Development of Renewable Energy under *Clean Development Mechanism* in India: 2004-2010

Dissertation submitted to the Jawaharlal Nehru University in partial fulfillment of the requirements for the award of the degree of

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DECLARATION

I declare that the dissertation entitled **"Development of Renewable Energy under *Clean Development Mechanism* in India: 2004-2010"** submitted by me for the award of the degree of **Master of Philosophy** of Jawaharlal Nehru University is my own work. The dissertation has not been submitted for any other degree of this University or any other university.

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CERTIFICATE

We recommend that this dissertation be placed before the examiners for evaluation.

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Acronyms

CDM	-	Clean Development Mechanism
CERs	-	Certified Emission Reductions
CoP	-	Conference of Parties
CWET	-	Centre for Wind Energy Technology
DNA	-	Designated National Authority
DOEs	-	Designated Operational entities
EB	-	Executive Board
FDI	-	Foreign Direct Investment
GBI	-	Generations Based Incentives
HFCs	-	Hydrofluorocarbons,
IPCC	-	Intergovernmental Panel on Climate Change
MNRE	-	Ministry of New and Renewable Energy
NAPCC	-	National Action Plan on Climate change.
NCDMA	-	National CDM Authority
NSDP	-	Net State Domestic Product
PDD	-	Project Design Document
RBI	-	Reserve Bank of India
RECs	-	Renewable Energy Certificates
RPOs	-	Renewable Purchase Obligations
SERCs	-	State Electricity Regulatory Commission
UNEP	-	United Nation's Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change

CHAPTER 1

INTRODUCTION

Background

Climate change and issues related to it have become matters of heated debate among countries, scholars and the general public in the recent times. Environmental issues started gaining international attention with the Stockholm Conference held in 1973. As a result of the conference, the United Nations Environmental Programme (UNEP) was set up with the task of research on environmental impacts and providing advice to governments and other agencies. The 1992 UN Earth Summit in Rio de Janeiro, discussed a host of environmental issues with a major focus on climate change. An agreement called UN Framework Convention on Climate Change (UNFCCC) was introduced in Rio Summit and was signed by 166 countries. In 1997, 160 countries negotiated the Kyoto Protocol to the Framework Convention. Under the Protocol, the countries in the Annex-I of the Convention, which includes the developed nations and economies in transition, accepted binding commitments of emissions reduction targets. They agreed to reduce their emission levels of four green-house gases (CO_2, Methane, Nitrous Oxide and Sulfur Hexafluoride) by 5.2% of their 1990 levels.[1] Specific targets of reduction by 5.2 percent of their 1990 emission levels were given for 38 industrialized (Annex I) countries over the commitment period 2008-2012. The targets apply to six classes of greenhouse gases: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluorocarbons, and sulfur hexafluoride. Developing countries took no obligations under Kyoto.

The Kyoto Protocol also provided options to the Annex-I countries to achieve their commitments in a cost-efficient manner by authorizing four different types of emissions trading schemes

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[1] Article 3 (1) of the Kyoto Protocol to United Nations Framework Convention on Climate Change:
"The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, ... with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012."

(Tietenberg T. , 1998). Article 17 allows these countries to trade emission with each other.[2] Article 4 allows bubbles in which a group of countries may meet their aggregate requirement as a single unit.[3] Article 6 of the Protocol allows these countries to trade emission reduction credits from emissions reduction projects in these countries.[4] Similarly, Article 12 allows certified emission reduction generated from emission reduction projects undertaken in non-Annex-I countries to be used to meet a part of their emissions reduction commitments. The mechanism defined under Article 12 of the Kyoto Protocol was called the *Clean Development Mechanism*. Thus the three flexibility mechanisms provided under the Kyoto Protocol were: Emissions Trading, Joint Implementation and Clean Development Mechanism in addition to a bubble scheme which although general in scope was primarily targeted to the EU.

In the recent years the focus of debates in relation to climate change has been centered on the issue of how to distribute the responsibility of climate change mitigation among the developed and developing countries. There is a strong demand from the developed nations that fast growing developing countries like China and India, which are increasingly contributing to higher emissions, should take up a part of the responsibility of emissions reductions. On the other hand developing countries like China and India have vehemently opposed any attempt to shift the responsibility of emission reductions to the developing countries as the major portion of the emissions in the atmosphere has been the result of the process of economic growth and industrialisation since the advent of the Industrial Revolution. Although in the recent *2011 United Nations Climate Change Conference (COP17)*, an agreement was reached to establish a

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[2] Article 17, Kyoto Protocol to the United Nations Framework Convention on Climate Change: "…*The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling their commitments under Article 3. Any such trading shall be supplemental to domestic actions for the purpose of meeting quantified emission limitation and reduction commitments under that Article."*

[3] Article 4 (1), Kyoto Protocol to the United Nations Framework Convention on Climate Change: "*Any Parties included in Annex I that have reached an agreement to fulfill their commitments under Article 3 jointly, shall be deemed to have met those commitments provided that their total combined aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts.*"

[4] Article 6 (1), Kyoto Protocol to the United Nations Framework Convention on Climate Change: "… *any Party included in Annex I may transfer to, or acquire from, any other such Party emission reduction units resulting from projects aimed at reducing anthropogenic emissions…"*

legally binding agreement by 2015 to take effect in 2020, India and China emphasized on equity in the responsibility of climate change mitigation in any agreement[5].

Till any new agreement is reached, the Kyoto Protocol would continue in the interim. Under this the only mechanism that involves the participation of developing countries in climate change mitigation is the Clean Development Mechanism. As mentioned earlier, Article 12 of the Kyoto Protocol defined the Clean Development Mechanism (CDM) which allows the Annex-I countries to invest in emissions reduction projects in non-Annex-I countries in association with host country project developers and in turn use the '*certified emission reductions*' to count against their reduction commitments. The certified emission reduction would be issued after certification by designated operational entities, on the basis of voluntary participation by parties and *real, measureable and long-term* and *additional* emissions reductions.[6] Additionality means that the emissions from the CDM projects are less than a baseline scenario which is a counterfactual construct of what would have been the situation in case the CDM project was not implemented. The rules and procedures for the Clean Development Mechanism were finalized in Marrakesh in 2001.

As stated in the Kyoto Protocol, the major objectives of the Clean Development Mechanism are 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."*[7]

The benefit of achieving sustainable development forms the major incentive for the developing nations to participate in this mechanism. It was believed that the investment flows from the Annex–I countries to the developing countries would generate employment, poverty alleviation, rural development and cleaner environment etc. One form in which CDM was expected to help in the sustainable development of the host countries is through the transfer of clean technology and know-how not already available in the host countries. This was expected to happen by the

[5] *"Does fighting climate change mean we have to give up on equity? We have agreed to protocol and legal instrument. What's the problem in having one more option? India will never be intimidated by any threat or any kind of pressure…We're talking of livelihoods and sustainability here. I'm not accusing anybody, but there are efforts to shift the (climate) problem to countries that have not contributed to it."* – Jayanthi Natarajan, India's representative at the COP17.

[6] Article 12 (5) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change
[7] Article 12 (2) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change

investment of funds by Annex-I agents in CDM projects using clean technology in the non-Annex-I countries.

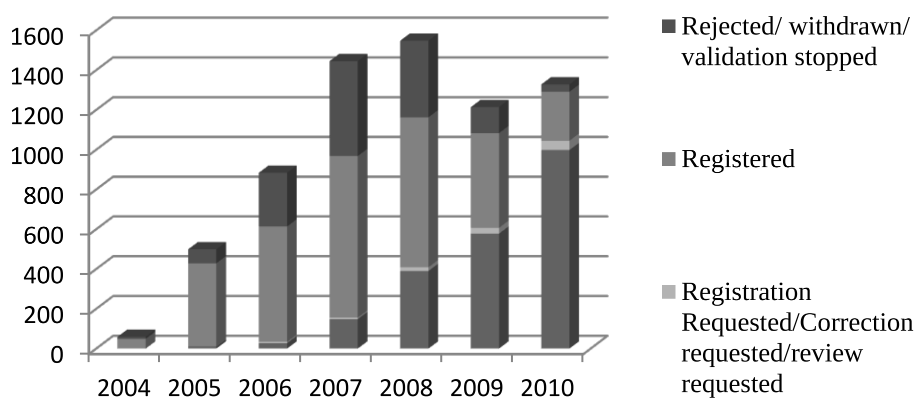
The first CDM project was registered in 2004. As of August 2011, there were 6559 live projects in the CDM pipeline.[8] Considering only the projects that entered the Pipeline between 2004 and 2010, 3333 projects have been registered by the CDM Executive Board as of August 2011 (see Table 1.1 for year-wise detail).

Table 1. 1: Status of CDM Projects by Year of Entry into the Pipeline

Year of entry into the CDM Pipeline	*At Validation Stage*	*Registration Requested/ Correction requested/ Review Requested*	*Registered*	*Rejected/ Withdrawn/ Validation Stopped*	*Total*
2004	1	0	48	10	**59**
2005	11	1	417	70	**499**
2006	27	7	580	270	**884**
2007	148	8	812	477	**1445**
2008	390	19	754	385	**1548**
2009	578	29	476	131	**1214**
2010	998	47	246	37	**1328**

Source: UNEP Risoe CDM Pipeline, August 2011

Fig 1.1: : Status of CDM Projects by Year of Entry into the Pipeline



[8] UNEP Risoe CDM Pipeline, August 2011

Figure 1.1 above shows the breakdown of projects entering the CDM pipeline according their status up to August 2011. The number of projects entering the CDM pipeline has shown an increasing trend up till 2008 after which there has been a decline between 2008 and 2009 after which it marginally increases in 2010.

The CDM was introduced with one of the objectives being to help the developing countries achieve sustainable development. Given this it becomes important that CDM projects be established in the developing world evenly so that any region is not left behind in benefitting from it. But since the inception of the mechanism, it has been observed that there has been a clear bias in the location of these projects in favour of the relatively fast growing developing countries like India and China, while many of the poorer developing countries have only a negligible share in the CDM projects established all around the developing world. Even within India, there seems to be a biased distribution of CDM projects. An example would be the distribution of renewable energy CDM projects across different states which cannot explained by the natural resource endowments of the different regions.

Motivation and Rationale of the study

The empirical literature on CDM has focused on national level factors affecting the distribution of CDM projects across the different countries. There are no studies with an analysis of intra-country distribution of these projects in a large developing country like India. However, it is increasingly obvious that distribution of CDM projects across the country is rather skewed, which suggests that state level policies and regulations, economic factors and business environment may actually be playing a major role in the emerging distribution of CDM projects and the benefits thereof.

The establishment of CDM project in a region does not in itself guarantee greater benefits for the host region. The way in which the projects are functioning is even more important. The projects' success in achieving the mechanism's objectives and the factors affecting the successful achievement of these objectives become important for us to understand. Although not explicitly mentioned in the Kyoto Protocol, one of the major expectations from the CDM was the transfer of clean technology from the developed countries to the currently developing countries. But it has been found that the proportion of projects involving technology transfer has varied significantly across countries. Previous studies have again mainly focused their attention on cross country analysis of determinants of technology transfer and there are hardly any econometric studies focusing on technology transfer in individual countries.

In this study our objective is to fill in this gap in the literature by undertaking an analysis of factors particularly at the state level that impact the benefits reaped by a developing nation through the CDM. Our study focuses on the two issues mentioned in the preceding two paragraphs. In particular, we wish to address the following two questions in our study:

- *What has driven the regional bias in CDM energy projects across India? Is it based on efficiency (energy resource endowment) and/or policy and economic conditions? Is the bias in green investment yet another dimension of regional inequality observed across the states in India?*
- *Track the evidence of technology transfer under CDM projects in India and find what determines technology transfer under CDM projects in India.*

In *chapter 2* of the dissertation we provide a review of previous literature on CDM and various aspects related to it and thus helps us to identify the above two questions. To answer the first question we study the determinants of the location of the registered renewable energy CDM projects across different states in India. This involves an econometric analysis based on a panel of 17 states across 11 years (covering Indian renewable energy CDM projects entering the CDM Pipeline between years 2004-2010). We analyse the determinants of renewable energy CDM location by putting particular emphasis on state-level variables. In particular, we include variables to show the impact of certain regulatory incentives provided by state electricity regulatory commissions as well as other economic variables relevant at the state level. This analysis forms *chapter 3* of this dissertation. In *chapter 4* we analyse the factors affecting technology transfer and the type of technology transfer under registered CDM projects in India. Since our unit of analysis is a registered CDM project by state location, we control for various state-level factors. *Chapter 5* concludes the study and discusses the policy implications of the finding.

CHAPTER 2

LITERATURE REVIEW

2. 1 Introduction

The Clean Development Mechanism has been a matter of discussion, especially due to its involvement of developing countries in the emissions reduction activities. Gains in terms of technology transfer, investment and development benefits were expected from the mechanism while concerns were raised about the biased regional and sectoral composition of these projects, elimination of low cost emission reduction opportunities for the developing countries in the future, additionality of these projects etc. In this chapter, I review the literature that looks at the economic aspects, theoretical basis and empirical analysis country experiences under the Clean Development Mechanism Projects. The basic idea of the Clean Development Mechanism is derived from emissions trading. Annex-I country entities can buy Certified Emission Reductions from non-Annex-I countries awarded for emission reduction projects, to count against their emission reduction commitments under the Kyoto Protocol. In section 2.2, we examine the theoretical background of emission trading mechanisms and a comparison is made with the Clean Development Mechanism. In Section 2.3 we review the empirical literature on the topic, which although scant, focuses their attention on widely different aspects of the mechanism.

2.2 Theoretical Background

When the objective is to achieve a fixed amount of emission abatement, efficiency would require the equalization of marginal abatement costs across all polluters. The Clean Development Mechanism essentially involves an element of emissions trading through which cost efficient attainment of emissions reductions are to be achieved. Thus, before proceeding any further, it would be pertinent to delve a little into the idea of emissions trading.

