists a Nash-equilibrium with a positive number of supporters who find it optimal to directly incentivize the behavior of recipient countries with financial transfers. We adapt their approach in order to model a continuous emission choice of the recipient countries.

The structure of the game is as follows: there are N donor countries and M recipient countries. Each donor chooses to pay transfers to the recipients to incentivize emission reductions. To do so, each donor sets a transfer scheme, where the transfer paid depends on the recipients final emissions. Given the structure of the transfer scheme, each recipient chooses its optimal emission level.

The maximisation problem of a donor country j is now

$$\underset{e_j,\sum_{i=N+1}^{N+M} tr_{j,i}}{max} W_j^D = B_j^D(e_j) - D_j^D\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right) - \sum_{j=N+1}^{N+M} tr_{i,j}(e_j), \tag{13}$$

where W_j^D denotes the welfare of donor j, consisting of the benefits of emissions $B_j^D(e_j)$ depending on its own emissions e_j, the damages from global emissions $D_j^D\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right)$, the transfers $tr_{j,i}$ paid to recipient i by donor j, and the total amount of transfers recipient i receives from the N donors $tr_i = \sum_{j=1}^{N} tr_{j,i}$.

We first model how a donor sets an incentive-compatible transfer scheme. To derive this optimal transfer scheme, we adapt the approach developed by Habla and Winkler (2013). The transfer scheme has to satisfy the following conditions:

1. The donor cannot be worse-off when paying the transfer as opposed to not offering it. The reduced damage due to e_j has to compensate the transfer.
2. The recipient has to find it optimal to reduce its emissions and receive a transfer, as opposed to unilaterally choosing its emissions.
3. The donor pays the minimal necessary transfer to convince the recipient to reduce its emissions and receive the transfer.

We propose the following transfer scheme

$$tr_{j,i}(e_i) = max[0, W_j^{D*} - \overline{W}_j^D], \tag{14}$$

with W_j^{D*} being the realised welfare of donor j depending on the emissions of recipient i, net of all transfers

$$W_j^{D*} = B_j^D(e_j) - D_j^D\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right) \tag{15}$$

and $\overline{W}_j^D$ some fixed reference welfare with

$$\overline{W}_j^D \geq W_j^{D'}, \tag{16}$$

where $W_j^{D'}$ denotes the donor's welfare under unilateral maximisation of all countries. Condition (16) states that $\overline{W}_j^D$ is at least as high as the donor's welfare in case of non-cooperative emissions and ensures the donor is not worse-off through the transfers.

From (14), we obtain the marginal transfer

$$-\frac{\partial tr_{j,i}(e_i)}{\partial e_i} = -\frac{\partial W_j^{D*}(e_j)}{\partial e_i} = \frac{\partial D_j^D(e_j)}{\partial e_i}. \tag{17}$$

The resulting mechanism of the transfer scheme is as follows: by conditioning the amount on some reference welfare $\overline{W}_i^D$ satisfying $\overline{W}_j^D \geq W_j^{D'}$, the donor ensures to never be worse-off under the transfer scheme. But since $\overline{W}_j^D$ is fixed, the marginal transfer is unaffected by $\overline{W}_j^D$ and equals the marginal effect of the recipient's emission on the donor. Thus, the donor country sets the marginal transfer to exactly equal the relieved damages if a recipient decreases its emissions. This property ensures full internalization of the external damages on the donor by the recipient.

Knowing this transfer scheme, the recipient maximizes

$$\max_{e_i} W_i^R = B_i^R(e_i) - D_i^R\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right) + \theta_i \sum_{j=1}^{N} tr_{j,i}(e_i), \tag{18}$$

with W_i^R denoting the welfare of recipient country i, consisting of the benefits of emissions $B_i^R(e_i)$ depending on its own emissions e_i, the damages from global emissions $D_i^R\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right)$, the transfers $tr_{j,i}$ paid to recipient i by donor j, and a recipient-specific scaling factor θ_i, indicating how much the transfer is valued.

The resulting FOC

$$\frac{\partial W_i^R}{\partial e_i} = \frac{\partial B_i^R(e_i)}{\partial e_i} - \frac{\partial D_i^R\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right)}{\partial e_i} + \theta_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i} \stackrel{!}{=} 0 \tag{19}$$

yields the optimality condition

$$\frac{\partial B_i^R(e_i)}{\partial e_i} = \frac{\partial D_i^R\left(\sum_{j=1}^{N} e_j, \sum_{i=N+1}^{N+M} e_i(tr_i)\right)}{\partial e_i} - \theta_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i}. \tag{20}$$

The marginal benefits of emissions are now equated to the own marginal damages plus the sum of the marginal transfers from all donor countries. In comparison to Equation (4), the marginal benefits are higher as they include the transfers. They hence incentivize an emission reduction. Note that this framework does not yield a global optimum since donor countries do not internalize the damages they impose on recipient countries and damages imposed on each other.

2.2 Introducing functional forms for the benefit and damage functions

To deduct an equation for the empirical estimations, we impose functional forms on the benefits and damages. In a first-step, we wish to abstract from strategic interactions in the optimal emission setting and impose a linear marginal damage function. Current emissions of a single country are always small compared to global cumulative emissions. This means that mapping emissions to damages via a linear specification is a good approximation. It is also consistent with the current literature (Habla and Winkler, 2018; Holtsmark and Weitzman, 2020).

Using the definition employed by Habla and Winkler (2018), we propose the following structural forms for the benefit and damage functions. We define the benefit function as

$$B_i(e_i) = \frac{1}{\phi_i} e_i \left(\epsilon_i - \frac{1}{2} e_i\right) \quad \text{with} \quad e_i \in (0, \epsilon_i), \tag{21}$$

where ϵ_i denotes the maximal emissions, which are the emissions a country would choose in the absence of any damages, e_i the realised emissions of country i and ϕ_i a country-specific scaling of the marginal benefits.

This specification exhibits diminishing marginal benefits:

$$B_i^{'}(e_i) = \frac{\epsilon_i - e_i}{\phi_i} \geq 0 \;\; \forall \;\; e_i \leq \epsilon_i \tag{22}$$

$$B_i^{''}(e_i) = -\frac{1}{\phi_i} < 0. \tag{23}$$

We define the damage function as

$$D_i(E) = \delta_i E, \tag{24}$$

where E denotes the global emissions and δ_i country-specific marginal damages.

This specification exhibits constant marginal damages:

$$D_i^{'}(E) = \delta_i \tag{25}$$

$$D_i^{''}(E) = 0. \tag{26}$$

We use the definitions (21) and (24) to obtain the equation describing the optimal emission choice under the two transfer schemes from (10) and (20).

