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Abstract

This study assesses the impact of the Clean Development Mechanism (CDM) on the transfer of clean technology in India. The reason this study is unique is because firstly, it adopts an outcome-oriented approach to define 'technology transfer', which means that technology transfer occurs if firms are able to upgrade their 'dynamic capabilities'. It uses three indicators of firms' dynamic capabilities: R&D expenditures to sales ratio, fuel consumption to sales ratio and total factor productivity growth. Secondly, it moves away from the analysis of technology transfer claims made in either Project Development Documents or primary surveys to using actual information on firms' performance for the analysis. The empirical analysis is based on a difference-in-difference design. It draws on the balance sheet data of 612 firms from India between 2001 and 2012 from the PROWESS database. The results reveal that CDM has the potential of laying a foundation for capability building in developing countries but in its current form, it is not effective.

Key words: CDM, dynamic capability, India, R&D, fuel efficiency, total factor productivity
JEL: C21, O3, Q54, Q55

1. Background

It is widely recognised that innovations and technological solutions are critical for an effective global response to the challenge of climate change (Blackman, 1999; IPCC, 2000; Olsen, 2007; Yang, 1999). However, so far, most of these solutions have only been developed and tested in developed countries. Developing countries are at a greater risk of climate change impact due to the majority of their population living in physically exposed locations and their being largely dependent on climate-sensitive sectors (agriculture, fisheries, tourism) and resources (such as water, biodiversity, mangroves, coastal zones, grasslands) for their subsistence and livelihoods (World Bank, 2010). These countries have low technological capability to shift to low carbon and climate-resilient growth paths (Johnstone, et al., 2010, and Sterk et al., 2009). They have three options to catch up with the developed world: i) developing the technology by their own means; ii) purchasing it from developed countries; and iii) relying on technology transfers from the developed nations through foreign direct investment and trade in goods and services. Since the first two options are expensive, developing countries may need to depend more on the third one.

Realising this, leaders of developing countries brought the issue of technology transfer in the environmental context on the international agenda in as early as 1972 when they called on the international community at the 'United Nations Conference on the Human Environment in Stockholm', "to make available science and technology in order to progress their development" (as cited in Cox, 2010: 182). As a result, Principle 9 of the Stockholm declaration called for remedying environmental challenges by "accelerated development through the transfer of substantial quantities of financial and technological assistance as a supplement to the domestic effort of the developing countries and such timely assistance as may be required" (UN 1972: 2). Since then, discussions on technology transfer have been a key component in deliberations and negotiations in international forums and multilateral agreements on environment and climate change. In 1992, the United Nations Framework Convention on Climate Change (UNFCCC), formed to provide solutions to the growing problem on climate change under the guidance of the Intergovernmental Panel on Climate Change (IPCC), mandated developed countries through articles 4.3. to 4.5, "to take all practicable steps to promote, facilitate and finance the transfer of environmentally sound technologies and know-how to developing countries".

Several alternative arrangements and organisational designs ensued to implement this mandate. One such arrangement is the Kyoto Protocol's Clean Development Mechanism (CDM). Established in 1997, this is a carbon offset market-based mechanism that incentivises the private sector to transfer low-carbon technology to developing countries. It is a project-based mechanism that allows eligible entities from developed countries to invest in emission-reduction projects in developing countries to earn certified emission reduction (CER) credits. They can sell or use these CERs to meet a part of industrialised countries' emission reduction targets under the Kyoto Protocol. With project costs typically much lower in developing countries than in industrialised countries, the latter can comply with their emission reduction targets at much lower costs by receiving credits for emissions reduced in developing countries. Although technology transfer is not an explicit mandate of the mechanism, it is expected to facilitate technology transfer by financing emission-reduction projects that use technologies currently not available in the host developing countries (Ockwell et al., 2008; OECD/ IEA, 2001; UNFCCC, 2010:10).

