Assessing the Additionality of the Clean Development Mechanism: Quasi-Experimental Evidence from India

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Abstract

In order to assess the additionality of the Clean Development Mechanism, this paper exploits the fact that CDM wind power projects co-exist alongside wind power projects that are not registered under the mechanism. We use quantitative data to characterize the differences between both types of projects and develop two methods to test whether these differences may be related to project economic returns. Both yield the converging result that the CDM projects present no evidence of additionality. Controlling for different factors, CDM projects are located in windier areas, have higher power capacity and benefit from higher feed-in tariffs, three factors that are said to increase a project's profitability.

Key-words: Clean Development Mechanism, additionality.

1 Introduction

The Clean Development Mechanism (CDM) is a key component of the Kyoto Protocol. It allows industrialized countries that have committed to carbon emissions reduction targets (Annex 1 countries) to implement or finance projects that reduce greenhouse gas (GHG) emissions in non-Annex 1 countries in exchange for emission reduction credits. The CDM provides countries committed to climate mitigation the flexibility to carry out emissions reductions efforts where costs are lowest. Furthermore, it allows developing countries to take on domestic mitigation opportunities even though they do not have emissions reduction targets with the added intention of contributing to the sustainable development of host countries.

As the CDM was initially created to help achieve the targets of the first commitment period (2008-12) of the Kyoto protocol, the future of the CDM in the post-2012 regime has remained unclear for a long time. This uncertainty was dealt with at the 18th session of the Conference of Parties in Doha during 2012 when the decision was made to maintain the CDM and to allow any country to purchase CDM credits, including ex Annex-1 countries like Canada, New Zealand, Russia, and Japan who have decided not to commit to new emissions reduction target for the second period of the Protocol (2013-20).[1]

Since carbon credits created by the CDM are used by developed countries or emitters located in these countries as offsets to meet their own domestic mitigation targets, it is important that CDM projects result in "additional" emissions reductions to maintain the environmental integrity of the Protocol. By

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[1] Although a nearly zero CER price currently plagues the functioning of the mechanism.

definition, a CDM project is additional if "anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project".[2]

Whether CDM projects truly generate additional carbon emissions reductions has been a subject of controversy since the beginning of the scheme. Several studies have expressed serious doubts over the additionality of many CDM projects, in particular renewable energy projects and projects that reduce hydrofluorocarbon-23 (HFC-23) emissions (Haya, 2007; Wara and Victor, 2008; Haya and Parekh 2011; Schneider, 2009; Schneider, 2011). However, assessing the additionality of a CDM project is a difficult task for an external observer as the counterfactual – the emissions that would have occurred in the absence of the CDM – is, by definition, not observable. Therefore, in the absence of a convincing counterfactual scenario, the evidence so far has remained mostly anecdotal.

This paper provides the first large-scale empirical evaluation of the additionality of the CDM using a unique dataset of 1,352 wind power projects in India, extracted from the Bloomberg New Energy Finance database.[3] Wind power in India has a key feature that allows us to identify and assess the additionality of the CDM in a systematic way: CDM wind projects co-exist with wind farms that

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[2] Report of the Conference of the Parties held in Montreal in 2005, decision 3/CMP.1, paragraph 3

[3] India's wind power CDM projects obviously do not account for the diversity of the CDM projects over the world. Still, India is the second most important host country with 25% of the CDM projects in the world, after China (39%), and wind farms represent 38% of Indian CDM projects (UNEP-RISOE CDM Pipeline and database, Feb. 2013)

are *not* registered under the mechanism.[4] Our dataset includes 577 Indian CDM wind power projects and 775 wind farms not registered under the CDM.[5]

It is safe to assume that non-CDM farms are not additional as they have been implemented without the help of revenue from carbon emissions reductions (CER). This implies that, if additional, CDM projects should differ from non-CDM projects in some characteristics that affect their economic returns, thereby justifying the grant of carbon credits to make them profitable.

In order to assess the additionality of CDM projects we collected data from various sources on a range of factors that allow us to estimate the economic return associated with these wind power projects: power capacity, equipment provider, average wind speed at the project's location, feed-in-tariff available from the state, and starting year of the project. These characteristics cover all major drivers of wind power projects' profitability. Importantly for our analysis, some of these variables – wind speed, power capacity, and feed-in-tariff – can be used to rank the profitability of individual projects. As an illustration, all other factors being equal, a project located in a windy area is more profitable than one installed in a less windy location.

Based on this information, we evaluate additionality with two methods. The first consists in estimating the decision to register a project under the CDM with a logit model controlling for the factors affecting profitability. The second method relies on a matching algorithm which seeks to find, for each individual CDM

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[4] This is not the case in China for example, where *all* renewable energy projects tend to be registered as CDM projects.

