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Examining the regional pattern of renewable energy CDM power projects in India ☆

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ABSTRACT

India is one of the leading host countries of Clean Development Mechanism (CDM) projects, but these projects have been concentrated within ten states of the country. While the skewed distribution of CDM projects across countries is well recognized, little attention has been given to the skewed distribution of CDM projects within a country like India. We examine the different factors that account for the regional distribution of renewable energy based CDM power projects in India using state-specific and renewable form-specific explanatory variables including natural potential, economic conditions, and government policies. We find that state implementation of fiscal incentive measures and CDM benefit-sharing were the most significant factors in locating these projects within the states, apart from natural renewable potential. In the top ten states, controlling for the government incentives and subsidies, the pre-installed renewable power capacity was also a significant factor. State financial incentives and CDM benefit clause were also found to be the most significant factor in the generation of certified emission reductions from CDM projects. Unfortunately states with relatively higher natural potential lost out on the additional product gains through CERs, and an important aspect of the CDM approach seems to have been missed in India — that of promoting development in other regions of the country which had natural potential.

1. Introduction

The drive to develop renewable energy sources as an alternative to conventional energy in India began more than thirty years ago with the first major oil crisis in the seventies, and gained momentum with increasing multilateral pressure on climate change mitigation efforts, especially during the last decade. The growth of renewable energy (RE) technology in India has sought to address the goal of climate mitigation as well as energy poverty and security, and has used a plethora of instruments to encourage private investment in the sector. In the spectrum of renewable sources of energy, four forms have been particularly promoted in the country, namely: wind, biomass, solar, and small hydro. The Clean Development Mechanism (CDM) instituted under the Kyoto Protocol offered another channel of investment and technology flows in clean energy into India from the industrialized Annex I countries.[1]

A recent study across eighty countries found that CDM projects can be a significant stimulus to low-carbon development (Huang and Barker, 2012). Although embedded in a framework for sustainable development across the globe, the distribution of CDM projects has been biased towards the high-growth emerging economy of China. By August 2011, of the total 3337 registered CDM projects, 1510 projects were in China, 705 in India, 194 in Brazil and 129 in Mexico, with few in poorer developing countries. More than two-thirds of the CDM projects in India have been in the renewable energy power sector (with 485 of the total 705), with the largest number being in wind, followed by biomass energy, and small hydro. Through an analysis of the differential distribution of CDM projects across developing countries, Winkelman and Moore (2011) found that factors including carbon intensity, education level and growing electricity markets in countries have been significant determinants in the hosting of CDM projects. In an earlier study, Niederberger and Saner (2005) observed that the determinants of the location of CDM projects go beyond the standard economic factors attracting foreign direct investment (FDI) into countries. They pointed out that a FDI-underperformer country like India emerged as a leading host country of CDM projects due to other factors like institutional pre-requisites, a growing power sector, and participation of Indian project developers.

However cross-country studies miss the startling features of the location of CDM projects within a country. While the skewed distribution of CDM projects across countries is well recognized,

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[1] As stated in the Kyoto Protocol, the major objectives of the Clean Development Mechanism were to help non-Annex-I countries "… in achieving sustainable development" and "… to assist Parties included in Annex-I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3" (Article 12 (2) of Kyoto Protocol). In this regard, the CDM allowed for emission reduction credits from projects hosted in developing countries since 2000.

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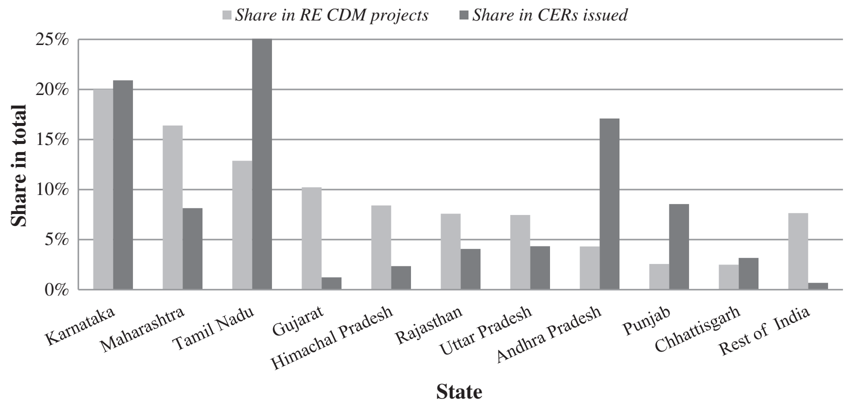

Fig. 1. Distribution of capacity installation and CERs issued under RE-based CDM power projects. Authors' calculation based on data from UNEP Risø CDM Pipeline (projects registered until August, 2011).

little attention has been given to the skewed regional distribution of CDM projects within a country like India. As the states in India vary widely in terms of economic development and regional policy incentives, the business environment for potential investment is quite diverse. Although there are twenty-nine states in India,[2] a set of ten states have hosted 90% of the RE-based CDM power projects and accounted for 99% of the total number certified emission reductions (CERs) issued from such projects in India. The extremely skewed distribution of RE-based CDM power projects raises the question of whether this is driven predominantly by the natural potential (due to natural resource endowment) of the states. Or, did economic and institutional factors determine the location of the CDM projects across India? What role did state government regulatory policies and incentive instruments play in locating RE-based CDM power projects in the different states?