Transfers as a surplus sharing

In the approach considering transfers as surplus sharing, we obtain

$$\frac{\epsilon_i - e_i}{\phi_i} = \delta_i - \lambda_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i} \tag{27}$$

$$e_i = \epsilon_i - \phi_i \delta_i + \phi_i \lambda_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i}. \tag{28}$$

Transfers as direct incentive payments

In the approach considering transfers as direct incentives, we obtain

$$\frac{\epsilon_i - e_i}{\phi_i} = \delta_i - \theta_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i} \tag{29}$$

$$e_i = \epsilon_i - \phi_i \delta_i + \phi_i \theta_i \sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i}. \tag{30}$$

In both cases, e_i negatively depends on the marginal damages, δ_i, and the sum of the marginal received transfers per emission reduction, $\sum_{j=1}^{N} \frac{\partial tr_{j,i}(e_i)}{\partial e_i}$. Equations (28) and (30) give rise to the testable implication that transfer payments from donor countries can incentivize emission reductions in recipient countries.

3 Empirical analysis

3.1 Econometric Specification

We now empirically test the hypothesis derived from the theoretical framework developed in Section 2 that transfer payments from donor countries can incentivize emission reductions in recipient countries.

Equations (28) and (30) both express the optimal emission decision as a function of the transfers received per unit of reduced emissions. We cannot directly observe the marginal transfers. We use the available transfer data in absolute levels and normalize them by the one-year lagged emissions from the recipient countries. By doing so, we inspire from Feyrer et al. (2016) to address the challenge that an additional billion of dollars of transfers to a very small country (like a small island state) is likely to have a very different effect than the same amount of transfers to a major world economy such as China.

We exploit the panel-structure of our data and opt for a country fixed-effect specification, as presented in Equation (31) below, estimating an unrestricted finite distributed lag model.[4] We decompose the transfers in mitigation and adaptation finance. Marginal damages are represented by the national vulnerabilities and included in the set of controls $X_{i,t}$, together with the national GDP, population and industry share of value added. α_i represents the country fixed-effect, ω_t the time fixed-effects and $\upsilon_{i,t}$ the error term

$$\begin{aligned} ln(Emissions_{i,t}) = & \sum_{s=1}^{6} \beta_{a,s} AdaptationFinance_{i,t-s} + \sum_{s=1}^{6} \beta_{m,s} MitigationFinance_{i,t-s} \\ & + \gamma X_{i,t} + \alpha_i + \omega_t + \upsilon_{i,t}. \end{aligned} \tag{31}$$

We estimate the model in first-differences to adress country-specific heterogeneity without having to impose strict exogeneity. Therefore, possible feedback from emissions to future transfers does not compromise the consistency of our estimates. The use of lags for the financial transfers reflects

[4]The decision to include a country-fixed effect is based on a Hausmann-test indicating the existence of a country fixed-effect.

the potential time it takes for payments to impact emissions. Assuming that there is no contemporaneous reverse causality, we can estimate the effect of the first lag without endogeneity issues. We employ a feasible generalized least squares estimator to ensure we obtain efficient estimates in the presence of country-specific autocorrelation of the residuals.[5] In order to validate the necessary sequential exogeneity assumption and to ensure the consistency of our estimates, we have to assume a correctly specified lag-dynamic of our dependent variable. We conduct robustness check including lagged emissions as explanatory variable and show, in Section 3.3, that the results hold. We conduct additional robustness checks with other with-in country correlation structures, such as the canonical random-effects correlation matrix.

Our estimates have to be interpreted as an Intent-to-Treat estimate (ITT) as what we observe is the value of transfer commitments.

3.2 Data

For the econometric analysis, we build a panel containing data covering 204 countries and territories from 2005 to 2017.[6] We identified 34 donor countries, which we exclude from the estimations. Due to data limitations, we keep 168 mostly non-OECD recipient countries in our estimation sample.[7] They receive transfers from 34 richer countries. The estimates consider only the transfers from donor to recipient countries.

Emissions

We use the CO_2-emission data from the interdisciplinary research project "Global Carbon Project" (Le Quere et al., 2018). This dataset synthesizes estimates from varying sources into one comprehensive panel. It combines estimates from the Carbon Dioxide Information Analysis Center (CDIAC) - which estimates historical emissions based on coal, oil, and gas consumption (Marland et al., 2008) - with the official UNFCCC inventory reports (UNFCCC, 2018) published for 42 Annex-I countries whenever available.[8]

Control Variables

Our controls include data on GDP (World Bank, constant 2010 $), population (World Bank) and the percentage of the national value added that is produced in the industry sector (World Bank). These are natural drivers of CO_2 emissions. We also include the Notre Dame Climate Vulnerability

[5]We use a portmanteau test for fixed-effects models suggested by Inoue and Solon (2006) and find evidence of residual autocorrelation.

[6]The original data sources include a number of offshore territories of OECD countries, such as Puerto Rico and French Martinique, which have separate data-points. These offshore territories from OECD countries are excluded from the estimations.

[7]A detailed list can be found in Appendix 5.1

[8]In this dataset, emissions caused by cement production are included using the estimates by Andrew (2018).

Index published by the Global Adaptation Initiative of Notre Dame University (Chen et al., 2015).[9] We utilize the dataset indicating a country's vulnerability to climate change and extreme weather events in order to obtain a measure for the damages a country faces due to global emissions. We add a range of potential control variables identified in the literature (Halimanjaya, 2015), such as the "Political Stability and No Violence" indicator from the World Governance Indicators (Kaufmann et al., 2010) and forest area as percentage of land-mass published by the World Bank.

Transfer Payments

To measure transfer payments, we use financial inflow data from private and public sources to potentially identify different effects on emissions. For public transfer flows, we follow Halimanjaya (2015) and employ data from the OECD RIO marker database. In the latter, public finance flows from OECD to non-OECD countries are marked as a function of their relevance for various environmental considerations. Climate change mitigation and adaptation are the markers of interest for our analysis.

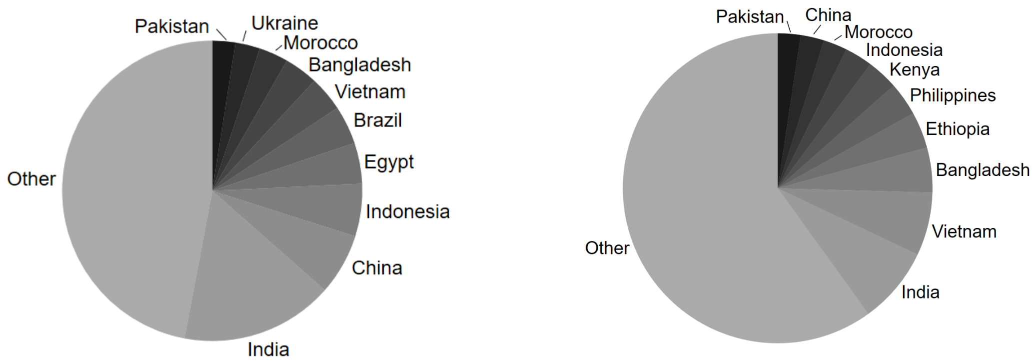
According to the Handbook on OECD DAC Climate Markers (OECD, 2011), activities eligible for the mitigation marker include investments into renewable energy generation, waste management to produce biofuels, and the promotion of energy efficiency standards for industrial production. For example, this marker was used for projects such as the construction of hydro-power plants in Georgia, the promotion of the use of biogas in Brazil, and the development of public urban mobility to minimize transport emissions in Ghana. Activities eligible for the adaptation marker include the promotion of climate-resilient agriculture, food protection measures and water resource conservation. One example of projects classified as adaptation-related is the protection of rural communities against extreme weather events by building dikes and other climate resilient infrastructure measures in transportation, water supply and health care in Laos. Other examples of adaptation related investments target food safety through promoting climate resilient crops and agriculture in Niger, or the protection of marine eco-systems against ocean water warming in order to protect local fisheries in Peru.