[5] None of the previous studies includes data on non-CDM projects. An exception is the recent paper by Kirkman et al. (2013) that compares CDM projects with Annex I projects. However the analysis cannot discuss additionality, since the two sets of projects are implemented in very different contexts: in developing countries for CDM projects, in developed countries for the others.

project, at least one non-CDM project which is unambiguously less profitable when looking at the above-mentioned variables affecting economic returns.

Our regression analysis shows that, all other things being equal, CDM wind farms tend to be larger, to benefit from higher feed-in-tariffs, and to be located in windier areas, three factors which increase profitability. Our non-parametric approach yields converging results. Out of the 577 CDM projects included in the database, we are able to establish the non additionality of 299 projects (52%) and the additionality of only 4 projects (less than 1%). We cannot conclude for the others. Hence, the paper provides robust evidence that the majority of CDM projects are not additional. Overall, these results highlight severe flaws in the implementation of the CDM and corroborate the qualitative evidence suggesting that a large share of CDM credits does not represent real emission reductions. This calls for a complete rethinking of project-based mechanisms for the future international climate policy architecture.

The paper is organized as follows. In Section 2, we provide some background information by briefly describing the development of the wind power sector in India and the policies which promote its development, including the CDM. Section 3 presents our dataset. In Section 4, we compare CDM projects with non-CDM projects based on various methodologies. Section 5 concludes.

2 Evaluating the additionality of CDM projects

As previously explained, the central objective of the paper is to test for the additionality of CDM wind power projects. In advance of this analysis, it is important to describe how additionality is evaluated in practice during the CDM registration process. The evaluation involves three main steps. First, project developers initiate the process by writing a Project Design Document (PDD) which describes the project and proposes a demonstration of its additionality. The PDD is then transmitted to a Designated National Authority (DNA) which evaluates whether the project meets the CDM requirements (including additionality). Finally, the CDM Executive Board, which supervises the CDM globally, decides whether to register the valid projects submitted by the DNA. In India, the DNA is the Ministry of Environment and Forests.

All PDDs of registered wind power CDM projects in India rely on the same guidelines to determine additionality. These guidelines are presented in detail in the methodology ACM0002, and in the related AMS-I.D., which is a simplified version of the former that is used for small-scale projects. In CDM parlance, a methodology is a standard procedure agreed by the CDM board which describes in detail how to establish additionality in Project Design Documents. The methodologies ACM0002 and AMS-I.D. apply to renewable energy project and comprise the “Consolidated baseline methodology for grid-connected electricity generation from renewable sources”, the “Tool to calculate the emission factor for an electricity system” and the “Tool for the demonstration and assessment of additionality”.

The general principle of these two methodologies is simple. Emission reductions are calculated by multiplying the electricity generated by the wind farm with an emissions factor which can be calculated in different ways. In practice, most projects use a factor equal to the generation-weighted average CO_2 emissions per unit net electricity generation (tCO_2/MWh) of all generating power plants serving the same regional grid. That is, the baseline scenario corresponds to the continuation of the current average situation. Then the non-profitability of the project is established by comparing the Internal Rate of Return (IRR) without CDM revenue and a benchmark rate.

It is clear that PDDs provide an imperfect basis for judging the additionality of a given project. Based on a systematic evaluation of the PDDs of 93 projects registered across the world, Schneider (2011) is very critical, arguing that the analysis frequently relies on subjective arguments or neglect to provide the data used in the calculations displayed in the documents. Michaelova and Purohit (2007) essentially make the same point by analysing the PDDs of 52 CDM Indian projects. But, even in the case where detailed information is available and rigorous analysis is performed, such results are simply not verifiable by the authorities in charge of CDM registration. The fundamental problem for the regulators is the impossibility to observe what would have happened had the project not been registered, a difficulty which concerns all external observers.

3 Wind power and CDM in India

3.1 Wind power in India

The Indian wind energy sector started to boom in 2000. Between 2007 and 2011, wind capacity installations increased at an impressive annual growth rate of 19.7% (Shrimali et al 2013). Wind power represented about 7% of the Indian power generation capacity in 2012; as wind is an intermittent energy source and currently lacks the effective technology to store generated power its contribution to actual generation is considerably less (closer to 3%). India was the 4th largest market for new installations at the world level in 2012.[6] This development has also given rise to a competitive domestic industry. The Indian-based Suzlon group is now a major wind turbine manufacturer with 7.6% of the world production in 2012.[7]

The sector is forecasted to continue to grow in the coming years: India's National Action Plan for Climate Change (NAPCC) published in 2008 set a target of 15 % of power generation from renewable energy source by 2020. This requires a fourfold increase in currently installed capacities with a significant share of both onshore and offshore wind.

