Distributional implications of international clean energy investment: Evidence from CDM investment into Brazil

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Abstract

Since 2004, the Clean Development Mechanism (CDM) of the Kyoto Protocol has facilitated more than US$ 550 billion of new investment into low and middle income countries, much of which is supporting clean energy infrastructure and related energy projects. An explicit objective of the CDM is to promote 'sustainable development'. Most definitions of sustainable development describe development that prioritizes equality of opportunity in the development process and/or equity in the distribution of the benefits of development. There is growing concern that these equity objectives are being over-ridden by economic efficiency concerns.

This paper examines distributional issues connected to CDM investment flows using new project- and municipality-level data for Brazil. It examines the distribution of CDM investment, projects, and GHG emission reductions across municipality quintiles in terms of municipality economic prosperity and income inequality. The analysis also explores which characteristics of CDM investment projects associate with localisation in relatively poor municipalities and in relatively unequal municipalities. At least in Brazil, CDM investment is flowing disproportionately to more prosperous municipalities and, to a lesser extent, to more unequal municipalities. The analysis shows that CDM projects have the potential to reduce income inequality, particularly for certain types of projects widespread among CDM projects in Brazil, like methane avoidance projects. National and regional policy should give greater attention to intra-country distribution issues with CDM and other similar clean energy investment insofar as it is envisioned to play a role in sustainable development.

Keywords

Foreign direct investment, distributional impact, clean development mechanism (CDM), Brazil

1. Introduction

In some respects the Clean Development Mechanism (CDM) has been one of the most successful elements of the Kyoto Protocol in that it has mobilized the flow of very large quantities of private financial capital into low emission development projects in low and middle income countries. These financial flows have achieved large emission reductions relative to a business as usual counterfactual, shifted a substantial portion of cost of emissions mitigation to the private sector, and reduced the cost of mitigation relative to what it would have been if the public sector had undertaken it directly (Zhang & Maruyama, 2001). By our calculations, 'clean' FDI under the CDM may have accounted for 6% of all FDI globally during the period 2004 to 2016, and over 30% of all FDI into some countries such as Ecuador, Kenya, Laos and Nepal.

Over the same period, a large body of research has examined the 'sustainable development' benefits that CDM investment creates in the localities where CDM projects are located (Olsen, 2007; Sutter and Parreño, 2007; Boyd *et al.*, 2009; Subbarao and Lloyd, 2011; Olsen and Fenhann, 2012; Crowe, 2013; Wittman and Powell, 2015). This body of research has been motivated partly by Article 12 of the Kyoto Protocol which states that the purpose of the CDM is to assist developed countries in complying with their emission reduction commitments *and* to assist developing countries in achieving sustainable development.[1] This body of research consistently finds that CDM projects either do not deliver meaningful sustainable benefits to the localities where projects are located, or that the extent of the contribution to sustainable development is limited or 'moderate at best' (Crowe, 2013) or that the effects on sustainable development outcomes like local income and employment are mixed, specific to certain project types, and/or short lived. A reasonable summary of this prior

[1] Clause 2: "The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3." Clause 3: "Under the clean development mechanism: (a) Parties not included in Annex I will benefit from project activities resulting in certified emission reductions; and (b) Parties included in Annex I may use the certified emission reductions accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol."

research is that the CDM is failing to produce the sustainable development benefits intended in the protocol. A leading explanation for this outcome is that the CDM creates ample incentives for private investors to locate efficient mitigation opportunities but that the lack of incentives in the CDM to produce sustainable development benefits undermines investment that might otherwise result in more equitable development. (Ellis, Winkler and Corfee-morlot, 2007; Olsen, 2007; Pearson, 2007).

The current research starts from the premise that this finding should not be surprising and that research that continues to look for widespread sustainable development benefits is unlikely to find positive result. It argues that it is true that clean inward investment has the *potential* to create sustainable development benefits in host localities *a priori*, but that the investment and legal provisions of the CDM are not designed to do this. Moreover, there is no compelling reason why future revisions to the CDM within the United Nations Framework Convention on Climate Change (UNFCCC) *should be* designed to do this given that the primary institutional objective of the UNFCCC is to stabilize atmospheric GHG concentrations and not to promote sustainable development.[2] This position does not mean that parties to the UNFCC should not pursue sustainable development in tandem with emission reductions or that sustainable development should not be a precondition doing that. The Kyoto Protocol does mention 'sustainable development' as a goal of the CDM and the Preamble to the UNFCCC includes a reference to 'coordinating' climate change response with development and the eradication of poverty in developing countries (United Nations, 1992). The reality is that these rhetorical statements are not supported by incentives in policy designs that shape real-world outcomes. It only means that it seems unreasonable from a scientific point of view to expect the current UNFCCC treaty framework to produce an outcome other than that for which it is designed.

A finding that has emerged from prior research in this area is that the institutional capacity of the Designated National Authorities (DNAs) that coordinate and approve project proposals from investors is related to the extent to which recipient countries benefit from CDM

[2] Article 2 of the original 1992 treaty declaration: "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

investment. DNAs can and in some countries do screen and shape clean investment project proposals so that they conform with national development priorities (World Bank, 2010). If it is reasonable to hold an entity responsible for the delivery of sustainable development benefits in recipient countries then that entity is the DNAs. The reality however is that there is a lot of variation in the institutional capabilities of DNAs to channel CDM investment into national development priorities and that some DNAs are in too institutionally weak or too weak relative to project proposers in the international market for clean inward investment to insist too strongly that proposal proposals conform to those priorities.

This paper explores a different question arising in the CDM policy context which bears on the capacity of DNAs to fully exploit the potential of CDM to their national development objectives. The question is whether there is a difference between 'clean' and 'ordinary' inward investment in terms of the economic benefit it creates across income groups within a country. If there are indeed differences, then the following question is, what are the characteristics of clean investment projects that locate in regions that are below the median in terms of economic prosperity or above the median in terms of the equitability of the income distribution? Answers to these questions can shed light on how DNAs can discriminate among CDM project and CDM project designs to further nations' development goals.

The research explores the hypothesis that 'clean' inward investment is indeed different to ordinary FDI in terms of the locations in a country that it flows to. If clean inward investment flows to different locations, the distribution of its economic benefits may be different. If the economic benefits of clean inward investment were more unequal than ordinary inward investment, this would not make the problem of weak DNA capacity go away, but it would offer one clue as to why CDM projects have not contributed strongly to sustainable development goals to date, whether or not the CDM includes appropriate investor incentives.

