Climate Finance as a Principal-Agent Problem

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Abstract:
Climate change mitigation finance, when wealthy states fund emissions reduction projects in poorer states, constitutes a principal-agent problem in which funders and recipients must cooperate despite diverging information and interests. This paper develops a novel theory of the tension between donor and recipient preferences over which of three possible counterfactual investments are replaced by green financing: brown, green, and none. While donors prefer financing to replace brown investments, recipients will seek financing to replace green investments or no investment. Democracy, corruption, and project attributes also predict heterogeneity in this funder-recipient divide. I test these hypotheses on a cross-sectional time series of outcomes from projects funded by the Clean Development Mechanism. This article generates both practical recommendations for the rapidly growing use of mitigation finance and theoretical opportunities for future research on mitigation finance as a cooperation dilemma in international relations.[1]

1 Introduction

In response to worsening climate change, governments have experimented with a range of policy solutions at both the domestic and international levels. One highly regarded instrument to this end is mitigation finance, i.e., investment agreements through which actors in rich countries pay for those in poorer countries to lower emissions. This tool is one type of climate finance, which also includes finance for adaptation or for loss and damages. Mitigation finance is perceived as both more equitable and more efficient than the same mitigation investments remaining in rich countries. The most high-profile deployment of this concept is the Green Climate Fund (GCF), a multilateral fund set up in 2010 that is now the primary focus of climate finance debates at yearly UN climate change conferences. But a longer-running and more extensive example is the Clean De-

[1]This project's hypotheses and model specifications were pre-registered on the Open Science Framework (OSF).

velopment Mechanism (CDM), a venue for donors to earn carbon credits from financed mitigation projects, established by the Kyoto Protocol and in operation for thousands of mitigation projects from 2001 to the present.

Mitigation finance, which aims to reduce greenhouse gas emissions, is meant to provide a global public good shared by all states on the planet. Although the costs of climate change are asymmetric both within and across societies, the costs are negative and even severe for all or nearly all. Moreover, mitigation is a global quantity which cannot be provided for oneself alone. Recipients of mitigation finance, therefore, stand to gain little more from the investment than donors do. This is problemmatic because it is difficult to tell when mitigation occurs. Mitigation requires the replacement of a more polluting action in the counterfactual. But this presents a problem analogous to "the fundamental problem of causal inference" (Holland, 1986): the counterfactual is unobserved. And because of the principal-agent structure of mitigation finance deals, donors and recipients will have diverging interests and information about this unobserved counterfactual.

Instead of the global public good of climate change mitigation, rational recipient actors and functioning recipient markets will prefer to use financial injections for local goods, or goods whose benefits accrue to the recipient society. While mitigation finance is meant to replace counterfactual brown investments with real green investments, recipients will be incentivized to use green investments to replace no investment, gaining the local public good of economic development, or to replace other green investments, gaining the local private good of a cash transfer. But while mitigation finance may fail everywhere, it will fail differently in different types of recipient states. Autocratic and high corruption recipients will fund local private goods, while democratic and low corruption recipients will be more open to funding local public goods. And not all kinds of mitigation projects will face the same degree of difficulty. Recipients will be more likely to implement projects that provide significant local co-benefits in addition to mitigating. I unpack this fundamental dilemma of mitigation finance and explain my conditional hypotheses in Section 2.

Previous research on climate finance has closely tracked the extensive literature on traditional foreign economic aid, also known as official development assistance (ODA). And indeed, all forms of climate finance face many of the same problems as ODA, such as selfish donor interests (Graham and Serdaru, 2020), implementation problems (Brunner and Enting, 2014; Bhandary, Gallagher and Zhang, 2021; Chelminski, 2022), and public opinion (Gaikwad, Genovese and Tingley, forthcoming). These problems represent important barriers to the efficacy and scaleability of climate finance and therefore to the global green transition. But mitigation finance faces an additional dilemma, not shared by ODA, adaptation finance, or loss and damage finance, and not adequately explored in the academic literature. Unlike mitigation finance, these other types of programs are meant to provide a local good in the recipient country and therefore enjoy a donor-recipient alignment of interests about which counterfactual investment to replace. Even if the traditional barriers to effectual aid are solved, meaning that donor states can agree on large financial transfers and international organizations can enforce robust implementation plans, mitigation finance would suffer from the further fundamental dilemma that I describe in this article.

I evaluate my hypotheses empirically in Section 3 with several models fit to cross-sectional timeseries of states and sub-state units receiving CDM projects. I find support for some predictions of my theory. Mitigation finance seems to be an ineffectual way to boost green powerstation development and there is mixed evidence as to its effect on emissions and economic development. Democracy and corruption are associated with puzzling effects, indicating the need for future model and data refinement. I conclude by discussing future paths for research and policy reform in Section 4.

2 The Promise and Perils of Mitigation Finance

One reason that mitigation finance is appealing is normative. In the face of severe global inequality, many would prefer that climate change solutions be redistributive, such that poorer economies could benefit from increased investment. This would be especially fitting because climate change itself has highly inequitable impacts, with the greatest burden falling on already poor states. This is true for three interrelated reasons. First, geographic divergence in past economic development, due to varied geophysical systems and to patterns of colonization, has led to concentrated poverty in equatorial regions, which are also the most exposed to extreme temperatures and weather events (Nordhaus, 2006; Sokoloff and Engerman, 2000; Acemoglu, Johnson and Robinson, 2001). Second, the most crucial investments for adaptation to the harms of climate change, such as physical infrastructure, health care systems, and personal mobility, are expensive and inaccessible to underprivileged communities (Hsiang and Narita, 2012). Third, these same communities are more likely to be economically reliant on agriculture and natural resource extraction (i.e., "unmanaged systems"), meaning that their sources of income are also highly vulnerable to degradation and instability from climate change (Burke, Hsiang and Miguel, 2015; Nordhaus, 2013).