The development of wind energy has mostly been driven by public policies which do not differentiate between CDM and non-CDM projects. The main instruments are listed in Table 1. Historically, the growth was primarily driven by state-level Feed-in-Tariffs (FITs) introduced in 2000. Since 2011, the central Government has implemented a new system of Renewable Energy Certificates (RECs) which allows for inter-state trading. RECs can be chosen as an alternative to FITs. However, the success of RECs to date has been limited as most developers of wind power projects have continued to use FITs. Other subsidies and tax rebates – Accelerated Depreciation (AD), Generation-Based Incentive (GBI), partial income tax exemption – mainly serve as complements to preferential tariffs.

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[6] Source: Global Wind Statistics 2012, Global Wind Energy Council. Accessed 23 Dec 2013 http://www.gwec.net/global-wind-energy-solid-growth-2012-2. India accounted for about 5% of new installations in 2012. This figure however lags far behind that of China (about 27%) or the US (21%).

[7] IHS Emerging Energy Research. Gamesa back in wind top-five as GE drops out - analysts Global Wind Turbine Supply Market Share Evolution, 6 March 2012. Retrieved: 8 March 2012.

Table 1. Policy framework in India, 2012. Source: Shrimali et al. 2013

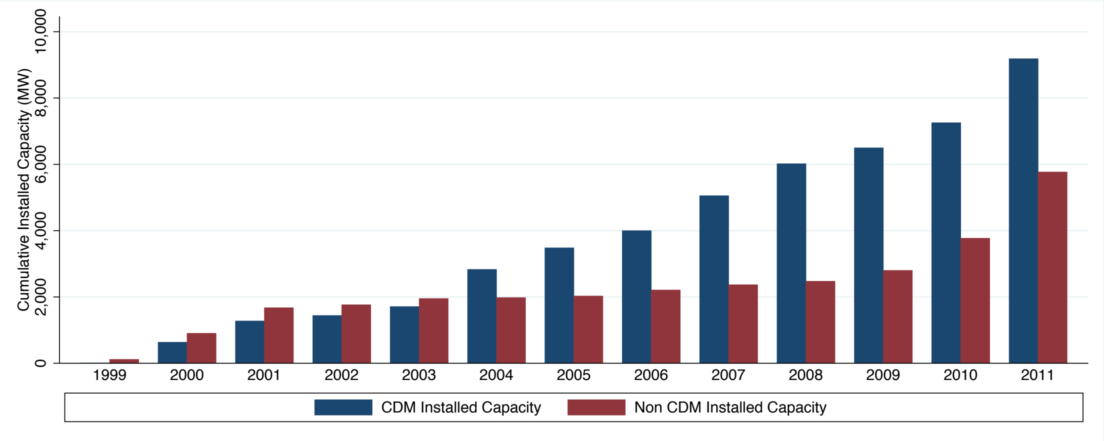
Policy framework	Dates	Institutional level
Accelerated depreciation (AD) Renewable (including wind and solar) projects are allowed to depreciate 80% in the first year	Introduced in the mid-1990s; discontinued in April 2012	Central level
Generation based incentive (GBI) As an alternative to AD: a subsidy of USD 0.01per kWh generated	Introduced in 2009	Central level
Feed-in (or preferential) tariffs (FIT) Set by State Electricity Regulatory Commissions	Introduced at the state level since early 2000	State level
Renewable energy certificates (RECs) Market-based instruments to address the mismatch between availability and requirement of the obligated entities to meet their state-level renewable purchase obligation (RPO). Developers have a choice between using FITs or RECs[a]	Introduced in 2011	Central level
Income tax exemption A 100% tax waiver on profits for any single 10-year period during the first 15 years of the operational life of a power generation project	Introduced in 2002; Discontinued in March 2013	Central level
Other benefits (excise, wheeling charges) Concessional rates for excise (reduced from 8% to 0%) and customs duty (reduced by 2.5–5%) for specific renewable sources of energy including wind, solar, and biomass. Several states in India levy relatively lower wheeling or transmission charges for renewable energy	Introduced in 2002	Central level
Clean Development Mechanism (CDM) Project developers are free to get their project registered to participate in certified emission reduction (CER) credits markets	Introduced in 2005	Global level

3.2 The CDM in India

As mentioned previously, project developers are also free to get their project registered to participate in certified emission reduction (CER) credits markets. The CDM is widely used in India as it contributes to national GDP almost 1.5 times more than China, and 5.5 times more than Brazil, the other two main CDM host countries.[8] Wind farms accounts for about 40% of the total number of Indian CDM projects and the CERs generated from the projects are estimated to generate about 2.5 billion euros in revenues across their life.

As mentioned previously, not all Indian wind farms are registered under the Clean Development Mechanism. There are no official statistics about the share of CDM projects in the wind sector, but they represent about 40% in the data used for this study. As shown in Figure 1, the installed capacity of CDM projects has increased exponentially since 2003, while the non-CDM capacity has started to increase much more recently.