In this paper, we examine the different factors that have determined the distribution of all RE-based CDM power projects across the Indian states until August 2011. While we consider all the 19 states[3] in which such projects have been located, we also examine the top 10 states separately. Our focus is the renewable energy based electricity sector, and we differentiate between three types of renewable energy form namely biomass, small hydro, and wind. The unit of our analysis is the state, and we utilize state-specific and RE-specific explanatory variables, in order to distil the significance of different factors like natural potential, economic, and government policies.

We find that CDM-benefit clause and fiscal incentives for renewable energy power investment in a state were significant factors in locating RE-based CDM power projects. The natural resource-based potential of the states was an important determinant in attracting these projects, and for the top 10 states the pre-existing capacity of RE-based power was also a significant factor. Similarly, we find that the co-generation of CERs was significantly higher in states with fiscal incentives and CDM benefit-sharing clause. Unfortunately, however, states with higher potential in RE-based power failed to derive gains through greater generation of CERs, although they did gain in terms of capacity installation under CDM projects. The rest of the paper is organized as follows: in Section 2 we begin with an overview of the pattern of CDM projects across Indian states and the federal electricity regulatory framework in India in reference to renewable energy. In Section 3 we specify the models for our analysis based on the literature on determinants of CDM project location. In Section 4 we discuss the data; and in Section 5 we present the regression results. In Section 6 we conclude.

2. Overview of renewable energy CDM projects in India and RE-based power policies

The CDM was expected to attract capital for climate change abatement in developing countries and promote technology transfer from the Annex I countries; however, as India emerged as one of the leading host countries of CDM projects it was apparent that the experience was quite different. In an early review, Niederberger and Saner (2005) had observed that the determinants of the location of CDM projects go beyond the standard economic factors attracting FDI into countries, and in India CDM projects are located due to other factors like institutional pre-requisites, a growing power sector, and participation of Indian project developers. The private sector in India (as also in China) undertook unilateral CDM projects (projects registered without an Annex I country partner),[4] indicating that the private sector was able to set up and maintain such technologies without the cooperation of a developed country partner.

2.1. Pattern of RE CDM projects

The distribution of CDM projects, in general, and renewable energy based CDM power projects, in particular, has been skewed across India. The ten states of Andhra Pradesh, Chhattisgarh, Gujarat, Himachal Pradesh, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh have accounted for more than 90% of the RE-based CDM power projects and 99% of the total number of CERs issued from these projects in India. The subset of the ten states is quite diverse in terms of their economic development; among them Gujarat, Maharashtra, Punjab, and Tamil Nadu are relatively richer states, Andhra Pradesh, Karnataka and Himachal Pradesh are in the middle cadre, while Chhattisgarh, Rajasthan and Uttar Pradesh are among the poorer states in India. The set of 10 states accounts for approximately 60% of the Indian population and 64% of the country's GDP. On the other hand, the 19 states, which have registered CDM RE-power projects, account for 92% of the country's population and 90% of the total GDP (see Table A3 for details). Fig. 1 shows the distribution of the total installation capacity under registered CDM projects in renewable energy based power (including biomass energy, wind, small hydro, and solar) across the states in India.

The CDM projects in RE-based electricity in India have been mostly in wind, followed by biomass and small hydro, while that in solar has been negligible. This is apparent not merely in terms of the number of

[2] There are also 6 union territories.

[3] Among the excluded ten states, the north-eastern states of Arunachal Pradesh, Assam and Meghalaya have by far the highest potential for RE-based power (in small hydro). While these states have had central government financial assistance to develop RE power projects, state initiatives have been negligible and private investment in RE-power projects has not been forthcoming. The zero CDM projects in these regions (in biomass, wind and small hydro) can be explained completely by fixed effects in our model, and hence are dropped from our analysis.

[4] Unilateral CDM projects have been prevalent in China as well (Shen, 2011).

Table 1
Distribution of registered RE-based CDM power projects in India.

Renewable form	Total number of projects	Total capacity (in mW)	Issued kCERs	Expected kCERs
Biomass energy	187	1596.4		
Hydro	80	1286		
Solar	3	5.5		
Wind	215	3852.1		
Total	*485*	*6740*		
Of which projects with CERs				
Biomass energy	91	788.4	8651	9741
Hydro	29	280.1	2589	2893.8
Wind	59	1515	9312	9795
Subtotal	*179*	*2583.5*	*20,552*	*22,429.8*

Authors' calculations based on data from UNEP Risø CDM Pipeline for projects registered until 1st August 2011.

registered projects, but also in terms of the size (installation capacity) of the registered RE-based CDM power projects and certified emission reductions (CERs) issued from these in India. Table 1 gives the summary of the total number of CDM power projects and capacity by renewable form (projects registered until 1st August 2011). It also gives the number of issued and total expected CERs from these RE-based CDM power projects.[5] It is important to note here that for a large number of registered CDM projects in India, the issue of CERs was done on a retroactive basis, i.e. the "credit start date" was earlier than the CDM registration date.[6] This reflects the *prompt start* exception in the UNFCC[7] that allowed for the credit date to commence before the Kyoto Protocol came into effect.