A second reason that mitigation finance is a compelling idea is efficiency. Poorer states tend to have higher carbon intensities of GDP due to the use of cheaper but dirtier equipment and processes in economic production. Thus, poor states likely have a lower marginal cost of mitigation than rich states due to more opportunity for green capital substitution. In other words, spending in poor states will have a higher return in mitigation per dollar spent. Mitigation finance, therefore, serves to connect actors with an abundance of funding to actors with an abundance of opportunities for mitigation. Indeed, in the case of the Kyoto Protocol, some analysts argued that the only possible way for states to meet their targets at an acceptable cost was to allow some form of emissions trading, such as mitigation finance (Victor, 2001).[2]

But mitigation finance carries significant risks. When mitigation finance is incentivized by credits that relieve donors of their own emissions reduction mandates, then

[2]Mitigation finance was one of Kyoto's four distinct forms of interstate emissions trading, or the cross-border exchange of mitigation obligations. The others are national emissions trading, or the inter-government trade of headroom on national emissions targets; joint implementation, or direct inter-government collaboration on mitigation projects; and bubbles, or the assumption of treaty targets for a group of states followed by allocation within that group (as practiced by the EU). This article focuses solely on mitigation finance, which is distinct for involving private actors and is perceived as the most scaleable solution for global mitigation cooperation.

mitigation finance will crowd out direct mitigation by donors (Victor, 2011). Therefore, if mitigation finance credits are being generated without real mitigation occurring in recipient states, then these bad emissions projects abroad will crowd out real emissions projects at home. In other words, a badly designed or operated mitigation finance system will not only waste money but will actually lower total global mitigation.

This fear is well-founded, because scholars have already demonstrated significant problems with mitigation finance in practice. Studies have found that despite significant project certification requirements which generate heavy transaction costs, CDM projects have also been plagued by the kind of poor oversight, fraud, and mismanagement that certification procedures are meant to eliminate (Sovacool and Brown, 2009). Scholars and policymakers have debated various solutions to these problems, including a further increase in certification procedures or a narrowing of eligibility requirements. Victor (2001, 2011) proposes a transition of the credits system from seller liability to buyer liability, thereby putting the onus of project verification on buyers who tend to be in rich and democratic states with robust legal systems.

These criticisms of mitigation finance, while serious, are focused on the first-order problems shared with ODA or wiht adaptation or loss and damage finance. Donors must verify that the proposed project is being built and that waste or corruption are minimized. Analysts have thus far have given less attention to a second-order problem with mitigation finance transactions, which is more difficult to solve and potentially more damaging. Even if a designated project is built, it is unclear what that financed project has replaced in the un-financed counterfactual. Without the mitigation finance award, would a more polluting action have been taken, would no action have been taken, or would the same action have been taken? The theory of mitigation finance espoused by parties to the CDM or GCF, that financial transfers will mitigate climate change, relies not only on the first-order success of the project being efficiently built but on the second-order replacement of one specific counterfactual. The financed action must replace a more polluting counterfactual action in order to mitigate climate change.

This may sound like a trivial requirement, but it is difficult to meet due to the principal-agent structure of mitigation finance agreements. In a principal-agent problem, a principal (the funder, i.e., the "donor") and an agent (the do-er, i.e., the "recipient") must work together but have diverging information and interests (Ross, 1973; Mitnick, 1975; Jensen and Meckling, 1976). This model can describe some of the first-order problems of mitigation finance. Waste or corruption can result from the asymmetric power of agents to subvert the intentions of the far-away principal. It also drives the second-order problem. Donors and recipients may have diverging preferences for what counterfactual should be replaced and diverging information for what counterfactual is being replaced. Specifically, while donors try to replace more polluting action, thereby providing the global collective good of climate change mitigation, recipients will prefer the replacement of inaction or of self-funded identical action, thereby providing the local goods of economic development or cash transfers. Meanwhile, although donors may struggle with information asymmetry about use of the finance in reality, their information deficit about the un-financed counterfactual is likely to be even more acute.

2.1 Three Scenarios for Mitigation Finance

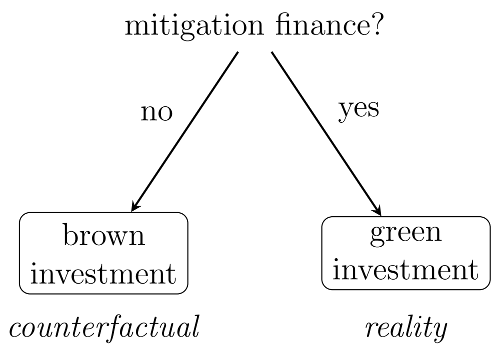
To understand why donors and recipients may disagree on both the preferred and the actual counterfactual to a mitigation finance investment, it is instructive to specify the universe of possible counterfactuals. Assume that the first-order problem is solved, i.e., that when mitigation finance is awarded, the green investment is actually made. Thus, a green investment occurs in reality. Also assume that the green investment is not replacing an even greener investment. In other words, recipients are not reducing mitigation because they have received mitigation finance. Three ideal-type scenarios represent the possible types of investment that could have occurred in the absence of the mitigation finance award.[3]

First, in the absence of mitigation finance for a green investment, the recipient may have implemented a brown investment. For example, mitigation finance may fund a new wind powerstation that forestalls plans to build a new natural gas powerstation. Equiv-

[3]I do not intend to draw normative distinctions between the possible counterfactual scenarios.

alently, the new wind powerstation may allow the recipient to shut down an old natural gas powerstation ahead of its intended end-of-life. In this case, the green investment is replacing a counterfactual brown investment. Insofar as the investments differ only in their environmental impact, mitigation finance in this scenario is carbon negative, but economically neutral and cash neutral. I call this the *mitigation scenario*, because climate change is being mitigated relative to the counterfactual. This scenario is the stated purpose of mitigation finance and is the ideal scenario from the perspective of the donor (or of the institution that the donor is acting through), who is attempting to spend money on climate change mitigation.

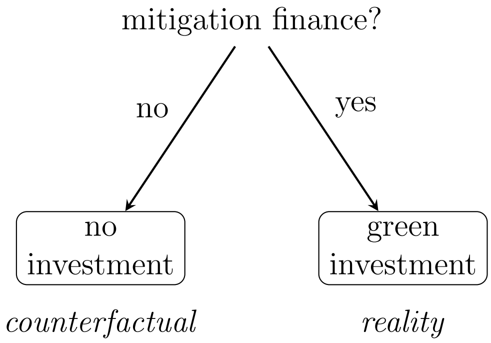
Figure 1: The Mitigation Scenario



Second, in the absence of mitigation finance, the recipient may have implemented no investment. For example, mitigation finance may fund a new wind powerstation in a setting where no new powerstation would have been built otherwise, leading to an increase in local electrification. In this case, the green investment is replacing nothing in the counterfactual. Thus, mitigation finance in this scenario is carbon neutral and cash neutral, but economically positive. I call this the *development scenario*, because recipients are gaining economic investments even though no mitigation is occurring relative to the counterfactual.[4]

[4]If the assumption that mitigation finance does not fund negative mitigation is relaxed, the development scenario can also be carbon negative and economically positive, while cash neutral. For example, mitigation finance may fund a wind powerstation that would have been built already and the influx of investment may be used to build a coal plant in addition.