Figure 1. Cumulative wind capacity in India for CDM and non-CDM projects (1999-2011)



Sources: Authors' own calculation from the Bloomberg database

4 Methodological approach

We now start presenting the methodology with a few equations. Assume that there exists N potential wind power projects in India. Let V_n denote the net

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[8] This is calculated as the amount of CERs generated by CDM projects relative to GDP.

present value of project n excluding CDM-related costs and benefits (CER revenue and the CDM registration cost). By definition a project is additional if $V_n \leq 0$. The problem is that we do not observe this value.

Reasoning in continuous time and assuming support through FITs, we can however express V_n as follows:[9]

$$V_n = -I_n + \int_0^{T_n} \left(m_n + p_n q_n\right) \mathrm{e}^{-rs} ds$$

$$= -I_n + \left(\frac{1-\exp(-rT_n)}{r}\right)\left(m_n + p_n q_n\right) \qquad (1)$$

where I_n is the initial investment, T_n is the lifetime of the project; m_n is the maintenance cost; p_n is the level of the Feed-In-Tariff which is guaranteed over the wind farm's lifetime[10]. q_n is the annual quantity of electricity generated. Finally, r is the discount rate. In the (less frequent) case where the developer opts for the REC system, p_n is the electricity price agreed upon with utilities which are constrained by the Renewable Portfolio Standard.

Using (1), we could compute the value V_n if we knew the values of I_n, q_n, m_n, r, and p_n. But project-level data are not available for most of these variables. Based on interviews with wind energy experts and a careful study of a detailed report on the cost of wind power by the International Renewable Energy Agency (IRENA, 2012), we have been however able to collect data on the main factors which influence the profitability:[11]

- The level of the FIT p_n.

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[9] Reasoning in discrete time would require making assumptions on the frequency of maintenance expenditures and electricity payments. If this frequency is sufficiently high, continuous time is a good approximation.

[1010] In reality, the preferential tariff is guaranteed for a period of 25 years in India which exceeds the average lifetime of wind turbines which is about 20 years (IRENA, 2012).

[11] We thank Charles Desjardins and Saurabh Shah for many helpful discussions.

- The capacity of the wind farm, which influences both I_n, the maintenance cost m_n, and the quantity of electricity generated q_n.
- The equipment provider which is a proxy for the quality of the wind turbine and its price and which thus have a decisive influence on I_n, m_n, and q_n.
- The wind resource available at the location of the project which is the main variable influencing the quantity of electricity generated q_n, together with capacity.
- The State in which the project is located, which determines the institutional environment in which the project operates (including various benefits and subsidies granted by State authorities).
- The date of the investment which influences both the institutional context, the cost of capital (and thus the discount rate r), and the performance of the wind equipment available in the market at that time (which continuously improve over time).

Importantly for our analysis, some of these variables are quantitative with a clear monotonic relationship with the project's value. This is the case of the FIT, the capacity of the wind farm and the amount of wind resources which all increase with V_n. The others are either qualitative or quantitative, but with an ambiguous relationship with a project value, thereby preventing us from relating their value to V_n. These include the date of investment, the State in which the farm is located, and the equipment provider. The first set of variables is obviously more interesting for the analyst as they could potentially be used to rank individual projects' value. In particular, in the hypothetical case where two projects are identical except for the value of one of these quantitative variables, we can unambiguously identify which is the most profitable one.

We now present two methods that we will use to test for the additionality of the CDM projects.

Estimating participation in the CDM

The starting point of the first method is that we observe the binary decision to participate in the CDM and this choice is arguably influenced by V_n. More precisely, if the CDM is perfectly enforced, we can deduce that

1. a project from the sample is implemented and not registered as a CDM if $V_n > 0$;
2. a project is implemented and registered if it is (i) additional: $V_n \leq 0$

Then, assume that the project value is given by a linear combination of the explanatory variables:

$$V_n = X_n\beta + Y_n\gamma + \varepsilon_n \qquad (2)$$

where X_n is the vector of quantitative variables listed above with non-ambiguous relationship with the value and Y_n is the vector of the other variables which are used as controls. ε_n is a random term capturing unobserved heterogeneity and β and γ are two vectors of parameters. We know that $\beta > 0$: A project's value increases with X_n.

Assuming that ε_n has a logistic distribution, McFadden (1973) shows that:

$$\Pr(V_n > 0) = \frac{e^{X_n\beta+Y_n\gamma}}{1+e^{X_n\beta+Y_n\gamma}} \qquad (3)$$

and the additionality condition implies that $\Pr(V_n > 0) = \Pr(CDM_n = 0)$ where CDM_n is the dummy variable indicating that the project is CDM-registered.

As we observe CDM_n, we can estimate the logit equation (3) with a maximum likelihood estimator in order to retrieve the parameters' value.

Following this process all that is required is to check whether the results are consistent with the additionality requirement. That is, the probability of being not registered increases with the FIT, the wind farm capacity, and the amount of wind resources:

Hypothesis 1: $\boldsymbol{\beta} > 0$.