The current research fits with widening criticism of the distributional impact of policies that use economic incentives to reduce environmental damage. The financial benefits of clean investment and clean technology deployment policies tend to flow disproportionally to higher income groups. This finding persists across the deployment of residential solar PV installations in the UK and California (Borenstein, 2015; Grover and Daniels, 2017), within programs incentivizing private investment in home weatherization in the US, under policies providing tax credits for the purchase of electric vehicles in the US (Borenstein and Davis, 2015), and under policies that discourage GHG emissions through taxation (Feng *et al.*, 2010).

The research questions set out above are approached in the next section by reviewing the literature on the relationship between FDI and inward investment flows on the one hand,

and distributional outcomes and equity outcomes on the other, from the new point of view of those flows being characterized by 'clean' investment content. Section 3 describes the research methodology and data including CDM project data matched to information on Brazilian municipalities. Section 4 describes the results. Section 5 discusses the results for theory and for DNAs and suggests some possible ways for DNAs to work with clean investment flows specifically.

2. Distributional outcomes from 'clean' FDI

FDI involves the flow of firm-specific capital across international borders where the capital itself may take the form of proprietary production technologies, brands and trademarks, and organizational and/or managerial practices (Pandya 2014). There is a wide literature on the impact that FDI has on development outcomes in developing countries, and much of this research finds a positive relationship of FDI on growth (Makki and Somwaru, 2004; Almfrajiab and Almsafir, 2014), although some studies find a negative or null relationship. Other research carried out at broader analytical scales argues that FDI creates economic dependency relationships between developing country hosts of capital and developed country senders of capital, implying standard economic and econometric analyses may be insufficient to empirically test whether these relationships exist and their economic consequences.

From a modern neoclassical economic perspective, many of the arguments for the existence of positive benefits to growth and development from FDI in developing countries are persuasive. It is hard to see from a theoretical perspective how certain channels between FDI and development outcomes would *not* be activated by FDI relative to a counterfactual world where FDI did not occur. One channel is the transfer of modern production technology and softer managerial practices to the host country, which eventually get adopted by elements of the host country labour force and so raise labour productivity and wages. Another channel is that FDI produces goods and services that are often consumed in the host country and even if they are not create business revenue that gets taxed by governments and eventually re-spent on the country's development agenda(P. Tsai, 1995). It is hard to see how FDI would not generate at least some growth in the host countries in these ways, and even if it did generate negative growth effects simultaneously, how the net effect would be negative.

The approach taken in this research is to assume that a large influx of FDI into a developing country generates at least some economic growth benefits, even if those benefits are not directly or immediately observable, and even if they are not 'sustainable' in the sense defined by the Kyoto Protocol. Assuming this, the interest is in how the benefits of FDI distribute across income groups within the country when the type of FDI is characteristically 'clean' as are the flows under the CDM.

Various cross-country studies have found a positive relationship between the level of FDI in a developing host country and the level of income inequality there (Bornschier and Chase-Dunn, 1985). Jaumotte, Lall and Papageorgiou (2013) for example find that financial globalization and particularly FDI is a leading explanatory factor in the rapid rise in income inequality in many developing countries over the last two decades. Also in an empirical study, Basu and Guariglia (2007) find that FDI leads to an increase of both income inequality and economic growth. Tsai (1995) finds that FDI and income inequality in the host country are positively related and that the relationship has been especially strong in east and south Asian countries. Kentor (2001) attempts to provide a unified model of the relationship between FDI and inequality for developing countries, finding a positive relationship between them. Remarkably, both Choi (2006) and Huber *et al.*, (2006) in their respective studies have had to consider exceptionally higher inequality indexes when it comes to Latin America and the Caribbean. This indicates that when it comes to studying inequality related to FDI in this region (in the present case, Brazil), it might be necessary to study them uniquely as a country.

There are various mechanisms proposed in the literature for why FDI may reinforce existing income inequality or generate new income inequality, most of which have to do with the type of workers FDI benefits. Pandya (2014) suggests in their theoretical model that FDI competes with local investment, hence decreasing incomes for the holders of capital (i.e. the higher-income sections of society) while increasing incomes for the non-holders of capital (i.e. the lower-income sections of society). Feenstra and Hanson (1996) look at a traditional model of a product requiring labour and capital to be produced, dividing labour into high- and low-skilled labour. Arguing from a standpoint that postulates the 'north' to have a competitive advantage in high-skilled labour and the 'south' to have the same in low-skilled labour, they find that FDI inflows tend to increase income inequality, in the case of a transfer of capital from the 'north' to the 'south'. Another model proposed by Im and Mclaren (2015) could be thought of as a more nuanced version of Pandya's (2014) theory, and essentially says that FDI inflows would raise the demand for skilled labour, increasing the wage levels for skilled labour, and hence increasing inequality along with it. Another possible mechanisms is that there is variability in the composition of FDI in terms of which types of workers it benefits, and these compositional effects may lead to FDI generating labour force inequality. In empirical work, Raveh and Reshef (2016) find that the share of the investment that supports R&D and other skill-intensive activities is what contributes to inequality (by increasing the wages of skilled relative to unskilled workers), not the monetary value of inward investment on its own.

Less of the research on this relationship in the last 10 years has acknowledged Kuznets' hypothesis that some amount of inequality may be necessary in the short run in the development process in order to achieve growth and equality in the long run. This hypothesis states that a country's early growth experience involves labour moving into the high income modern sector of the economy initially which widens the income gap between income groups.

The question in this research however is how equitably the benefits of 'clean' FDI distribute across income groups within a country and whether these benefits distribute more or less equitably than those of ordinary FDI. Standard theories of FDI and investment location outcomes are well established (Dunning 1980) and without much elaboration can be used to make inferences about the location preferences of inward investment that is characteristically 'clean'.

In standard theory, the location of inward investment is partly driven by the strategic priorities of investing firms and partly by the specific differentiating characteristics of regions (Chakrabarti, 2003). When the comparative advantage of a region matches with the strategic priorities of the firm, investment occurs. The most common location determinants are factor input costs including the cost of land and the cost of labour; proximity to a sizeable market for the produced good or service; the favourableness of the policy environment to the inward investment activity; and agglomeration forces. From these pillars of standard theory can be derived various predictions about why clean FDI in particular is more likely to flow to some places in a country.

Clean inward investment in energy generation specifically should flow to regions with physical geographic and meteorological characteristics that clean energy technologies need and can exploit, as these features influence project revenue generation. For wind power technology, windiness is an input factor.