Figure 2: The Development Scenario

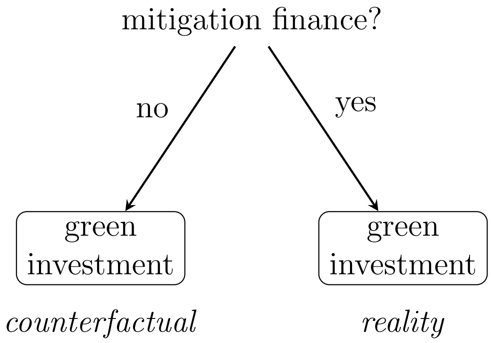


Finally, in the absence of mitigation finance, the recipient may have implemented a green investment anyways. For example, mitigation finance may fund a new wind power-station in a setting where the powerstation was already going to be built with local funds. In this case, the green investment is replacing a green investment in the counterfactual. Thus, mitigation finance in this scenario is carbon neutral and economically netural, but cash positive. I call this the *transfer scenario*, because recipients are receiving a cash transfer that does not result in mitigation or economic development. This scenario is a problem already recognized by mitigation finance institutions and sometimes referred to as the additionality problem.[5] While the CDM and GCF attempt to ensure additionality in the certification process, their capability is severely limited because the counterfactual cannot be directly observed.

These scenarios differ not only in their climate implications, but in their relative benefits for recipients. While the donors are assumed to want climate change mitigation and therefore to prefer the mitigation scenario, recipients are likely to prefer the other two scenarios. Climate change mitigation is a global collective good, the benefits of which are diffusely enjoyed across the planet. Economic growth or cash transfers, on the other hand, are local goods, enjoyed entirely by recipients themselves. If mitigation finance

[5] In this case, "additionality" means that the financed project is additional to what would be completed without the finance. The term "additionality" is also sometimes used to mean that the finance provided by the donor is additional to what aid would have been provided without climate institutions. In other words, a financed project is additional if it is not simply replacing an identical project, and finance is additional if it is not simply replacing other types of aid, such as ODA.

Figure 3: The Transfer Scenario



could be used to fund an equivalent amount of either global mitigation benefit or local benefits, utility-maximizing local actors would choose the latter (Samuelson, 1954, 1955; Olson, 1965). Thus, recipients should always prefer the development or transfer scenarios to the mitigation scenario.

While all recipients will prefer the development or transfer scenarios over the mitigation scenario, recipients may vary in which scenario they prefer the most. Economic growth may be considered a local public good, which provides diffuse benefits across the local economy. Meanwhile, cash transfers may be considered a local private good, which can be captured by local concentrated interests or rent seekers. Democracies tend to be relatively more interested in public goods provision than autocracies (Deacon, 2009). This is because democracies rely on the support of a broader share of the public, which decreases the inefficiency of public goods provision relative to private goods provision. Thus, democratic recipients should be more interested in the development scenario than autocracies (although both may strictly prefer the transfer scenario). Other features of governance may also lead to diverging scenario preferences. Cash transfers may facilitate corruption, which tends to rely on concentrated transfers of private goods. Thus, recipient regimes with low corruption should also be more interested in the development scenario than recipients with high corruption.

The tradeoff between local and global benefits is fundamental to any mitigation finance scheme. But the resulting tension may be reduced by local co-benefits. Mitigation co-benefits occur when projects that contribute to the global collective good by reducing GHG emissions also bring auxiliary local benefits. This would be the case, for example, if a mitigation-financed wind powerstation produced cheaper local power than the natural gas powerstation that it replaced. In this hypothetical mix of the mitigation and development scenarios, the mitigation finance investment was both carbon negative and economically positive relative to the counterfactual. Another example would be if a mitigation-financed wind powerstation replaced a coal powerstation. While coal, oil, and natural gas all emit greenhouse gases when burned, coal also emits a large amount of heavy particulates, resulting in significantly more smog and local health problems than relatively clean-burning oil or gas. Thus, while replacing a coal powerstation with a wind powerstation constitutes the mitigation scenario, it also yields significant auxiliary co-benefits for local public health. Potential co-benefits from green investments are numerous, but smog reduction may be the most significant (Ürge Vorsatz, Herrero, Dubash and Lecocq, 2014). Coal replacement may therefore provide the clearest example of a mitigation scenario with a strong co-benefit, which should alleviate the tension between recipient and donor interests.

2.2 Market-Based Mechanisms

Thus far, I have described the three mitigation finance scenarios and their relations to attributes of the recipient government and society as if the recipient was a unitary and rational actor, choosing which investment to replace in order to maximize utility. This causal process can be called the unitary agent mechanism. But the same scenarios and the same conditionality on recipient attributes can be reached by modeling recipients as markets. Two mechanisms lead to my predicted outcomes under these alternative assumptions: the price mechanism and the income mechanism. My theoretical predictions therefore enjoy equifinality, or the existence of multiple causal pathways leading to the same outcome.

The price mechanism makes the development scenario and the transfer scenario each more likely to occur, conditional on recipient attributes. Recipient markets will have counterfactual prices reflecting self-contained supply and demand of goods like electricity, land, and investment capital. Financed projects will affect relative prices within the recipient markets by altering the supply and demand of these goods. A mitigation financed wind powerstation, for example, will increase the supply of electricity in the local economy. In the mitigation scenario that donors hope for, this increased supply of electricity will result in a corresponding decrease of supply from brown sources such as through the closure or cancellation of a gas-fired powerstation. Thus the equilibrium supply and demand of electricity is equivalent between the financed reality and the un-financed counterfactual. But an increased supply of electricity is instead likely to result in a decrease in electricity prices and a corresponding increase in electricity consumption in the local market. This results in the development scenario. Moreover, if increased electricity supply does not translate into lower electricity prices, as may be more likely under dirigistic autocratic economies or corrupt oligopolistic economies, then the increased supply of electricity is just as likely to result in the closure or cancellation of a wind powerstation as a gas powerstation. This results in the transfer scenario. This price mechanism is a form of market adjustment known as leakage. Cross-border leakage is a serious problem for national efforst to mitigate: if one state raises its effective carbon price, polluting economic activity may simply relocate to another state. But within-border leakage can also occur, probably even more easily due to lower internal market barriers. In one well-studied example, paying for the protection of a forest may simply shift deforestation to other forests through the requisite price mechanism (Swingland et al., 2002).