2.2.1 Emissions Trading

One of the most commonly discussed market based mechanism for environmental regulation is the tradable permit system. Under this system, each polluter is given a fixed amount of emissions permits which can be freely traded in the permit market. Agents who wish to emit more than their allocation of permits may do so by buying permits from agents who emit less than their allocation of permits. Polluters having a marginal cost of abatement greater than the market price of permits would buy permits till a point where the two are equalized. Similarly, polluters whose marginal abatement costs are less than the permit price would sell their permits as long as the two are not equalized. Thus, in equilibrium, the marginal costs of abatement for all polluters are equalized.

Emissions trading may be implemented through different policy instruments. These may be *offsets, bubbles, netting* and *emissions banking* (Tietenberg, 1990). For many pollutants, the extent and spatial pattern of the damages to the environment depend not only upon the level of emissions but also on the location and dispersion characteristics of the sources. The impact of a unit of a particular pollutant at a receptor point depends on the dispersion coefficient of that pollution source for that receptor point. Under a Pollution Offset approach, sources are not allowed to trade permits on a one-to-one basis. The trading of permits is subject to the condition that the air quality standards at all the receptors are met. The implication is that when any proposed trade encounters a binding constraint at any receptor point, then emissions would be traded at a rate equal to the ratio of transfer coefficients. (Krupnick, Oates, & van de Verg, 1983)

Under the Clean Air Act in the United States of America, an offset policy was introduced under which new entrants in the areas not conforming to ambient standards to attain emission permits from existing firms in the area. Thus, the emission levels would be lower after the entry of new firms. (Tietenberg, (1990), Tietenberg (1998))

A *bubble* policy regulates only the total emissions of all emitters within a given area (bubble); the agents within the bubble are free to trade permits between them as long as their aggregate emissions do not exceed the permitted level of emissions for all the agents as a whole(Tietenberg, (1990), Tietenberg (1998)). *Netting* allows the old sources that are expanding or modifying their plants to avoid technological requirement for pollution control (New source performance standards) by allowing them to meet any increase above the emission standards by using credit generated within the firm. *Banking* allows firms to store credits generated in the current period to be used in the future. (Tietenberg, (1990), Tietenberg (1998))

Hahn & Hester (1989), found from the experience of emissions trading implemented in the US that cost savings among the four programmes vary widely, greatest cost reductions resulting from netting. They also found that the overall effect on the environment from these programmes have been insignificant.

2.2.2 CDM versus Emissions Trading

The Clean Development Mechanism most closely resembles an offset based emission trading scheme in that the credits are issued for the emissions reduction undertaken in the non-Annex-I country which do not have any binding commitments for emissions reductions. One would expect that there would be global cost reductions when developing countries with lower marginal abatement costs take up a part of abatement from the developed countries through CDM based projects. But a major differentiating factor between the kind of offset scheme that was implemented in the US under the Clean Air Act and the CDM is that, CDM allows for the transfer of technology and investment by the Annex-I participant in the non-Annex-I country.

Under the Kyoto Protocol, what is of importance is the achievement of global emission reductions and hence a unit of CO_2e emissions from any part of the world is treated to have same impact on the environment under the Clean Development Mechanism. This is the polar case under pollution offsets where a unit of emissions from any point has the same effect on concentrations at all points in the area. In this case the offset system involves trading of emissions on a one to one basis and is similar to simple trading of permits between polluters.

The attainment of efficiency under an international permit trading scheme would be affected by the internal environmental regulations of the participating countries as well. In case there is a domestic tradable permit system in the Annex-I country, then there are incentives for exchange only if the project specific marginal abatement costs in the non-Annex-I country are lower than the permit price in the Annex-I country. Similarly in case of an emission tax in the Annex-I country, CDM would be effective only if the tax rate per unit of emissions is greater than the marginal abatement cost in the non-Annex-I country. In the case of fixed quantity standards, there exists incentives for Annex-I entities to setup CDM projects regardless of the relation between the marginal costs (Hahn & Stavins, 1999).

For an Annex-I agent who is interested in acquiring CERs, the decision to invest in a CDM project would depend on the comparison of the profitability of investing in the project vis-à-vis just acquiring CERs from an existing project. In this regard, the type of investment is an important issue; whether the investment involves only a technical cooperation or financing through FDI for investment in physical assets and the agreed distribution of CERs among the project partners. Literature focusing on these aspects has been wanting. Under a profit maximizing framework, investment would be made in a CDM project only if it yields the maximum profits. Thus, for project with co-products, investment would be market seeking type along with the possibility of cheap production of the products (cheap emission reduction possibilities as well as cheap production of co-products) (Winkelman & Moore, 2011). Focusing on only the CER trading aspect of CDM projects, Brechet, Germain, & van Steenberghe (2004), using a simple theoretical model analyse at the behaviour of CDM host participants and find that the decisions depend on the various ranges in which the present and future prices of CERs lie.

A major controversy with offset programmes in general has been the concern regarding whether the offsets generated are actually additional, because in case they are not, there would be a net increase in the global emission levels. Asymmetric information can lead to moral hazard and adverse selection in such markets. (Bushnell, 2010). Firms may intentionally pursue investments in high-carbon sources so that they can claim credits for droping them. Adverse selection is a problem when the regulator doesn’t have sufficient information about the actual baseline of the firm resulting in a situation where low cost firms are paid for emission reductions that would have happened even without the payments. (Bushnell, 2010)

2.3 Empirical Literature on Clean Development Mechanism

The empirical literature on CDM projects can broadly be divided into papers that focus on the various features of the Clean Development Mechanism projects: 1) cost efficient emission reductions, and the achievement of the objective of real, additional and measurable emission reductions 2) technology transfer through CDM, 3) sustainable development impacts on host nations, 4) regional/sectoral composition of the CDM projects and their concentration in particular areas.

2.3.1 Cost Efficient Emissions Reduction

Emission reductions

The major objective of emission reductions through CDM projects would be achieved only if the projects satisfy the condition of additionality. The CDM Executive Board, have suggested a framework to prove additionality of a project. It involves 1) Identification of alternatives to the project, 2) whether the project would have been undertaken without the revenue from the sales of CERs (investment analysis); 3) determine whether there are barriers for implementation of such projects (barrier analysis) and 4) whether the project activity is commonly practiced (common practice analysis). Steps 1 and 4 are compulsory for all projects while project developers have the option of satisfying either step 2 or step 3. (CDM Rule book). In their study of a sample of 52 Indian CDM projects registered until May 20, 2006, Purohit and Michaelowa (2007) find that the additionality of many of these projects were quite doubtful. They find only about 50% of the projects identify alternatives. For only 17 (33%) of the projects, investment analysis have been done. A majority (94%) of the projects have presented barrier analysis to demonstrate additionality. It was found that the presentation of information made a lot of difference to whether a project was accepted or rejected.

Transaction Costs

Due to the various procedures involved in the development of a CDM project, there are certain transaction costs involved in these projects. In case of unilateral CDM projects such costs would be greater owing to search costs for finding a suitable buyer for the CERs, negotiation costs etc. It has been found from an empirical survey (Krey, 2005) held during 2003, of CDM project developers, CDM consultants, financial institutions and government representatives that for unilateral non-sink projects in India, search costs were negligible. Project documentation costs accounted for 90% of the costs for 10 projects for which these costs could be quantified. It was found that the share of search and negotiation costs formed a smaller proportion in the highest transaction costs. On the other hand the share of PDD costs rise from lowest to highest transaction costs. Thus, one can conclude that economies of scale do exist especially for costs of finding a buyer and PDD costs. Theoretically, this should imply a bias in favour of large scale projects rather than small scale projects under unilateral category.

2.3.2 Technology Transfer

A major expectation from the Clean Development Mechanism (although not mentioned as one of the objectives of the CDM in the Kyoto Protocol) was the transfer of climate friendly technology from the developed to developing countries. Transfer of climate-friendly technology can benefit developing countries by: 1) helping in sustainable development of developing countries and 2) lowering a country's compliance costs to future climate treaties (Popp, 2011).

The rate at which technology has been transferred to CDM host countries has shown a wide variation over time and space. Among the major host nations like China, India and Brazil, only 13% of Indian projects were expected to have some kind of technology transfer while 19% and 25% of the projects in China and Brazil respectively, were expected to have technology transfer taking place (UNFCCC, 2010). It thus becomes important to understand the various factors driving technology transfer under the Clean Development Mechanism. Schneider, Holzer, & Hoffmann (2008) developed a framework that identifies the main factors that characterise technology transfer and apply this framework to the case of CDM. The main channels of private sector technology transfer are trade, licensing and foreign direct investment (FDI). In developing the framework, they focus on purchase of technology via trade and transfer of technology as part of an investment. They identify four main barriers to technology transfer: *1) lack of commercial viability:* Imported technology is often quite expensive and usually involves high initial investment costs and therefore projects that are less commercially successful are less likely to involve technology transfer; *2) lack of information about the investment opportunity, a lack of confidence in the information and high transaction costs for obtaining reliable information and negotiating the deal, and the lack of knowledge about the recipient's local needs and technological capabilities*; *3) lack of access to capital* for the recipients to finance the transfer of technology because they may not be able to find an investor because of the level of development of the financial market in developing countries or high costs of borrowing; *4) institutional framework in the host country e.g.* weak enforcement of regulatory framework as in the case of protection of intellectual property rights may impede the international transfer of technology into the host nation. Another important issue dealt with is the quality of technology transfer. They define the quality of the technology transfer as the degree to which the transfer raises the recipient's technological know-how. They identify two determinants of the quality of technology transfer: 1) *type of technology*: depending upon the complexity of technology transferred it may need the transfer of extensive know-how along with it. 2) *nature of the deal structure:* influences the willingness to continually cooperate. Long term collaboration increases the likelihood of know-how transfer while short-term deals are less likely to contribute to high quality technology transfer.

The authors based their analysis on 21 expert interviews. They analysed the impact of CDM on each of the barriers to technology transfer mentioned earlier. Regarding commercial viability, they find that project whose CDM revenue stream's contribution to commercial viability was high was likely to involve technology transfer. On lack of information they found that general information about CDM, potential emission reduction opportunities and information about various actors in CDM projects is being disseminated by various public actors such as development organizations, host countries and UNEP Risoe Centre. With regard to access to capital, their opinion is that access to capital is likely to become easier over time because of maturity of the market and the greater experience with different financing structures. Also, as a result of the interest of international intermediaries to devise financial structures for CDM projects, financing know-how is transferred to entities in developing countries. As far as institutional barriers to technology transfer are concerned, CDM institutions were not likely to have an impact on general investment conditions. Although the authors provide a framework for the analysis of the determinants of technology transfer, they stop short of statistically identifying the significant determinants of technology transfer under the CDM.

Dechezlepretre, Glachant, & Meniere (2009) study the factors affecting technology transfer through CDM projects using a pooled data of 644 registered projects as of May 1st 2007. They use a logit regression with a binary dependent variable indicating the presence or absence of technology transfer. The source of information for technology transfer is the Project Design Documents for each of the Clean Developments Mechanism projects under study. In order to statistically identify the determinants of technology transfer under CDM projects, the authors specify the following logit equation for estimation:

$$Pr\ (TECH\_TRANSFER = 1) = e^{\Omega}/1+e^{\Omega} \quad (1)$$

with

$$\Omega = \alpha_0 + \alpha_1\ LOG\_SIZE + \alpha_2\ CREDIT\_BUYER + \alpha_3\ SUBSIDIARY + \alpha_4\ SIMILAR\_PROJECTS + \alpha_5\ TRADE + \alpha_6\ FDI\_INFLOWS + \alpha_7\ GDP\_GROWTH + \alpha_8\ LOG\_POPULATION + \alpha_9\ GDP\_PERCAPITA + \alpha_{10}\ CARBON\_INTENSITY + \alpha_{11}\ TECH\_CAPABILITY + \alpha_n\ SECTOR_n + \alpha\ COUNTRY + \varepsilon \quad (1.1)$$

Following the analysis of Schneider, Holzer, & Hoffmann (2008), Dechezlepretre, Glachant, & Meniere (2009) identify three variables at the project level that can potentially alleviate the barriers pertaining to the lack of commercial viability, lack of information on existence and functioning of the CDM or on available technologies and lack of access to capital. The first variable was log of project size (*LOG_SIZE)* measured by the project's annual emissions reduction. Upfront investment costs related to technology are higher when it is imported from industrialised countries. The second variable was *CREDIT_BUYER* which is a dummy variable indicaing the participation of a credit buyer in the project acitvity. Presence of a credit buyer can alleviate financial barriers, e.g, sale of credits through a forward contract can reduce the risk surrounding the investment by guaranteeing a revenue stream. The third project level variable *SUBSIDIARY* was a dummy variable indicating whether the project was implemented in the subsidiary of an Annex-I country company. The involvement of a parent company can facilitate technology transfer by helping manage CDM registration, providing expertise at technology level and providing easier access to capital. The other variables used in the analysis represented the country level characteristics. Country size (*LOG_POPULATION),* the per capita GDP *(GDP_PERCAPITA),* and the carbon intensity of the economy (*CARBON_INTENSITY)* were used as control variables. Although these variables were expected to positively influence the number of projects in a host country, it was not certain how they would affect the probability of technology transfer for the projects. Another variable, *GDP_GROWTH*, was expected to positively affect the probability of technology transfer as a faster growth requires sustained investments which offer greater opportunities for implementing new technologies.

In addition to the above mentioned variables, they used a measure of the technological capability of the host country, ArCo technology index, developed by Archibugi & Coco (2004), which includes three measures of technological capability: creation of technology (number of papers and number of scientific articles), the technological infrastructures (internet penetration, telephone penetration and electricity consumption) and the development of human skills (percentage of tertiary science and engineering enrolment, mean years of schooling and literacy rate). Although a higher technological capability may positively affect technology transfer, it may also imply that the required technology is available locally. To take this into account, a variable *SIMILAR_PROJECTS* indicating the number of projects using the same technology in the host country was included. Since there is empirical evidence to suggest that greater openness to international trade and foreign investment increases technology transfer, two variables, *TRADE (sum of exports and imports as a proportion of GDP)* and *FDI_INFLOWS* (*level of incoming FDI into the host country)* were also included in the analysis.