The reported flows include both grants as well as debt instruments, all of which are reported at commitment value in constant US$.[10,11,12] A database reporting realized disbursement as opposed to commitment amount is only available with very limited coverage, both across time and countries, which is why we opt for the use of commitment values. In the RIO marker reporting

[9] We have conducted robustness checks using other vulnerability indices such as the Climate Vulnerability Index (CRI) score from GermanWatch e.V. and found similar results. However, due to data limitations, we have chosen to utilize the Notre Dame Climate Vulnerability Index for our analysis.
[10] Debt instruments include both standard loans, debt relief, and debt swaps.
[11] We are aware that it would be good to convert all those values into grant equivalent. This is, however, not possible with the information provided in the dataset, even though the latter is still the best available source.
[12] Constant 2016 US$.

system, markers can be attributed to projects as a principal or significant objective. We utilize the RIO marker database as published: 100% of the funds for projects with a principal objective are counted as flows towards this objective, in comparison with 40% of the funds for projects for which the objective is marked as significant.

Regarding public financial flows, Figure 1 presents a descriptive analysis of their distribution across recipients, depicting both RIO mitigation and adaptation finance. Part (a) shows the distribution of mitigation finance flows across recipient countries. We see that the top 10 recipients of public mitigation inflow account for 51% of total public mitigation flows in our sample, with India receiving the largest share (16,5%). Part (b) depicts the distribution of public adaptation finance flows. The top 10 recipients account for only 35%. Comparing the recipients of public mitigation and adaptation finance, we can see that a large share of public mitigation finance flows into emerging countries such as Brazil, Indonesia, India, and China. These emerging markets account for 31% of total public mitigation flows. The recipients of public adaptation finance however include more developing countries such as Ethiopia, Bangladesh, and the Philippines. India is the highest recipient of both adaptation and mitigation inflows.



(a) Mitigation finance (b) Adaptation finance

Figure 1: Distribution of public financial flows (top 10 recipient countries)

Looking at the development of public flows over time in Figure 2, one observes a strong increase in aggregate global RIO mitigation flows since the start of systematic reporting in 2000. Whilst this increase is partially fueled by improvement in the coverage of reporting (Halimanjaya, 2015), it still shows a growing importance of public mitigation finance. There is also an increasing trend in adaptation finance flows since the marker's introduction in 2010.

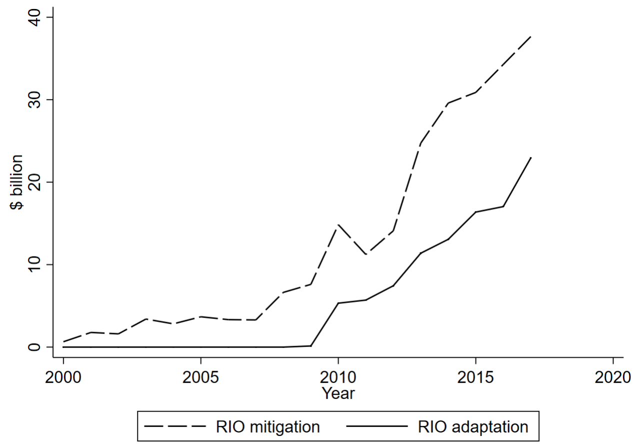


Figure 2: Development of public climate finance over time

For private flows, we use the data from the Clean Development Mechanism (CDM) as a proxy as it is the most comprehensive database with consistent definitions available. The CDM applies to mitigation projects such as renewable energy generation, energy efficiency improvement or carbon storage. Examples are the financing of the switch from coal to natural gas in a local power plant in Chile, investment to improve cement production of a construction company in Brazil or the construction of a biomass power plant in Thailand. The flows are reported in full realized investment amounts. All flows used for the estimations are converted into $billion. Figure 3 presents transfers associated with CDM projects. We observe that the distribution of flows across countries is not as even as for public finance flows: 5 countries receive 83% of the total inflow. China alone accounts for almost half of all registered CDM flows in our sample. Part of the explanation is that private investments are conducted in countries with favourable economic prospects, explaining the large share of investment flowing into emerging markets. This strong concentration of CDM projects has already been observed at earlier stages of the CDM in studies such as Lecocq and Ambrosi (2007). When interpreting the results for CDM investment, this needs to be kept in mind. We have run estimations with and without China from the data and discuss the impact on our results in the following section.

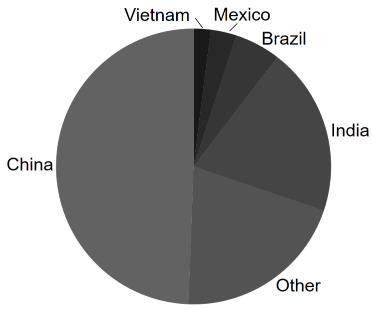


Figure 3: Distribution of CDM flows (top 5 recipients countries)

Looking at the development of private CDM flows over time, the picture is different as opposed to what we observe for the public flows. Having peaked in 2011, CDM flows decline afterwards due to institutional restrictions and decreased private demand: this is likely due to the fact that in January 2011, the European Commission announced the list of the restrictions for acceptance of CDM credits in the EU Emission Trading Scheme, the largest market accepting them for compliance until then (EC, 2011).[13]

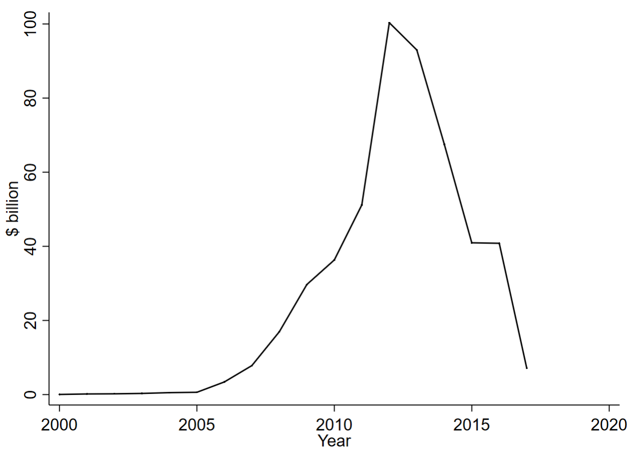


Figure 4: Development of private climate finance from the CDM over time

[13]For further development on how these restrictions were introduced, as well as their potential impact on the price of CDM credits and on the development of CDM projects, see Gavard and Kirat (2018).