A drawback of this approach is that the estimation sample is not random. The reason is that a CDM project is actually implemented – and thus included in our database – if it is additional ($V_n \leq 0$), but also if it is profitable when registered: $V_n + R(q_n) - C > 0$ where $R(q_n)$ is the CER revenue which is project-specific and directly related to the quantity of electricity generated and C is the administrative cost of registration which is uniform across projects. The problem then stems from the fact that the sample does not include projects that are not profitable even with CDM revenue. There is little to do to mitigate this problem, except for using robust standard errors. In particular, we cannot rely on the standard Heckman's selection model as we have no information on the projects that have not been implemented at all.

Another disadvantage is that the tested coefficients β are estimated at the sample mean. We are thus only able to say that on "average" CDM projects are not additional, however, there may be heterogenous treatment effects resulting in significant shares of individual projects actually being additional. The second method does not suffer from this weakness. It is also non-parametric in the sense that we do need to assume a functional form like (1) to describe the relationship between profitability and the explanatory variables.

Comparing CDM projects with non-CDM projects individually

The second method is inspired by matching methodologies. The starting point of our strategy is that a sufficient condition for a CDM project *not to be additional* is that there exists a non-CDM project in India that is less profitable and was nevertheless implemented even without the help of carbon credits. As explained above, we do not directly observe projects' profitability, but we observe some of the drivers of this profitability (the vector X_n) as well as some other characteristics of the projects that have an ambiguous relationship with respect to their value (Y_n). When comparing CDM projects with non-CDM projects we are thus able to rank them in terms of their profitability, controlling for characteristics with an ambiguous effect, such as state of implementation and equipment provider.

For a simple illustration of our methodology, consider two wind power projects located in Tamil Nadu, implemented under the same feed-in-tariff regime and using turbines from the same manufacturer Suzlon, one of which is registered under the CDM and the other is not. We can compare the two projects in terms of the production capacity and the available wind resources. If the non-CDM project has both a smaller production capacity and is located in an area with fewer wind resources than the CDM project, we can unambiguously rule out that the CDM project is additional since there exists at least one strictly less profitable non-CDM project that has been implemented.

Formally, the tested hypothesis for each CDM project is thus:

Hypothesis 2: For each CDM project i, there exists no non-CDM project $k \neq i$ such that: $X_k < X_i$ and $Y_k = Y_i$

In practice, we count the proportion of CDM projects that are unambiguously not additional. Symmetrically, we also count the number of CDM projects that are potentially additional because we cannot assign them to a strictly less profitable non-CDM project. In addition, we count the number of strictly less profitable non-CDM projects that we are able to find for each CDM project and analyse to what extent the non-CDM projects are less profitable than CDM projects.

5 Data

5.1 Data sources

The main source of our dataset is the Bloomberg Renewable Energy Projects database (BRP) to which we had access through a commercial agreement. The BRP database contains detailed information on renewable energy projects across the world. We collected data on 1,351 wind power projects implemented in India between 1992 and February 2013.

Importantly, the BRP database includes a variable that identifies projects that are registered or submitted for registration as Clean Development Mechanism projects. To make sure we correctly classify all CDM projects we merge the BRP database with the UNEP Risoe CDM/JI Pipeline. The CDM pipeline is a constantly updated and comprehensive database of all CDM projects that have been submitted, rejected or registered by the UNFCCC. We then apply a fuzzy matching approach, whereby we compare a range of projects' information (title, location, project developer) in terms of word similarity to identify CDM projects within the BRP database. Our analysis reveals that all CDM projects have been correctly identified in the BRP database.

From the BRP database, we obtain key information on projects: geographical location (State, district and city), production capacity (in MW), financing year and name of the equipment provider(s).

Wind resources

To obtain data on wind resources at the location of the project we first use information on the project's location to determine its GPS coordinates through a computer algorithm that fetches information from Google Maps and OpenStreet Maps.[12] We then use the GPS coordinates to determine the wind resources available at the project's location based on data from the ERA-Interim Reanalysis archive, provided by the European Centre for Medium-term Weather Forecasting, which combines remote-sensing data with global climate models to produce estimates of wind-speed data is on a uniform grid of 0.75 degrees x 0.75 degrees (75 km x 75km).[13] This database provides the finest resolution data for daily measures over India. Average daily wind speed and wind direction is then calculated for each project using all points within 100km and inverse quadratic distance weighting. These measures are then averaged over the 10 years period prior to the year each project was financed – an important measure of each projects expected performance.

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[12] Note that the GPS coordinates of CDM projects are available from the Projects' Design Documents. However this information is not available from non-CDM projects. For consistency we have obtained GPS coordinates from our algorithm for both CDM and non-CDM projects.