The income mechanism makes the development scenario more likely to occur, conditional on recipient attributes. Even if the financed investment displaces equivalent economic activity, such as a financed wind powerstation leading to the closure or cancellation of a wind or gas powerstation, this leads to an economic surplus for the recipient of the finance. In an autocratic or corrupt economy, concentrated interests or rent seekers may be likely to capture this surplus and to store it, offshore it, or spend it on luxury goods. But in other economies this surplus in one market actor's income will result in increased spending on diffuse core goods throughout the economy, increasing demand for goods like electricity. In non-autocratic and low corruption economies, even if a wind powerstation is financed when there is not unmet electricity demand, the economic stimulus of the finance infusion may itself increase electricity demand, forestalling the closure or cancellation of other wind powerstations or gas powerstations. This result leads to the development scenario.

2.3 Hypotheses

In short, recipients are unlikely to replace brown investments when receiving mitigation finance, unless doing so brings significant local co-benefits. This means that mitigation finance should have no effect on the number or size of oil or gas powerstations, whose replacement yields little local benefit. But mitigation finance should have a negative effect on the number or size of coal powerstations, whose replacement yields significant local benefits. If mitigation finance is effective at replacing coal but not other forms of brown investments, it is likely to have a limited effect on emissions overall. Despite this lack of mitigation, mitigation finance should have an effect on GDP growth, conditional on recipients being democratic and having low corruption. Based on this reasoning, I make five hypotheses, tailored to the available outcome data outlined in Section 3.2: powerstations and GDP at the state and sub-state level (i.e., state, province, region), and powerstations, GDP, and emissions at the state level. When predicting powerstation outcomes, I focus on mitigation finance that funds green powerstations rather than other forms of mitigation. When predicting GDP or emissions, I use all mitigation finance projects.

H1: At both the sub-state and state levels, mitigation finance projects for green powerstations will have no effect on the number and size of oil-fired or gas-fired powerstations.

H2: At both the sub-state and state levels, mitigation finance projects for green powerstations will have a negative effect on the number and size of coal-fired powerstations.

H3: At the state level, mitigation finance projects will have no effect on emissions.

H4: At both the sub-state and state levels, mitigation finance projects will have a positive effect on GDP only in democracies.

H5: At both the sub-state and state levels, mitigation finance projects will have a positive effect on GDP only in low corruption states.

3 Evaluating the CDM

I test these hypotheses with a cross-sectional timeseries of locations receiving CDM grants for mitigation projects. I focus on the CDM over the GCF for three reasons. First, while the GCF attempts to balance mitigation and adaptation goals, the CDM is focused on mitigation finance, which is the type of finance that will create the second-order problem that is the focus of this study. Second, because the CDM generates carbon credits for each project, its procedures may place more emphasis on quantifying projected emissions reductions, thereby lowering measurement error in my study, and avoiding non-additionality, thereby making my study a hard case for the detection of additionality and related problems. Third, although CDM activity has declined since the creation of the semi-redundant GCF, it is a longer running program with significantly more cases of financed projects. While the CDM financed over 13,000 projects from 2001 to the present, the GCF has only financed fewer than 100 projects from 2010 to the present. This means that analyzing the CDM provides significantly more empirical leverage than analyzing the GCF. Moreover, while the GCF and CDM have important institutional differences, they share the principal-agent structure that makes my theory applicable. The results from my study of the CDM can therefore inform the ongoing debate over future reforms of the GCF, as I discuss in Section 4.2.

Before discussing the CDM data in Section 3.2, I outline my research design in Section 3.1. In each model I use a linear regression and estimate the average treatment effect on the treated (ATT). Each model assumes positivity (treatment probability is never 0 or 1, conditional on covariates) and relies on standard linear regression assumptions and causal inference assumptions (SUTVA).

Focus on the ATT is methodologically necessary due to data availability and in order to fulfill positivity, as real world observations of mitigation finance are highly targeted towards a particular type of recipient state. But the ATT is also a more substantively compelling estimand in this case. While the hypothetical effect of mitigation finance on France, for example, could be interesting in the abstract, it is unrelated to both policy and academic debates.

3.1 Research Design

At each level of analysis and for each combination of dependent and independent variables, I fit two different model specifications based on a different conceptualization of the mitigation finance treatment. These alternative specifications rely on different assumptions and therefore have different strengths and weaknesses.

First, I model treatment with a staggered adoption pattern. In this setup, illustrated in Table 1, treatment can be given to different units at different times, but is permanent once given. In the test of green powerstation development, for example, a unit that received a CDM grant to build 30MW of wind power in 2005 will be coded as receiving 30 units of treatment from 2005 until the end of the time series. The relevant outcomes are treated as absolute levels. In the test of green powerstation development, for example, the outcome variable will be the total number of MWs of green power within the unit for that year.

Table 1: Staggered Adoption

	Year 1	Year 2	Year 3	Year 4
State 1	C	C	C	T
State 2	C	T	T	T
State 3	C	C	T	T
State 4	C	T	T	T

Staggered adoption assumes parallel trends and allows the use of two-way fixed effects (unit and time) to adjust for time-invariant and unit-specific confounding. The ATT, therefore, will describe treatment effects within treated units. This approach, however, will be biased by uneven treatment effects over time (Imai and Kim, 2019, 2021). This could occur, for example, if a new mitigation-financed wind powerstation causes the shutdown of a nearby coal powerstation, but only several years after the treatment.

For staggered adoption of treatment, I fit the following model:

$$Y_{i,t} = \beta_0 + \beta_1 D_{i,t} + \beta_2 G_{i,t} + \beta_3 D_{i,t} * G_{i,t} + \beta_4 X_{i,t} + \beta_5 \tau_t + \beta_6 \gamma_i + \epsilon_{i,t}$$

where $D_{i,t}$ is treatment of unit i in year t, $G_{i,t}$ is a governance indicator for state i in year t, $X_{i,t}$ is a matrix of control variables for unit i in year t, τ_t is the year fixed effect, and γ_i is the unit fixed effect.