3.3 Results

We estimate Equation (31) and report the results in Table 1. Regressions (1) to (3) include adaptation, mitigation finance and CDM inflows separately while regression (4) includes them all. The explanation below employs the estimation results obtained with regression 4 and the corresponding cumulative effects are plotted in Figures 5, 6 and 7 for adaptation, mitigation finance and CDM flows respectively.

Regarding public finance transfers, we observe that, contrary to expectations, both adaptation and mitigation finance tend to induce a rise in emissions. Adaptation finance increases emissions in the third to sixth year after the transfers take place. An additional billion dollars in adaptation inflow per million tons of national carbon emissions increases them by between 0.22 and 0.57% in each of the third to sixth years. The cumulative effect results in a positive and significant impact from the fourth year onwards (Figure 5).[14] This increases over time as the year-specific effects are all positive and accumulate. Over six years, the total multiplier corresponds to a more than 1.74% rise in national emissions of the recipient country (with a 95% confidence interval from 0.66 to 2.82%.) What can explain these results is that adaptation measures (e.g. building irrigation networks or dikes) are likely to involve significant construction efforts, which are themselves carbon intensive. This could momentarily increase emissions. In addition, the developed infrastructures might contribute to enhance the economic activity.

Surprisingly, we find that public mitigation finance ("RIO Mitigation Inflow") also tends to have a positive impact on emissions, although smaller than adaptation finance. An additional billion dollars in mitigation inflow per million tons of national carbon emissions increases them by between 0 and 0.283% in each of the six years after the transfers. The computation of the cumulative effect (Figure 6) shows that mitigation finance inflow may result in a more than 1.05% rise in national emissions of the recipient country over six years (with a 95% confidence interval from 0.56 to 1.65%). One explanation could be that construction efforts and enhanced economic activity involved by the corresponding investments[15] outweigh the emission reductions aimed at by mitigation finance. In the time range allowed by data availability, the mitigation objective seems to be only visible in the lower positive impact on emissions as compared to adaptation finance. From the fourth year onward, the coefficient associated with mitigation finance tends to decrease and even become insignificant in the sixth year. It is possible that emission reductions take place in a longer time horizon than what current data allow to consider.

[14]The total multiplier in an unrestricted finite distributed lag model corresponds to the sum of the coefficients. The confidence interval is constructed using the variance-covariance matrix of the coefficients from the estimation.

[15]Using GDP as a control only captures the average effect of value-added on emissions. We suspect that the economic activity increase involved by the investment supported by mitigation finance is mostly in industrial sectors which are still more carbon intensive than the average economy, especially during initial construction efforts. Exceeding emissions from the increased industrial activity could explain the positive coefficient of mitigation finance.

Table 1: Impact of Transfers on Emissions

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0932	0.0488
			(0.534)	(0.744)
L2.RIO Adaptation Inflow			0.250**	0.152
			(0.015)	(0.103)
L3.RIO Adaptation Inflow			0.409***	0.326***
			(0.000)	(0.002)
L4.RIO Adaptation Inflow			0.539***	0.421**
			(0.005)	(0.043)
L5.RIO Adaptation Inflow			0.333**	0.222*
			(0.012)	(0.082)
L6.RIO Adaptation Inflow			0.476**	0.572**
			(0.022)	(0.018)
L.RIO Mitigation Inflow		0.136*		0.100
		(0.071)		(0.193)
L2.RIO Mitigation Inflow		0.273***		0.202***
		(0.000)		(0.003)
L3.RIO Mitigation Inflow		0.271***		0.120
		(0.000)		(0.151)
L4.RIO Mitigation Inflow		0.440***		0.283***
		(0.000)		(0.003)
L5.RIO Mitigation Inflow		0.362**		0.257**
		(0.012)		(0.035)
L6.RIO Mitigation Inflow		0.200**		0.143
		(0.028)		(0.145)
L.CDM Inflow	-0.0000677			0.000267
	(0.999)			(0.995)
L2.CDM Inflow	0.0321			0.0240
	(0.368)			(0.446)
L3.CDM Inflow	0.0634			0.0497
	(0.123)			(0.133)
L4D.CDM Inflow	0.0424			0.0281
	(0.376)			(0.458)
L5.CDM Inflow	-0.168			-0.186
	(0.242)			(0.177)
L6.CDM Inflow	-0.334*			-0.351**
	(0.069)			(0.040)
Controls				
ln(Population)	1.036***	0.981***	0.956***	0.950***
	(0.000)	(0.000)	(0.000)	(0.000)
ln(GDP)	0.463***	0.474***	0.480***	0.483***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.00100	0.000941	0.000914	0.000877
	(0.324)	(0.359)	(0.356)	(0.380)
Vulnerability	-1.597*	-1.476	-1.552*	-1.462
	(0.088)	(0.115)	(0.093)	(0.119)
Constant	0.000796	-0.00444	-0.00543	-0.00581
	(0.880)	(0.402)	(0.317)	(0.267)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1375	1375	1375	1375

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

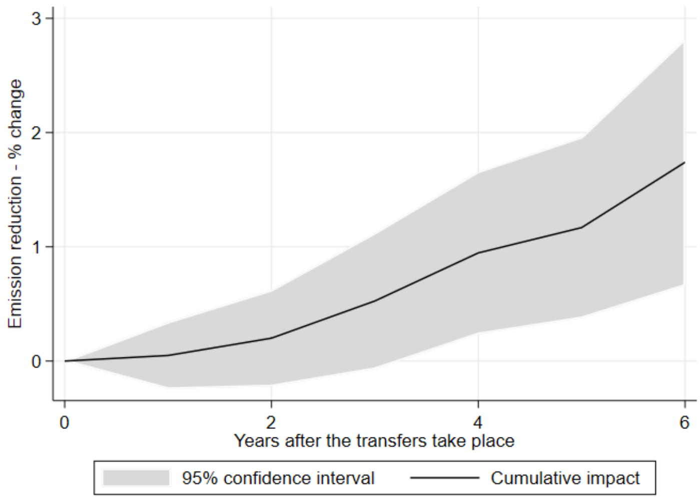


Figure 5: Cumulative impact of adaptation finance over time (total multiplier effect of 1 $billion per national tons of CO_2 emissions)

Regarding the effect of private transfers, the results found for the CDM flows used as a proxy suggest no significant impact on emissions in the five years following the transfers, but a negative effect for the sixth lag at the 5% significance level: an additional billion in CDM inflow per million tons of national carbon emissions increases them by more than 0.35% in the sixth year after the transfers. The absence of observations of a clear effect in the first five years seems to support the existing literature on CDM effectiveness and, in particular, the criticism of a lack of additionality. Several studies based on project reviews had highlighted the risk of limited effectiveness of the CDM mechanism in enabling sustainable economic development without substantial emission increases (Sutter and Parreno, 2007; Boyd et al., 2009).