2.2. Renewable energy policies and electricity regulations in India

The efforts to institutionalize the development of renewable sources of energy in India began in 1981 with the establishment of the Commission for Additional Sources of Energy, followed by the Department of Non-Conventional Energy Sources in 1982. The department became an independent federal ministry in 1992, the Ministry of Non-Conventional Energy Sources (MNES), later renamed the Ministry of New and Renewable Energy (MNRE) in 2006. The initial efforts to encourage the development of renewable energy were through centrally funded research and demonstration projects. The renewable energy development approach in India has been top–down, with the federal department directing the states to adopt commensurate policies. A recent survey in India indicates that the renewable energy governance at the federal level has had "a decisive influence over the direction of clean energy development and over the role of the CDM in supporting clean energy" (Phillips and Newell, 2013, p. 656). The most substantial change in the institutional framework for renewable energy-based electricity generation came with the enactment of the Electricity Act 2003.

It should be noted that the electricity sector comes under the concurrent list in India's constitution, which makes the provision of electricity and development of the sector a shared responsibility of both the Central and the State governments.[8] Thus, the planning and regulation of electricity sector in India involves a host of entities at both the center and state levels. The Central Electricity Authority[9] formulates the federal electricity policy plans, specification of technical standards for the construction of power plants, skill training, etc. The Central Electricity Regulatory Commission[10] (CERC) is the independent regulator at the federal level, while all the state governments have independent regulators, the State Electricity Regulatory Commissions (SERCs).

The SERCs function as independent, quasi-judicial bodies with the powers of a civil court, and serve important functions[11] of determining tariffs for generation, supply, transmission and wheeling[12] of electricity both intra-state and inter-state, etc. Under the Electricity Act 2003, the SERCs were made responsible for the regulatory decisions on renewable resources (Section 61 (h) of the Electricity Act 2003). The Act also made the SERCs responsible for promoting "*… co-generation and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution license.*" (Section 86 1 (e) of the Electricity Act, 2003).

As per the Electricity Act 2003, the two main instruments through which the SERCs were expected to incentivize the production of renewable energy were the *preferential feed-in tariff* and *renewable purchase obligations*.

- *Feed-in tariffs* (FIT) provide the minimum price at which renewable energy based power must be purchased from the generators by the distribution licensees[13];
- *Renewable Purchase Obligation* (RPO) is the minimum percentage of total electricity purchased by a distribution licensee that has to be in the form of renewable energy.
- *Fiscal incentives* include various incentives like tax holidays for renewable energy generation; provision of banking, wheeling and third party sales; other financial incentives and subsidies include concessions on land acquisition, rent, water cess, and power charges.

The National Electricity Policy 2005 and the National Tariff Policy in 2006 re-emphasized the role of SERCs in the promotion of renewable sources of energy. In particular, the National Tariff Policy 2006 provided the guidelines to SERCs for fixing minimum RPOs at the state level, which were to be based on regional availability of resources and the RPOs' impact on retail tariffs (Sect. 6.4 (1)). In 2008, the Prime Minister's Council on Climate Change approved the National Action Plan on Climate Change (NAPCC), which stipulated a dynamic minimum renewable purchase target of 5% in 2009–10 increasing by 10% each year which would imply that by 2020 India should be producing 15% of its energy from renewable energy. Other policy initiatives of the Central

[5] In terms of total issued CERs, China and India have been the leading countries. As of August 2011, China leads with 57.3% and India followed in a distant second with 15% of the total issued CERs worldwide. Of the total 705 CDM projects located in India, only 274 projects had issued CERs for the Annex I investing countries.

[6] For example, a RE-based power project registered in 2007 (and with a "comment start date" in 2005) can be found to have a "credit start date" in 2000. In our dataset, about 19% of the 485 registered RE projects have "credit start" year earlier than the "start comment" year; and about 39% of the 179 projects which generated CERs in the dataset were issued CERs retroactively.

[7] Decision 17/CP.7 of the COP allowed for a prompt start of the CDM even before the Protocol entered into force, such that projects begun before the start of the Kyoto Protocol (as early as 2000) could claim CERs retroactively.

[8] Part-III, Seventh Schedule of the Indian Constitution.

[9] Established under the *Electricity Act 1948* (replaced by the Electricity Act, 2003, Section 70).

[10] Established under the *Electricity Regulatory Commissions Act, 1998* (replaced by the Electricity Act 2003, Section 76).

[11] Section 86 (1) of the Electricity Act, 2003, Government of India.

[12] Wheeling refers to the movement of electricity from the generators to consumers over transmission and distribution lines owned neither by the consumers nor the generators (REEP, 2009).

[13] All tariffs are fixed on the basis of the estimates of costs of operation, maintenance, debt repayment, etc.

Table 2
Estimation results of capacity installation in RE-based CDM power projects.