Clean inward investment should also flow to regions with policy conditions that favour clean investment activities, such as regions that provide subsidies to clean energy producers or regions that use taxation to discourage damaging production externalities (thereby giving clean producers a relative competitive advantage). If this standard theory prediction is true that clean inward investment location is influenced by local policy conditions, then this would mean that local decision-makers and DNA personnel have agency, in the form of policy levers, to attract clean investment. The favourableness of the policy environment could also extend to planning efforts by regional governments to promote ‘clean’ land-intensive production activities in regions where agriculture or forestry form a high proportion of GDP.

Inward investment projects under the CDM typically have a two-part revenue structure where a more or less standard good is produced for the local market (electricity) and as a result of that production, a non-standard good is produced for the international market (carbon credits). Standard good production should favour regions with low land costs and low labour costs, and also geographic proximity to electricity load centres including areas with strong demand for electricity as an input such as manufacturing (Markusen and Strand, 2009; Coughlin, Terza and Arromdee, 1991). The non-standard good on the other hand, carbon credits, has an intangible quality that gives it similar qualities a financial or legal service. The location of carbon credit production is inseparably bundled with the production of the standard good, but the carbon credits themselves once produced are hardly sensitive at all to transportation costs.

Agglomeration effects imply that a region becomes a more attractive investment location for firm A because the region has already been invested in by firm B (Dunning and Lundan, 2008). Following firms may invest around a pre-existing agglomeration of like-producers in order to avoid losing market share to competitors, a competitive motivation, or in order to capture positive externalities and ‘untraded interdependencies’ that arise from the agglomeration milieu (Storper, 1997; Head, Riesat and Swensonb, 1995). In the clean inward investment context a relevant positive externality is the demands that an investing firm places on local authority officials to understand and approve sophisticated international projects. The demands placed on local authorities should build administrative familiarity and project approval capacity at various tiers of government, which should reduce permitting and administrative costs for sequent investors.

Few of these expectations about the distinct location preferences of clean inward investment are informative about whether the social and economic benefits of clean inward investment distribute more or less equally than those of ordinary inward investment. Prior research on whether inward investment facilitates greater inequality is an open debate although more studies than not find a positive relationship.

A smaller literature has tested whether clean inward investment has reduced poverty in the areas where projects are located and/or generated employment. Mori-Clement and Bednar-

Friedl, (2019) estimate the impact of CDM projects on local employment in municipalities. They find that CDM projects have mixed effects on local employment. They effects that they do find are small and transitory, and seem to have occurred immediately or within the early projects phases of registration, construction and initial operation. Mori-Clement (2019) finds that the effect of projects on these outcomes are mixed by project type. Various CDM project types have raised average incomes (which does not in itself tell us anything about inequality) and hydroelectricity projects have alleviated poverty. Mori-Clement finds that the Theil index of inequality dropped by 2 percent in municipalities with a CDM project between the pre-treatment and treatment period. On the other hand, the results are inconsistent. Mori-Clement's data for hydro projects show a decrease in inequality but she reports an increase in inequality. Her data for biomass projects show an increase in inequality of 4 percent and this is interpreted as a reduction in inequality (p. 228). Their waste management project data show an increase in inequality of 3 percent but this is interpreted as a reducing inequality. Their methane avoidance project data show a decrease in inequality of 1 percent and they do not interpret this result.

Outside of Brazil, CDM projects have had similarly mixed results on poverty and inequality. Du and Takeuchi (2018) find that CDM biomass projects only have reduced poverty in rural China. In a reviews of the literature on the effects of CDM projects on poverty alleviation, Dirix et al (2016) and Olsen (2007) conclude that there is little evidence that CDM projects have substantially helped reduce poverty. Crowe (2013) finds that regular CDM projects are only 'moderately' successful at delivering pro-poor benefits and that projects that do delivery pro-poor benefits are characterized by the use of add-on project standards, a high degree of stakeholder participation, and the involvement of not-for-profit and government entities as project developers.

A five-year review China's CDM activities evaluated the distribution of project activities across Chinese provinces with attention to the different prosperity levels of the provinces. It finds that

> ' . . . Yunnan, Inner Mongolia, Hunan, and Gansu, poorer provinces on a *per capita* GDP basis, host among the largest numbers of CDM projects. In recent years the geographic distribution of projects has shifted toward the southwest . . . . There also is a general trend toward relatively fewer new projects in the wealthier provinces compared with projects already registered. This is consistent with the government's aim that CDM should contribute to local sustainable development, particularly in the poorer regions of the country. It may also indicate that it is more challenging to demonstrate the additionality of CDM project activities with respect to normal business practices in provinces with better developed human and financial capabilities. CER

> volumes, however, have a more uneven distribution that favours the [wealthier] eastern provinces.'

The distribution of CDM activities is more unequal in terms of CER volumes, mainly due to the relatively high concentration of large-scale industrial HFC destruction projects in wealthier eastern provinces, whereas the small scale renewable energy projects that tend to locate in poorer interior regions result in lower CER volumes. In the later years in their study they find a trend of fewer projects flowing to wealthier provinces compared with those already registered. They suggest that this may be because it is more challenging to demonstrate the additionality of a CDM project with respect to business as usual practices in provinces with better developed human and financial capacities. China has relatively strong project approval institutions which have succeeded in channelling investment and project activities into pre-existing state development goals, which may also explain the shifting distribution of project activities to poorer provinces.

Koo (2017) performed an investment analysis on four CDM projects in Korea to understand how CER issuance rules under the CDM policy framework affects project-level financial returns. Koo finds that the CDM framework favors large scale projects that deliver large emission reductions and that small, capital intensive projects can be deterred from registering. Koo concludes that the CDM favors particular project types.

3. Research approach

Brazil was chosen for the empirical analysis because it is a major recipient of CDM investment and because policymakers there continue to address high levels of income inequality (Medeiros, 2016), including through the CDM project approval process. For example, the Brazilian Ministry of Science, Technology, Innovations and Communications requires project proposers to 'evaluate' in the CDM project proposals the contribution of the project to local environmental sustainability, the development of work conditions and employment opportunities, the distribution of income, technology development, and integration with regional development initiatives (MCTIC, 2003).

The research approach proceeds by testing two inter-related questions. The first is whether the presence of CDM investment has any causal impact on the level of income inequality in the places where it locates. Further, if it does have an impact, it would be important to know what type of projects associate with this impact. The second question assumes that even if CDM investment does not have an identifiable causal impact on economic welfare, it is still a desirable thing for DNAs and local government authorities to recruit. The question tested here is why CDM investment flows to some places and not others, and among the places that it flows to, what locational characteristics associate with larger flows.