Second, I model treatment with a general treatment pattern. In this setup, illustrated in Table 2, treatment is specific to the period in which it is given. In the test of green powerstation development, for example, a unit that received a CDM grant to build 30MW of wind power in 2005 will be coded as receiving 30 units of treatment in 2005 only. The relevant outcomes are treated as changes. In the test of green powerstation development, for example, the outcome variable will be the yearly difference in MWs of green power within the unit.

Table 2: General Treatment Pattern

	Year 1	Year 2	Year 3	Year 4
State 1	C	C	T	C
State 2	C	C	C	T
State 3	C	T	C	C
State 4	C	T	C	C

A general treatment pattern assumes sequential ignorability (treatment is independent of potential outcomes, conditional on pre-treatment covariates) (Robins, 1986). Doing so, it allows the researcher to include lags of past treatments and outcomes as covariates in order to account for delayed or gradual effects of treatment and for feedback from past outcomes. This model will be biased, however, insofar as it will only allow time fixed effects. The lack of unit fixed effects makes it unable to adjust for time-invariant and unit-specific confounding. This model may also be less precise due to the inclusion of substantially more covariates (due to the lags) and due to the inherent noisiness of using changes rather than levels as outcomes.

For the general treatment pattern, I fit the following model:

$$Y_{i,t} = \beta_0+\beta_1 Y_{i,\{t-1,t-2,t-3\}}+\beta_4 D_{i,\{t,t-1,t-2,t-3\}}+\beta_8 G_{i,t}+\beta_9 D_{i,\{t,t-1,t-2,t-3\}}*G_{i,t}+\beta_7 X_{i,t}+\beta_8 \tau_t+\epsilon_{i,t}$$

where $Y_{i,\{t-1,t-2,t-3\}}$ is a matrix of the outcomes of unit i in years $t-1$, $t-2$, and $t-3$; $D_{i,\{t,t-1,t-2,t-3\}}$ is a matrix of the treatments of unit i in years t, $t-1$, $t-2$, and $t-3$; $G_{i,t}$ is a governance indicator for state i in year t; $X_{i,t}$ is a matrix of control variables for unit i in year t, and τ_t is the year fixed effect.

For all models I cluster standard errors at the unit level. I use the standard $p < 0.05$ criteria for determining statistically significant results.

3.2 Data

I conduct this analysis by leveraging six datasets collected by third party institutions:

Projects: I take a list of funded CDM projects from the project search portal on the UN website (**?**).

Powerstations: I take a global list of powerstations from the Global Integrated Power Tracker dataset (May 2024 release) maintained by the Global Energy Monitor (**?**).

Subnational GDP and Population: I use the DOSE dataset (MCC-PIK Database of Sub-national Economic Output), which compiles harmonized economic statistics from substate regions from both government agencies and independent studies (Wenz et al., 2023).

National GDP and Population: I use the World Bank Development Indicators for data on state-level GDP and population (**?**).

Governance Variables: I take national institutional variables from the V-Dem country-year dataset (Version 14, March 2024) maintained by the Varieties of Democracy Institute (Coppedge et al., 2024; Pemstein et al., 2022).

Emissions: I use emissions data from the PRIMAP dataset from the Potsdam Institute for Climate Impact Research, which combines both self-reported and third-party estimates of GHG emissions (Version 2.5.1, Feb 2024) (Gütschow et al., 2016; Gütschow, Pflüger and Busch, 2023).

After merging and cleaning this data, the sample size and scope of the analysis is determined by data availability. Some project regions are not covered by the sub-state regional GDP data, and some projects cannot be matched to a particular sub-state region. These regions and projects will be excluded from the sub-state level analysis, but will be included in the state-level analysis, for which data is complete. Other projects span multiple states and may be excluded due to the difficulty of ascertaining a division of projected impacts. There are 13,173 projects in the CDM database and 6,876 that funded green powerstations.

3.3 Analysis

Table 3 summarizes all models that predicting powerstation development by sub-state region. The treatment variable is the number of new green power MWs funded by mitigation finance projects, indicated by an ATT label. As discussed above, the staggered adoption models use MW levels as an outcome and include year and region fixed effects, while the general treatment pattern models use MW changes as an outcome, include lagged outcome and treatment variables, and only include year fixed effects. I predict three different outcomes: green MWs, oil or gas MWs (i.e., brown investments with no co-benefits to replacing), and coal MWs (i.e., brown investments with large co-benefits to replacing). For each model type and outcome variable, I run separate specifications with democracy and corruption as governance variables interacted with the treatment, indicated by an HTE (heterogeneous treatment effects) label. I do not include these variables in the same specification because they are highly (negatively) correlated.

I find that mitigation finance for green MW installation has a negative effect on actual green MW installation in autocracies, but a positive effect in democracies. Puzzlingly, I also find that this type of mitigation finance may have a negative effect on green MW development in low corruption states but a positive effect in high corruption states. This finding indicates low efficacy for mitigation finance to build green powerstations, although the heterogeneous effects by regime type warrant further investigation. While green MW mitigation finance has varying effects on green MW installation, it also tends to have a null effect on oil/gas MW installation and a significant negative effect on coal MW installation, again with the possible exception of projects in democracies or high corruption states.

Table 4 summarizes the same specifications fit to country-level data. Again, mitigation finance funding green MWs does not have a positive relationship with actual green MW installation, with the possible exception of projects in democracies and highly corrupt states. The effect on oil and gas MWs is mixed, but the effect on coal MWs tends to be negative, with the exception of projects in democracies and in highly corrupt states. Combined, these results imply partial support for Hypotheses 1 and 2, which predicted that green MW mitigation finance projects would displace coal (for which large co-benefits exist) but not oil or gas powerstations.

Table 5 summarizes models predicting region-level economic development, using the amount of capital delivered through mitigation finance as the treatment variable. Mitigation finance is associated with economic development, but this effect reverses for democracies and states with high corruption. These findings stand in contrast to one another, but the significance of each disappears for the general treatment pattern models. This may be due to the overpowering effect of past economic outcomes on present outcomes.

Table 6 summarizes the same specifications fit to country-level data. Mitigation finance is associated with economic development, but this effect again reverses for democracies and states with low corruption. This surprising finding would refute Hypotheses 4 and 5, which predicted the opposite: that democracies and states with low corruption would be most eager to leverage mitigation finance funds for economic development. But again, the significance of these finding disappear for the general treatment pattern models.