	(1)	(2)	(3)	(4)	(5)	(6)
				Top ten states only		
Log (per capita state net domestic product)	−1.629	−2.011	−1.679	−0.884	−1.175	−0.236
	[2.021]	[2.128]	[2.167]	[2.282]	[2.257]	[2.365]
State electricity capacity annual growth	0.003	0.006	0.007	0.001	0.004	0.007
	[0.008]	[0.007]	[0.007]	[0.008]	[0.007]	[0.007]
State CDM benefit clause dummy	1.019*	1.135**	1.191**	0.970*	1.017*	1.078*
	[0.552]	[0.562]	[0.576]	[0.563]	[0.572]	[0.611]
State RPO dummy	0.52	0.685	0.636	0.396	0.432	0.406
	[0.406]	[0.429]	[0.435]	[0.427]	[0.434]	[0.451]
Feed-in-tariff dummy	0.432	0.461	0.399	0.315	0.312	0.218
	[0.292]	[0.300]	[0.295]	[0.304]	[0.306]	[0.304]
State fiscal incentives specific-RE dummy	0.884**	0.728*	0.702*	0.992**	0.764*	0.752*
	[0.372]	[0.368]	[0.380]	[0.381]	[0.388]	[0.400]
Log (state potential specific-RE capacity)		0.430***	0.366***		0.463***	0.365**
		[0.131]	[0.139]		[0.150]	[0.154]
Log (lagged specific-RE installed capacity)			0.118			0.203**
			[0.081]			[0.091]
State share in FDI						−0.022
						[0.019]
Observations	145	145	145	121	121	121
Number of states	19	19	19	10	10	10
State fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
RE-form fixed effects	*Yes*	*No*	*No*	*Yes*	*No*	*No*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
F test	2.584	2.426	2.683	2.323	2.602	3.215
Prob > F	0.001	0.003	0.001	0.005	0.002	0.000
R-squared	0.503	0.488	0.499	0.401	0.398	0.435
Adjusted R-squared	0.337	0.324	0.332	0.226	0.232	0.263

Robust standard errors in brackets.
*** Indicates significance at 1% level.
** Indicates significance at 5% level.
* Indicates significance at 10% level.

Government include a Generations Based Incentives scheme in 2009 for grid connected wind energy projects, and tradable Renewable Energy Certificates in 2010 (introduced by the Central Electricity Regulatory Commission), which allows the utilities across states to trade in these certificates in order to meet their renewable purchase obligations.

3. Determinants of CDM project location and model specification

The factors determining the location of CDM projects for prospective foreign investors are driven by the scope for cheap emission reductions, institutional capacity of the host region, and general investment climate for optimizing returns (Fankhauser and Lavric, 2003; Jung, 2006). Given this premise, it becomes easier to identify the reasons behind the location of a CDM project in a particular region by identifying the regional level factors that affect the profitability of these projects. Winkelman and Moore (2011) identified the determinants of the location of CDM projects by distinguishing CDM projects into two types: first, those which have only emission reductions as the only source of revenue; and second, those which in addition to emission reductions have a co-product which can be sold at a price in the market (or self-consumed and thus save on input cost, in case of captive power generation in some industries). The RE-based CDM power projects fall under the second category; however, as noted earlier, most of the Indian projects in our analysis did not generate CERs. Indian RE-based CDM power projects can be characterized by two measures, the size in terms of capacity installation and the co-product CERs for a subset of these projects.

For a renewable energy CDM project the major factors affecting the profitability are the natural resource endowment as well as economic conditions to exploit the resource optimally. Since renewable energy based electricity uses relatively advanced and newer technologies, the underlying technological absorptive capacity is necessary in order to understand, use and adapt such technologies (Doranova et al., 2010; Haites et al., 2006; Hascic and Johnstone, 2011). Winkelman and Moore (2011) thus used education level (human capital) as one of the determinants of location of CDM projects. In our model, where the state is the unit of analysis, we measure the technological prowess in renewable energy through the prevalence of similar RE-based power plants.

Other factors affecting the profitability of a project are the market and policy conditions in each region. These include the growing electricity markets (Winkelman and Moore, 2011), openness to private and foreign investment, availability of sources of clean energy, renewable energy policies and preferential tariffs for renewable energy power (Benecke, 2008).

In our model, we incorporate regional economic factors by including the per capita state output, the growth rate of the state electricity sector, and the state annual share of the total FDI inflows into the country (as proxy for FDI attractiveness or rank). The state renewable energy based power policies include the RPO, FIT and fiscal incentives. We also incorporate the state CDM benefit-sharing clause as an institutional factor. Typically, the states which implemented RE-based electricity policies and feed-in tariff also built-in CDM benefit-sharing clause, whereby the co-benefits from these projects (carbon credit financial benefits) would be shared by the project developer with the distribution licensee (state electricity distribution company) after a certain period.[14] For

[14] Typically, the project developer would keep 100% of the CDM financial benefits in the first year, and then begin sharing incrementally more (10%, 20%, etc, with a maximum limit of 50%) over the successive years with the distribution licensee with whom the power purchase agreement is signed. The logic underlying the clause being that since the power purchaser supported the generation of renewable energy through higher tariffs, it was deemed essential for the CDM project developer to share benefits with the licensee and their consumers. So states with stronger institutional structure brought in this clause before the Central Electricity Regulatory Commission order in this regard in 2009, for example the Gujarat Electricity Regulatory Commission, stipulated the benefit sharing clause in CDM projects in August 2006, where 25% benefit sharing with the distribution licensee was proposed.

renewable resource availability, we incorporate the state's potential power capacity from a specific renewable energy form (differentiating biomass, small hydro, and wind).