4. Data

4.1. Data collection and descriptive statistics

Data for all CDM projects registered in Brazil to the end of 2017 were obtained from the UNFCCC website and supplemented with data from the CDM Project Database of the Institute for Global Environmental Strategies in Japan.

Additional information about the geographic location of each project was obtained by manually reading the Project Design Document (PDD) for each project. Sections A.4.1.3 and A.4.1.4 of the PDD provide information on the municipality or municipalities that project activities are located in. The municipality data collected from each project's PDD showed that 39% of projects spread over two or more municipalities and 12% spread over more than five municipalities (see appendix for the distribution). However the PDD provided no useful information about how much of a project's activities located in each municipality listed. In lieu of this information it was assumed that the project activities, and project investment, were spread equally across the municipalities listed, an assumption that is likely to be truer for some projects than others. Nonetheless, apportioning the project's investment value equally to the municipalities listed made it possible to match the project data to socioeconomic information about the municipality. In this way, the 341 whole projects became 801 fractional projects.

Other data used in the analysis included socioeconomic data for Brazilian municipalities obtained from the Brazilian Institute of Geography and Statistics (IBGE). These data make it possible to compare the socioeconomic characteristics of the municipalities that have received CDM investment with those that have not. Data on 'ordinary' FDI into Brazilian federal units (states) come from the quinquennial census of foreign capital compiled by the Central Bank of Brazil. State-level FDI data make it possible to compare the distribution of CDM investment across states with the distribution of non-CDM ordinary FDI across states. The Gini and Theil income inequality indices were obtained from the United Nations Development Programme's 'Human Development Atlas' from 2013.

The search of the UNFCCC database produced 383 projects. There were 341 registered projects, the earliest of which was registered in November 2004 and the latest in July 2016. The main variable of interest was the level of capital investment associated with each project, but this information was missing for 117 projects. This information might not have been disclosed by the project proposer because it was strategically sensitive or in flux at the time of PDD submission.

Since the projects with missing investment values are likely to account for a large part of CDM investment to Brazil during the period, values for those projects were estimated. A model was fitted for the investment variable for the projects with investment data, then the estimated coefficients were used to predict investment values for the projects with missing investment data. The procedure for doing this is explained in the appendix. Descriptive statistics are in Table 1.

Table 1: Descriptive statistics

Variable	Units	N	Mean	SD	Min	Max
INVESTMENT	Investment, mil. USD	224	104.9	466.2	0.1	5,437.3
INVESTMENTPR	Investment, mil. USD (predicted)	341	76.0	380.3	0.1	5,437.3
REDUCTIONS	GHG reductions, thou. tons p.a.	341	144.2	538.7	0.9	6,180.6

The table 2 below splits the municipalities into two groups, those with CDM investment and those without, and compares them in terms of economic and social characteristics of the municipalities. The meanings and units of the variables are described below.

Table 2: Comparison of municipalities with and without CDM investment

	No CDM investment	CDM investment	Difference	T-test of no difference
N	5,213.0	357.0		
GINI	49.4	49.5	-0.1	-0.15
THEIL	45.6	44.9	0.7	0.94
GDPSTOCKPC	138.5	233.6	-95.1	-12.15
IDHM	65.6	70.7	-5.1	-13.13
EMPLOYMENT	1.3	1.9	-0.6	-10.28
P_SUPER	6.9	9.3	-2.4	-12.36
P_ELECT	97.1	99.0	-1.9	-5.99
P_RURAL	36.8	26.9	9.9	8.24

FDI	81,744.6	118,502.3	-36,757.7	-4.41
P_TAX	7.0	9.8	-2.8	-8.51

4.2. Panel dataset construction and analysis

The breadth of socioeconomic data gathered from various sources in Brazil allows us to get deeper insights into the patterns of CDM project distribution in the country. A panel dataset was constructed that included geographical and socioeconomic data from the years 2000 and 2010 (corresponding to the income inequality data available in those years).

To assess the intra-municipal effects of the presence of a CDM project in a municipality, a question of natural interest is whether the presence of CDM projects had any influence on either the income inequality of the municipality. A range of studies including Sutter and Parreño (2007), Subbarao and Lloyd (2011), and others have noted potential effects of CDM projects on certain socioeconomic factors such as poverty alleviation, income generation, and employment generation, but few studies touch upon income inequality specifically, which in a Brazilian context is a very important parameter to study. Mori-Clement (2019) notes a small but statistically significant impact of CDM projects on improving income inequality. To supplement these studies, a fuller analysis of the causal effects of CDM projects on municipalities is presented in this present study. A difference-in-differences test was done to test a causal effect of the presence of CDM projects on the income inequality of the municipality, with the following model, where D_{CDM} is a dummy to indicate the presence of a CDM project, $D_t$is a time dummy, and $\boldsymbol{X}$ is a vector of covariates. The dependent variable $GINI$ can be replaced by another variable such as the Theil income inequality index as necessary.

$$GINI_{it} = c + \beta_1 D_{CDM} + \beta_2 D_t + \beta_3 D_{CDM} \times D_t + \beta_4 \boldsymbol{X}$$

To establish the validity of the difference-in-differences estimation, a “parallel trends assumption” can be verified from a visual inspection of the data before and after the treatment. Since this is a 2x2 test design (2 time periods and a binary treatment variable), the changes before and after treatment are clear to see. The mean income inequality before the treatment was higher in the municipalities that were to get a CDM project, and after the treatment the income inequality as measured by both the inequality indices is lower than the municipalities that did not get a CDM project (figures 1 and 2). To verify the statistical significance of these changes, however, we perform a fractional regression (for the Gini income inequality index as the dependent variable) and an OLS regression (for the Theil income inequality index as the dependent variable).