Table 3: Mitigation Finance for Green Powerstations (by Substate Region)

	Dependent variable:											
	Green MWs (1)	Δ Green MWs (2)	Green MWs (3)	Δ Green MWs (4)	Oil/Gas MWs (5)	Δ Oil/Gas MWs (6)	Oil/Gas MWs (7)	Δ Oil/Gas MWs (8)	Coal MWs (9)	Δ Coal MWs (10)	Coal MWs (11)	Δ Coal M (12)
Δ Green MWs (t-1)		0.2*** (0.01)		0.2*** (0.01)								
Δ Green MWs (t-2)		0.4*** (0.01)		0.4*** (0.01)								
Δ Oil/Gas MWs (t-1)						0.3*** (0.01)		0.3*** (0.01)				
Δ Oil/Gas MWs (t-2)						0.2*** (0.01)		0.2*** (0.01)				
Δ Coal MWs (t-1)										0.5*** (0.01)		0.5*** (0.01)
Δ Coal MWs (t-2)										0.3*** (0.01)		0.3*** (0.01)
ATT: MW Finance (t)	−1.5*** (0.02)	−0.4*** (0.04)	−4.1*** (0.1)	−2.1*** (0.2)	−0.01 (0.01)	−0.01 (0.01)	0.2*** (0.1)	0.2*** (0.1)	−1.9*** (0.04)	−0.1** (0.03)	−1.3*** (0.3)	0.4*** (0.1)
MW Finance (t-1)		0.4*** (0.1)		2.2*** (0.4)		0.04 (0.03)		−0.2 (0.1)		0.1 (0.1)		−0.4* (0.2)
MW Finance (t-2)		−0.1 (0.04)		−0.04 (0.2)		−0.03** (0.02)		−0.1 (0.1)		0.00 (0.03)		0.04 (0.2)
Democracy	452.2*** (144.4)	62.0*** (12.3)			45.7 (56.3)	14.1*** (4.9)			2,297.0*** (284.4)	94.0*** (11.1)		
Corruption			565.8** (237.0)	50.6*** (16.3)			379.7*** (93.6)	25.5*** (6.5)			982.8** (472.3)	−3.5 (4.4)
HTE: MW Finance (t) * Dem	1.5*** (0.1)	0.5*** (0.1)			−0.6*** (0.1)	0.00 (0.04)			1.4*** (0.3)	−0.1 (0.1)		
MW Finance (t-1) * Dem		−0.5*** (0.2)				−0.1 (0.1)				−0.2 (0.2)		
MW Finance (t-2) * Dem		−0.1 (0.1)				0.1 (0.05)				0.3*** (0.1)		
HTE: MW Finance (t) * Corr			6.5*** (0.3)	3.6*** (0.5)			−0.5*** (0.1)	−0.5*** (0.2)			−1.1* (0.6)	−1.0*** (0.3)
MW Finance (t-1) * Corr				−3.8*** (0.8)				0.4 (0.3)				0.7 (0.5)
MW Finance (t-2) * Corr				−0.2 (0.5)				0.2 (0.2)				0.5 (0.5)
Constant	592.5 (419.3)	−24.6 (22.6)	71.3 (479.5)	−29.4 (24.2)	382.9** (163.7)	−11.2 (9.0)	17.1 (189.3)	−21.2** (9.7)	1,501.9* (826.1)	−53.2*** (20.0)	638.9 (955.3)	−6.9 (10.1)
Fixed Effects	region, year	year	region, year	year	region, year	year	region, year	year	region, year	year	region, year	
Observations	17,432	15,763	17,432	15,763	17,432	15,763	17,432	15,763	17,432	15,763	17,432	33,146
R^2	1.0	0.4	1.0	0.4	0.9	0.1	0.9	0.1	0.9	0.6	0.9	0.6
Adjusted R^2	1.0	0.4	1.0	0.4	0.9	0.1	0.9	0.1	0.9	0.6	0.9	0.6
Residual Std. Error	1,586.5	369.8	1,572.7	369.5	619.2	147.3	620.9	147.2	3,125.7	327.7	3,133.4	231.6
F Statistic	946.9***	223.0***	963.9***	224.2***	301.7***	59.2***	300.0***	59.8***	148.4***	570.9***	147.5***	1,098.0**

Note: *p<0.1; **p<0.05; ***p<0

Table 4: Mitigation Finance for Green Powerstations (by Country)

	Dependent variable:											
	Green MWs	Δ Green MWs	Green MWs	Δ Green MWs	Oil/Gas MWs	Δ Oil/Gas MWs	Oil/Gas MWs	Δ Oil/Gas MWs	Coal MWs	Δ Coal MWs	Coal MWs	Δ Coal M
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Δ Green MWs (t-1)		0.12***		0.17***								
		(0.02)		(0.02)								
Δ Green MWs (t-2)		0.08***		0.13***								
		(0.02)		(0.02)								
Δ Oil/Gas MWs (t-1)						0.41***		0.41***				
						(0.02)		(0.02)				
Δ Oil/Gas MWs (t-2)						0.19***		0.19***				
						(0.02)		(0.02)				
Δ Coal MWs (t-1)										0.99***		0.99***
										(0.02)		(0.02)
Δ Coal MWs (t-2)										0.03		0.01
										(0.02)		(0.02)
ATE: MW Finance (t)	−3.09***	−0.56***	−7.53***	−2.02***	−0.39***	0.003	−0.55***	0.28	−5.46***	−0.09**	−7.23***	1.10***
	(0.03)	(0.04)	(0.18)	(0.30)	(0.01)	(0.02)	(0.08)	(0.17)	(0.03)	(0.05)	(0.22)	(0.31)
MW Finance (t-1)		0.63***		2.25***		−0.002		−0.12		0.37***		−1.26**
		(0.08)		(0.46)		(0.04)		(0.27)		(0.09)		(0.49)
MW Finance (t-2)		−0.44***		−0.76***		−0.02		−0.24*		−0.26***		0.10
		(0.05)		(0.24)		(0.02)		(0.14)		(0.04)		(0.25)
Democracy	762.09	3.99			3,230.56***	172.93***			2,875.43	97.91		
	(1,937.08)	(81.44)			(809.97)	(47.92)			(2,101.62)	(87.07)		
Corruption			−3,044.15	−107.18			−137.82	42.47			352.46	57.32
			(2,044.77)	(76.74)			(915.32)	(44.14)			(2,532.16)	(80.78)
HTE: MW Finance (t) * Dem	2.83***	0.37**			−0.06	0.06			5.19***	0.02		
	(0.19)	(0.17)			(0.08)	(0.10)			(0.21)	(0.18)		
MW Finance (t-1) * Dem		−0.60*				−0.17				−0.53		
		(0.33)				(0.19)				(0.35)		
MW Finance (t-2) * Dem		0.57***				0.13				0.52**		
		(0.19)				(0.11)				(0.20)		
HTE: MW Finance (t) * Corr			11.36***	3.04***			0.36*	−0.49			5.57***	−2.48**
			(0.42)	(0.61)			(0.19)	(0.35)			(0.51)	(0.64)
MW Finance (t-1) * Corr				−3.21***				0.01				3.15***
				(1.00)				(0.57)				(1.05)
MW Finance (t-2) * Corr				0.74				0.63*				−0.50
				(0.56)				(0.32)				(0.59)
Constant	4,420.25**	−30.41	5,964.21**	37.13	2,892.16***	−113.75*	3,360.21***	−72.38	2,527.92	−32.79	1,842.28	−29.98
	(2,057.81)	(108.47)	(2,462.23)	(115.00)	(860.45)	(63.29)	(1,102.19)	(66.15)	(2,232.61)	(115.77)	(3,049.12)	(121.11)
Fixed Effects	state, year	year	state, year	year	state, year	year	state, year	year	state, year	year	state, year	
Observations	3,651	3,319	3,641	3,311	3,651	3,319	3,641	3,311	3,651	3,319	3,641	3,311
R^2	0.99	0.92	0.99	0.92	0.93	0.47	0.93	0.47	0.98	0.93	0.98	0.93
Adjusted R^2	0.99	0.92	0.99	0.92	0.93	0.46	0.93	0.46	0.98	0.93	0.98	0.93
Residual Std. Error	10,312.53	1,079.00	9,661.07	1,093.68	4,312.07	628.69	4,324.67	628.86	11,188.52	1,151.10	11,963.84	1,151.5
F Statistic	2,769.95***	1,013.11***	3,159.40***	983.99***	329.30***	75.81***	327.19***	75.90***	1,481.72***	1,083.25***	1,292.88***	1,082.57*