[13] By combining remote-sensing data with global climate models, a consistent best estimate of atmospheric parameters can be produced over time and space (see Aufffhammer et al., 2013). This results in an estimate of the climate system that is separated uniformly across a grid, that is more uniform in quality and realism that observations alone, and that is closer to the state of existence than any model could provide alone. Economists, especially in developing countries where the quality and quantity of weather data is more limited, are increasingly using Reanalysis data.

Policy support

We collected information on policies in place in every Indian state between 2000 and 2013, in particular the level of the feed-in-tariff which applies to all wind power projects. We gathered this data from the Bloomberg Policy and Measures database and a review of the literature (Bridge to India, 2012; Lewis, 2007; Shrimali et al., 2012; Altenberg & Engelmeier, 2013; ClimateConnect, 2013; REN21, 2013 ; PVMagazine, 2013 ; UERC, 2013 ; MNRE, 2012).

5.2 Data description

Table 2 below reports the descriptive statistics of our sample of 1,351 projects for the quantitative variables.

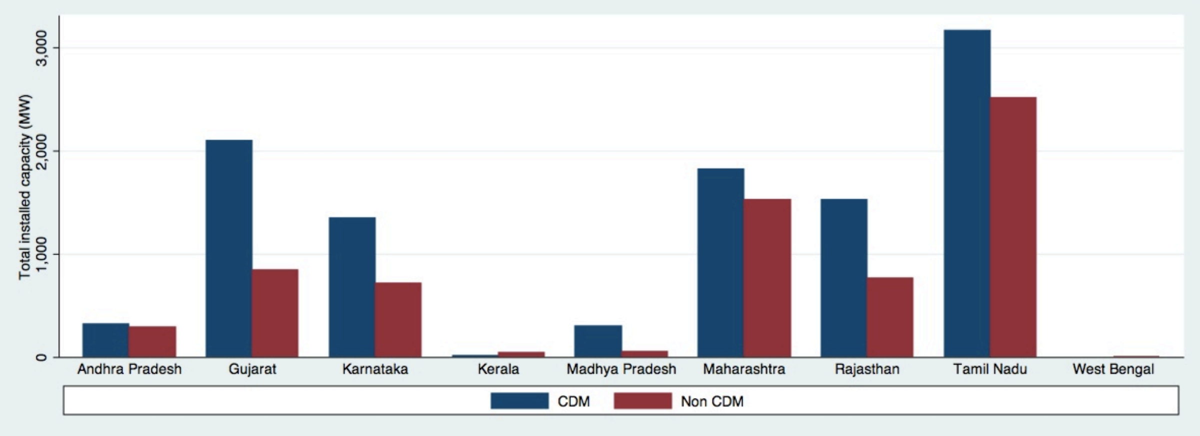
Table 2. Summary Statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
cdm	= 1 if the project is registered under the CDM, 0 otherwise	0.427	0.495	0	1
FIT	FIT in 2012 rupees per kWh	2.070	1.376	0	4.700
capacity	Project total capacity in MW	12.831	26.447	0.200	467.810
speed	Average wind speed in the last 10 years in mph	8.264	2.820	1.726	11.697
year	Starting year of the project	2005.4	4.7	1992	2011

Note: N=1,351

The distribution of the total capacity installed varies considerably across Indian states, and is a function of wind resources and the amount of policy support for wind power. Looking at Figure 2 it appears that most of the capacity has been installed in Tamil Nadu, Gujarat and Maharashtra, while Kerala, Andhra Pradesh and Madhya Pradesh host a small fraction of the wind projects. What is more important, though, is that as can be seen from the figure, CDM and non-CDM projects coexist in all Indian states and represent 28 and 64% of projects across states (representing between 28 and 85% of installed capacity).

Figure 2. Total installed capacity by state in India (1992-2011)



As for equipment providers, five of them represent 83% of projects: Suzlon, Enercon, RRB, Vestas and Gamesa.[14] Table 3 reports the distribution of CDM and non-CDM projects across the six providers that include more than 10 projects. Again, we find that CDM and non-CDM projects are relatively well balanced across equipment providers, thus providing us with many potential comparators.

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[14] We treat a combination of different providers as a distinct provider.

Table 3. Main equipment providers

Equipment provider	Number of projects	Number of CDM projects	Number of non-CDM projects
Suzlon	557	284	273
Enercon	163	104	59
RRB Energy	64	22	42
Vestas	48	32	16
Gamesa	44	13	31
Regen Powertech	37	16	21

Table 4 offers a comparison between CDM and non-CDM projects along the quantitative dimensions, namely capacity, wind speed and level of the feed in tariff. In all three dimensions, CDM and non-CDM projects display statistically significant differences. In particular, CDM projects are characterized by a much larger size than non-CDM projects and on average are located in less windy areas. Surprisingly, the average project funded under the CDM, benefits from a significantly higher feed-in tariff, a fact that clashes with CDM purpose and applicability.