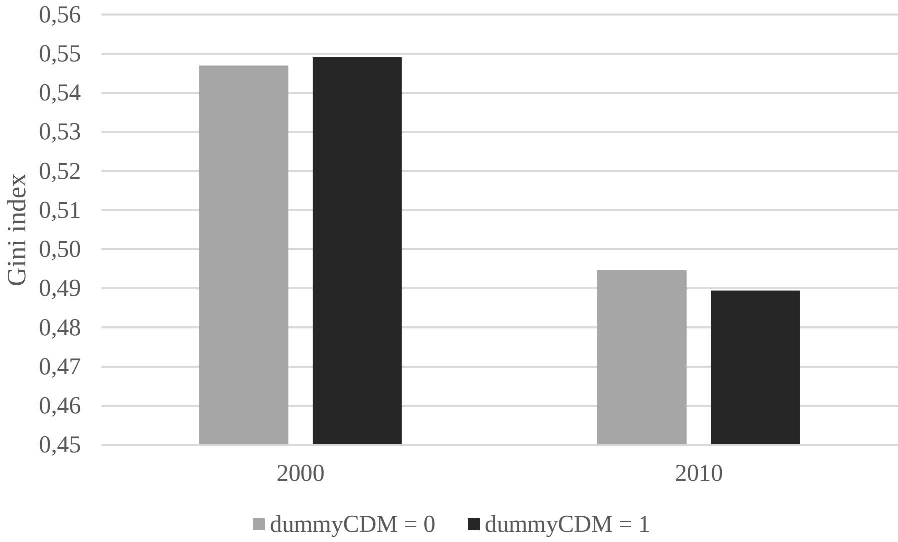

Figure 1: The Gini income inequality index before and after treatment

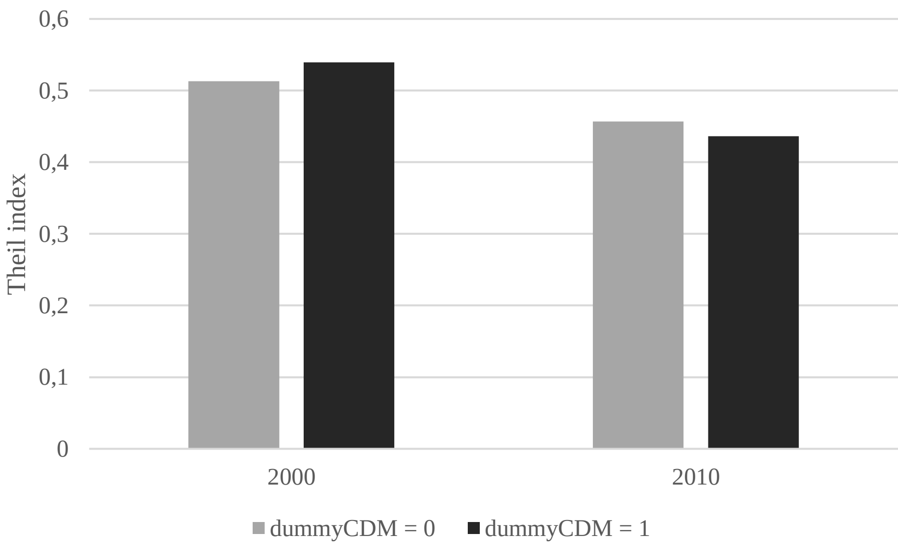

Figure 2: The Theil income inequality index before and after treatment

In addition to measuring the overall effect that the CDM projects had on the income inequality of the municipalities, we were interested in examining which type of projects had the highest impact, and we did that by including project type dummies (binary variables that took a value of 1 if at least one project of that type was present in that municipality, 0 otherwise). After clarifying the impact of the projects on inequality, we move on to analyse how the projects themselves are distributed across the Brazilian geography.

4.3. Analysis of spatial distribution of CDM projects

Figure 3 compares the distribution of CDM investment across Brazilian states to the distribution of all other 'ordinary' (non-CDM) FDI across Brazilian states. The comparison is only possible at state level and not at municipality level because ordinary FDI data only exist at state level. Both investment measures are given as stocks. CDM investment is the stock of investment for all years 2004 to 2016. Ordinary investment is the stock of investment for 2006, 2011, and 2016 less CDM investment.

There are substantial differences within states in the proportion of CDM and ordinary FDI investment locating there. Less than 0.1% of all ordinary FDI in Brazil flowed to the relatively poor northern state of Rondônia while 38.5% of CDM investment did. Over 51.0% of ordinary FDI located in the relatively rich, industrialized state of São Paulo while 2.9% of CDM investment located there.