The probability of technology transfer was found to increase with the size of the project and the presence of credit buyers. Also being a subsidiary of an Annex-I country company increased the likelihood of technology transfer. They also found that GDP growth has a positive impact on the likelihood of technology transfer. Further, they found that trade had a positive impact while FDI inflows had a negative impact on the probability of technology transfer. National technological capability was found to have a positive impact on technology transfer.

Using a similar approach and similar explanatory variables, Doranova, Costa, & Duysters (2010) attempt to explain the technology sourcing pattern of CDM projects through knowledge base determinants. While Dechezlepretre, Glachant, & Meniere (2009) used a binary variable indicating technology transfer, this paper constructed a categorical variable with three categories: local, foreign and combined, representing the origin of technology. As measures of knowledge base of the host country, two constructs were used. One to measure the diffusion level of climate friendly technology: two proxies were used, the production share of renewable energy in total energy and the share of climate friendly technology in the total export of goods. Secondly, to measure the scientific effort in climate friendly technology, share of scientific articles in CFT in total pool of scientific articles and the number of patents in CFT by host country inventors. Other independent variables were similar to the ones used by (Dechezlepretre, Glachant, & Meniere, 2009).

A multinomial logistic regression model is estimated. The log odds of each response follow a linear model:

$$\eta_{ij} = \log \frac{Pr_{ij}}{Pr_{i3}} = \alpha_j + \beta_j x_i \quad (2)$$

j indicates the category of technology used (1= local, 2= combined or 3= foreign; 3 being the base category); *i* refers to a particular observation.

Doranova, Costa, & Duysters (2010) find that knowledge base was significant in explaining technology sourcing patterns. Scientific contribution in terms of publications in CFT in a country was estimated to contribute positively to preference for local over imported technologies. Contrary to expectations, patenting activity showed a negative effect on using purely local technology and strongly associated with a preference for combined technology over local. This in line with the finding of Dechezlepretre, Glachant, & Meniere (2009) that technology transfer is positively related to the technological capability of the host country. But with the addition of the variable denoting the export of CFT in the analysis, the authors have been also able to isolate the availability of required technologies locally and hence an indication of the host nation's technological capability in the production of such technologies. The export of CFT showed a positive influence on the preference of local over foreign technology. Being a subsidiary has a significant and positive influence on the choice of combined over purely local or purely foreign technology. Also, as expected, the existence of similar projects in the host country increases the probablility of combined and local over foreign technology. They also found a statistically significant and positive effect of the country size and income level on the preference for local over foreign technologies. Trade openness has a positive impact on the application of foreign and combined over local techology. In another similar exercise, Haites, Duan, & Seres (2006) analysed the determinants of technology transfer using a logit regression. They also find that the probability of technology transfer increases with the size of the project and declines if the project is unilateral.

Velasco (2007) categorized the determinants of technology transfer into three groups: 1) *Climate policy variables* which show the country's capacity to deliver emission reductions and the development of its climate policy institutions. Under this included are the carbon intensity of power generation, country energy intensity (in 2000), country carbon intensity (in 2003), total emissions (in 2003), rating of climate change institutions (in 2006); 2) *Economic variables* which indicate the host country's ability to attract new investment. These include Gross Fixed Capital Formation (GFCF) (in 2004), annual growth of GFCF(between 2000-2004), Foreign Direct Investment and GDP growth (in 2004); 3) *Natural resources* which tell us about the abilty of the host country to host renewable energy projects. Wind resources, theoretic gross hydroelectric capacity, forestry biomass, potential availability of bagasse and per capita availability of agricultural land. A simple cross sectional regression analysis was done to understand the significant determinants of technology transfer. The results show that a higher FDI, better climate policy institutions and higher potential bagasse availability raised the number of CDM projects involving technology transfer. On the other hand, higher hydroelectric capacity led to a smaller number of CDM projects involving technology transfer.

All the above mentioned analyses involved the use of Project Design Documents as their primary source of information. Hascic & Johnstone (2011) took an alternative approach which used patent data to determine the impact of CDM on technology transfer. Protection for an invention may be sought in different countries. Since applying for patent involves a lot of cost, patents for an invention in multiple countries would be an indicator of potential market for the technology. Thus, it may be used as a proxy for the international transfer of technology. Data on this was extracted from the European Patent Office's (EPO) *World Patent Statistics Database,* or PATSTAT for years 1988 to 2008 in the field of *Wind power generation (International Patent Classification(IPC) code F03D – wind power generators and turbines)*. In order to measure the impact of CDM on technology transfer, a measure of the involvement of host countries in CDM is required. This was constructed by the taking the sum of average annual certified emission reduction associated with CDM projects of a host country in a given year (projects with starting date in a particular year) (CER). As identified in previous empirical studies, technology transfer is likely to decline with the number of similar projects in the host country. To control for this effect, the discounted (at 10%) stock of CERs was used (CERSTOCK). Domestic absorptive capacity is another factor affecting technology transfer. Discounted stock of patents by the recipient country inventors in wind power technologies was used as a measure of their absorptive capacities (ABSCAP). To measure the supply of inventions in the source country that are potentially available for transfer elsewhere, number of patent applications filed by domestic inventors in wind power in the current year or in the previous three years was used (SUPCAP). To capture more general economic factors that are likely to influence technology transfer, the total number of duplicate patent applications in the two countries is taken (TOTALTT). TOTALTT is expected to positively influence technoilogy transfer in wind energy sector. The authors estimated the following model:

$$WINDTT_{ijt} = f(CER_{jt}, CERSTOCK_{jt}, SUPCAP_{it}, ABSCAP_{jt}, TOTALTT_{ijt}, \alpha_t, \delta_j, \varepsilon_{ijt}), \qquad (3)$$

i = source country, j= recipient country, t = 1988, 1989,…,2008

α_t, δ_j *are respectively the year and recipient country dummy variables.*

The dependent variable being of count nature, the relationship was estimated using a negative binomial model. The results validated the principal hypothesis that involvement in CDM affects technology transfer. CER was found to have a positive and statistically significant effect on technlogy transfer in wind power sector. All the other explanatory variables also had the expected signs and were statistically significant.

Technology transfer process is considered essentially a knowledge accumulation process. The effectivenes of technology transfer in terms of the ability of the recipient to use it to its own benefit depends on the technical capabilities of the host firm. In contrast to the above mentioned papers, (Doranove, Costa, & Duysters, 2011) study the impact of CDM projects on the technological capabilities of the host country firms involved in the CDM projects.

The analysis drew its data from a survey of CDM project host companies in the four major CDM host countries (Brazil, China, India and Mexico) covering 380 projects. The authors distinguished between three diferent technological capability levels which in total further involved ten types of technological capabilities:1) abilities to use and operate technologies; 2) abilities related to process improvement; 3) innovation or advanced capabilities. The respondents were asked to assess the impact of the experience with CDM projects on scale of 0 (zero impact) to 6 (very high impact) on each of the three categories of technological capabilities. They make three hypothesis on the impact of CDM project on the technical capabilities of the recipients.

Based on prior theoretical finding the authors expect that companies having prior experience with technologies used in CDM projects would benefit more in terms of their technology capability building. Hence the hypotheses:

H1(a) The recipient's prior level of knowledge about relevant technology positively influences technological learning outcomes of CDM projects.

H1(b) In the CDM projects technological learning is an inverted U-shaped function of a recipients organisation's prior knowledge level

But the relationship between technological learning and prior knowledge is not expected to be a linear one. A small difference in the knowledge bases of the supplying and recipient firms is unlikely to have great impact on the technological capability of the recipient firm. Thus, there is expected to be an optmal technological distance. The qualification of employees is expected to positively affect an organisation's absorptive capacity. Therefore, the authors hypothesise the following:

H2 A higher representation of human resources such as engineers and technical personnel in an organisation is positively associated with more dynamic technological learning in CDM projects.

Training of employees is also expected to improve the absorptive capacity of the employees.

H3 Training delivered by the technology provider contributes more to the building of basic technological capabilities and less to the advanced capabilities of the CDM project recipient organisations.

The analysis is based on a simple linear regression of technological capability as the dependent variable. For the purpose, the authors construct three different different dependent variables for each of the technological capability categories: *basicTC*, *intermediateTC* and *advancedTC.* Each of them were constructed by averaging over the responses on each of the categories of technological capabilities.

Following hypotheses *H1a and H1b,* the authors constructed two independent variables. The first one was, *relevant prior experience(previousTC),* measured by asking if the company had cetain technological capabilities before CDM experience and taking the average of responses for all ten categories (values would lie between 0 and 1. In order to take account of *H1b,* a squared term had to be included. But since previousTC and its squared variable showed a high correlation, square of the deviation from the mean was used ($previousTC^2$). Another indicator used to measure the prior experience was the *involvement in other CDM projects.* This was introduced into the model through a binary variable, *other_projects (=0 if the CDM project host company has implemented more than one project and 0 otherwise).*

Regarding the hypothesis *H2, Qualification* variable which is the share of trained staff having university degrees/engineering qualifications and tecchnical school education among the total pool of employees. In order to measure the impact of training, *training* variable calculated as the average of the binary variables associated with the following three categories: 1) training, 2) on job coaching and 3) other capacity building activities by the technology provider.

The authors used control variables related to host company characteristics as well as the coutry level characteristics. The resource richness of the company was proxied by the *size* of the company, measured by the number of employees. Larger firms may have advantages in accessing and also possessing, better and more diversified knowledge. However there is also a view that sometimes the size of a company may contribute to inertia and thus inhibit learning.

Age of the host company may have a positive or negative impact on technological learning. Older companies have greater experience and better prior knowledge and hence may have a positive effect on technological learning , but on the other hand, older companies may learn very little from CDM projects. Foreign equity participation is likely to increase the chances for host company to acquire more advanced knowledge and technologies. Hence, to measure this effect, a binary variable, ownership, indicating whether it is local (100 percent local ownership) or foreign (joint venture and 100 percent foreign) was used.

In addition to the host company related control variables, the authors used certain country related control variables . Country related characteristics were captured by introducing country dummies *India, China, Mexico and Brazil.* Respondents were asked to evaluate a number of policies relevant to CDM on a scale of 0 to 6. By taking the average score for all policies, a variable, *policy* was created to measure the quality of institutions as perceived by the respondents.

The results on prior level of knowledge shows a positive sign in all three types of technological capabilty. The magnitude of the effect is higher on *basicTC*, decreases for *intermediateTC* and the least for *advancedTC*. *advancedTC*^{2} has a statistically signficant and negative effect for *basicTC* and *intermediateTC*. *Other_projects* was not found to be statistically significant in any of the models. *Qualification* was found to have a positive and significant effect only in the case of *intermediateTC*. *Size* shows a negative and statistically significant effect on all three categories of technological capabilities.

The literature on technology transfer under CDM projects mainly has focused on studying the determinants of technology transfer. These papers involved cross country studies that emphasized on the cross country differences in economic attractiveness and technological capability in determining technology transfer. They are also quite similar in terms of their result. There has been no country level study on the determinants of technology transfer. More importantly, these studies have looked at only whether there has been a transfer of technology or not or whether there has been cooperation in the development of technology. Although it would involve some amount of subjectivity, no analysis has been done on the factors determining the quality of the technology transferred in terms of an ordering of the type of technology transfer taking place.

2.3.3 Impact on Sustainable Development of Host Nations

One of the stated objectives of the Clean Development Mechanism is sustainable development in the host countries[1]. First of all there is no clear definition of sustainable development that is unanimously accepted although various methods to assess the sustainable development benefits of CDM projects have been proposed (Sutter and Parreno (2007), Olsen and Fenhann (2008) etc.). Usually, sustainable development is broadly agreed to include aspects of economic, social and environmental well being. However, it is the prerogative of the host country to determine whether a project meets its sustainable development requirements.

[1] Article 12 (2) of the Kyoto Protocol to the United Nations Framework Convention on Climate Change

Since the host countries decide the requirements of sustainable development, and since most countries do not have market power to influence prices, there could be a tendency for the host countries to attract more CDM projects by lowering their sustainable development requirements and hence leading to a *race to the bottom* (Sutter & Parreno, 2007). Rindefjall, Lund and Stripple (2011) studying the case of CDM projects in Chile suggest that the race to the bottom phenomenon is a voluntary choice by the national authorities as attention is given mostly to the economic gains from CDM projects while sidelining the other sustainable development aspects. But Headon (2008-2009) finds that China, which is the world leader in CDM projects, has more stringent regulations than many other developing nations.

When talking about sustainable development, it becomes important to analyse the inclusive nature of any development policy. Examining the impact of CDM on rural poverty in India, Sirohi (2007) finds that the potential of CDM projects in supplementing agricultural incomes was very limited. The scope of increase in agricultural incomes is limited only to biomass energy projects and there was hardly any technology transfer taking place that could increase agricultural productivity. Subbarao and Lloyd (2011), based on their study of 500 PDDs and five case studies from Indian sub-continent, find that CDM has not been successful in helping in the development of rural areas to the extent they were expected to.

2.3.4 Regional and Sectoral Composition of CDM projects

The composition of CDM projects has shown a clear bias in terms of both the sectors of activity as well as the regional distribution. In terms of sectoral distribution, some sectors like afforestation have very few projects. Thomas, et al. (2010) analysed the reasons for the small number of CDM projects in afforestation. They find that delay in returns from these projects, constraints in access to funds, high transaction costs and lack of knowledge and technical capacity in developing countries as the major reasons for the lack of projects in spite of the social and environmental gains expected from these projects.

Regarding regional distribution of CDM projects, Winkelman and Moore (2011) empirically determine the country level determinants of CDM activity. They first estimated a probit regression model on full sample of 114 countries to assess the determinants of CDM activity hosting across eligible countries. For this their dependent variable was a binary variable which takes a value 0 if the country has not hosted any CDM project, takes a value 1 otherwise. Their analysis was based on the idea that the profits of a CDM project depend on carbon revenue from the sale of CERs, non-carbon revenue from the sale of co-products like electricity and the costs associated with establishment of the CDM project. The independent variables in the analysis were average growth in electricity generating capacity over the years 2003-2007 as a proxy for non-carbon revenues, greenhouse gas emissions as a measure of carbon revenue (larger emissions provide for the possibility of larger projects and thus produce greater emission reductions), the number of CDM capacity building efforts, educational Index of UN HDI, Institutional index (combining two corruption measures and political stability/ absence if violence indicator from World Bank's governance indicators), and FDI inflows.