Note: *p<0.1; **p<0.05; ***p<

Table 5: Mitigation Finance and Development (by Substate Region)

	Dependent variable:			
	ln GDP	Δ ln GDP	ln GDP	Δ ln GDP
	(1)	(2)	(3)	(4)
Δ ln GDP (t-1)		0.005		0.01
		(0.01)		(0.01)
Δ ln GDP (t-2)		0.01*		0.02**
		(0.01)		(0.01)
ATT: ln Finance	0.03***	−0.0001	0.01***	−0.005*
	(0.001)	(0.002)	(0.002)	(0.002)
ln Finance (t-1)		0.002		0.002
		(0.002)		(0.004)
ln Finance (t-2)		−0.001		0.002
		(0.002)		(0.003)
Democracy	0.52***	−0.03***		
	(0.04)	(0.01)		
Corruption			−1.30***	−0.01
			(0.06)	(0.01)
HTE: ln Finance (t) * Dem	−0.06***	0.001		
	(0.002)	(0.003)		
ln Finance (t-1) * Dem		−0.01		
		(0.004)		
ln Finance (t-2) * Dem		0.001		
		(0.003)		
HTE: ln Finance (t) * Corr			−0.02***	0.01**
			(0.003)	(0.004)
ln Finance (t-1) * Corr				−0.01
				(0.01)
ln Finance (t-2) * Corr				−0.003
				(0.005)
Constant	22.22***	−0.01	23.61***	−0.01
	(0.10)	(0.01)	(0.12)	(0.01)
Fixed Effects	region, year	year	region, year	year
Observations	34,813	31,614	34,813	31,614
R^2	0.97	0.17	0.97	0.17
Adjusted R^2	0.97	0.17	0.97	0.17
Residual Std. Error	0.37	0.17	0.37	0.17
F Statistic	664.23***	157.98***	655.82***	155.09***
Note:			*p<0.1; **p<0.05; ***p<0.01	

Table 6: Mitigation Finance and Development (by Country)

	Dependent variable:			
	ln GDP	Δ ln GDP	ln GDP	Δ ln GDP
	(1)	(2)	(3)	(4)
Δ ln GDP (t-1)		0.21***		0.22***
		(0.02)		(0.02)
Δ ln GDP (t-2)		0.13***		0.13***
		(0.02)		(0.02)
ATT: ln Finance	0.01***	0.0004	−0.0001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)
ln Finance (t-1)		0.0001		0.001
		(0.001)		(0.001)
ln Finance (t-2)		−0.0004		0.001
		(0.001)		(0.001)
Democracy	0.20***	−0.01		
	(0.04)	(0.01)		
Corruption			−0.29***	0.002
			(0.05)	(0.01)
HTE: ln Finance (t) * Dem	−0.02***	−0.001		
	(0.002)	(0.002)		
ln Finance (t-1) * Dem		−0.001		
		(0.002)		
ln Finance (t-2) * Dem		0.001		
		(0.002)		
HTE: ln Finance (t) * Corr			0.01***	0.002
			(0.002)	(0.002)
ln Finance (t-1) * Corr				−0.001
				(0.002)
ln Finance (t-2) * Corr				−0.001
				(0.002)
Constant	23.99***	0.02***	24.25***	0.01*
	(0.05)	(0.01)	(0.06)	(0.01)
Fixed Effects	state, year	year	state, year	year
Observations	5,477	4,972	5,453	4,952
R^2	0.99	0.19	0.99	0.19
Adjusted R^2	0.99	0.18	0.99	0.19
Residual Std. Error	0.21	0.06	0.21	0.06
F Statistic	2,840.53***	28.27***	2,733.30***	29.71***
Note:				*p<0.1; **p<0.05; ***p<0.01

Finally, Table 7 summarizes each specification predicting country-level emissions with mitigation finance, using the projected emissions cuts from mitigation finance projects as treatment variables. Contrary to the intended effect of mitigation finance, CDM projects are associated with increased state-level emissions, although this effect is reversed for democracies in the staggered adoption model. This finding lends support to H3, which predicts that mitigation finance will be ineffectual in reducing emissions due to the tension between donor and recipients preferences.