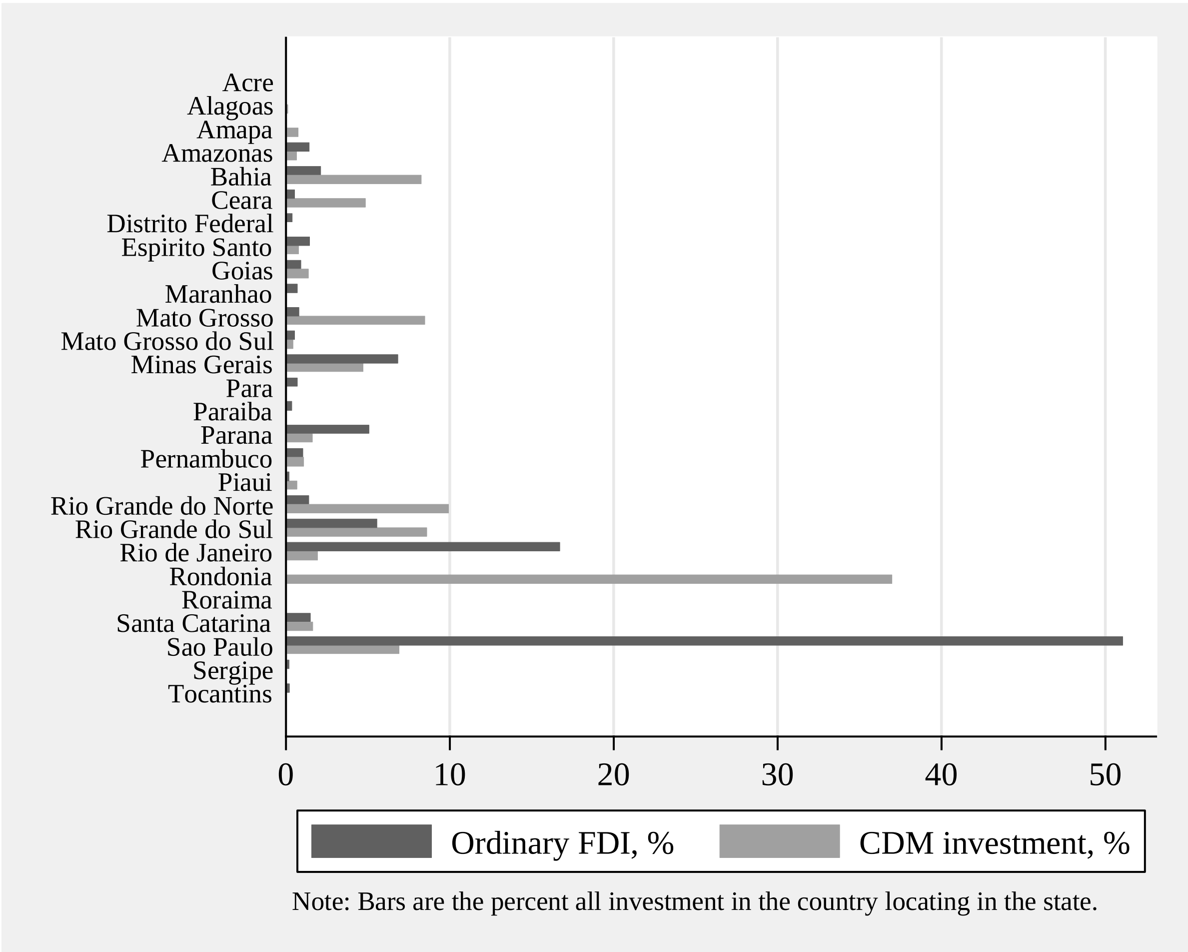

Figure 3: CDM investment across states, compared to ordinary FDI

The degree of equality in the distribution of CDM investment across municipalities was calculated via Gini coefficients. The Gini for the distribution of CDM investment was compared to the distribution of the stock of GDP (2004-2016), an indicator of ordinary economic activity. The table below shows that CDM investment is more unequally distributed than the stock of GDP. This is the case when the calculation is weighted by household per capita income in the municipality, when the calculation includes only municipalities that received CDM investment, and when the calculation includes both weighting and CDM municipalities only.

Table 4: Degree of inequality in CDM project distribution

	Gini	**Gini, municipalities weighted by per capita household income**	**Gini, only municipalitie s with CDM investment**	**Gini, weighting and only CDM**
GDPSTOCK	85.3	88.3	86.5	87.4
INVESTMENT	99.3	99.2	92.1	93.9
INVESTMENTPR	98.9	98.8	88.1	90.5

The 5,570 municipalities were divided into quintiles according to the mean household monthly per capita income of the municipality. There are 1,113 municipalities in each quintile. The average income in the first quintile is BRL 218 per person per month and in the fifth quintile it is BRL 860. More CDM investment is located in the fifth quintile than in the first four quintiles combined as can be gathered from figure 4.

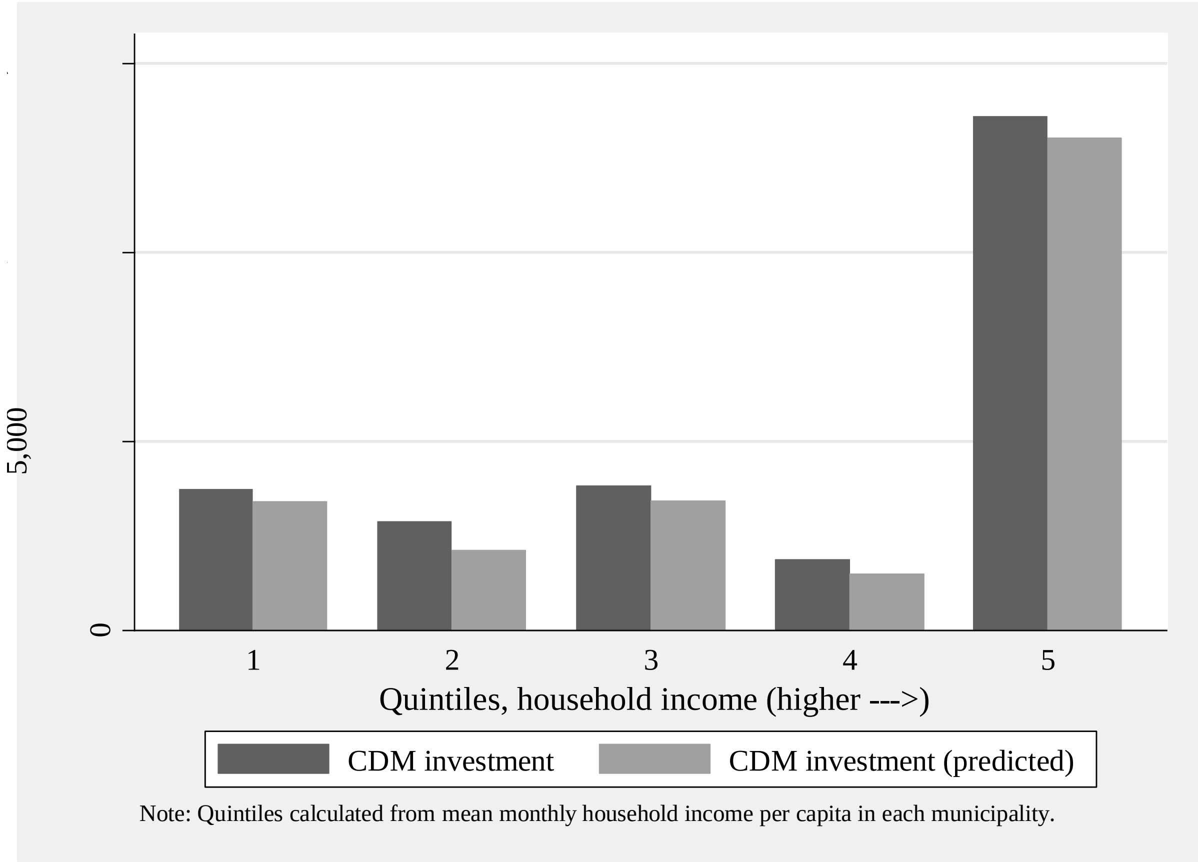

Figure 4: CDM investment across quintiles

The descriptive analysis suggests that CDM investment tends to locate in municipalities with higher GDP per capita, higher household income, higher human development index scores, higher employment rates, high skill levels, more electrification, and where more ordinary FDI is present (at the state level). CDM investment is more unequally distributed across municipalities than ordinary economic activity even after weighting municipalities by household income and after restricting the data to only those municipalities that received CDM investment.

To test the determinants of CDM investment more formally, the CDM investment variable was regressed on municipality geographic, economic and social characteristics in a two part model. The first part tests the municipality characteristics that associate with the location of any CDM investment at all, implemented by logistic regression where a positive outcome is a non-zero value of the variable INVESTMENT (or INVESTMENTPR). The second part tests the municipality characteristics that associate with higher investment values in the municipalities that do experience CDM investment. This part of the model is estimated by OLS. The non-zero values of the dependent variable are in logs and the independent variables are all linear.

The variables used in these exploratory regressions are described below. The first set of variables capture fixed geographic characteristics of municipalities including longitude and latitude, whether it is a state capital, and land area. The second set capture economic characteristics of the municipality: the proportion of occupied individuals working in the agriculture, commerce, and industry sectors. The third set of variables captures social characteristics of the municipality including skill level, the degree of inequality, and the proportion of individuals in extreme poverty. All explanatory variables are included in both parts of the model.