They found that carbon intensity and education level of host economy are significant determinants of whether a country hosts CDM projects. Also, countries that offered growing markets for CDM co-products such as electricity were more likely to host CDM projects. Further, they estimate a truncated regression for 58 successful hosts with the dependent variable as the estimated number of CERs generated within a country. They found emissions and years since first CDM project to be significant and positive determinants.

Jung (2006) did a cluster analysis to classify CDM host countries according to three measures of CDM attractiveness namely, mitigation potential, institutional CDM capacity and general investment climate and found that CDM projects were expected to be concentrated in a few countries. Huang and Barker (2009) study the effect of geographic factors on average CER flows (over the period Dec 2003 to Sep 2008). First they estimated a simple OLS regression on a sample of 48 CDM host countries, taking geographical factors like latitude, elevation along with dummy variables for countries being exporters of manufacturing, non-fuel primary goods or services. Control variables included are per capita GDP in 2003, population in 2003, ethnic fractionalization index, religious fractionalization index and dummies for legal system. Higher latitudes and higher elevation were found to have positive and significant impact on CER flows. Being a service exporting country was also found to have a positive impact on CER flows. Further, the authors use a spatial autoregressive model with autoregressive disturbances of the order (1,1), i.e. , SARAR(1,1) model,

$$Y_n = X_n\beta + \lambda W_n Y_n + u_n , |\lambda|<1 \quad (4)$$

$$u_n = \rho M_n u_n + \varepsilon_n, |\rho|<1$$ where,

W_n and M_n are spatial weighting matrices. The GS2SLS estimate of λ shows that the CDM credit flows in a country increases by 0.34 units if those in its neighbourhood increases by one unit. They also find that in their spatial econometric model, the countries that had higher absolute latitudes and higher elevation had higher average CERs. All the control variables were also found to be significant. Studying permit trading between Annex-I and non-Annex-I host countries using a gravity model, Wang & Firestone (2009) find that emissions of CO_2 to be a significant determinant for bilateral emissions trading. Looking at permit trading between Annex-I and non-Annex-I host countries using a gravity model, Wang & Firestone (2009) find that emissions of CO_2 to be a significant determinant for bilateral emissions trading.

$$CDM_{ij} = E_{i\,.}\,Ej/D_{ij} \quad (5)$$

$$Ln\ CDM_{ij} = \alpha_0+\beta+\alpha_1 lnE_i+\alpha_2 lnE_j+\alpha_3 lnD_{ij}+\alpha_4 lnO_{ij} +\alpha T_i \quad (5.1)$$

Where, i represents the credit buying country and j the host country. β stands for the fixed effects of project type; E_i represents emissions in country i, O_{ij} represents trade openness, D_{ij} represents the distance between the two trading partners, T_i represents all other co-variants that may influence country to country CDM trade. They find that green house gas emissions in the two countries and openness to trade are significantly and positively related to CDM credit trading.

The regional policies of various territories are a significant determinant of the location of any business activity. Benecke (2008) studied the wind energy sectors in Kerala and Tamil Nadu and found that the large disparity in the number of wind energy projects in the two states was due to mainly the differences in policy conditions, the design of policy and the stability in the policy which are very important for private investment.

2.4 Conclusion

The literature that has been reviewed here has its focus on a wide range of issues ranging from issues of additionality, transaction costs, achievement of sustainable development objectives of

CDM projects to the regional and sectoral bias in the distribution of these projects at the international level. Regarding the empirical studies of regional bias in the distribution of CDM projects, considerable attention has been given to the concentration of these projects in relatively advanced developing countries like India and China, all the econometric studies being undertaken at the international level (e.g. Winkelman & Moore (2011)). No attempt has been made to study the intra-country distribution of CDM projects for any country. Moreover, these studies involve the assessment of factors affecting location for projects from all sectors. This leads to ignoring the factors that are particularly relevant for certain sectors and not for others. Also there are a lot of variations in the policies and regulatory incentives at the state level giving rise to marked differences in the abilities of different states to attract investment in CDM projects. These differences can never be accounted for in cross country studies.

It has been observed that the level of technology transfer has been very less in India in comparison to many other CDM host nations like China. To understand the factors impacting the technology transfer with specific reference to India, the cross country studies would not shed ample light on them. It becomes important to do a country specific study to gain a better understanding of such factors. This also provides us with the opportunity to analyse the state level factors affecting technology transfer within the country that would otherwise not be captured through cross-country analyses.

The chapters 3 and 4 are an attempt to fill this gap in literature through an analysis of the factors at the state level within India. In chapter 3 we analyse the factors influencing the regional distribution of renewable energy CDM projects in India between the different states. The analysis is based on data on 17 Indian states over the period 2000 to 2010 (covering registered renewable energy CDM projects that entered the CDM pipeline between 2004 and 2010). Similarly in chapter 4 we look at factors affecting technology transfer under registered Indian CDM projects. We include the various state level variables that can affect the technology transfer and thus provides us with greater insights than previous studies which look at only national level factors.

CHAPTER 3

ANALYSIS OF REGIONAL BIAS IN CDM RENEWABLE ENERGY PROJECTS IN INDIA

3.1 Introduction

One of the stated objectives of the Clean Development Mechanism under the Kyoto Protocol was to help in the sustainable development of developing countries[1]. This was to be achieved by the investment and technology flows expected from the developed countries to the developing countries and the setting up of emission reducing and climate friendly projects. In order to assess the success of such a mechanism it would be of prime importance to see that the projects under the scheme are being set up evenly in the different parts of the developing world. Even within the developing countries, there exists a lot of variation in terms of their levels of economic development and standard of living. One would expect that the gains from increased investment and particularly green investment would be maximized if these are taking place in the most backward regions. But, it has been observed that there has been a clear regional bias in the distribution of the CDM projects in favour of the relatively more advanced developing countries like India and China.

Looking at the cross country distribution of registered CDM projects we find that out of the total 3337 registered CDM projects, 1510 projects are in China while 705 are in India. These account for respectively 69% and 19% of the CERs expected to be generated till 2012. Mexico and Brazil follow in the list with 129 and 194 registered CDM projects. On the other hand when we look at the African countries, we find that the whole of Africa accounts for only 66 registered CDM projects[2].

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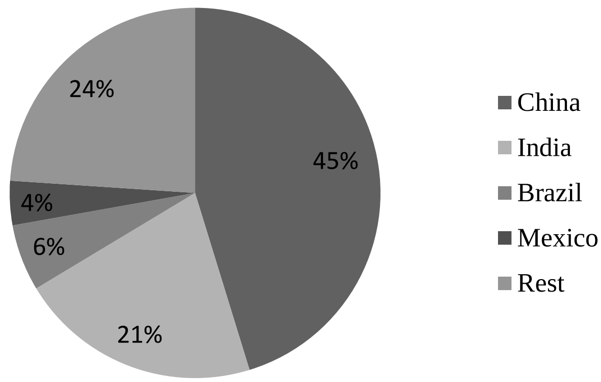
[1] As stated in the Kyoto Protocol, the major objectives of the Clean Development Mechanism are to help non-Annex-I countries "... in achieving sustainable development" and "… to assist Parties included in Annex-I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3" (Article 12(2) of Kyoto Protocol)

[2] UNEP Riso CDM Pipeline Database, August 2011.

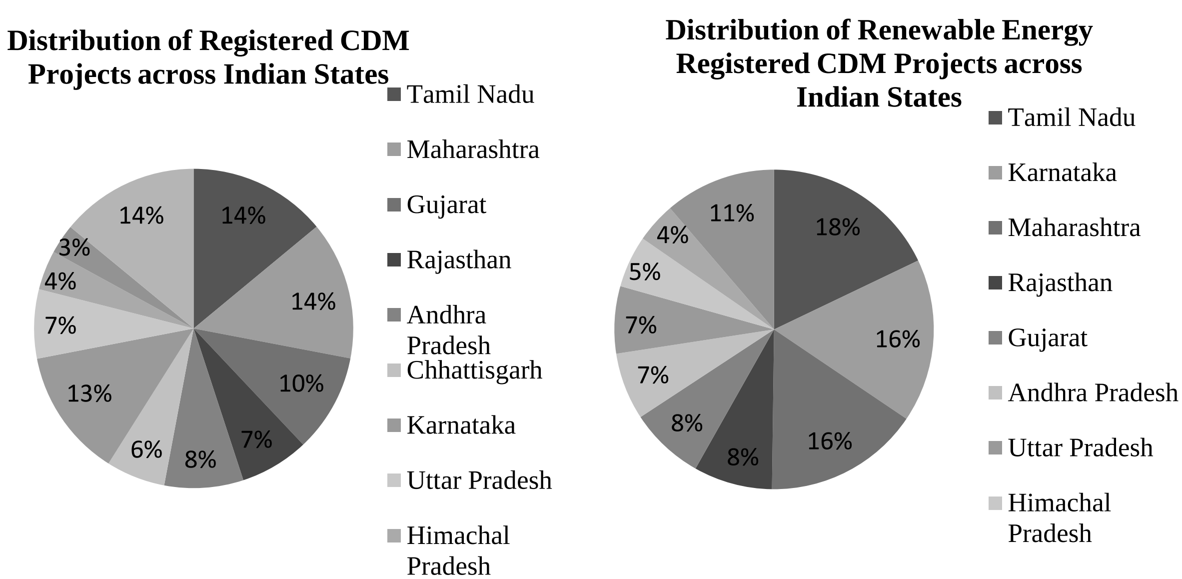
Fig 3.1: Distribution of Registered CDM Projects Across



Data source: UNEP Risoe CDM Pipeline, August,2011

The distribution of CDM projects across different host countries tells us that the distribution of these projects has been highly biased. But the countries where there is a concentration of these projects wide differences exist between the various regions in terms of their economic characteristics and policies. The following figure shows the distribution of the registered CDM projects across different states in India.

Fig 3.2: Regional Distribution of renewable energy CDM projects in India



Data source: UNEP Risoe CDM Pipeline AUG, 2011

A look at the distribution of registered CDM projects in India would tell us that these projects are mainly concentrated in a few states with the states of Tamil Nadu, Maharashtra and Gujarat accounting for 14%, 14% and 10% respectively of the total number. The right hand side panel of the above figure shows the distribution of registered Indian CDM projects in the renewable energy sector (biomass energy, wind, solar and small hydro projects). Again we find a concentration of projects in Tamil Nadu, Karnataka and Maharashtra.

Looking at such a distribution of renewable energy CDM projects the question that arises in one's mind is: what is the reason for the observed bias in the regional distribution of these projects. In order to answer this question, the first step would be to understand the distribution of the renewable energy potentials across the country. The major part of the renewable energy CDM projects in India is in the Wind energy sector. The following table shows the distribution of installed capacity under CDM wind energy projects and the potentials for these states.

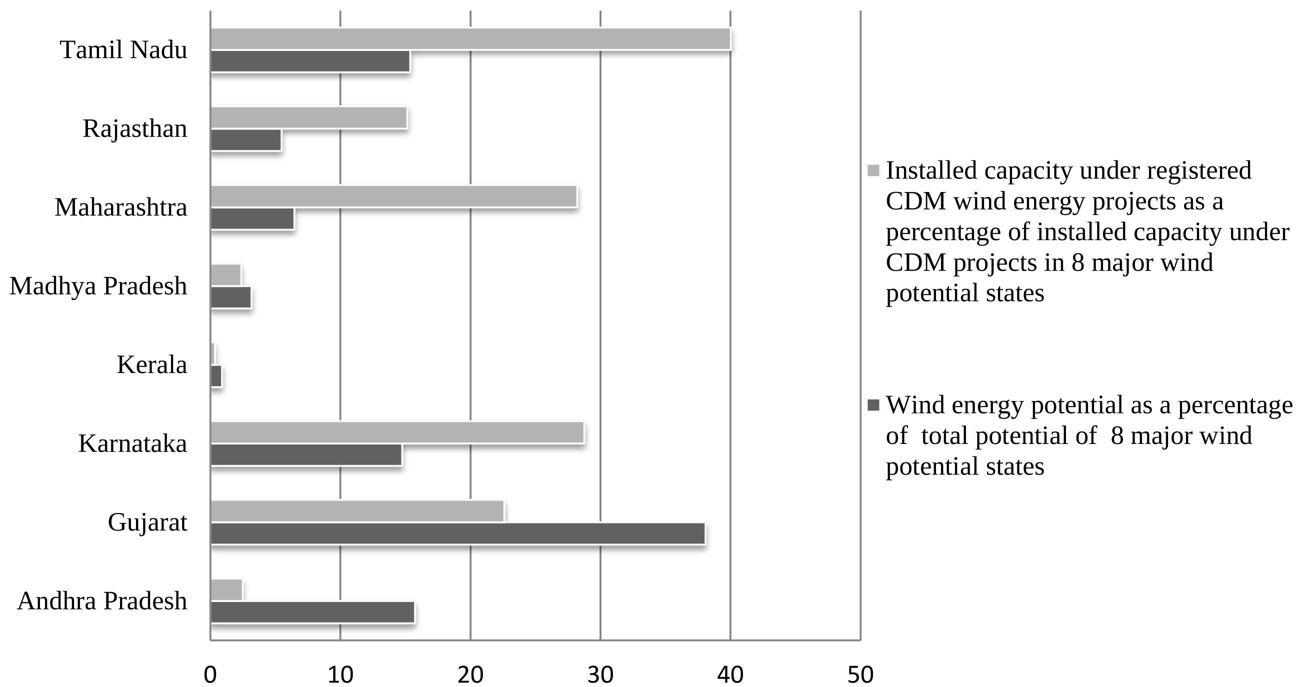
Table 3. 1: Wind energy potentials and installed capacity under registered CDM projects

States	**Wind Energy Potential(MW at 80m height)[3]**	**MW in Registered Wind Energy CDM projects[4]**
1. Andhra Pradesh	14497	68.4
2. Gujarat	35071	619.6
3. Karnataka	13593	787.92
4. Kerala	837	9.75
5. Madhya Pradesh	2931	65.05
6. Maharashtra	5961	772.85
7. Rajasthan	5050	415.92
8. Tamil Nadu	14152	1096.46

3 Source: CWET

4 Source: CDM project PDDs for registered CDM projects that entered pipeline between 2004 and 2010 and starting before 2011

Fig 3. 3: Wind Energy Potentials and Installed Capacity Under Registered CDM Projects as percentages of totals of each respectively



It can be seen from the table and the figure given above that the state natural resource potentials do not completely explain the regional distribution of these projects. Consider the state of Maharashtra. It accounts for only about 6.4 percent of the wind energy potential but has around 23 percent of the installed capacity under the registered CDM wind energy projects in the country. Similarly, Tamil Nadu, which has around 15 percent of the potential accounts for 20 percent of the installed capacity under registered CDM projects. On the other hand, the state of Andhra Pradesh which has around 15 percent of potential has only 2 percent of the installed capacity under registered CDM projects (a stark contrast in comparison with 20 percent of the installed capacity in Karnataka which has around 14 percent of the potential). These wide in the installed capacities, not accounted for by the natural resource potentials of the states, motivates us to search for the reasons behind the observed regional bias.