Consequently, the cumulative effect is not significant within the six years after the transfers (7). However, the observation of a negative impact in the sixth year after the transfers and the downward trend in the cumulative effect from the fourth year onwards could indicate that the CDM may contribute to emission reductions in recipient countries in the longer term. This could be explained by the capacity building it triggered. The issuance of CDM credits indeed required compliance with defined methodological approaches and procedural standards to measure emission reductions for each specific project type, e.g. AM0019 for renewable energy projects (UNFCCC, 2019). This may have triggered the development of local emission monitoring capacities, which is a prerequisite for more elaborated climate policies. As for mitigation finance, it is possible that private flows induce emission reductions in a longer term. The current time range of historical data does not allow to check this but it will be an interesting topic for further research after additional years of climate action.

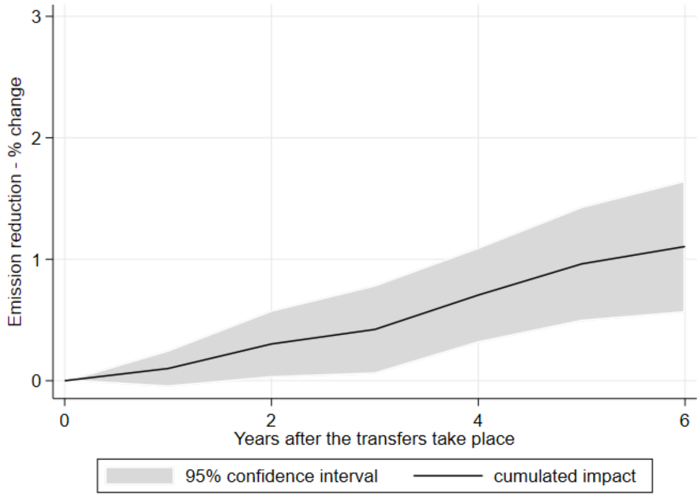


Figure 6: Cumulative impact of mitigation finance over time (total multiplier effect of 1 $billion per national tons of CO_2 emissions)

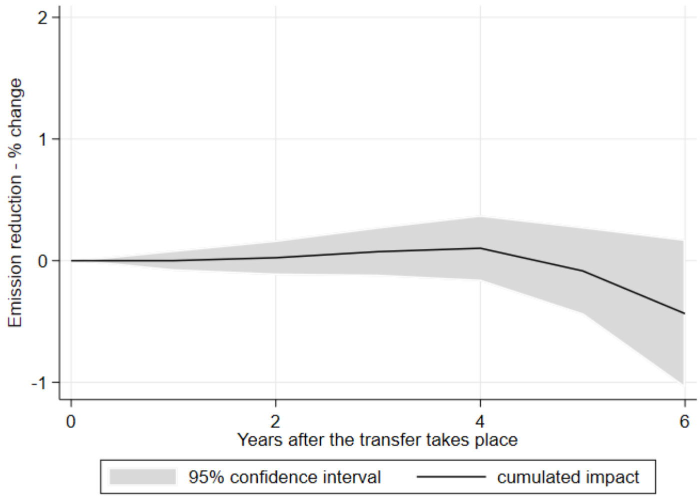


Figure 7: Cumulative impact of CDM inflow over time (total multiplier effect of 1 $billion per national tons of CO_2 emissions)

To summarize, our estimations suggest that public mitigation inflow does not really reduce emissions. We find it may even increase emissions during the six years after the transfers. Public adaptation finance seems to induce an even higher increase in emissions, potentially due to associated construction efforts. Private finance inflow associated with the CDM appear to have no significant impact on emissions reductions in the five years after the transfers, but might contribute to emission reductions afterwards.

4 Discussion and conclusion

Our analysis aims at assessing the potential of international climate finance transfers in enabling emission reductions, shedding light on this issue for the next steps of the Paris Agreement implementation via the global stocktake and the associated review process. Our study comprises a theoretical model development and consequent econometric estimations on the basis of historical data on climate finance transfers and emissions over the past 20 years.

Our main contribution consists in the empirical assessment of the effect of international financial transfers on national emission reductions. To our knowledge, it is the first analysis which employs historical data as opposed to relying on simulation studies. Our econometric analysis is derived from a conceptual framework which we develop from the current theoretical literature on international climate agreements. We relaxe the focus on coalition formation and modelling continuous national emission choices. We incorporate financial transfers in two ways: (i) as direct bilateral incentives provided by utility-maximizing donor countries to receiving countries or (ii) as surplus sharing schemes redistributing the global welfare gains from emission reductions. Our econometric estimations distinguish between private and public financial flows as well as between mitigation and adaptation investment.

Contrary to expectations, we find a potentially emission enhancing effect of mitigation and adaptation finance. We suggest this is due to directly related construction efforts, activities which are carbon intensive, and the consequently enhanced economic activity due to improved infrastructures. The effect of mitigation is smaller in magnitude, but still in the same direction. As opposed to the effect of adaptation finance, we see a decay of the impact of mitigation finance over time. This could possibly hint towards some emissions reducing effect in the longer term. However, given the data availability for the transfer variables, we cannot estimate further lags to examine the impacts in a longer time range.

To analyze the impact of private investment, we used CDM flows as a proxy. We do not detect any significant effect of CDM investments in the five years after the transfers. This would be consistent with the existing literature on the low expected effectiveness of the CDM to reduce emissions. However, we observe a negative impact in the sixth year, which involves a downward trend in the cumulative effect over time. This indicates that the CDM might help emission reductions in a longer time range than what the current data availability allows to analyse. It is possible that the CDM triggers capacity building, which leads to emission reductions after the first five years. Given the emission monitoring and reporting required to obtain credits in the CDM framework, this mechanism might encourage the development of local expertise and institutional processes to support less carbon-intensive development paths.

Our analysis shows that we need to differentiate public and private transfers as well as mitigation and adaption investments when we discuss the effectiveness of international climate finance in facilitating emission reductions. They indeed seem to have different effects.

Based on our findings of a potential emission increasing effect of climate finance, we highlight the need for accompanying these international transfers by stronger requirements for developing national measures and processes to limit emissions and ensure less carbon-intensive development paths in recipient countries in the medium and long-term. In particular, while the process for CDM credits to be validated involves a detailed computation of emission reductions that are claimed, the conditions for public flows to be considered as adaptation or mitigation finance do not seem strict enough for these transfers to effectively lead to emission reductions. Stricter conditions for public flows to be taken into account as climate finance would help these transfers to keep addressing equity concerns raised by ambitious global climate objectives while still effectively conducing to emission reductions.