Table 7: Mitigation Finance and Emissions (by Country)

	Dependent variable:			
	ln Emissions	Δ ln Emissions	ln Emissions	Δ ln Emissions
	(1)	(2)	(3)	(4)
Δ ln Emissions (t-1)		0.001 (0.01)		0.002 (0.01)
Δ ln Emissions (t-2)		0.08*** (0.01)		0.08*** (0.01)
ATE: ln Financed Emission Cuts (t)	0.01*** (0.002)	0.003** (0.001)	0.003 (0.002)	0.0002 (0.002)
ln Financed Emission Cuts (t-1)		−0.004** (0.002)		−0.0003 (0.002)
ln Financed Emission Cuts (t-2)		0.002 (0.001)		0.0002 (0.002)
Democracy	0.31*** (0.04)	−0.01 (0.01)		
Corruption			−0.22*** (0.05)	−0.005 (0.01)
HTE: ln Financed Emission Cuts (t) * Dem	−0.02*** (0.002)	−0.005* (0.003)		
ln Financed Emission Cuts (t-1) * Dem		0.01 (0.004)		
ln Financed Emission Cuts (t-2) * Dem		−0.001 (0.003)		
HTE: ln Financed Emission Cuts (t) * Corr			0.004 (0.002)	0.001 (0.002)
ln Financed Emission Cuts (t-1) * Corr				−0.001 (0.003)
ln Financed Emission Cuts (t-2) * Corr				0.001 (0.002)
Constant	10.97*** (0.04)	0.01 (0.01)	11.19*** (0.05)	0.01 (0.01)
Fixed Effects	state, year	year	state, year	year
Observations	3,922	3,409	3,916	3,407
R^2	0.99	0.09	0.99	0.09
Adjusted R^2	0.99	0.09	0.99	0.08
Residual Std. Error	0.16	0.07	0.16	0.07
F Statistic	2,922.83***	11.62***	2,909.69***	11.36***
Note:				*p<0.1; **p<0.05; ***p<0.01

4 Discussion

Together, the empirical results in Section 3 provide partial confirmation of some of my hypotheses and prompt compelling questions for future research. While hypotheses 1, 2, and 3 are weakly confirmed, hypotheses 4 and 5 appear to be wrong. In other words, the results confirm general shortcomings in the efficacy of mitigation finance, and an interesting heterogeneous effect between projects replacing oil or gas powerstations (and therefore lacking co-benefits) and projects replacing coal powerstations (and therefore with significant co-benefits). But these results do not confirm my theoretical prediction of a heterogeneous effect by regime type. Democracies and low corruption states were not more likely to use mitigation finance for development.

4.1 Future Research

Future research can build on this study to pursue several important questions. First, how do incentives differ between mitigation finance deals managed by an IO (e.g., the CDM) and those managed directly by states (e.g., joint implementation)? And what differs between deals struck between private actors across states (e.g., mitigation finance) and those between states themselves (e.g., national emissions trading)? My expectation is that similar principal-agent problems will plague any interstate mitigation transaction, but variation in the structure of the dilemma could have important implications for outcomes.

Second, how do different mitigation finance institutions (e.g., the CDM, the GCF, and alternatives from the World Bank) interact? Some research has already found complications arising from multiple forums for mitigation finance, but these studies could benefit from a focus on donor-recipient tension over counterfactuals (Pickering, Betzold and Skovgaard, 2017; Weikmans and Roberts, 2019). Moreover, how does mitigation finance interact with other forms of international aid, such as adaptation finance or traditional economic development finance? Recipients' ability to "shop around" between varying programs and institutions, especially ones with distinct goals, may affect both recipient outcomes and the operation of each institution (Clark, 2022).

This article also lacks complexity in its treatment of donors. Donors are modeled as a non-strategic and monolithic block of actors who are solely interested in funding real mitigation. To some extent, this assumption makes sense: if donors did not want to mitigate, they would spend their money on something else. But this simplification overlooks two potential complexities behind donors' aims. First, there may be an additional principal-agent problem within donor states themselves. In this case, the government (the principal) may be interested in real mitigation, hence its mandates for emissions cuts either at home or through mitigation finance abroad. The firms or individuals responding to this regulation (the agents) may care only about formal compliance rather than effective mitigation. This domestic gap in information and interests may further complicate the interstate transaction. Second, donor governments themselves may not be truly interested in mitigation but rather may seek to leverage mitigation finance as a political tool to achieve other aims. This possibility mirrors findings from the literature on the politics of development aid. Indeed, some research has already found evidence of power considerations in mitigation finance institutions (Graham and Serdaru, 2020).

4.2 Policy Reform

In addition to the academic contribution of this research, the results will be highly relevant to the policy community. A number of governments, IOs, and NGOs are increasingly focused on climate change mitigation, for which mitigation finance remains a crucial tool. Negotiations are ongoing to replace the CDM with an updated version through the Paris Agreement, tentatively titled the Sustainable Development Mechanism (SDM). Future mitigation finance efforts, through the CDM/SDM, the GCF, and other parallel organizations, are certain to expand in coming years. Academic research, therefore, can decisively contribute to the design and use of mitigation finance and related mechanisms.

A simple policy recommendation generated from my findings is that, in addition to ameliorating the first-order problem of mitigation finance by finding an appropriate balance between transaction costs and the prevention of waste and fraud, donors can ameliorate the second-order problem of mitigation finance by focusing on projects that are likely to provide large co-benefits relative to the counterfactual. This means, for example, that green powerstations should be prioritized in coal-dependent rather than gas-dependent recipients. Such attention to co-benefits will increase the alignment of interest between donors and recipients.

Another way to circumvent the second-order problem of mitigation finance would be to avoid significant local benefits entirely. If the technology of direct air capture (DAC) of greenhouse gases advances to a level at which the cost per ton of carbon captured allows feasible operations at scale, mitigation finance could be used to build DAC plants in recipient states. Because DAC plants are themselves carbon negative, their construction will mitigate climate change relative to the counterfactual of nothing being built. Moreover, because DAC plants provide no significant local benefits such as electricty, donors can be assured that those plants built with mitigation funds are additional. There will be no reason to believe that DAC plants would have been built anyways in the un-financed counterfactual. Although this lack of significant local benefits would help to ensure that mitigation is being achieved, it also would weaken the moral argument for siting mitigation in poor states and undercut the willingness of those states to host these plants. Nevertheless, any investment project will carry some amount of local benefit relative to the counterfactual of no investment. Constructing DAC plants will require short-term construction labor and materials from local suppliers, and operating these plants will create long-term employment in the local community.

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