***3.2 Determinants of CDM project location**:*

To understand this we look at the CDM projects from perspective of conventional economics as profit maximizing firms. Given this premise, it becomes easier to identify the reasons behind the location of a CDM project in a particular region by identifying the state level factors that affect the profitability of these projects. Following Winkelman & Moore (2011) we can identify the determinants of the location of CDM projects by dividing the projects into two types: one whose only source of revenue is through emission reductions and the other type which in addition to emission reductions has a co-product which can be sold at a price in the market. Renewable energy CDM projects fall under the second category. Given this understanding we are in a position to further elaborate on the possible determinants of location of these projects. For a renewable energy CDM project the major factor affecting the profitability is the availability of the respective natural resource. Once the necessary condition of the availability of natural resource endowment is satisfied, other factors become important. The renewable energy policies, political pressure from industrial lobbies, issuance of preferential tariffs for renewable energy sector and the openness to private and foreign investment are all major forces shaping the environment for investment in these projects. (Benecke, 2008). The major factor that affects the location of any project is the state policies and is the major focus of this study. Other factors affecting the profitability of a project are the market conditions in each state. These include the power supply situation in each state, the availability of alternative sources of clean energy (Benecke, 2008). Since about two-thirds of the wind energy generation in India is used for captive consumption in energy intensive industries like textiles and steel (Benecke, 2008), the growth of the industrial sector in the states is an important determinant of development of renewable energy projects. Also, the use of relatively advanced and newer technologies necessitates the ability to understand, use and adapt such technologies ((Doranova, Costa, & Duysters, 2010) (Haites, Duan, & Seres, 2006) (Hascic & Johnstone, 2011)). Thus, the technological absorptive capacity is likely to be an important determinant.

We arrange the paper as follows. In the following section, we discuss the renewable energy policies in India. In section 3.4, we elaborate on the electricity regulatory framework existing in India. Section 3.5 specifies the data sources for the analysis. Section 3.6 provides the econometric analysis and section 3.7 provides a discussion of the results. Finally, in section 3.8, we conclude the paper.

3.3 Renewable Energy Policies in India:

The beginning of governmental efforts at finding and developing new and alternative sources of energy in India may be traced to the establishment of Commission for Additional Sources of Energy in 1981. The Commission was given the responsibility of formulating policies and programmes for the development of new and renewable energy in the country. The Department of Non-Conventional Energy Sources was created in 1982. In 1992, the Department of Non-Conventional Energy Sources was converted to the Ministry of Non-Conventional Energy Sources (later renamed as the Ministry of New and Renewable Energy (MNRE) in 2006). Efforts were made in the mid- 90s to encourage the development of renewable energy by MNRE. But the real change in the legal and regulatory framework for the renewable energy sources came with the enactment of the Electricity Act 2003. The promotion of renewable sources of energy has been made the responsibility of the State Electricity Regulatory Commissions which have to take these considerations into account while making their regulatory decisions.[5] The Act also makes the State Electricity Regulatory Commissions 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."*[6]In compliance of the policies mentioned in the Electricity Act, the Central Government also came out with the National Electricity Policy and the National Tariff Policy in 2005 which re-emphasised the role of SERCs in the promotion of renewable sources of energy. In October 2006, the Indian Planning Commission came out with "*Integrated Energy Policy: Report of Expert Committee*". The broad vision of the Integrated Energy policy is to meet the energy needs of the country using safe, clean and convenient energy at the least cost. In 2008, the Prime Minister's Council on Climate Change approved the National Action Plan on Climate change. The NAPCC stipulates 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. Recent policy initiatives from the Central Government include a Generations Based Incentives (GBI) scheme in 2009 for grid connected wind energy projects. Under this a GBI of Rs. 0.50 per KWh over and above the tariff provided

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[5] Section 61 (h) of the Electricity Act 2003, Government of India

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

by the respective SERCs over 10 years of the lifetime ofthe project is being offered to wind energy projects not using accelerated depreciation benefits and commissioned before 31st March 2012 (GWEC, WISE and IWTMA, 2011). Tradable Renewable Energy Certificates have been introduced by the Central Electricity Regulatory Commission in 2010. This scheme allows the utilities with renewable purchase obligations to buy these certificates and allows renewable energy generators to trade RECs through a power exchange.

3.4 Regulatory framework in India's Electricity Sector:

The electricity sector comes under the concurrent list in India's constitution. That is, the provision of electricity and development of the sector is a shared responsibility of both the Central and the State governments[7]. Thus, the planning and regulation of electricity sector in India involves a host of entities at both the centre and state levels (fig 3.3 gives a simplified view of the regulatory framework). The Central Electricity Authority was constituted under the erstwhile *Electricity (Supply) Act, 1948* (replaced by the Electricity Act, 2003)[8]. The functions of the Central Electricity Authority includes advising the Central Government on electricity policy issues, formulation of plans, specification of technical standards for the construction of power plants, skill training, etc.[9]

The *Electricity Regulatory Commissions Act, 1998* established the independent regulator at the Central level in the form of Central Electricity Authority and also required all the state governments to set up independent state level regulators for the electricity sector.

3.4.1 *Central Electricity Regulatory Commission:*

The Central Electricity Regulatory commission was established under the Electricity Regulatory Commissions Act, 1998. The functions of the Commission have been elaborated in the Electricity Act, 2003:[10]

- To regulate the tariffs of the generating companies under the control of the Central Government,
- To regulate inter-state transmission of electricity,

[7] Part-III, Seventh Schedule of the Indian Constitution
[8] Section 70 of the Electricity Act, Government of India, 2003
[9] Section 73 of the Electricity Act, Government of India, 2003
[10] Section 79 of the Electricity Act, Government of India, 2003

- To issue licenses to entities to function as transmission licensees and traders with respect to inter-state transmission of electricity,
- To adjudicate upon disputes arising between generating companies or transmission licensees,
- To specify grid code with respect to establishing grid standards, etc.

3.4.2 State Electricity Regulatory Commissions:

Under the Electricity Regulatory Commissions Act, 1998[11] (now repealed and replaced with the Electricity Act, 2003), all the states were required to establish electricity regulatory commissions in the states. The chairperson and members of the Commission are to be appointed at the recommendation of a selection committee. State Electricity Regulatory Commissions are independent, quasi-judicial bodies with the powers of a civil court. Some important functions of the State Electricity Regulatory Commissions are as follows[12]:

- To determine the tariffs for generation, supply, transmission and wheeling[13] of electricity within the state;
- To regulate the energy purchase and procurement process of distribution licensees, including the prices for procurement;
- Facilitate inter-state transmission and wheeling of electricity;
- Issue licenses to entities to act as transmission licensees, distribution licensees and electricity traders for functioning within the state;
- Promote co-generation and generation of electricity from renewable sources within the state;
- Adjudicate upon disputes among between licensees and generating companies;
- Specify the State Grid Code;
- Specify or enforce standards with respect to quality, continuity and reliability of service by licensees.

[11] Section 17 of the Electricity Regulatory Commissions Act, 1998, Government of India
[12] Section 86 (1) of the Electricity Act, 2003, Government of India
[13] 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 (REEEP, 2009).

As mentioned in the Electricity Act, the two main tools through which the SERCs were expected to incentivize the production of renewable energy were the *preferential feed-in tariff* and *renewable purchase obligations. Preferential feed-in tariff* is the price at which the distribution licensees are required to procure renewable energy. All tariffs are fixed on the basis of the estimates of costs of operation, maintenance, debt repayment etc. Renewable Purchase Obligations are fixed percentage of total electricity consumption that has to be procured by the distribution licensees in the form of renewable energy. These two together are the basic instruments that SERCs use to promote renewable energy development in the states.

Table 3.2: Policy instruments at the state level in India for renewable energy

Policy Instrument	***Description***
Feed-in tariffs	minimum price at which renewable energy based power must be purchased from the generators by the distribution licensees
Renewable Purchase Obligations (RPOs)	minimum percentage of total electricity handled by a distribution licensee that has to be in the form of renewable energy
Policy and fiscal incentives	these include various incentives like tax holidays for renewable energy production; provision of banking wheeling and third party sales; other financial incentives, subsidies etc.

3.5 Data:

The basic information on the location of all the CDM projects that have entered the CDM Pipeline in terms of the country and states/provinces is available in the UNEP Risø CDM Pipeline. This information has been extracted from the Project Design Documents of each of the CDM projects.

Under section A.4.1 of the Project Design Documents, information on the location of the project activity is required to be given by the project developers. Under section A.4.1.4, details of physical location including information enabling the unique identification of the project activity is to be given. But the information on exact location is not often provided in the PDDs for all the projects. The PDDs also provided the information on the installed capacity of renewable energy under the registered Indian CDM projects at each project site. Data on the natural resource potentials were obtained from two sources. Since almost all of the installed capacities under renewable energy CDM is in wind and biomass, we have taken the electricity potentials under these as a measure of the natural resource potential. The wind energy potential at 80m height was obtained from the CWET, Government of India[14]. The information on the state natural potential in biomass (agro) was obtained from the Biomass Resource Atlas of India V2.0 (a project of Ministry of New and Renewable Energy, executed by Indian Institute of Science, Bangalore)[15]. To obtain information on regulations of the State Electricity Regulatory Commissions, the regulatory orders related to renewable energy from 17 State Electricity Regulatory Commissions were obtained from the websites of respective regulatory commissions. The data on the net state domestic product and manufacturing sector's share in the state domestic product was taken from the Handbook of Statistics on the Indian Economy, published by the RBI. The data on FDI inflows was taken from the SIA newsletters of the Department of Industrial Policy and Promotion. For years 2000 to 2004, these newsletters provide information on the aggregate FDI inflow approvals by state for years starting from 1991 till the concerned year. In 2004 the reporting pattern has been changed and the information on actual inflows is given according to the RBI Regional offices. For our analysis we take each state's percentage contribution in the total approvals each year for the years 2000 to 2004. For the subsequent years we have considered the percentage contribution of each state as the percentage contribution of the regional office of RBI under which it comes.

Data on installed capacities was obtained from the Central Electricity Authority Annual Reports for the years 2004 onwards. For the years 2001 to 2003, the figures were obtained from the Ministry of Power Annual Reports. For these years the installed capacity only under wind energy is provided under the renewable energy category in these reports. Data for the renewable energy installations for the year 2000-01 were taken from the Annual Report on the Working of State Electricity Boards and Electricity Departments 2001, by the Power and Energy Division,

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

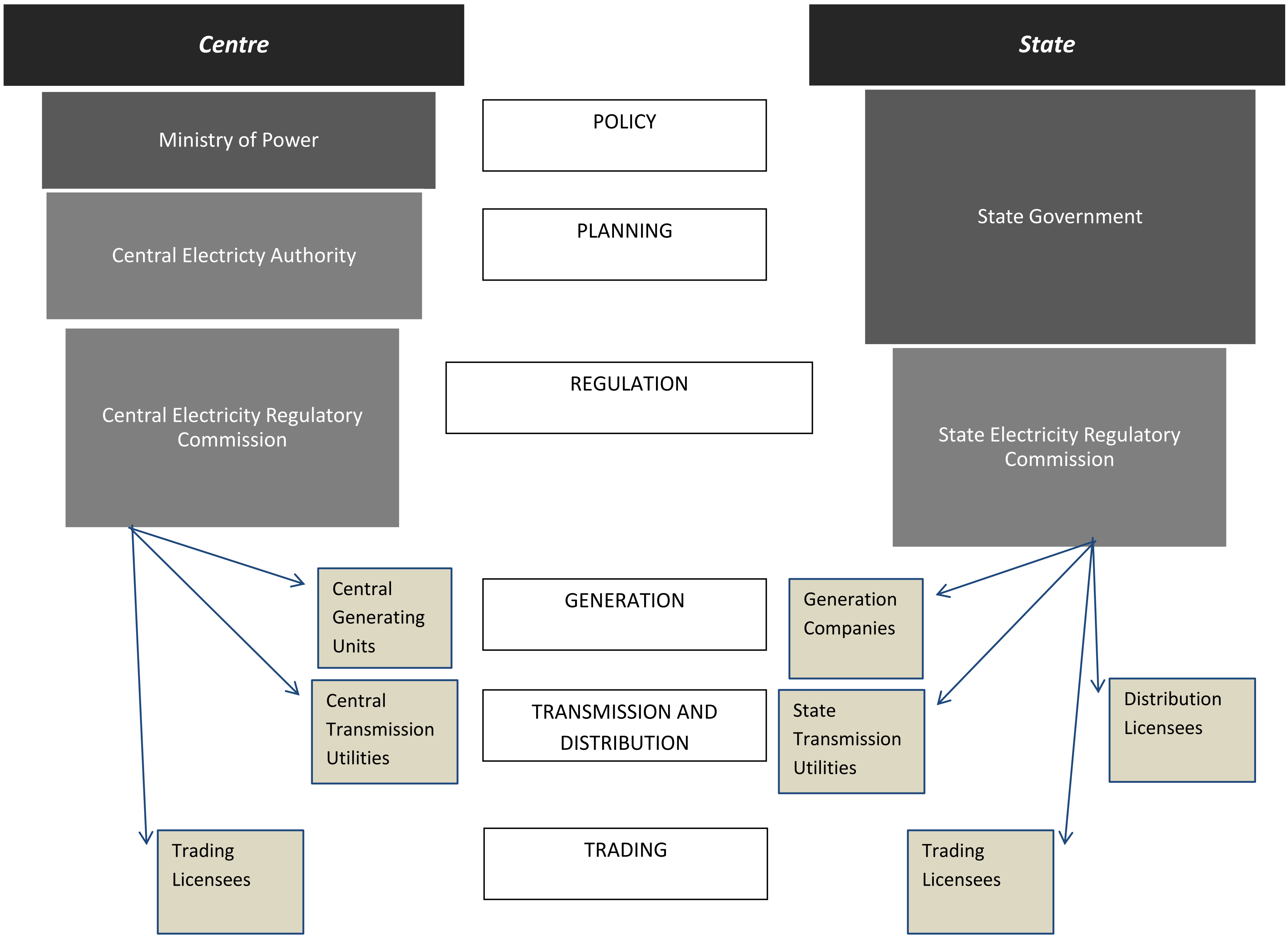
[15] Relevant tables extracted from: http://lab.cgpl.iisc.ernet.in/atlas/Tables/Tables.aspx

Planning Commission, Government of India. The data for the newly formed states (Jharkhand, Chhattisgarh and Uttaranchal/Uttarakhand formed in 2000) was not available for the years 2000 and 2001. Hence, the renewable energy shares in total installed capacity for these states have been taken to be the same as their parent states (i.e Uttar Pradesh for Uttarakhand, Bihar for Jharkhand and Madhya Pradesh for Chhattisgarh .