While we recognize the necessity of adaptation finance, especially for the most vulnerable countries, we recommend being aware of the potential adverse effects on abatement. We hence suggest to design adaptation support as well as corresponding projects and programs in a way that minimizes the resulting emission increase.

Finally, to ensure that private investment contributes to mitigation efforts more significantly, we suggest designing regulatory frameworks (whether market or non-market based) in ways that clearly control emissions. For example, with regard to the Paris Agreement Article 6.4 mechanism as a potential successor to the CDM, we suggest defining its rules so they clearly ensure the additionality of the emission reductions which are claimed and low-carbon development paths.

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5 Appendix

5.1 List of recipient countries included in the analysis

Afghanistan, Albania, Algeria, Andorra, Angola, Antigua and Barbuda,Argentina, Armenia, Aruba, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belize, Benin, Bermuda, Bhutan, Bolivia, Bosnia and Herzegovina, Botswana, Brazil, Brunei Darussalam, Bulgaria, Burkina Faso, Burundi, Cabo Verde, Combodia, Cameroon, Cayman Islands, Central African Republic, Chad, Chile, China, Colombia, Comoros, Congo Dem. Rep., Congo Rep., Cook Islands, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Djibouti, Cyprus, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Eritrea, Ethiopia, Fiji, Gabon, Gambia, Georgia, Ghana, Greenland, Grenada, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Islamic Republic of Iran, Iraq, Jamaica, Jordan, Kazakhstan, Kenya, Kiribati, Kosovo, Kuwait, Kyrgyszstan, Laos, Lebanon, Lesotho, Liberia, Libya, Macao, Macedonia, Madagascar, Malawi, Malaysia, Maldives, Mali, Malta, Marshall Islands, Mauritania, Mauritius, Mexico, Micronesia, Moldova, Mongolia, Montenegro, Morocco, Mozambique, Myanmar, Namibia, Nauru, Nepal, Nicaragua, Niger, Nigeria, Niue, North Korea, Oman, Pakistan, Palau, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Puerto Rico, Qatar, Romania, Russia, Rwanda, Samoa, San Marino, Sao Tome and Principe, Saudi Arabia, Senegal, Serbia, Seychelles, Sierra Leone, Singapore, Solomon Islands, Somalia, South Africa, South Sudan, Sri Lanka, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Sudan, Suriname, Swaziland, Syria, Tajikistan, Tanzania, Thailand, Timor-Leste, Togo, Tonga, Trinidad and Tobago, Tunisia, Turkmenistan, Tuvalu, Uganda, Ukraine, United Arab Emirates, Uruguay, Uzbekistan, Vanuatu, Venezuela, Vietnam, West Bank and Gaza, Yemen, Zambia, Zimbabwe

5.2 Robustness checks

Table 2: Impact of Transfers on Emissions - Additional Controls

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.Adaptation Inflow			0.0915	0.0480
			(0.539)	(0.746)
L2.Adaptation Inflow			0.237**	0.138
			(0.024)	(0.138)
L3.Adaptation Inflow			0.397***	0.312***
			(0.001)	(0.004)
L4.Adaptation Inflow			0.525***	0.403**
			(0.005)	(0.048)
L5.Adaptation Inflow			0.330***	0.218*
			(0.010)	(0.077)
L6.Adaptation Inflow			0.462**	0.557**
			(0.025)	(0.020)
L.Mitigation Inflow		0.132*		0.0994
		(0.080)		(0.196)
L2.Mitigation Inflow		0.266***		0.200***
		(0.000)		(0.003)
L3.Mitigation Inflow		0.263***		0.119
		(0.000)		(0.160)
L4.Mitigation Inflow		0.435***		0.288***
		(0.000)		(0.002)
L5.Mitigation Inflow		0.362***		0.261**
		(0.010)		(0.030)
L6.Mitigation Inflow		0.211**		0.153
		(0.024)		(0.135)
L.CDM Inflow	0.000831			0.00145
	(0.984)			(0.973)
L2.CDM Inflow	0.0323			0.0250
	(0.387)			(0.449)
L3.CDM Inflow	0.0673			0.0534
	(0.137)			(0.142)
L4.CDM Inflow	0.0464			0.0319
	(0.367)			(0.435)
L5.CDM Inflow	-0.160			-0.180
	(0.268)			(0.195)
L6.CDM Inflow	-0.336*			-0.353**
	(0.064)			(0.037)
Controls				
Population	1.016***	0.960***	0.945***	0.935***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.472***	0.482***	0.486***	0.489***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000967	0.000910	0.000892	0.000852
	(0.338)	(0.372)	(0.366)	(0.391)
Vulnerability	-1.623*	-1.502	-1.571*	-1.484
	(0.084)	(0.109)	(0.090)	(0.114)
Political Stability	-0.0135	-0.0115	-0.00912	-0.00912
	(0.223)	(0.301)	(0.396)	(0.407)
Forest Area	-0.00239	-0.00302	-0.00143	-0.00259
	(0.776)	(0.712)	(0.851)	(0.740)
Constant	0.000591	-0.00454	-0.00544	-0.00585
	(0.912)	(0.395)	(0.320)	(0.268)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1375	1375	1375	1375

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 3: Impact of Transfers on Emissions - Robustness to Lag Dynamics

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0985	0.0542
			(0.523)	(0.727)
L2.RIO Adaptation Inflow			0.221**	0.125
			(0.039)	(0.196)
L3.RIO Adaptation Inflow			0.388***	0.305***
			(0.001)	(0.006)
L4.RIO Adaptation Inflow			0.578***	0.443**
			(0.003)	(0.039)
L5.RIO Adaptation Inflow			0.378***	0.259**
			(0.004)	(0.027)
L6.RIO Adaptation Inflow			0.452**	0.538**
			(0.034)	(0.036)
L.RIO Mitigation Inflow		0.144*		0.109
		(0.055)		(0.156)
L2.RIO Mitigation Inflow		0.269***		0.202***
		(0.000)		(0.004)
L3.RIO Mitigation Inflow		0.277***		0.132
		(0.000)		(0.131)
L4.RIO Mitigation Inflow		0.451***		0.296***
		(0.000)		(0.001)
L5.RIO Mitigation Inflow		0.353***		0.242**
		(0.005)		(0.030)
L6.RIO Mitigation Inflow		0.198**		0.134
		(0.024)		(0.202)
L.CDM Inflow	0.00421			0.00564
	(0.921)			(0.897)
L2.CDM Inflow	0.0406			0.0364
	(0.332)			(0.352)
L3.CDM Inflow	0.0791			0.0699
	(0.121)			(0.114)
L4.CDM Inflow	0.0586			0.0483
	(0.299)			(0.316)
L5.CDM Inflow	-0.162			-0.172
	(0.288)			(0.247)
L6.CDM Inflow	-0.331*			-0.344*
	(0.085)			(0.060)
Transfers				
L.ln(Emission)	-0.0636	-0.0694*	-0.0669*	-0.0705*
	(0.109)	(0.077)	(0.089)	(0.073)
Population	1.078***	1.026***	1.010***	1.005***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.495***	0.502***	0.506***	0.508***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000706	0.000692	0.000662	0.000631
	(0.494)	(0.503)	(0.512)	(0.535)
Vulnerability	-1.571*	-1.437	-1.489*	-1.413
	(0.078)	(0.108)	(0.091)	(0.115)
Political Stability	-0.0151	-0.0132	-0.0115	-0.0114
	(0.161)	(0.218)	(0.270)	(0.282)
Forest Area	-0.00239	-0.00291	-0.00112	-0.00248
	(0.780)	(0.730)	(0.886)	(0.759)
Constant	0.000829	-0.00429	-0.00564	-0.00609
	(0.881)	(0.436)	(0.317)	(0.262)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1385	1385	1385	1385