Table 4. Comparison of CDM and non-CDM projects

	CDM	**Non-CDM**	**Difference**
	Mean	Mean	
Capacity	18.365 (1.407)	8.705 (0.654)	9.660*** (1.431)
wind	8.044 (0.121)	8.428 (0.098)	-0.384* (0.154)
FIT	2.304 (0.050)	1.895 (0.053)	0.409*** (0.075)

Note: Standard deviation in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

6 Results

6.1 Logit estimation

We first estimate the following logit equation describing the decision not to register a given project in the CDM:

$$\begin{aligned}\Pr(CDM_n = 0) \\ &= \Phi\big(\alpha + \beta_1 FIT_n + \beta_2 \ln\big(capacity_n\big) + \beta_3 wind_n + \gamma state_n + \delta year_n \\ &+ \theta equipment_n\big) + \varepsilon_n\end{aligned}$$

where Φ is the logistic function. The equation includes the three main variables of vector X_n, and a complete set of state, time and equipment provider dummies: $state_i$, $year_i$, and $equipment_i$. Finally, $\alpha, \beta_1, \beta_2, \beta_3, \gamma,$ and δ are the parameters to be estimated.

We are primarily interested in the signs of β_1, β_2 and β_3 which are supposed to be positive if the CDM applies to projects that are less profitable than the others. Table 5 displays the results with robust standard errors in order to mitigate the bias resulting from the sample does not include the potential projects which have not been implemented. They are very clear: All three coefficients exhibit negative signs, meaning that the estimation disconfirms the additionality hypothesis: less profitable projects are less likely to be registered.

Table 5. Results of the logit estimation of non-participation in the CDM

Variables	Coefficients
FIT	-0.370^{***}
	(4.12)
ln(capacity)	-0.596^{***}
	(6.97)
Wind speed	-0.186^{*}
	(2.45)
State dummies	Yes
Year dummies	Yes
Equipment provider dummies	Yes
_cons	-5.216^{***}
	(-5.69)
N	925

t statistics in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Robust standard errors.

These results then need to be cautiously interpreted. In particular we should explain why the developers do not register the less profitable projects. In fact, our findings are consistent with a view where developers are rational and aware that the additionality criterion is imperfectly enforced. If a developer does not seek registration, its benefit is simply V_n. In the opposite case, its gain is equal to $V_n + (1-\pi)R(q_n) - C$ where π is the probability of being detected as non-additional by the Designated National Authority or by the CDM Executive Board. In that case, the sanction is simply the loss of CER revenue. Hence, the developer seeks registration if

$$(1-\pi)R(q_n) > C$$

Note then that the left-hand side term of increases with the quantity of electricity generated whereas the right-hand side term is fixed. Hence, the higher the quantity of electricity generated, the higher the incentives to cheat. Our results are then explained by the fact that electricity generation is driven by capacity, wind resources and the FIT

6.2 Comparing CDM with non-CDM projects individually

The second method consists in trying, for each CDM project in the database, to find a non-CDM project that is unambiguously less profitable. We do so by grouping projects that are located in the same state, are implemented under the same feed-in-tariff regime and use turbines from the same manufacturer, and comparing them in terms of production capacity and available wind resources. Of course, we cannot analyse the additionality of all CDM projects as some groups will inevitably include only CDM projects, so that no comparator is available. We exclude 137 projects through this process. For these projects, we are not able to establish with certainty whether or not they are additional, but we come back to these projects later. For now we focus on the remaining 413 projects, representing 75% of wind power CDM projects implemented in India.

Table 6 summarizes the main results. Within each group, we simply compare each CDM project with the least profitable non-CDM project and compare the two in terms of capacity and wind resources. For 299 CDM projects (representing 72% of the 413 assessable projects), we are able to find at least one non-CDM project that has both smaller production capacity and smaller wind resources available. These projects are unambiguously not additional.

In the last line of the table, we find 4 CDM projects for which all the non-CDM projects in the same group have higher capacity and larger wind resources. These projects (representing less than 1% of our "matched" sample) are unambiguously additional because we cannot assign them to a single strictly less profitable non-CDM project. Finally, 110 CDM projects (the remaining 23%) lie in the middle. For these projects, we were able to find at least one non-CDM project in the same group that has either smaller capacity or smaller wind resources, but not both at the same time. These projects might or might not be additional.

Table 6. Within-group comparison of CDM and non-CDM projects in terms of power capacity and wind resources

	# of CDM projects	Additionality
$cap_{CDM} > cap_{nonCDM}$ & $wind_{CDM} > wind_{nonCDM}$	299	Not additional
$cap_{CDM} < cap_{nonCDM}$ or $wind_{CDM} < wind_{nonCDM}$	110	Ambiguous
$cap_{CDM} < cap_{nonCDM}$ and $wind_{CDM} < wind_{nonCDM}$	4	Additional

Note: N=413

Robustness

For 299 CDM projects, we are able to find at least one non-CDM project which is unambiguously less profitable. But how less profitable are they? Table 7 compares CDM projects that are not additional with the least profitable non-CDM project in each of the group defined above. We find that the difference is large – especially as regards installed capacity – and statistically significant.