Table 5: Description of variables

Variable	Label	N	Mean	SD	Min	Max
LAT	Latitude	5,565	-16.4	8.3	-33.7	4.6
LONG	Longitude	5,565	-46.2	6.4	-72.9	-32.4
CAPITAL	State capital	5,565	0.0	0.1	0.0	1.0
AREA	Area, km2	5,565	1,527.9	5,622.3	3.6	159,533.4
P_ELECT	Households with electricty, %	5,565	97.2	6.0	27.4	100.0
P_AGRO	Occupied individuals working in agriculture, %	5,565	35.6	18.3	0.1	85.1
P_COM	Occupied individuals working in commerce, %	5,565	10.6	4.4	0.7	36.6
P_EXTR	Occupied individuals working in extraction, %	5,565	0.6	1.7	0.0	28.2
P_RURAL	Households living rurally, %	5,565	36.2	22.0	0.0	95.8
P_FUND	Occupied individuals with fundamental education, %	5,565	46.2	11.8	13.1	86.5
P_MED	Occupied individuals with intermediate education, %	5,565	30.4	9.8	4.2	73.7
P_SUPER	Occupied individuals with higher education, %	5,565	7.0	3.6	0.3	37.5
THEIL	Theil index	5,565	45.5	12.8	14.0	100.0
P_EXTPOV	Individuals in extreme poverty, %	5,565	11.3	11.8	0.0	69.7
GDPSTOCKPC	GDP stock (2004-2016) per capita (2016)	5,565	144.7	145.0	27.7	3,867.1

5. Results

5.1. Intra-municipality effects on income inequality

While investigating the intra-municipal effects of the presence of a CDM project, it was found that the presence of CDM projects unambiguously had a positive causal effect on reducing income inequality as measured by both the Gini and the Theil income inequality indices (tables 6 and 7). In other words, the presence of a CDM project in a municipality tended to decrease the income inequality index of that municipality to a greater extent than municipalities without a CDM project.

Table 6: Intra-municipal effects of CDM projects on the Theil income inequality index

	(1) THEIL	(2) THEIL	(3) THEIL	(4) THEIL	(5) THEIL	(6) THEIL	(7) THEIL	(8) THEIL
Overall_interaction	-0.049*** (-4.95)							
Time dummy	-0.056*** (-23.18)	-0.056*** (-23.56)	-0.059*** (-24.89)	-0.058*** (-24.28)	-0.059*** (-25.09)	-0.059*** (-25.15)	-0.059*** (-24.88)	-0.059*** (-25.12)
CDM project dummy	0.031*** (3.82)							

Bolsa Familia spending 2004, log	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***	0.029***
	(23.81)	(24.23)	(24.67)	(24.68)	(24.41)	(24.69)	(24.59)	(24.70)
Methane avoidance dummy		0.053***						
		(4.74)						
Methaneav_interaction		-0.075***						
		(-5.73)						
Biomass dummy			-0.002					
			(-0.17)					
biomass_interaction			-0.017					
			(-1.05)					
Hydro dummy				0.045***				
				(3.72)				
hydro_interaction				-0.042***				
				(-2.92)				
Landfill gas dummy					-0.013			
					(-0.65)			
landgas_interaction					0.001			
					(0.03)			
Fossil fuel switch dummy						-0.020		
						(-0.89)		
ffswitch_interaction						0.019		
						(0.63)		
Other project dummy							0.021	
							(1.28)	
other_interaction							-0.037*	
							(-1.73)	
Wind dummy								0.006
								(0.24)
wind_interaction								0.016
								(0.62)
N	10178	10178	10178	10178	10178	10178	10178	10178
r2	0.250	0.251	0.248	0.250	0.248	0.248	0.248	0.248

Note : t-statistics in parentheses.
Using robust standard errors. Constant and individual state dummies omitted for presentation.
* = 10% significance level, ** = 5%, *** = 1%

Table 7: Intra-municipal effects of CDM projects on the Gini income inequality index

	(1) GINI	(2) GINI	(3) GINI	(4) GINI	(5) GINI	(6) GINI	(7) GINI	(8) GINI
Overall interaction	-0.032*							
	(-1.77)							
CDM dummy	0.027*							
	(1.91)							
Time dummy	-0.210***	-0.209***	-0.212***	-0.210***	-0.212***	-0.212***	-0.211***	-0.212***
	(-44.71)	(-45.12)	(-46.37)	(-45.73)	(-46.74)	(-46.70)	(-46.35)	(-46.47)
Bolsa Familia spending 2004, log	0.061***	0.061***	0.062***	0.061***	0.063***	0.062***	0.062***	0.061***
	(27.03)	(27.33)	(27.63)	(27.68)	(27.57)	(27.67)	(27.58)	(27.63)
Methane avoidance dummy		0.068***						
		(3.83)						
methaneav_interaction		-0.076***						
		(-3.35)						
Biomass dummy			-0.015					
			(-0.61)					
biomass_interaction			0.001					
			(0.02)					
Hydro dummy				0.067***				
				(3.36)				
hydro_interaction				-0.036				
				(-1.41)				
Landfill gas dummy					-0.092***			

					(-2.67)			
landgas_interaction					0.076			
					(1.44)			
Fossil fuel switch dummy						-0.077*		
						(-1.78)		
ffswitch_interaction						0.112*		
						(1.71)		
Other project dummy							0.025	
							(0.84)	
other_interaction							-0.042	
							(-1.07)	
Wind dummy								0.040
								(1.02)
wind_interaction								-0.007
								(-0.17)
N	10178	10178	10178	10178	10178	10178	10178	10178

Note : t-statistics in parentheses.
Using robust standard errors. Constant and individual state dummies omitted for presentation.
* = 10% significance level, ** = 5%, *** = 1%

5.2. Analysis of spatial distribution of CDM projects

The results from the binary outcome part of the model are as follows (table 8). The coefficients are interpreted for variables that are significant across both versions of the dependent variable. Larger municipalities in terms of land area are more likely to host CDM investment as are municipalities with a larger proportion of individuals working in commerce. Municipalities with a higher proportion of individuals who have completed basic education are more likely to host CDM investment, all else equal, but municipalities with a higher level of intermediate education are less likely to host CDM investment. These skill level variables could be collinear. CDM investment is more likely to locate in municipalities with more unequal income distribution, all else equal, and less likely to locate in municipalities with high levels of extreme poverty. CDM investment is more likely to locate in municipalities with high GDP per capital.