3.1. Model specification

We first model the location of the CDM projects by size (capacity installation) across the states. Our basic regression equation for the capacity installation under the RE-based electricity CDM projects is given by the following:

$$\log\left(CDM_{ijt}\right) = \alpha_i + \beta_j + \gamma_1 . \log\left(NSDP_PC_{jt-1}\right) + \gamma_2 . \log\left(REpotential_{ij}\right) + \gamma_3 .Elec_{growt}h_{jt-1} + \gamma_4 . \log\left(Renew_{i,j,t-2} + 1\right) + \gamma_5 .FDI_{jt} + \theta_1 .CDM_{claus}e_{jt-1} + \theta_2 .G_{ijt-1} + \theta_3 .FIT_{ijt-1} + \theta_4 RPO_{jt-1} + \epsilon_{ijt} \quad (1)$$

i renewable form (biomass, small hydro, wind)
j state
t year
where

α_i fixed effect for renewable energy form i
β_j fixed effect for state j
δ_t fixed effect for year
CDM_{ijt} capacity installation under CDM projects of RE type i in state j in year t
$NSDP\_PC_{jt-1}$ is the per capita net state domestic product (in constant Rs) in state j in year $t-1$
$REpotential_{ij}$ is the estimated potential of RE form i in state j
$Elec\_growth_{jt-1}$ is the growth in total electricity capacity of the state in year $t-1$
$Renew_{ijt-2}$ is the installed capacity in RE form i in state j in year t
FDI_{jt} is share of state j in India's total FDI inflow in year t
CDM_clause_{jt-1} is the dummy for clause on CDM benefit sharing in state j in year $t-1$
G_{ijt-1} is dummy for fiscal incentives in RE form i in state j in year $t-1$
FIT_{ijt-1} is the dummy for preferential feed-in-tariff in RE form i implemented in state j in year $t-1$
RPO_{jt-1} is the dummy for renewable purchase obligation implemented in state j in year $t-1$.

In Eq. (1) above, the capacity installation in state i of j-type RE-based CDM power project in year t is modeled as a function of the per capita state net domestic product in year $t-1$; state potential capacity in the jth RE-based power (reflecting the natural resource endowment of the state). The *state potential capacity* in each of the RE-technology is the potential capacity as estimated by the Indian Ministry of New and Renewable Energy for each state based on their geographical attributes and do not vary over time, and so we drop this variable in the regression specification when the RE-form fixed effect is included (as the two are correlated). The share of the state in FDI inflows is taken as a measure of the attractiveness of the state for investment and also reflects the ease of doing business, and we expect it to have a positive impact on the dependent variable.

As the CDM-investment in period t is determined by infrastructure, institutional and regulatory factors observed prior to that period, we lag the latter variables. The factors include the growth in total grid-connected electricity (reflecting the growth in the underlying power infrastructure); state regulations and incentives in RE-based power (including state CDM-clause, fiscal incentives, FIT and RPO in year $t-1$); and the pre-installed capacity in jth RE-based power in year $t-2$ (reflecting the scale and technology advantage of the state in the specific RE-form). Since the implementation of regulations and provision of financial incentives also drives non-CDM projects in the RE-based power installation in the states, our variable on renewable energy installed capacity (*Renew*) is lagged by two periods to avoid the endogeneity problem.[15] When considering the log value of the pre-existing capacity, we add one in order to prevent the loss of observations where pre-installed capacity is zero.

Our second regression model for the joint product of certified emission reductions (CERs), de-scaled by capacity installation of the CDM power projects in Indian states, is given by Eq. (2). While we use the first model to examine the significance of various factors in locating RE-based CDM projects (by capacity size) in the states, our second model examines the factors significant in the generation of co-benefits (CERs) from these CDM projects after controlling for capacity size.[16] As noted earlier, the second model represents only a subset of RE-based CDM power projects examined in our first model (1), since all the CDM projects did not generate CERs. Here we examine the different state characteristics that determined the generation of CERs per kW:

$$CER_{ijt} = \alpha_i + \beta_j + \delta_t + \gamma_1 . \log\left(NSDP_PC_{jt-1}\right) + \gamma_2 . \log\left(REpotential_{ij}\right) + \gamma_3 .Elec_{growt}h_{jt-1} + \gamma_4 . \log\left(Renew_{i,j,t-2} + 1\right) + \gamma_5 .FDI_{jt} + \theta_1 .CDM_{claus}e_{jt-1} + \theta_2 .G_{ijt-1} + \theta_3 .FIT_{ijt-1} + \theta_4 RPO_{jt-1} + \epsilon_{ijt} \quad (2)$$

where

CER_{ijt} CER issued per kW from CDM projects in RE type i in state j in year t.