A fairly large body of literature has investigated the role of CDM in promoting transfers of clean technology and expertise from the technologically advanced North to the South (Chatterjee, 2011; Cox, 2010; Das, 2011; de Coninck et al., 2007; Dechezleprêtre et al., 2008, 2009; Doranova et al., 2011; Gandenberger et al., 2016; Haites et al., 2006; Hansen, 2011; Lema and Lema, 2013; Murphy et al., 2013; Schneider et al., 2008; Sepibu, 2009; Wang 2009; Weitzel et al., 2014; Xie et. al., 2013; among others). The present study contributes to this literature in two ways. First, while most studies are based on either ex-ante evidence of technology transfers projected in the project design documents (PDDs) or perceptions of managers of the CDM-implementing firms gathered through primary surveys, this study uses the balance sheet data of host firms to establish the relationship between CDM implementation and its impact on them. Second, while most existing studies focus on the process of technology transfer through CDM projects, the present study analyses the outcomes of CDM implementation on host firms' 'dynamic capabilities', which goes beyond the focus on the accumulation of technology assets and instead, refers to a firm's capability to appropriately adapt and integrate the new technology and enhance its competence based on it (as conceptualised in Zahra and George, 2002 and formalised by Teece and Pisano, 1994; Teece et al., 1997). The concept of dynamic capability is captured by using three indicators: indigenous R&D efforts, fuel efficiency and total factor productivity growth. It employs a quasi-experimental design, the difference-in-difference (DiD) technique, for the analysis. The analysis is based on the balance sheet data of 612 CDM-implementing and randomly selected non-implementing firms over the period 2001 to 2011, using the PROWESS database.

Currently, "the CDM is imperilled" (CDM Policy Dialogue, 2012: 2). Carbon prices in the CDM market have declined sharply in the recent period and are projected to fall further, signalling the potential death of this instrument. The usefulness of the mechanism is being increasingly questioned by both policy makers and climate advocates. However, there is also a realisation that it will not be easy to design a new instrument and make it operational at short notice. According to the CDM Policy Dialogue (2012: 2), "In the absence of new solutions, CDM is likely to remain the world's foremost – and possibly sole – means of gaining the benefits of a global carbon market". There is thus a strong need to analyse the impact of CDM on various stakeholders, and draw implications regarding reforms in this mechanism so that it contributes to the global climate action effectively. Against this background the present study is expected to provide useful insights on CDM benefits in terms of upgrading the dynamic capabilities of firms in developing countries.

The analysis focuses on India, where CDM projects have been one of the highest in the world. According to the UNFCCC database, as of 31 December 2016, there were 7762 projects registered worldwide; of which, India alone registered 1639 projects accounting for over 21 per cent of the global share. India occupies second place in terms of its share in registered CDM projects and the investment undertaken therein, after only China. It hosted the largest number of CDM projects between 2005 and 2007 with over 33% global share. In 2007, it lost its top position to China in the face of global slow down and a fall in the international prices of CERs. It regained the top position in 2013, and continues to retain that position**,** despite a drastic decline in the number of CDM projects due to its uncertain future. The insights provided by this study could therefore have useful implications for other developing countries.

2. CDM, Technology Transfer and Dynamic Capabilities: A Theoretical Framework and Major Hypotheses

The available evidence shows that the bulk of technology is transferred from developed country firms to their developing country counterparts via three channels (Maskus, 2004). 'Trade in capital goods and equipment' is one. These imports bear some potential for transmitting technological information to developing countries. A second channel is 'foreign direct investment' (FDI). Multinational enterprises (MNEs) generally transfer their proprietary technologies to their subsidiaries (Dunning, 1993). A third major channel of international technology transfer is technology licensing. Licensing typically involves the outright/ royalty-based purchase of production and distribution rights for a product, and the underlying technical information and know-how necessary for its production (Dunning, 1993; Markusen, 1995). This may occur within firms, among joint ventures, or between unrelated firms.

CDM projects can facilitate technology transfer through any of the above channels depending on the mechanism used for financing them. There are three mechanisms of funding CDM projects. These are 1) direct investment by foreign investors in CDM projects, 2) purchase of yet-to-be-generated CERs, and 3) purchase of CERs in the secondary market. Each of these mechanisms corresponds to one of the three forms of technology transfer described above. For instance, the first one involves equity investment via joint venture companies/wholly owned subsidiaries or indirect (portfolio) investments via purchase of securities. It results in inflows of FDI to developing countries (Niederberger and Saner, 2005; UNCTAD, 2010). The second mode of financing CDM projects involves forward contracts with a foreign company (for instance, in the form of a carbon purchase agreement) involving the purchase of a specified amount of CERs generated by the CDM project, normally with some up-front payment. It benefits the host country firm by transferring know how and /or equipment of the foreign partner or of any other source suggested by it. In the third mode of financing, host countries' entities develop and finance their own projects and sell or bank CERs generated by them (Lütken and Michaelowa, 2008; Seres and Haites, 2008); the developed country buyers purchase them in the secondary market. In this case, there is a possibility for the local project developer to buy foreign technology from anywhere through technology licensing and/or capital goods imports. Thus, the CDM projects are expected to involve technology transfer from developed to developing countries through a variety of channels depending on the financing mechanism.