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 4: Impact of Transfers on Emissions - Excluding China

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0928	0.0484
			(0.536)	(0.746)
L2.RIO Adaptation Inflow			0.248**	0.150
			(0.015)	(0.107)
L3.RIO Adaptation Inflow			0.407***	0.323***
			(0.000)	(0.003)
L4.RIO Adaptation Inflow			0.536***	0.417**
			(0.005)	(0.045)
L5.RIO Adaptation Inflow			0.328**	0.217*
			(0.014)	(0.089)
L6.RIO Adaptation Inflow			0.471**	0.567**
			(0.023)	(0.019)
L.RIO Mitigation Inflow		0.135*		0.100
		(0.072)		(0.194)
L2.RIO Mitigation Inflow		0.272***		0.202***
		(0.000)		(0.003)
L3.RIO Mitigation Inflow		0.270***		0.120
		(0.000)		(0.150)
L4.RIO Mitigation Inflow		0.438***		0.283***
		(0.000)		(0.003)
L5.RIO Mitigation Inflow		0.361**		0.256**
		(0.012)		(0.035)
L6.RIO Mitigation Inflow		0.199**		0.143
		(0.029)		(0.147)
L.CDM Inflow	-0.000854			-0.000395
	(0.983)			(0.993)
L2.CDM Inflow	0.0308			0.0230
	(0.385)			(0.465)
L3.CDM Inflow	0.0618			0.0485
	(0.131)			(0.144)
L4.CDM Inflow	0.0406			0.0267
	(0.396)			(0.482)
L5.CDM Inflow	-0.166			-0.184
	(0.245)			(0.180)
L6.CDM Inflow	-0.330*			-0.347**
	(0.069)			(0.040)
Controls				
Population	1.029***	0.976***	0.951***	0.945***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.466***	0.476***	0.482***	0.485***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000987	0.000925	0.000898	0.000863
	(0.333)	(0.369)	(0.366)	(0.389)
Vulnerability	-1.591*	-1.470	-1.547*	-1.457
	(0.090)	(0.118)	(0.094)	(0.121)
Constant	0.000998	-0.00426	-0.00522	-0.00562
	(0.850)	(0.422)	(0.337)	(0.284)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1365	1365	1365	1365

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 5: Impact of Transfers on Emissions:
Estimation with Random Effects Weighting Matrix

Dependent Variable: Logarithmic emissions of the recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0917	0.0490
			(0.537)	(0.743)
L2.RIO Adaptation Inflow			0.228**	0.136
			(0.018)	(0.125)
L3.RIO Adaptation Inflow			0.379***	0.303***
			(0.000)	(0.003)
L4.RIO Adaptation Inflow			0.566***	0.441**
			(0.004)	(0.040)
L5.RIO Adaptation Inflow			0.341**	0.236*
			(0.012)	(0.073)
L6.RIO Adaptation Inflow			0.500**	0.587**
			(0.022)	(0.022)
L.RIO Mitigation Inflow		0.134*		0.0968
		(0.075)		(0.209)
L2.RIO Mitigation Inflow		0.258***		0.186***
		(0.000)		(0.007)
L3.RIO Mitigation Inflow		0.267***		0.114
		(0.000)		(0.166)
L4.RIO Mitigation Inflow		0.437***		0.273***
		(0.000)		(0.002)
L5.RIO Mitigation Inflow		0.319**		0.205*
		(0.012)		(0.078)
L6.RIO Mitigation Inflow		0.172**		0.109
		(0.048)		(0.287)
L.CDM Inflow	0.00718			0.00938
	(0.869)			(0.838)
L2.CDM Inflow	0.0455			0.0411
	(0.281)			(0.301)
L3.CDM Inflow	0.0761			0.0669
	(0.112)			(0.107)
L4.CDM Inflow	0.0512			0.0400
	(0.336)			(0.372)
L5.CDM Inflow	-0.172			-0.187
	(0.258)			(0.208)
L6.CDM Inflow	-0.335*			-0.352*
	(0.090)			(0.059)
Controls				
Population	1.039***	0.983***	0.960***	0.957***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.477***	0.484***	0.490***	0.491***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000656	0.000626	0.000599	0.000560
	(0.519)	(0.538)	(0.545)	(0.574)
Vulnerability	-1.469	-1.348	-1.384	-1.318
	(0.106)	(0.138)	(0.122)	(0.147)
Constant	0.000611	-0.00450	-0.00565	-0.00596
	(0.908)	(0.396)	(0.297)	(0.256)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1385	1385	1385	1385

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 6: Impact of Transfers on Emissions - Additional Controls: Estimation with Random Effects Weighting Matrix

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0886	0.0480
			(0.548)	(0.746)
L2.RIO Adaptation Inflow			0.212**	0.138
			(0.032)	(0.138)
L3.RIO Adaptation Inflow			0.365***	0.312***
			(0.001)	(0.004)
L4.RIO Adaptation Inflow			0.551***	0.403**
			(0.004)	(0.048)
L5.RIO Adaptation Inflow			0.340***	0.218*
			(0.009)	(0.077)
L6.RIO Adaptation Inflow			0.486**	0.557**
			(0.024)	(0.020)
L.RIO Mitigation Inflow		0.128*		0.0994
		(0.089)		(0.196)
L2.RIO Mitigation Inflow		0.248***		0.200***
		(0.000)		(0.003)
L3.RIO Mitigation Inflow		0.256***		0.119
		(0.000)		(0.160)
L4.RIO Mitigation Inflow		0.432***		0.288***
		(0.000)		(0.002)
L5.RIO Mitigation Inflow		0.321***		0.261**
		(0.010)		(0.030)
L6.RIO Mitigation Inflow		0.185**		0.153
		(0.039)		(0.135)
L.CDM Inflow	0.00811			0.00145
	(0.857)			(0.973)
L2.CDM Inflow	0.0456			0.0250
	(0.303)			(0.449)
L3.CDM Inflow	0.0801			0.0534
	(0.128)			(0.142)
L4.CDM Inflow	0.0551			0.0319
	(0.335)			(0.435)
L5.CDM Inflow	-0.167			-0.180
	(0.278)			(0.195)
L6.CDM Inflow	-0.336*			-0.353**
	(0.086)			(0.037)
Controls				
Population	1.021***	0.964***	0.951***	0.935***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.487***	0.493***	0.497***	0.489***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000623	0.000597	0.000578	0.000852
	(0.537)	(0.553)	(0.557)	(0.391)
Vulnerability	-1.497*	-1.377	-1.408	-1.484
	(0.100)	(0.130)	(0.117)	(0.114)
Political Stability	-0.0147	-0.0130	-0.0111	-0.00912
	(0.170)	(0.225)	(0.285)	(0.407)
Forest Area	-0.00177	-0.00219	-0.000472	-0.00259
	(0.830)	(0.786)	(0.950)	(0.740)
Constant	0.000381	-0.00463	-0.00571	-0.00585
	(0.943)	(0.386)	(0.297)	(0.268)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1385	1385	1385	1375