3.6 Econometric Analysis:

The econometric analysis covers the registered renewable energy CDM projects that entered the pipeline between years 2004 and 2010. These projects have their starting dates between 2000 and 2010. The panel covers data for 17 states across these 11 years. The dependent variable is the addition in installed capacity under registered renewable energy (wind, biomass and solar) CDM projects. To measure the impact of the state regulatory commissions' policies for wind, biomass or solar energy sectors we have used three dummy variables. The first is the dummy variable for the presence of preferential feed-in tariffs which takes a value 1 if the state electricity regulatory commission has specified a preferential feed-in tariff for the procurement of electricity from either wind, biomass or solar energy in that particular state in that particular year. Similarly the other two dummy variables are for the presence of RPO and the presence of any specification on the sharing of CDM benefit between project developers and distribution licensees. These are expected to have a positive effect on the installed capacities. The natural resource potential of each state is measured as a sum of the potential electricity production in wind and biomass energy. One would expect that higher the natural resource potential the higher would be the installed capacities. The share of the state in FDI inflows is taken as a measure of the attractiveness of the state for investment. It is also expected to have a positive impact on the dependent variable. We have used the share of manufacturing in net state domestic product as a measure of the technological absorptive capacity of the state In addition, we also use the share of renewable energy in the total installed capacity in each state as a measure of the state's experience with and previous knowledge in setting up renewable energy based projects. The per capita net state domestic product is used as a control variable.

Fig 3.4: Institutional framework in the Electricity sector in India



The analysis involves panel regression to examine the factors affecting the dependent variable. The basic framework of panel data is of the form

$$y_{it} = X_{it}b - \varepsilon_{it} \tag{3.1}$$

Where i = 1… n is the number of cross-section units, and

t = 1… T is the number of time periods.

y = dependent variable

X = matrix of explanatory variables

b = vector of coefficients

ε = disturbance term

The disturbance term has the following structure:

$$\varepsilon_{it} = \alpha_i + \eta_{it} \tag{3.2}$$

Where we have assumed that η_{it} is uncorrelated with $\boldsymbol{X_{it}}$ .The first term of the decomposition, α_i, is called an individual effect. Regarding the individual effect, the following assumptions can be made:

1. *Random effects model:* α_i is uncorrelated with X_{it} .
2. *Fixed effects model:* α_i is correlated with X_{it}..

To determine which is a better model under the current conditions, we use have used Hausman test. From this test we are not able to reject the null hypothesis that the difference in the coefficients is not systematic. Thus we use the results under the random effects regression. Table 3.3 presents the results under the random effects regression. Columns 1 and 3 include natural resource potential as one of the explanatory variables among others.

Table 3. 3: Regression results

DEPENDENT VARIABLE: ***ADDITION TO INSTALLED RENEWABLE ENERGY CAPACITY UNDER REGISTERED CDM***	**1**	**2**	**3**	**4**
Feed-in -tariffs dummy	23.54378**	23.64691***	20.52018**	36.69116***
RPO dummy	-22.26777**	-22.52383**	-19.78206*	-13.58393
CDM benefit dummy	8.434491	8.902719	6.309997	13.35517
Natural resource potential	0.0000415*		0.000616	
FDI inflow share	1.526364***	1.531855***	1.704419***	1.28053*
log(per capita net SDP)	-18.43534*	-18.5257*	-8.943883	-10.04949
share of manufacturing in NSDP	204.5544**	208.1009**		254.7618**
Share of renewable energy in total installed capacity	3.118698***	3.131387***	3.015595***	
Constant	162.0198*	162.6658*	89.46589	79.07151
R^2 *within*	0.1089	0.1089	0.0967	0.0544
Between	0.8954	0.8957	0.8696	0.7046
Overall	0.3458	0.3457	0.3287	0.2434
Number of observations	187	187	187	187

***,** and * indicate significance at 1%, 5% and 10% levels respectively.

Models 1, 2 and 4 include share of manufacturing as an explanatory variable. Share of renewable energy in total installed capacity is used in the first three specifications. The presence of feed-in tariffs is found to have a positive and significant effect on the installed capacity under registered renewable energy CDM projects. The presence of a guideline on the sharing of CDM benefits has a positive but insignificant impact on the dependent variable. But contrary to expectations the presence of renewable purchase obligations has a negative effect. FDI inflows are seen to have a positive and significant effect on the dependent variable in all the specifications. Log of SDP is found to have a negative and significant effect in the first two specifications. The manufacturing share is found to be significant and has a positive effect in all the specifications in which it has been included as an explanatory variable. The share of renewable energy in total installed capacity in each state is found to be highly significant and has a positive effect.

3.7 Discussion of Results:

The Clean Development Mechanism was initiated with one of its objectives being that of encouraging sustainable development in the non-Annex-I countries. Thus the success of the mechanism in achieving this objective could be gauged by its distribution among the various regions in the developing world. If state level policies have a major impact on the location of these projects then it has major policy implications.

- The positive and highly significant effect of the feed-in tariffs on the installed capacities under registered renewable energy CDM projects is indicative of the fact that state level regulatory incentives are important in terms of encouraging investment in such projects. Reading this along with the effect of RPO obtained in the econometric analysis tells us that price based incentives are effective means of encouraging renewable energy rather than command and control schemes.
- The positive and significant effect on the FDI inflows again shows us the importance of the local business climate on the location of renewable energy CDM projects. These projects being implemented by private profit maximizing entities would be located in areas where the profits are relatively high. Thus, we find that state level policies and general investment climate in a state are major factors affecting the location of renewable energy CDM projects.
- Also, the positive impact of the manufacturing base, which we use as measure of technological capability of the state, on the dependent variable is suggestive of the importance of the local knowledge base in encouraging investment in these projects. This may also be indicative of the local demand for the electricity from the local industries.

- Similarly, the positive impact of the share of renewable energy in total installed capacity in the state is also indicative of the importance of local experience in the setting up of renewable energy projects in encouraging further investment in renewable energy.

3.8 Conclusion:

Our study involves an econometric analysis into the determinants of location of registered renewable energy CDM projects in India across 17 states over the period 2000 to 2010 (covering projects entering CDM pipeline between 2004 and 2010). We find that the state level incentives are major determinants of the renewable energy CDM project location. In particular, the feed-in tariffs were found to be significant determinants of the location of CDM projects. Although the natural resource potential for renewable energy was found to have a positive effect on location, the effect was found to be statistically insignificant. In addition the FDI inflows were found to have a positive effect which together with the positive effect of feed-in tariffs shows us that a good business environment and encouragement through regulatory incentives are powerful influences on the location of these projects. Moreover we also find that a larger manufacturing base is also important suggesting that states with higher local knowledge in industrial activities are better able to attract renewable energy investments through CDM.

Thus we may conclude that a good business environment and incentives provided at the state level are important factors that can influence the location of renewable energy CDM projects and even override the impact of natural resource potentials. We can therefore say that CDM projects like any other business activity are guided by profits and would be located in areas where these are maximized. The way forward for states wishing to attract such investments is to incentivize investment in renewable energy through price based incentives and by ensuring attractive business environment.

CHAPTER 4

INTERNATIONAL TECHNOLOGY TRANSFER THROUGH CDM PROJECTS IN INDIA

4.1 Introduction:

In *chapter 3*, we discussed the regional distribution of renewable energy CDM projects and analysed the factors determining the location of these projects. While the establishment of a potentially beneficial project is a necessary condition for any region to gain from it, only the way in which it functions can guarantee that the gains are actually reaped. In the context of CDM projects, it then becomes crucial to analyse how the projects have fared in terms of achieving their objectives and what determines the success in achieving those objectives.

There are two strategies for the reduction of greenhouse gas emissions (Popp, 2011). The first is through the reduction of the carbon intensity of energy use (amount of carbon emitted per unit of energy consumed). The second is through the reduction of the energy intensity (energy used per unit of GDP). Both these strategies require the development and use of new technology (Popp, 2011). Most of the innovations in the climate friendly technologies take place in the developed countries and deployment of such technology in developing countries would require the transfer of such technology.

Although there is no universally accepted definition of technology transfer, in the context of climate change, IPCC defines technology transfer as "*a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions.*" (IPCC, 2000). The Clean Development Mechanism under the Kyoto Protocol provides the developed countries with the incentives to transfer clean technology to the developing countries and the developing countries to adopt such technologies. Since developed country entities are awarded Certified Emission Reductions for emission reductions undertaken in developing countries through CDM projects which can be used to meet a part of their emission reduction commitments under the

Kyoto Protocol, investment and technology flows are expected to take place from the developed to developing countries through CDM as it is usually assumed that the cost of reducing emissions by an additional unit is lower in the developing countries than in the developed countries.

The objective of the present study is to determine the factors affecting technology transfer using an econometric model. The study is different from those done previously in two ways. First, while all the previous studies concentrated on the technology transfer in the CDM projects across different host nations, our study is done on the technology transfers under the registered CDM projects within India. This is important as it helps us to understand the technology transfer under these projects shifting our attention away from national level policies and cross country differences and focus on other determinants of technology transfer. Also, for a country like India, with a large amount of variation within the country among the states, it becomes important to have a country level study on the issue. Secondly, our analysis divides the question of technology transfer into two parts. One, to understand the various factors that affect technology transfer and second to study the determinants of the quality of technology transfer. While earlier studies have focused mainly on the question of whether there has been a transfer of technology, we extend the analysis by ordering the outcome in terms of the quality of technology transferred.

4.2 Data Sources:

The Project Design Documents associated with each Clean Development Mechanism project is the primary source of information on the CDM projects. Every Clean Development Mechanism project is required to submit a Project Design Document which provides information about the CDM project. Specifically, the PDDs are expected to[1]

•Describe the project and establish a project boundary;

•Describe the baseline methodology;

•Establish the duration and crediting period of the project;

•Describe how the project is additional;

[1] CDM Rulebook website: http://cdmrulebook.org/405

•Describe the environmental impacts of the project;

•Provide information on the sources of public funding for the project;

•Summarise stakeholder comments;

•Describe the monitoring plan; and

•Set out all relevant calculations.

The UNEP Risø Centre has constructed a database on all the CDM projects that have entered the pipeline based on the information provided in the PDDs available on the UNFCCC website. The UNEP Risø CDM Pipeline contains a listing of all CDM projects that have been sent for validation. Information on the expected CERs from the projects, the details of credit buyers, the state where the project is located, date of the start of commenting period, and the type of the project etc. were obtained from the CDM pipeline. Number of similar projects for a particular type of project for a particular year was obtained by taking the total number of projects of that type with starting dates on or before that particular year. Starting dates for the projects were obtained from the PDDs. Although the CDM pipeline contains information on various aspects of CDM projects, they do not provide information on whether technology transfer is taking place through these projects. The information on technology transfer for the present study was collected from the Project Design Documents (PDDs) of the 705 registered CDM projects in India from the UNFCCC's website for CDM[2]. PDDs are documents required to be submitted by project proponents in a predetermined proforma. Under the section A.4.3 of PDD, the project developers are required to give a description of the technology used in the CDM project. Information on whether there is international transfer of technology and if so what is the nature of the technology transferred was collected from the PDDs. Many of the PDDs specifically mention whether there is a transfer of technology. Some do not mention anything at all. No mention of any transfer is taken to mean that the project does not involve any transfer. But such an assumption may underestimate the transfer of technology. (UNFCCC, 2010) finds that about 60% of the projects for which technology transfer could not be determined from the information given in the PDDs, actually involved technology transfer.

[2]cdm.unfccc.int

According to the information provided in the PDDs the projects have been found to mainly come under the following seven descriptions given in *Table 4.1*. Most common form of technology transfer in these projects is the import of equipment (around 27 projects)[3]. 22 of the projects claim to have achieved technology transfer by using equipment based on foreign technology but produced locally. 19 of these projects are in the wind sector and use wind energy generation equipments produced by Enercon.[4] Two projects involve a contract with a firm that markets a technology developed by a Norwegian firm.[5] 13 projects mention development of process with a foreign entity, implementation with technical assistance of a foreign entity or transfer of know-how/know-how as well as equipments or components[6]. Many of the PDDs clearly mention that the technology was locally available and there was no technology transfer involved in the project. Majority of wind energy projects depend on locally available technology, usually provided by Suzlon, an Indian company which is the 5th largest wind turbine manufacturing group in the World[7].