The dependent variables in Models 1 and 2 are installed capacity and CERs issued per kW installed capacity from registered renewable energy (biomass, small hydro and wind) CDM projects respectively. Our state- and RE form-fixed effects control for other state-specific, renewable form-specific, time invariant factors that our model does not cover. We also include year fixed effects to control for changes in the electricity and investment policies that are not covered in our specification, since electricity reform measures have impacted output and investment across the states in India (see Sen and Jamasb, 2012).

Our state regulatory and policy variables are binary variables: preferential feed-in tariffs (FIT) which take a value of 1 if the state electricity regulatory commission has specified a preferential feed-in tariff for the procurement of electricity based on RE form i in state j in that particular year, and 0 otherwise. Similarly for the other policies including the implementation of the renewable portfolio obligation (RPO) in the state, and the presence of any specification on the sharing of CDM benefit between project developers and distribution licensees. The state fiscal incentive (G) is also a binary variable; however it is specified by RE-form (biomass, small hydro and wind) by year. These government policies are expected to have a positive effect on the installed capacities.

The renewable energy policy regime in India has been driven by the federal ministry as discussed earlier in Section 2.2. Despite federal guidelines through the 1990s, the ministry noted that by 2001, only seven states had implemented preferential policies for private sector investment in renewable energy, and several states encountered

[15] Schmid (2012) demonstrated that the introduction of the RPO, feed-in-tariff and private participation played significant roles in promoting renewable energy power in 9 states in India. It may be noted that 8 of these states are part of the top 10 states that we track separately.

[16] On average biomass CDM power projects have generated the highest number of CERs per unit capacity, followed by small hydro and then wind. Our RE-form fixed effects in Eq. (2) control for this heterogeneity in CER generation per kW. The maximum number of total CERs in India during the period of our analysis, however, has been generated by wind-based CDM power projects (without controlling for capacity).

Table 3
Estimation results of CERs per kW from RE-based CDM power projects.

	(1)	(2)	(3)	(4)	(5)	(6)
				Top ten states only		
Log (per capita state net domestic product)	−4.82	−6.605	−3.326	−5.476	−6.407	−4.517
	[25.045]	[24.450]	[24.673]	[24.838]	[24.199]	[24.221]
State electricity capacity annual growth	−0.047	−0.036	−0.041	−0.045	−0.036	−0.041
	[0.056]	[0.052]	[0.058]	[0.056]	[0.051]	[0.057]
State CDM benefit clause dummy	8.168*	8.229*	7.846	8.249*	8.198*	8.062*
	[4.706]	[4.716]	[4.814]	[4.652]	[4.681]	[4.769]
State RPO dummy	2.995	2.71	2.212	3.024	2.683	2.208
	[3.356]	[3.278]	[3.609]	[3.282]	[3.257]	[3.504]
State fiscal incentives specific-RE dummy	7.641**	6.115*	6.038*	7.161**	6.202*	6.119*
	[3.414]	[3.548]	[3.277]	[3.494]	[3.522]	[3.356]
Feed-in-tariff dummy	−2.033	−2.236	−2.223	−2.07	−2.229	−2.251
	[3.061]	[2.982]	[3.002]	[3.030]	[2.953]	[2.949]
Log (state potential specific-RE capacity)		−3.530***	−3.203***		−3.637***	−3.422***
		[1.118]	[1.193]		[1.108]	[1.171]
Log (lagged specific RE installed capacity)			−1.451			−0.919
			[0.929]			[0.859]
State share in FDI			0.077			0.078
			[0.163]			[0.162]
Observations	86	86	86	83	83	83
Number of states	12	12	12	10	10	10
State fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
RE-form fixed effects	*Yes*	*No*	*No*	*Yes*	*No*	*No*
Year fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
R-squared	0.578	0.568	0.587	0.573	0.586	0.594
Adjusted R-squared	0.382	0.378	0.384	0.385	0.415	0.406

Robust standard errors in brackets.
*** Indicates significance at 1% level.
** Indicates significance at 5% level.
** Indicates significance at 10% level.

problems with restructuring the electricity sector and creating independent regulatory commissions to fix preferential tariffs (Sawhney, 2013, p. 300). The state-level policy variables in our model act as proxy of good governance, since as Phillips and Newell (2013) observed "many states lack the institutional capacity to promote and process CDM projects" and that the perceptions of effective governance among project developers could be "important in directing the geographic distribution of investment".

4. Data

Our data on the dependent variable capacity installation and CERs issued by location of RE-based CDM power projects is extracted from the Project Design Documents of these registered CDM projects in India, from the UNEP Risø CDM Pipeline registered as of August, 2011. Under Section A.4.1.4, details of physical location including information enabling the unique identification of the project activity are to be given; however, the information on exact location (by latitude and longitude) is not often provided for all projects. Since the state is specified for all projects, our unit of analysis is the state.