The transfer of technology may help firms build their technology assets; but this may not be sufficient to give them competitive advantage (Teece and Pisano, 1994). Gaining competitive advantages requires absorptive capacity. Traditionally, absorptive capability refers to the ability of a firm to choose, acquire, adapt, assimilate, and use technology for commercial ends, which in turn is determined mainly by domestic R&D expenditures (Cohen and Levinthal, 1989, 1990). Moving away from the ability-based conceptualisation, Zahra and George (2002) define absorptive capacity from a dynamic perspective. According to them, technology involves tacit knowledge that is embedded in firms' procedures and personnel, organisational structures, knowledge management, and external interactions and integrations. If a firm sources technology from external sources, its absorption requires change in the organisational routines, structures, and processes to produce desired outcomes (see Lim and Falk, 2013; Zawislak et al., 2012). The capacity of a firm to "appropriately adapt, integrate, and reconfigure internal and external organisational skills, resources, and functional competencies in changing environment to sustain its competencies" is termed as dynamic capability (Teece and Pisano, 1994: 557). Seen from this perspective, an externally acquired clean technology through a CDM project requires new processes and solutions that differ significantly from those used by the firm before its acquisition. Its success will depend on whether it initiates changes in the managerial and organisational strategies and procedures to learn, assimilate and use this technology. These initiatives generate technological learnings on the one hand and other organisational learnings (in skill management, marketing, distribution and production), on the other.

Even if there is no direct technology transfer involved, there are other channels through which CDM can have capability enhancing effects on the host firms. For instance, CDM participation exposes a firm to international carbon markets. This opens new sources of knowledge and experience for the firm, which facilitates its organisational learnings from others' experiences in clean tech areas, and its own experimentation with processes and procedures. It also offers an opportunity to enter into various forms of cooperation such as strategic alliances, contracts and joint ventures with international firms and other CDM projects. These inter-organisational networks generate learning and could thus increase competitiveness (Todeva and Knoke, 2005 for literature survey). The firm can leverage these technological, organisational and managerial learnings to ensure a superior performance.

To empirically assess the impact of CDM projects, therefore we argue that the CDM implementation can contribute to a firm's dynamic capability by strengthening three channels: one, capability to learn and absorb externally acquired technology; two, capability to adapt and assimilate it in its production processes, and three, capability to translate new knowledge into higher performance by augmenting organisational capabilities. For statistical testing, we formulate the testable hypotheses corresponding to these three channels.

Capability to learn and absorb externally acquired technology: Technological learning requires conscious allocation of funds in domestic R&D efforts (Cooper, 1994; Nelson and Winter, 1982; Teece, 1977). A technology transfer results in technological capabilities provided that the host firm accelerates its in-house technological efforts towards adapting or improving upon the imported technology and/ or equipment. Thus,

H1: CDM-implementing firms are likely to spend more on local R&D efforts than their non-implementing counterparts

Capability to adapt and assimilate it in its production processes: CDM implementation may enhance a firm's technology asset but it may not yield a competitive advantage unless it is effectively incorporated into its 'processes' through organisation and managerial restructuring. From the perspective of CDM implementation, "fuel efficiency" may be an important indicator of process change. This is because energy related projects dominate the portfolio of CDM projects worldwide. In India, too, over 95% of the CDM projects pertain to renewable energy and energy efficiency. As of 31 December 2013, biomass/biogas projects accounted for 18.5% of the total projects; the share of other renewable energy projects was 59.4% while energy efficiency/fuel switch comprised another 17.2%. We thus expect CDM implementation to affect the dynamic capability of implementing firms positively if it enhances their fuel efficiency by reducing fuel intensity.