Table 8: Results of the two-part model

	INVESTMENT		INVESTMENTPR	
logit				
LAT	-0.013	(-1.00)	-0.007	(-0.72)
LONG	0.003	(0.23)	-0.000	(-0.00)
CAPITAL	0.181	(0.36)	-0.053	(-0.11)
AREA	0.000	(2.33)*	0.000	(2.12)*
P_ELECT	0.062	(2.48)*	0.034	(1.94)
P_AGRO	-0.002	(-0.26)	-0.004	(-0.59)

P_COM	0.048	(2.85)**	0.052	(3.57)***
P_EXTR	-0.028	(-0.86)	-0.019	(-0.68)
P_RURAL	0.010	(2.07)*	0.004	(0.98)
P_FUND	0.053	(2.52)*	0.038	(2.10)*
P_MED	-0.046	(-2.01)*	-0.053	(-2.76)**
P_SUPER	0.033	(1.35)	0.054	(2.47)*
THEIL	0.025	(4.57)***	0.023	(4.77)***
P_EXTPOV	-0.047	(-3.40)***	-0.062	(-5.10)***
GDPSTOCKPC	0.001	(3.29)***	0.001	(3.42)***
regress				
LAT	-0.088	(-2.29)*	-0.069	(-2.37)*
LONG	0.048	(1.00)	0.051	(1.58)
CAPITAL	1.571	(1.56)	1.910	(2.11)*
AREA	0.000	(3.93)***	0.000	(4.17)***
P_ELECT	0.275	(2.38)*	0.210	(2.62)**
P_AGRO	-0.024	(-0.95)	-0.042	(-2.39)*
P_COM	0.074	(1.02)	-0.001	(-0.03)
P_EXTR	0.030	(0.20)	-0.107	(-1.13)
P_RURAL	0.025	(1.59)	0.020	(1.74)
P_FUND	0.009	(0.13)	-0.012	(-0.23)
P_MED	0.011	(0.14)	0.043	(0.74)
P_SUPER	-0.073	(-0.92)	-0.109	(-2.03)*
THEIL	0.000	(0.02)	0.001	(0.08)
P_EXTPOV	0.246	(5.34)***	0.236	(7.01)***
GDPSTOCKPC	0.001	(1.21)	0.001	(1.58)
Observations	5565		5565	
Pseudo R2	0.176		0.186	
F-statistic	6.003		10.60	
LL	-2108.3		-2852.6	
AIC	4280.6		5769.3	

Note: Two part estimator.
First part, logistic regression, DV is 1 if municipality has a CDM project.
Second part, OLS regression, DV is level of investment in CDM municipalities.
Heteroskedasticity robust standard errors, constant omitted for presentation.
t-statistic in parentheses.
* = 10% significance level, ** = 5%, *** = 1%

Turning to the second part of the model which is estimated by OLS, among municipalities that receive CDM investment, the further south a municipality is located the more CDM investment it receives on average. The land area of the municipality also associates positively with the level of investment, as does the degree of electrification. The level of inequality is not associated with the level of CDM investment but the degree of extreme poverty is strongly associated.

6. Discussion and conclusions

A widespread finding in the CDM policy evaluation literature is that the policy architecture creates strong incentives for investors to invest in efficient emissions credit production but weak or no incentives for investors to generate local social or economic benefits.

If CDM investment is not generating substantial local social and economic benefits then the policy outcomes are apparently misaligned with the stated policy objective, as the substantial literature in this area has noted.

One way of redistributing some of the socioeconomic benefits of CDM projects could be to strengthen the case for equitable distribution at the supranational level (i.e. in international climate negotiations). The next challenge for the Clean Development Mechanism of for the international sustainable development project that will replace it in the next few years will be to promote equity and force investors to direct their resources to the areas where they are needed, and not only where they can be profitable. As described by Robert Shiller, this is the challenge of finance itself to be redefined and reconfigured to serve "the greater goals for the good society"; even if a global consensus about the latter still has to be found (Shiller, 2012).

Boyd et al. (2009) propose five options for enhancing the sustainable development benefits of the CDM in future modifications to the policy design. These include minimum global standards for SD benefits that for example the project generates employment or royalties for local or national governments or that a global points system be created to systematically reward different project aspects such as generating tax revenues or creating energy infrastructure.

Such an argument for a top-level push is, however, rather unwieldy, given that different geographies and cultures have different definitions and targets for what 'sustainable development' is. And indeed, the 2015 Paris agreement by and large does not do any better than the Kyoto protocol in consolidating a definition of 'sustainable development'.

Instead, we argue that these targets should be set at the national or regional levels, and particularly so in the case of Brazil. Our analyses show that certain types of projects, namely methane avoidance, hydroelectric, and to a certain extent, landfill gas projects reduce the income inequality at a municipal level, and it is up to national and regional institutions to foster such projects in their locales. Specifically in Brazil, the analyses show that

DNAs can confront this discrepancy by re-examining whether sustainable development is a realistic objective in the presence of strong efficiency incentives or clarifying that sustainable development is in fact a goal and considering the various proposals that have been made to build additional incentives into the policy design (Boyd et al., 2009).

China is the first host country of CDM funding and the government has chosen to apply a specific tax on CDM projects to incentivize projects contributing more to its development priorities (Muller, 2007). Host nations interested in steering 'clean' (or other) FDI to promote the social equity element of their sustainable development goals more strongly, could implement such a tax. Such a tax might be justified by the logic that inward investment flows that exacerbate socioeconomic inequality are socially and politically destabilizing to the host country and so constitute a political externality of inward investment which the state and ultimately the tax payer would end up paying for. The tax could be equivalent theoretically to the social cost of increased inequality caused by the project caused at the margin for the spatial unit in question. Equivalently, a subsidy could be appropriate in regions where inward investment projects relieved the public and the tax payer of what would otherwise have been the cost of economic redistribution.

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Appendix A: Estimation of missing investment values

For the 224 projects with known investment values, the investment variable was regressed on the level of reductions achieved by the project, the square of reductions, dummies for each project type (biomass, methane capture, wind, etc.), dummies for project state, and a time trend. All variables were logged for the estimations and the predicted values were de-logged. The predicted values were then imputed for 117 projects to make the ‘predicted’ investment variable.

Appendix B: Project counts by municipalities touched

About 61 percent CDM projects in Brazil locate in 1 municipality while the remaining projects locate in 2 or more. A small number of projects spanned both municipalities and states.

Number of municipalities touched	**Count**	**Percent**
1	209	61.3
2	49	14.4
3	24	7.0
4	18	5.3
5+	41	12.0
Total	341	100.0