The year in our analysis corresponds to the Indian financial year (April through next March), since our explanatory variables are reported by the financial year in India. So we align our dependent variable also to the financial year based on the start date information of the project from CDM pipeline data. The start date of the CDM project is taken to be the "start comment date"; however since we find that many of the registered RE-based CDM projects in India have the "credit start date" prior to the date of "start comment", we consider the "credit start date" for the projects where it predates the start comment year. Thus in assigning the start date of a CDM project in our analysis we consider the date of "start comment" or "credit start date" depending on whichever is the earlier date.[17]

The data on existing RE-based power capacities, by the different forms is obtained from the annual reports of the Ministry of Non-Conventional Energy Sources (MNES, 1998–2005), the Ministry of New and Renewable Energy (MNRE, 2005–2011), as well as the *Energy Statistics* of India published by CSO (2006–2011). It should be noted here that the installed RE-based power capacity from these reports includes private as well as government plants, including capacity of installed demonstration projects. As we consider the installed RE capacity in states with a 2-year lag in the model, we match the CDM projects in biomass power in a year like 2004 to the biomass-based power capacity of the state as of 2002. Data for total installed electricity capacity in the states are taken from the annual reports of the Central Electricity Authority (CEA). We compute annual growth in the total installed power capacity to capture the growth in the state electricity market.

The states' natural resource potential in specific-renewable energy power which is taken from the MNRE publication is based on three sources: The wind energy potential at 80 m height from the Centre for Wind Energy Technology (CWET), Government of India[18]; the potential in biomass (agro-based) from the Biomass Resource Atlas of India V2.0 (a project of Ministry of New and Renewable Energy, executed by the Indian Institute of Science, Bangalore)[19]; and the small hydro potential estimates from the MNRE annual report (2007–08).

The data on the net state domestic product (NSDP), and per capita net state domestic product at constant prices (base financial year

[17] For example, a CDM project with registration year of 2007, "comment start" year of 2005 and a "credit start" year of 2000 is assigned the year 2000. While a CDM project with registration year of 2007, "comment start" year of 2005 and "credit start" year of 2007 is assigned the year 2005.

[18] Available at http://www.cwet.tn.nic.in/html/departments_ewpp.html.

[19] Relevant tables were extracted from: http://lab.cgpl.iisc.ernet.in/atlas/Tables/Tables.aspx.

2004–05) are taken from the Reserve Bank of India database. The data on FDI inflows are from the Department of Industrial Policy and Promotion (SIA newsletters). It should be noted that the FDI data is reported for the calendar year (January through December) and not the Indian financial year (April through March). For years 2000 to 2004, the data is on FDI inflow approvals by state, while for the period 2004–10 the data provides information on actual inflows. For our analysis, to gauge the attractiveness of each state to foreign investors, we consider the state share of annual total approved FDI in India for the period 2000–04; and for the subsequent years we consider the percentage share of each state in annual total FDI inflow in India.

The data on state regulations is based on the regulatory orders related to renewable energy of the SERCs and obtained from the websites of respective regulatory commissions. The information on state fiscal incentives provided for RE projects (including concessions on land acquisition, rent, water cess, power charges) is from IREDA (2010) and annual reports of MNES.

Our final panel data covers the registered CDM projects by type (biomass, small hydro, wind) with their starting dates between 2000 and 2011 (that entered the CDM pipeline between the years 2004 and 2011). The panel covers data for 19 states in 3 types of renewable forms, but is highly unbalanced. This reflects the regional bias and RE-form bias (see Appendix Tables A1 and A2) of the CDM projects in India. We also consider a subset of the final panel to examine the top 10 states separately.

5. Discussion of results

Table 2 presents the summary of regression results of the capacity installation under RE-based electricity CDM projects across 19 Indian states and the subset of the top 10 states (Model 1 specified in Eq. (1)). Table 3 gives the estimation results of the CERs issued from RE-based electricity CDM projects across India (Model 2 specified in Eq. (2)). Our specifications control for state-, RE type- and year-fixed effects. For both models, we report the results for all states, as well as for the subset of the top 10 states which account for more than 90% of all RE-based CDM power projects in India.

In Table 2, the staggered regressions (1)–(3) cover our entire panel data, and we drop the FDI variable in Model 1 in order to capture all states.[20] The regressions (4)–(6) show the staggered estimations of the specification of Eq. (1) for the subset of top 10 states. We find that the natural resource-based potential of the states was significant in locating CDM power projects on the whole, as well as in case of the top 10 states; while the pre-installed capacity of RE-based power in the states played a significant role only in the top 10 states but not in all states.

State government renewable policy implementation is found to be highly significant in all the specifications. In particular, state fiscal incentives and CDM benefit-sharing clause attracted larger RE-based CDM power projects. Thus we find that financial incentives and better state governance played an important role in enhancing RE-based power capacity under CDM projects. Given the predominance of unilateral CDM projects across India, it is not surprising that the FDI attractiveness of the states had no significant positive impact on locating RE-based CDM projects. Moreover, within the top 10 states, the pre-installed RE-based power capacity was also a significant determinant in attracting larger CDM projects indicating the presence of scale and technology advantage effect (regression 6).