H2: CDM implementation enhances fuel efficiency of the host firms

Capability to translate new knowledge into higher performance by augmenting organisational capabilities: Technology learning and its integration with production process need to be leveraged by other organisational capabilities (such as skill management, marketing and distribution) to yield it distinct competitive advantages. These competitive advantages reflect its superior performance. There are several measures of performance. But, in the literature, total factor productivity growth (TFPG) is considered to be one of the most comprehensive measures of technical and organisational efficiency of a firm. In general, we may expect a positive relationship between TFPG and CDM implementation.

H3: CDM implementation improves total factor productivity growth (TFPG) of the host firms

3. CDM and Dynamic Capabilities of Firms in India: Literature Review

The literature can be divided into three categories: one, those based on PDDs; two, those based on primary surveys; and three, case studies (Cox, 2010; Hansen, 2011; Lema and Lema, 2013; Walz and Delgado, 2012). The PDDs provide information on whether or not technology transfer will be involved in the implementation of the project. Most existing studies use these documents for analysing technology transfer through CDM (See Cox, 2010; Weitzel et al., 2014 for survey). Since 2007, the UNFCCC Secretariat has been compiling and publishing information contained in these documents on an annual basis to indicate the level of technology transfer that is occurring for different project types and host countries. Aggarwal (2011) pooled this information over time to show that the rate of technology transfer in India has not only been lower than the world average, whether measured in terms of number of projects or annual emission reductions, but it has also been declining over time. It is also shown that the technology transfer claims have been declining across all categories of projects, irrespective of their scale and foreign participation. The predominance of small scale (70.5% against the world average of 46%) and unilateral projects (84%) are further expected to limit the role of CDM in building capabilities to move towards a clean economy in India. It is also indicated that CDM projects hosted in India are concentrated in renewable energy including biomass energy. The high end industrial projects such as agriculture, hydro fluorocarbons (HFC), landfill gas, waste management, nitrogen dioxide (NO_2), tidal, geothermal, fuel switch, and energy efficiency, which tend to have more frequent recourse to foreign technology account for a small share of total projects in India (Chatterjee, 2011; Dechezleprêtre et al., 2009; Seres, 2007).

Das (2011) builds on the PDD data for 1000 global projects by collating information available on the relevant web pages of the UNFCCC web portal. That study finds that a mere 4.9% of the projects involved technology transfer for India against 26.5% for all 1000 projects.

The analysis shows that in most projects technological learning and capability building is confined only to the basic or operational level, and the role of CDM as a means of upgrading the technological capabilities of firms is limited in the Indian context.

In a cross country study based on primary surveys, however, Doranova et al. (2011) find that Indian (and Brazilian) CDM-implementing companies show higher technological learning than the Mexican ones. In contrast, FICCI (2012) based on interviews with industry comes to the conclusion that CDM has not contributed to technology transfer in India, and that technology transfer has not taken place either in unilateral projects or in bilateral/multilateral projects due to the lack of financial assistance.

Finally, in a case-based analysis of wind power projects in India and China, Lema and Lema (2013) conclude that most advanced skills and capabilities have been developed independent of CDM and have later been replicated in CDM projects. They opine that the nature of technology transfer in CDM may be an effect rather than a primary cause of domestic capabilities. Walz and Delgado (2012) however observe that CDM has been of high importance in contributing to wind power diffusion in India. It has played a key role as a profitability factor in about half of India's wind projects. "As of August 2009, 301 Indian wind projects had been registered with the CDM Executive Board, accounting for 5659 MW" (p:2013). Chaudharya et al. (2012) highlight how the compact fluorescent lamp (CFL) programme in India leveraged the CDM to diffuse this energy efficient technology. Altenburg and Pegels (2012) argue that India along with China have been able to benefit most from the CDM.

Overall, there is limited evidence of the usefulness of CDM in transferring clean technologies to India. The databases and methodologies used in the existing analyses are however subject to serious limitations. For instance, information on technology transfers provided in PDDs is *ex ante* and not actual and is found to understate the latter. UNFCCC (2011, 2012) reports that in post-CDM implementation surveys many of those projects involved technology transfers that were not anticipated when the PDD was prepared.

Similarly, studies based on primary surveys often suffer from a large non-response rate. The characteristics of non-respondents may differ from those of respondents, introducing the self-selection bias and limiting the validity of the survey's results. It is unclear how general the lessons from case studies are. Finally, the existing analyses focus only on technology transfers, other channels of outcome effects namely demonstration effects, and learning by doing and networking are completely ignored.