Very few biomass projects also mention any foreign source for the technology used in the project activity. CDM projects in the sectors methane avoidance, energy efficiency (Households) and transport have the maximum percentage of transfer of know-how as a percentage of projects involving technology transfer. Data on state level variables were obtained from various government of India sources. Data on the manufacturing sector and NSDP in each state is obtained from the Handbook of Statistics on the Indian Economy published yearly by the Reserve Bank of India. Share of the states in yearly FDI approvals/inflows is taken as a measure of the business and investment environment in each state. The data on this was collected from the SIA newsletters of the Department of Industrial Policy and Promotion, Government of India.

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[3] For example, PDD of CDM ref no. 3434, page 6: *"The technology is procured from China through purchase of turbine generators from M/s Zhejiang Machinery & Equipment I/E Co. Ltd."*

[4] All of them present an identical description:
"Enercon (India) Ltd has secured and facilitated the technology transfer for wind based renewable energy generation from Enercon GmbH, has established a manufacturing plant at Daman in India, where along with other components the "Synchronous Generators" using "Vacuum Impregnation" technology are manufactured."

[5] PDD of CDM project ref no. 2943 page 6: *"…contracted with Johnson Matthey plc who exclusively markets a secondary catalyst technology that has been developed by YARA International ASA (Norway). Deepak has contracted with Johnson Matthey plc to install the YARA 58 Y 1® catalyst system consisting of an additional base metal catalyst that is installed below the standard precious metal gauze pack."*

[6] For example, PDD of CDM project ref no. 1085, page 5 and ref no.339, page 5: *"Technology to be employed is the development of the process with help of KHD Humboldt Wedag technology services, Germany."*

[7] http://www.suzlon.com/about_suzlon/l2.aspx?l1=1&l2=1

Table 4. 1: Technology transfer descriptions in PDDs

Description given in the PDD	Type of technology transfer
Import of plant/equipment; upgradation of plant; use of equipment manufactured outside the host country; equipment sourced from a foreign country; equipment provided by a foreign firm; import of equipment spares etc.	International transfer of equipment
A mention of the equipment being sourced from a domestic plant but the technology of which is from a foreign firm	Equipment from Indian plant based on foreign technology
Any of the above descriptions along with a mention of any type of training given to the host firm employees	International transfer of equipment and training
Basic engineering and procurement assistance, inspection, expediting services, supervision and assistance during erection and commissioning provided by a foreign entity	Technology basic engineering and other services
Implemented with technical assistance from the associate company of a foreign company	Implemented with technical assistance from the associate company of a foreign company
Mention of transfer of know-how; process development with a foreign firm; transfer of know-how along with equipments/components; project based on foreign technology; technology procured from sole license holder	Transfer of know-how

For years 2000 to 2004, these newsletters provide information on the aggregate FDI inflow approvals by state for years starting from 1991 till the concerned year. In 2004 the reporting pattern has been changed and the information on actual inflows is given according to the RBI Regional offices. For our analysis we take each state's percentage contribution in the total approvals each year for the years 2000 to 2004. For the subsequent years we consider the percentage contribution of each state as the percentage contribution of the regional office of RBI under which it comes.

4.3 Technology transfer under registered CDM projects in India:

The basic unit of analysis in this study is each project location. Each project may be located in more than one location. That is different units of the same project may be registered as a single project under CDM. Thus to understand inter-regional variations, the best approach would be to take each project site in a different state as a separate observation. We have a total of 750 observations on the registered CDM projects that entered the CDM pipeline between years 2004 and 2010. Out of these only about 8.4 percent of the observations involve any form of international technology transfer and about 67 percent of this is in the form of transfer of equipment or equipment produced locally based on foreign technology.

Looking at the trend of technology transfer for the registered Indian CDM projects, we find that over the years there has been a decreasing trend in the percentage of project sites involving technology transfer from 2007 till 2010. After a rise in the percentage of projects involving technology transfer from zero in 2004 to above 4 percent in 2005, and further to 12.5 percent in 2006 and around 13.87 percent in 2007, the rate of technology transfer fell in years during the 2008 and 2009 (3.96 percent in 2009). The percentage of observations involving technology transfer has increased to around 13 percent in 2010. But the number of projects entering the pipeline has fallen drastically.

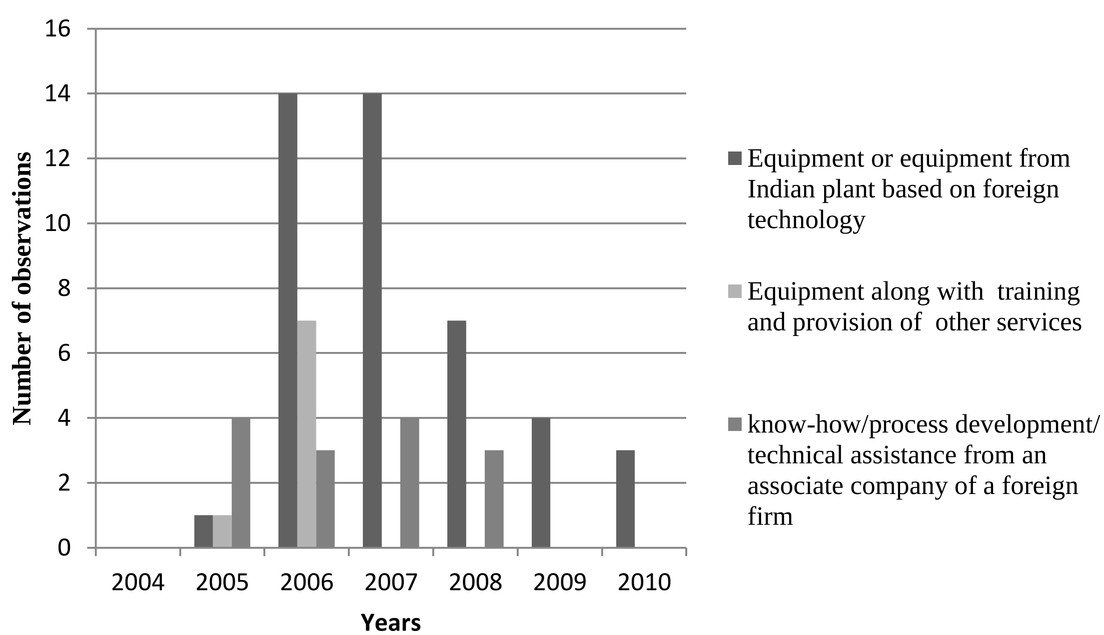
CDM projects in India consist mainly of Renewable energy projects, maximum number being in the wind energy sector (215 registered projects in 241 project locations). It is followed by biomass energy projects (187 registered projects in 187 locations). Only less than 10 percent of the registered wind energy CDM projects involve any kind of international technology transfer.

Table 4.2: Technology transfer in registered Indian CDM projects

Year of entering into the CDM pipeline	Number of Project Locations	Involving technology transfer	Percentage involving technology transfer	Equipment or equipment from Indian plant based on foreign technology	Equipment along with training and provision of other services	know-how/process development/ technical assistance from an associate company of a foreign firm
2004	7	0	0	0	0	0
2005	183	8	4.37	3	1	4
2006	168	21	12.5	12	6	3
2007	123	17	13.82	13	0	4
2008	145	10	6.897	7	0	3
2009	101	4	3.96	4	0	0
2010	23	3	13.04	3	0	0
Total	**750**	**63**	**8.4**	**42**	**7**	**14**

Source: Based on information in Project Design Documents of registered Indian CDM projects.

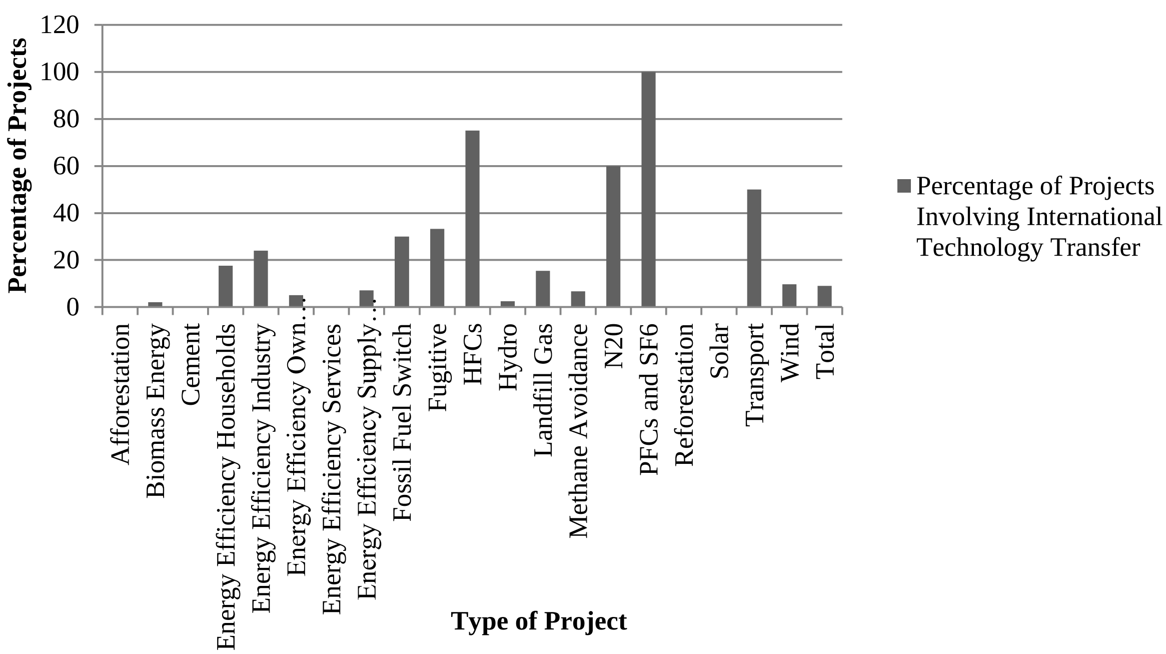
Figure 4.1: Technology transfer in Registered Indian CDM Projects



Source: Based on information in Project Design Documents of registered Indian CDM projects.

The Indian wind energy projects usually depend on locally manufactured equipments. The wind energy projects that mention technology transfer are majorly those which use equipments produced in India by Enercon India using technology procured from Enercon GmbH, Germany. Hydro power projects which account for a large number of registered projects also have a low level of technology transfer (only around 2.5% of the PDDs of registered CDM Hydro power projects mention any form of technology transfer). Around 24% of the industrial energy efficiency projects involve technology transfer out of which around 83 percent of these involve transfer of technology through importation of equipments. Looking at the types of technology transfer associated with each of the project types, we find that Energy efficiency (households), HFCs, landfill gas, methane avoidance and transport sectors account for all the transfer of know-how in India.

Figure 4.2: Percentage of registered Indian CDM projects involving international technology transfer by project type



Data source: Project Design Documents of registered Indian CDM projects

4.4 Determinants of technology transfer under CDM:

Various factors that drive technology transfer under CDM can be understood by identifying the major barriers to technology transfer. Schneider, Holzer, & Hoffmann (2008) identify four main barriers to technology transfer: 1) Lack of commercial viability, 2) Lack of information 3) Lack of access to capital and 4) Institutional framework in the host country. A study by UNFCCC (UNFCCC, 2010) mentions the following as the major determinants of technology transfer under CDM projects:

- Project size
- Whether the project is an unilateral project
- Number of similar projects in the host country
- Type of the project
- Availability of mitigation technology in the host country
- Technical capability of the host

At the project level the measure of commercial viability of a CDM project would be the potential emission reductions associated with the project. Dechezlepretre, Glachant, & Meniere (2009) Doranova, Costa, & Duysters (2010) and Haites, Duan, & Seres (2006) find a positive relationship between the size of emission reductions under a CDM project and probability of technology transfer. The presence of a credit buyer can alleviate the lack of access to capital by reducing the risk associated with the investment by guaranteeing a future revenue stream (Dechezlepretre, Glachant, & Meniere, 2009).

An important factor affecting technology transfer is the technological absorptive capacity of the host party. On the one hand, a minimum level of technological capability is required for technology to be absorbed and adopted for use by the recipient. On the other hand, a high level of technological capability may be indicative of the fact that the host may be self-sufficient in meeting its own need for the technology it requires. Dechezlepretre, Glachant, & Meniere (2009) use the ArCo index as a measure of technological capability. Further, to see the effect of local availability of technology, they use the number of CDM project using similar technology in the host country as an explanatory variable. Doranova, Costa, & Duysters (2010) use the production share of renewable energy in total energy and the share of climate friendly technology in total exports of goods. Additionally, to measure the scientific effort in the climate friendly technology share of scientific articles in climate friendly technology in total pool of scientific articles and the number of patents in climate friendly technology by the host country inventors have been used. Hascic & Johnstone (2011) measure the absorptive by the discounted stock of patents by the recipient country inventors. Dechezlepretre, Glachant, & Meniere (2009) find a positive influence of technological capability on technology transfer while Doranova, Costa, & Duysters (2010) find that the exports of climate friendly technology has a positive influence on the preference of local over foreign technology. These studies also find a positive influence of openness to international trade and FDI on international technology transfer through CDM projects

4.5 Econometric analysis

As mentioned earlier, for the purposes of our analysis, each observation corresponds to each project location. An important point to be noted is that, although we consider projects that entered the CDM pipeline between 2004 and 2010, these projects have their starting dates between 2000 and 2011. We have a total of 750 observations for our analysis (we exclude the projects that have starting dates in 2011 due to lack of data on state level variables for that year (4 projects) and also exclude the projects initiated by the Indian Railways(4 projects)). Our analysis is divided into two parts. First we estimate the relationship between the likelihood of technology transfer and the various factors that can potentially affect it. For this we use a binary dependent variable model in which the dependent variable takes a value of 1 if there is a technology transfer associate with the project and a value of 0 if there is no technology transfer associated with the project. Secondly, we study the factors affecting the quality of technology transfer. That is, we categorize the technology transfers taking place in India under CDM into a hierarchy of categories. Then we estimate an ordered logistic regression to establish the relationship.