In Table 3, our estimation results in Model 2 indicate that state financial incentives and CDM benefit clause played by far the most significant role in generating CERs (per kW) from CDM power projects, and are found to be robust with alternative specifications (regressions 1 through 6, Table 3) as under Model 1. However, the coefficient of the state potential in RE-based power is found to be negative and highly significant (regressions 2–3, 5–6, Table 3), in sharp contrast to our results under Model 1. Under Model 1, our result shows that states with higher potential benefited in terms of greater RE-based power capacity-building under the CDM projects; however, there were no commensurate gains in clean electricity generation and hence CERs (after controlling for size of the power plants) from such CDM projects in the high potential states. This suggests that although the higher potential states like Himachal Pradesh (in small hydro) and Uttar Pradesh (in biomass) gained in terms of capacity-building through RE-based power projects, they failed to obtain additional gains in terms of CER generation indicating lower operational efficiency and productivity of their power plants.

The results of Tables 2 and 3 indicate that state fiscal incentives and CDM benefit-sharing clauses were both significant determinants in the twin benefits of CDM power projects: first, the benefit of RE power capacity under Model 1, and second the co-benefit through CER generation per kW capacity (additional revenue earning) under Model 2. There are also two key differences that are evident from the analysis: first, while states with higher RE-potential gained in terms of locating larger size CDM projects, they did not gain in terms of higher CER generation; and second, pre-existence of similar RE power capacity in the states helped attract larger RE-based CDM power projects (importance of techno-economic or scale effect) but did not generate higher CERs.

The insignificance of the FDI control variable (proxy for infrastructure and ease of business in the state), while surprising, is understandable since large RE projects have been located in Indian states which are economically poor and otherwise failed to attract foreign investment. The positive and significant effect of the state fiscal and incentive policies indicates that state level institutional support instruments were important in encouraging investment in CDM projects.

6. Conclusion

Our analysis of the determinants of location of renewable energy CDM projects across the diverse Indian states showed that the state-level policy instruments have been the most significant factors in attracting renewable energy based CDM power projects — particularly, state CDM benefit-sharing clause and fiscal incentive measures. The state government instruments were critical in attracting renewable energy CDM projects even in states which otherwise attracted little FDI. Thus, state level policies played an overwhelming role in affecting the location of renewable energy CDM projects. For the top 10 states, we find that pre-installed capacity in RE-based power in the states was also important in locating larger RE-based CDM power projects. Since our analysis distinguished between RE-forms, the significance of pre-installed capacity reflects both a scale effect as well as the impact of expertise in the specific technology i.e. states with prior knowledge-base in similar RE power plants (biomass, small hydro, and wind) attracted larger CDM projects.

The state government fiscal incentives/subsidies and CDM benefit sharing clause also proved to be important factors in generating CERs from these renewable energy power projects. Our result implies that earning from the by-product of carbon credits per unit capacity installed under CDM projects was higher in states which subsidized the renewable energy sector and better institutional setup. Unfortunately we find that, after controlling for the government incentives and subsidies, the generation of per unit CER (i.e. CERs per kW installed) in CDM projects was significantly lower in states with higher natural RE potential, indicating lower operational efficiency and productivity of these projects. In other words, states with relatively higher natural potential lost out on the additional product gains through CERs among the twelve states that earned credits from RE-based CDM power projects. Thus one important aspect of the CDM approach seems to have been missed in India — that of promoting development in other regions of the country which had natural potential.

[20] For example, the FDI data for Jammu and Kashmir is not available.

Our empirical results corroborate the observation of Phillips and Newell (2013) in a recent review of clean energy governance in India, that "contrary to the intended role of CDM finance as a driver of investment in renewable energy, the range of incentives provided by the Indian state, central planning and domestic trading initiatives mean that the promise of CDM revenue provides the icing on the cake for investors, but rarely drives investment decision".

The significance of the state fiscal measures and incentives, in attracting larger capacity CDM projects and in generating higher carbon credits, reflects the core dependence of the RE-based power sector across Indian states on subsidies. While this is not surprising since RE-based power remains more expensive than conventional thermal power (the predominant source of power in India), it is disturbing that state fiscal incentive instruments played such an overwhelming role as compared to natural potential and other economic and infrastructure factors in generating certified emission reduction benefits. Moreover, given the prevalence of unilateral CDM projects and wide use of *prompt start* in the accounting of CERs in India, this would raise the question whether the RE-based capacity investments in the states would have occurred even without the CDM support, i.e. whether the RE-based CDM power projects indeed satisfied the condition of *additionality* (namely, emission reductions would not have occurred without the CDM projects). As Driesen and Popp (2010) noted "non-additional credits imply that the CDM is not encouraging meaningful technology transfer. Instead, at best, it is taking credit for technology transfer occurring for other reasons and, at worst, promoting projects for which the recipient country already has domestic capacity". It is likely that India missed out on achieving additional emission reductions under the CDM, and much of the RE-based power capacity installation would have taken place due to the state incentive policies.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eneco.2014.01.007.

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