Table 7. Within-group comparison of CDM and least profitable non-CDM projects

	CDM Mean	**Non-CDM** Mean	**Difference**
Capacity	16.10 (1.10)	1.66 (0.17)	14.44*** (1.08)
Wind speed	8.49 (0.16)	7.23 (0.17)	1.26*** (0.08)

Note: Standard deviation in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The fact remains that these less profitable non-CDM projects might simply be outliers within each group, in which case it would only be by luck that we were able to find these. However, for each apparently not additional CDM project, we find on average 7.7 less profitable non-CDM projects, and for 236 CDM projects (79% of the 299) we are able to find at least two less profitable non-CDM projects.

Based on the full set of less profitable non-CDM projects, we can associate each CDM project with an average less profitable non-CDM project constructed as the geometric average of all less profitable non-CDM projects within each group. If we now compare CDM projects with these average less profitable projects, we find that the difference between CDM and non-CDM projects decrease but remains highly significant both for capacity and wind speed (see table 8).

Table 8. Within-group comparison of CDM and less profitable non-CDM projects

	CDM Mean	**Non-CDM** Mean	**Difference**
Capacity	16.10 (1.10)	3.88 (0.24)	12.22*** (1.02)
Wind speed	8.49 (0.16)	7.82 (0.17)	0.67*** (0.05)

Note: Standard deviation in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

External validity

In the process of comparing CDM with non-CDM projects in terms of profitability we have had to exclude 137 CDM projects for which we couldn't find any non-CDM project located in the same State, using the same equipment provider and implemented under the same feed-in-tariff policy. We can compare these 137 projects with the rest of the population of CDM projects in terms of FIT, wind resources and production capacity. Table 9 shows the results of this comparison. In terms of wind resources and feed-in-tariff, excluded and included CDM projects are indistinguishable. However, excluded projects are significantly larger than included ones. If anything, thus, excluded projects are *more profitable* than included ones. Although we cannot conclude with certainty about their additionality, we find no compelling evidence that excluded projects are more likely to be additional than the projects we analyse above.

Table 9. Comparison of excluded and included CDM projects

	Excluded (n=137)	Included (n=413)	Difference
Capacity	29.71 (5.15)	15.11 (0.90)	14.60*** (3.35)
Wind speed	7.77 (0.26)	8.08 (0.14)	0.32 (0.29)
FIT	2.32 (0.12)	2.36 (0.05)	0.03 (0.11)

Note: Standard deviation in parenthesis. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

7 Conclusion

Are CDM wind power projects additional? To answer the question, this paper exploits the fact that, in India, wind farms registered under the Clean Development Mechanism coexist with wind farms that are not. If CDM projects are additional, the two sets of projects necessarily differ. Using data from a variety of sources we characterize the potential differences between 577 CDM projects and 775 wind farms not registered under the CDM and whether they could be related to differences in individual project economic returns.

We use two different methods that yield converging results. A logit estimation of participation in the CDM shows that all other things being equal CDM wind farms tend to be larger, to benefit from higher feed-in-tariffs, and to be located in windier areas, three factors which are said to increase profitability. A non-parametric approach which seeks to match individual CDM projects with less profitable non-CDM projects produces the same pattern: Out of the 577 CDM projects included in the database, we are able to establish the non additionality of 299 projects (52%) and the additionality of only 4 projects (less than 1%). We cannot conclude for the others.

Hence, the paper provides serious evidence of non additionality of the CDM. But, if certain project developers seemingly circumvent the additionality rule, why do they not register all existing wind farms (like in China for example)? Even less intuitive, why do they restrict registration to the more profitable ones? In fact, this is not that surprising when taking into account the CDM registration cost. This cost is said to be significant, thereby preventing the registration of all projects. It is also fixed and mostly uniform across projects as it consists in producing the so-called Project Design Document which is used by regulators to make the registration decision.[15] Accordingly, registration likelihood increases with the benefit of registration: the generation of carbon credits. And the quantity of credits is directly proportional to the quantity of electricity generated by the wind farm. It is thus not surprising to find ex post that CDM projects tend to be larger and located in windier areas.

Overall, these results highlight severe flaws in the implementation of the CDM and corroborate the qualitative evidence suggesting that a large share of CDM credits does not represent real emission reductions. This calls for a complete rethinking of project-based mechanisms for the future international climate policy architecture.

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[15] This statement strictly applies to the case where the project developers use the same methodology in the Project Design Document. As explained in Section 2, two methodologies are available for wind farms, one for small-scale projects of which capacity is less than 15 MWh and the other for larger projects. Hence, the registration is only uniform

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