The binary logistic model is given by the following expression. The probability that there is a technology transfer is assumed to be given by

$$P\{y_i = 1|x_i\} = \frac{e^{x_i'\beta}}{1 + e^{x_i'\beta}}$$

Where x_i is the vector of explanatory variables and β is the vector of regression coefficients.

For the purpose of our second part of the analysis, we group the projects first, into projects that involve technology transfer and those that do not involve technology transfer. Within those projects that involve technology transfer, we group the projects into three categories: *1) those that involve only transfer of equipments; 2) those which involve transfer of equipment and provision of training and other services; 3) those that involve transfer of know-how.* These three categories are expected to represent the type of technology transfer in respect of their degree of desirability from the perspective of the host country.

To establish the relationship between the probability of a particular category of technology transfer and the explanatory variables, we use an ordered logit model. In an ordered response model, the probability of observing a particular category of the dependent variable is estimated as a function of the explanatory variables.

Table 4.3: Categorisation of technology transfer

Type of technology transfer	**Technology transfer category**
No transfer of technology	*Category 0*
International transfer of equipment; or equipment from Indian plant based on foreign technology	*Category 1*
International transfer of equipment along with training and provision of other services	*Category 2*
Transfer of know-how; or technical assistance from the associate company of a foreign company	*Category 3*

The observed variable takes its values in accordance with the values that the latent variable (which cannot be observed) takes. Suppose the latent variable is given by y_i* and the observed variable is y_i.

$$y_i^* = x_i^{'}\beta + \varepsilon_i$$

$$y_i = j \; if \; \gamma_{j-1} < y_i^* \leq \gamma_j$$

$P\{y_i = j|x_i\} = P\{\gamma_{j-1} < y_i^* \leq \gamma_j\}$

The probability that the choice is j is given by the probability that the latent variable y_j* lies between the boundaries, γ_{j-1} *and* γ_j. γs are unknown parameters and are estimated along with the βs. When ε are *iid* and follow the logistic distribution, we get the ordered logistic model (Verbeek, 2004). In our case, there are three alternative choices for the CDM project proponents and higher categories correspond to higher welfare for the recipient parties.

We now describe the explanatory variables used in the analysis. Use of foreign technology usually involves high upfront costs and hence commercial viability of the project is an important factor for technology transfer (Dechezlepretre, Glachant, & Meniere, 2009). To measure the commercial viability of the CDM project, following previous studies, we use the annual emission reductions associated with the project as an indicator. As explained earlier, presence of a credit buyer can alleviate financial barriers, e.g, sale of credits through a forward contract can reduce the risk surrounding the investment by guaranteeing a revenue stream. *Credit Buyer*, a dummy variable to show the presence of an Annex-I credit buyer. Larger the number of CDM projects using a particular technology already established in a country, the lesser the likelihood of technology transfer taking place. This is because the technology is likely to be available in the host country. To measure the impact of similar projects, we use the number of projects of same type established in the host country in and before the year when each CDM project starts. The technological capability of each state is measured by the share of manufacturing in the state domestic product. Technological capability being necessary for technology transfer may be positively related to it. On the other hand, prior experience with clean technology may imply that the CDM host is self-sufficient in the required technologies. Net SDP is used as usual control variables. Sector dummies for renewable, energy efficiency and HFCs/landfill gas/Methane avoidance/other gas avoidance and removal projects are used to control for sector specific effects.

4.6 Results

The results of the econometric analysis are given in table 4.4. First we estimated the logistic model with the binary dependent variable. The results are given in table columns 1 to 4.

The size of the CDM project, measured in terms of the annual emission reductions is found to be positively related to the probability of technology transfer and is highly significant in all the three regressions. Although the credit buyer dummy variable has the expected sign on its coefficient, it is not statistically significant in any of the specifications. Number of similar projects in the country does not have the expected negative effect in any of the specification and is also not significant. Coefficient on manufacturing share has a positive sign but is not significant. FDI inflow/approval is found to have a positive effect and is statistically significant in all the two specifications in which it is included. Per capita state domestic product also does not have a significant effect. Sectoral dummy variables were found to be statistically significant for gas avoidance projects and energy efficiency which have a positive coefficient while being a renewable energy project does not increase the probability of technology transfer in registered CDM projects.

The table 4.5 presents the results for the ordered logistic regression. Again the results are in four columns. In the ordered regression we find that the size of the CDM project is again significant in all the specifications and has a positive effect on the quality of technology transfer showing that the probability of know-how being transferred increases with the size of the project. The coefficient of credit buyer dummy is positive but is not statistically significant. Per capita NSDP and manufacturing share are found to be having statistically insignificant effect on the probability of better quality technology being transferred. The FDI variable was again found to be significant in two of the specifications and has a positive effect on the transfer of know-how. Gas avoidance and energy efficiency sectoral dummies were found to have positive and statistically significant effect on the probability of better quality of technology transfer taking place.

4.7 Discussion of Results:

The Clean Development Mechanism was initiated with a major implicit aim of helping the developing countries benefit not only from higher investments but also associated technology transfers. But as the mechanism has evolved, the share of unilateral projects has increased and dominates. Also, it is doubtful whether the mechanism has been able to achieve its aims in terms of transfer of technology from the developed to developing countries.

With special reference to India, studies on technology transfer under CDM projects have observed the high reliance of Indian CDM projects on local technology (Dechezlepretre, Glachant, & Meniere, 2009). With regard to the factors affecting technology transfer under CDM projects in India, we find that

Table 4.4: Results for the logistic model of technology transfer in registered CDM projects

Dependent variable: *Tech transfer*	**1**	**2**	**3**	**4**
log(size)	0.5887843***	0.5829591***	0.5844586***	0.5806395***
Similar projects	0.00384	0.00421	0.0036957	0.004342
Expected operational life	-0.0504	-0.0467	-0.0467707	-0.0437711
credit buyer dummy	0.16193	0.19628	0.1623988	0.1910236
log(per capita NSDP)	0.17169		-0.0512596	-0.3206177
manufacturing share in NSDP			3.344151	3.068686
FDI inflows/approvals		0.0194564***		0.0204593**
Renewable dummy	0.15046	0.10295	0.1846421	0.127647
HFC/fugitives/other gas avoidance projects dummy	1.883189**	1.819033**	2.011987***	1.977682***
Energy Efficiency dummy	1.267098*	1.318425*	1.242077*	1.299633*
Constant	-6.247083**	-4.716049***	-4.566482	-2.011003
Pseudo R^2	**0.1383**	**0.1432**	**0.1413**	**0.1458**
Number of observations	**750**	**750**	**750**	**750**

***,**,* indicate significance at 1%,5% and 10% levels, respectively. The standard errors are clustered by state.

Table 4.5: Results of Ordered logit

Dependent variable: ***Tech transfer category***	**1**	**2**	**3**	**4**
log(size)	0.5759625***	0.5827353***	0.5807458***	0.5844728***
Similar projects	0.0042	0.0043	0.0040221	0.0037165
Expected operational life	-0.0448	-0.048	-0.0479903	-0.0516305
credit buyer	0.21505	0.21856	0.2228054	0.1954899
log(pcy)	-0.3133	-0.1349		0.1324
manufacturing share	2.74602	0.0188432**		
FDI inflows/approvals	0.0179724**	0.13034	0.0165835***	
Renewable dummy	0.15239	1.970213**	0.1377888	0.1773962
HFC/fugitives/ other gas avoidance projects dummy	2.06588***	1.377946*	1.928479**	2.000994**
Energy efficiency dummy	1.35635*	0.5827353***	1.378621*	1.329222*
Pseudo R^2	**0.122**	**0.1204**	**0.1202**	**0.1172**
Number of observations	**750**	**750**	**750**	**750**

***,**,* indicate significance at 1%,5% and 10% levels, respectively. The standard errors are clustered by state.

- The commercial viability of the project, measured in terms of the expected annual emission reduction, was the major determinant of technology transfer. Larger projects were expected to have not just a higher probability of technology transfer but also a higher probability of a superior type of technology transfer. This result is in line with the earlier findings on technology transfer through CDM projects ((Dechezlepretre, Glachant, & Meniere, 2009) (Doranova, Costa, & Duysters, 2010), (Haites, Duan, & Seres, 2006)).

- Although not statistically significant, the presence of a credit buyer was found to have a positive influence on technology transfer as well as the quality of technology transferred. This may imply that the presence of a credit buyer can reduce the risk associated with a project by ensuring a future flow of income and hence alleviate the problems related to lack of access to funds.
- The insignificant effect of renewable energy sectoral dummy may indicate the fact that renewable energy is an area where there is considerable local knowledge in India itself and hence does not need to depend on foreign technology.
- The attractiveness of a state to FDI inflows has a positive and significant effect on technology transfer and its quality .This shows us that a favourable investment climate is very important for technology transfer to take place and it to be of a superior kind.

4.8 Conclusion:

Our study involved an econometric analysis of the determinants of technology transfer under registered CDM projects in different states of India. The study confirms the assertion that commercial viability is the most dominant determinant of technology transfer. This was found in the large positive effect of the size of the project on the probability of technology transfer. Similarly the presence of a credit buyer might encourage technology transfer. The local knowledge base has a positive effect on technology transfer and its quality.

The results suggest that CDM projects are like any other business activity and the commercial success of the project is the major incentive for use of better technologies. The overall business environment in the regions where the projects are located is an important factor. First of all, the CDM projects would usually be established in states which provide a good business environment and opportunities for higher profits. Secondly, once the projects have been decided to be located in a particular region, our study shows that larger the commercial success the greater is the probability of technology transfer as well as a better quality of technology being transferred. The focus of the developing country governments should be on to encourage local research and development in areas where the countries have a comparative advantage. This leads to cost effective adoption of cleaner technologies in these countries. On the other hand in areas where the developing countries do not have a large knowledge base, the policies should focus on the encouragement of such projects by providing them sufficient economic incentives.

CHAPTER 5

CONCLUSION

Our study focused on analysing the factors affecting two significant issues that can have important impacts on the developing countries' gains from CDM. First, we studied the determinants of CDM renewable energy project location in India. Second we have made an attempt to determine the factors that impact the transfer of technology under CDM. While previous studies on both the issues were cross country studies and thus focused only on the country level variables, our study is done at the national level for India, looking at various state level factors that impact the variables of our interest.

In *chapter 3*, we have tried to answer the question of *what determines the location of renewable energy CDM projects and whether state policies and economic factors play a role in the visible bias in the distribution of renewable energy CDM projects*. The study was based on a panel of 17 states across 11 years from 2000 to 2010 covering projects that entered the CDM pipeline between years 2004 to 2010. We used panel regression to identify the statistically significant determinants of renewable energy CDM project location. The present study is a marked shift from previous studies due to its focus on the state level variables. The focus on only the renewable energy sector enabled us to analyse the impact of state level policies and incentives for that sector by including State Electricity Regulatory Commissions' regulatory policies as explanatory variables. Also we have made use of the state level natural resource potentials as an explanatory variable in the analysis which has also not been attempted in earlier studies. Our analysis found that:

- Feed-in tariffs had positive and highly significant effect on the installed capacities under registered renewable energy CDM projects. This is indicative of the fact that state level regulatory incentives are important in terms of encouraging investment in such projects.

Reading this along with the effect of RPO obtained in the econometric analysis tells us that price based incentives are effective means of encouraging renewable energy rather than command and control schemes.

- The positive and significant effect on the FDI inflows shows us that state level policies and general investment climate in a state are major factors affecting the location of renewable energy CDM projects.
- Also, the positive impact of the manufacturing base, which we use as measure of technological capability of the state, on the dependent variable is suggestive of the importance of the local knowledge base in encouraging investment in these projects.
- Similarly, the positive impact of the share of renewable energy in total installed capacity in the state is also indicative of the importance of local experience in the setting up of renewable energy projects in encouraging further investment in renewable energy.

In *chapter* 4, we analysed the *determinants of technology transfer* under registered CDM projects as well as the determinants of the *quality of technology transferred*. We made use of two types of regressions during our analysis. One was a logistic model with a binary variable indicating the presence of technology transfer under a particular project as dependent variable. For the purposes of the second part of the analysis we categorized the technology transfer taking place into a categorical variable according to their level of desirability for the host nation. For this analysis we used an ordered logistic model. We found that:

- The commercial viability of the project, measured in terms of the expected annual emission reductions, was the major determinant of technology transfer. Larger projects were expected to have not just a higher probability of technology transfer but also a higher probability of a superior type of technology transfer.
- The attractiveness of a state to FDI inflows had a positive and significant effect on technology transfer and its quality. This shows us that a favourable investment climate is very important for technology transfer to take place and it to be of a superior kind.

The analyses in the two chapters have found that both location of CDM projects and the probability of technology transfer are affected by the similar state level economic factors and the business environment prevailing in the states. The location of renewable energy CDM projects was found to be positively influenced by the presence of state level price based incentives while both, location of CDM projects as well as the probability of technology transfer are positively influenced by the investment climate in the state as can be seen from the positive influence of the FDI inflows. Thus, states wishing to gain from investment in CDM projects especially in the renewable energy sector in their states have to ensure attractive business environment and proper economic incentives. These policies can ensure that CDM projects are attracted to their states and at the same time increase the probability of technology transfer as well as that of a superior quality of technology when it takes place.

Our results suggest that the bias in the regional distribution may not directly be the result of richer states attracting CDM investments. Rather the bias in the regional distribution of renewable energy CDM projects can be attributed to factors such as availability of good infrastructure, stable policies, presence of good institutional framework, ease of procedures lesser bureaucratic delays, ease of acquisition of land, and a positive perception of governmental policies in the business community. The same factors may also lead to higher growth rates and higher state incomes. Thus, CDM provides the developing country governments the opportunity to attain the twin objectives of growing at a faster rate leading to eradication of poverty while at the same time gain from emission reductions associated with these projects. In addition many of the CDM projects are themselves providers of employment to the local populace and of course bring in new technology not available locally. Thus, the usual perception of the tradeoff between cleaner environment and better economic growth may not hold good in the case of a mechanism like the CDM. Thus, the government policies should be framed in such a manner that encourages the adoption of clean technologies like renewable sources of energy by providing economic incentives and in general ensure a good investment climate by providing the necessary infrastructure, public services and reducing procedural delays.

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