In summary, the current understanding of the contribution of CDM to technological capability is incomplete. This paper fills the gap by using a large secondary database of firms to retrospectively assess the impact of CDM projects.

4. The Model and Methodological concerns

In this study we use the panel data based Difference-in-Difference (DiD) technique for quantitative analysis. The DiD estimator represents the difference in outcomes between the pre- and post-CDM implementation periods in CDM-implementing (treatment) vs. non-implementing firms (control) after controlling for other factors. The DID technique used here required us to address several methodological concerns posed by the data. This section discusses the model and methodological issues that we addressed while estimating the model.

In our data, the CDM implementation year differs across firms, and so, there is no single year that represents the common year of treatment. The DiD model that we have adopted in this case is

$$Y_{it} = a_1 + a_2 \mathrm{CDM}_{it}.*T_{it} + bX'_{it} + cZ'_{it} + T_t + v_i + e_t \times \quad \ldots\ldots(1)$$

In this specification, X is a vector of project specific variables; Z represents firm and sector specific control variables while T_i and ν_i are year- and firm- specific unobserved effects respectively. The coefficient of interest, i.e. the DiD estimator, is α_2 because $\mathrm{CDM}_{it}*T_{it}$ indicates whether firm i implemented CDM in year t. We consider the time dummy (T_{it}) equal to 1 for the post CDM period and zero otherwise. This specification does not allow the effect of CDM participation to change over time (e.g., to become stronger or weaker later in the project). To capture the dynamics of CDM effects, we use an alternative specification:

$$Y_{it} = a_1 + a_2 \mathrm{CDM}_{it}.*\mathrm{T}_{i1\text{-}4\ i} + a_3\ \mathrm{CDM}_{it}.*\mathrm{T}_{i5\text{-}8} + bX'_{it} + cZ'_{it} + T_t + v_i + e_t \times \ldots(2)$$

where T_{it} is broken down into two dummies: $T_{i1\text{-}4}$ and $T_{i5\text{-}8}$ representing the first four years of implementation and the next four years, respectively. The alternative specifications (1) and (2) will also provide us a robustness check for the DiD estimates.

Y, the dependent variable is represented by three variables: local R&D expenditures as percent of sales (R&D intensity); fuel consumption as percent of sales (fuel intensity) and total factor productivity growth.

Self-selection bias is an important concern in the programme evaluation literature. It is a potential estimation issue not only in observational studies but in experimental designs as well (Clampet-Lundquist and Massey, 2008). This concern is addressed here by including a large set of observable and unobservable controls in panel fixed effect models. We identify four sets of variables capturing project-, firm-, sector- and time specific effects. The firm and sector specific controls are drawn from relevant literature.

Table 1 provides a summary list of variables with their definitions. In all, three sets of regression equations were estimated independently with alternative specifications of the independent variables. Since DiD estimation of the effect of a treatment that varies at the group level at any point in time using micro data is subject to within-group serial correlation (Bertrand, Duflo, and Mullainathan, 2004), we cluster standard errors by firm.

Table 1 : List of variables with definition

Variable name	**Variable definition**
Dependent variables	

R&D Intensity	R&D expenditure to sales ratio
Fuel intensity	Fuel expenditure to sales ratio
TFPG	Total factor productivity growth calculated using the Solow method[1]
Main independent variables	
CDM_{it}	A dummy that takes value 1 for firms that have implemented CDM projects and 0 for firms that have not implemented CDM projects.
T_i	T=1 for the post CDM implementation period for firm i
T_{i1-4} and T_{i5-8}	T_{i1-4}=1 for the first 4 years of CDM implementation and T_{i5-8}=1 for the later years for firm i
Project specific variables	
Type	A dummy that takes value 1 for unilateral projects and 0 for bilateral/multilateral projects.
Size	A dummy that takes value 1 for large or multiple projects and 0 for small projects.
d_proj**:**	A dummy that takes value 1 for projects that have a high potential for enhancing energy efficiency.
Controls: Firm specific	
Firm size	Log of sales
Export intensity	exports to sales ratio
Profit margins	Profits to sales ratio
Vi	Firm specific dummies/fixed effects
Controls: Sector specific	
d_rd	A dummy variable that takes value 1 if a firm is in a high-tech (or high-opportunity) sector i.e. chemical/engineering/electronics
Controls: Time specific	
Tt	Year dummies