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 7: Impact of Transfers on Emissions - Robustness to Lag Dynamics: Estimation with Random Effects Weighting Matrix

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0985	0.0542
			(0.523)	(0.727)
L2.RIO Adaptation Inflow			0.221**	0.125
			(0.039)	(0.196)
L3.RIO Adaptation Inflow			0.388***	0.305***
			(0.001)	(0.006)
L4.RIO Adaptation Inflow			0.578***	0.443**
			(0.003)	(0.039)
L5.RIO Adaptation Inflow			0.378***	0.259**
			(0.004)	(0.027)
L6.RIO Adaptation Inflow			0.452**	0.538**
			(0.034)	(0.036)
L.RIO Mitigation Inflow		0.144*		0.109
		(0.055)		(0.156)
L2.RIO Mitigation Inflow		0.269***		0.202***
		(0.000)		(0.004)
L3.RIO Mitigation Inflow		0.277***		0.132
		(0.000)		(0.131)
L4.RIO Mitigation Inflow		0.451***		0.296***
		(0.000)		(0.001)
L5.RIO Mitigation Inflow		0.353***		0.242**
		(0.005)		(0.030)
L6.RIO Mitigation Inflow		0.198**		0.134
		(0.024)		(0.202)
L.CDM Inflow	0.00421			0.00564
	(0.921)			(0.897)
L2.CDM Inflow	0.0406			0.0364
	(0.332)			(0.352)
L3.CDM Inflow	0.0791			0.0699
	(0.121)			(0.114)
L4.CDM Inflow	0.0586			0.0483
	(0.299)			(0.316)
L5.CDM Inflow	-0.162			-0.172
	(0.288)			(0.247)
L6.CDM Inflow	-0.331*			-0.344*
	(0.085)			(0.060)
Controls				
L.ln(Emission)	-0.0636	-0.0694*	-0.0669*	-0.0705*
	(0.109)	(0.077)	(0.089)	(0.073)
Population	1.078***	1.026***	1.010***	1.005***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.495***	0.502***	0.506***	0.508***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000706	0.000692	0.000662	0.000631
	(0.494)	(0.503)	(0.512)	(0.535)
Vulnerability	-1.571*	-1.437	-1.489*	-1.413
	(0.078)	(0.108)	(0.091)	(0.115)
Political Stability	-0.0151	-0.0132	-0.0115	-0.0114
	(0.161)	(0.218)	(0.270)	(0.282)
Forest Area	-0.00239	-0.00291	-0.00112	-0.00248
	(0.780)	(0.730)	(0.886)	(0.759)
Constant	0.000829	-0.00429	-0.00564	-0.00609
	(0.881)	(0.436)	(0.317)	(0.262)
Observations	1385	1385	1385	1385

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

Table 8: Impact of Transfers on Emissions - Excluding China: Estimation with Random Effects Weighting Matrix

Dependent Variable: Logarithmic emissions of recipient countries

Main Independent Variables: CDM, public mitigation and adaptation financial transfers to recipient countries (in $billion per million tons of national CO_2 emissions)

	(1)	(2)	(3)	(4)
Transfers				
L.RIO Adaptation Inflow			0.0913	0.0486
			(0.539)	(0.744)
L2.RIO Adaptation Inflow			0.226**	0.134
			(0.019)	(0.130)
L3.RIO Adaptation Inflow			0.377***	0.301***
			(0.000)	(0.003)
L4.RIO Adaptation Inflow			0.563***	0.438**
			(0.004)	(0.041)
L5.RIO Adaptation Inflow			0.337**	0.232*
			(0.013)	(0.078)
L6.RIO Adaptation Inflow			0.496**	0.584**
			(0.023)	(0.022)
L.RIO Mitigation Inflow		0.133*		0.0966
		(0.077)		(0.210)
L2.RIO Mitigation Inflow		0.257***		0.186***
		(0.000)		(0.007)
L3.RIO Mitigation Inflow		0.266***		0.114
		(0.000)		(0.165)
L4.RIO Mitigation Inflow		0.435***		0.273***
		(0.000)		(0.002)
L5.RIO Mitigation Inflow		0.318**		0.204*
		(0.012)		(0.079)
L6.RIO Mitigation Inflow		0.170**		0.108
		(0.050)		(0.290)
L.CDM Inflow	0.00649			0.00882
	(0.881)			(0.848)
L2.CDM Inflow	0.0444			0.0402
	(0.292)			(0.311)
L3.CDM Inflow	0.0747			0.0658
	(0.119)			(0.114)
L4.CDM Inflow	0.0495			0.0388
	(0.353)			(0.389)
L5.CDM Inflow	-0.171			-0.185
	(0.260)			(0.210)
L6.CDM Inflow	-0.331*			-0.349*
	(0.090)			(0.059)
Controls				
Population	1.033***	0.978***	0.955***	0.952***
	(0.000)	(0.000)	(0.000)	(0.000)
GDP	0.480***	0.486***	0.492***	0.493***
	(0.000)	(0.000)	(0.000)	(0.000)
Industry Share	0.000641	0.000612	0.000587	0.000549
	(0.529)	(0.547)	(0.554)	(0.582)
Vulnerability	-1.462	-1.342	-1.379	-1.313
	(0.108)	(0.140)	(0.124)	(0.149)
Constant	0.000822	-0.00431	-0.00545	-0.00577
	(0.876)	(0.416)	(0.316)	(0.272)
Year Fixed-Effects	Yes	Yes	Yes	Yes
Observations	1375	1375	1375	1375

p-values in parentheses; *, ** and *** respectively refer to the 10%, 5% and 1% significance levels of the estimated coefficients.

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ZEW – Leibniz-Zentrum für Europäische Wirtschaftsforschung GmbH Mannheim

ZEW – Leibniz Centre for European Economic Research

L 7,1 · 68161 Mannheim · Germany
Phone +49 621 1235-01
info@zew.de · zew.de