In a multi-equation analysis such as this, Seemingly Unrelated Regressions (SUR) may be a preferred technique. Panel data based fixed effect estimates of independent equations

[1] Productivity growth $\frac{\Delta A(t)}{A(t)}$ is calculated as $\frac{\Delta A(t)}{A(t)} = \frac{\Delta V(t)}{V(t)} - (S_L(t) \left(\frac{\Delta L(t)}{L(t)}\right) + S_k(t) \left(\frac{\Delta K(t)}{K(t)}\right))$ where V,L, and K are real gross value added, labour and real gross fixed represent capital respectively and S_L and $S_k$stand for the share of labour and capital.

are unbiased and consistent, but generally not as efficient as the SUR estimates, if error terms across the equations are correlated. Typically, SUR models are well-suited for cross-section data. Following Biorn (2004) SUR models can now be estimated for unbalanced panel models also, but the methodology yields only one way random effect estimates. The Hausman tests rejected the random effect models in favour of the fixed effect ones for all three equations. Therefore it was decided to estimate each equation independently of the others for this analysis.

In addition to estimating the models with the full sample, we performed separate regressions for small and large firms in the sample. While the use of CDM is widespread across a range of both large and small firms, the impact of CDM on them is likely to differ due to differing capability, capital, and the type of project implemented (Schneider et al., 2009). The large firm size subsample includes all firms with annual sales larger than the average sales for all firms, and the small firm size subsample includes all firms with sales equal to or smaller than the average value, therefore dividing the observations fairly into two categories. This estimation provides another robustness check for the DiD estimates.

Finally, a validity check was done to ensure that the key assumption behind DID is satisfied. The DID analysis is based on the assumption that in the absence of treatment, the trend in the outcome variable would have been the same for both the treatment and control groups. Violation of parallel trend assumption will lead to biased estimation of the causal effect. Since there is no statistical test for this assumption, visual inspection of trends in outcome variables for treatment and comparison groups is useful. While depicting these trends for the three outcome variables, we faced two challenges. Firstly, we didn't have a sufficiently large number of observations for the pre-treatment period to correctly identify the trends. It may be noted that the Designated National Authority was set up in India in 2003 for CDM registrations. We had only two years data prior to that. Secondly, the CDM programme is adopted by different companies in different years. There is thus no specific treatment year or treatment group for the entire sample. To address these issues we identified newly registered CDM firms each year and tracked the outcome variables for them over the entire period. We presented the summary graphs in Appendix A. The non-CDM firms shown in the graph never adopted the programme over the selected period of time. The CDM firms are the ones that are involved in CDM projects at a given point in time. The graph on fuel intensity seems to violate the assumption which is believed to have been addressed by controls included in the DID analysis.

5. The Database

The study uses two sources of data for testing the above model: the CDM database of the Institute for Global Environment Strategies (IGES); and the Centre for Monitoring Indian Economy's PROWESS database of Indian companies. Building the database involved several steps.

As a first step, we gathered information on all 864 projects registered in India as on 31 May 2012 from the IGES database. The database provides comprehensive information on the status of CDM projects, their category and scale, location, year of implementation, collaborators involved, implementing host country and its companies, and the issue of CERs.

In the second step, we created a list of host firms and mapped them with the firms covered in the PROWESS database. PROWESS is a database of large and medium Indian firms. It contains detailed information on over 27,000 firms. These comprise all companies traded on India's major stock exchanges and several others including central public sector enterprises. Collectively, the companies covered in PROWESS account for 75 per cent of all corporate taxes and over 95 per cent of excise duty collected by the Government of India. Of the 864 implementing companies, we were able to match 292 firms in PROWESS. We then compared the basic features of the projects implemented by the sample firms with those of the entire set of 864 CDM firms. For this, we examined a sample of the structure of the projects implemented, and also examined all firms separately in terms of the category, foreign participation and scale. The comparative analysis presented in Table 2 shows that the projects implemented by sample firms in the study are representative of CDM projects in general in terms of the sector, foreign participation and size.

As a next step, we identified the NIC codes for all 292 CDM firms. We selected non-CDM firms in the selected NIC categories by generating random numbers from the computer after ranking the firms by size. Since several firms had very little data with respect to the variables of interest, we discarded those firms and generated new random numbers. The process was repeated to extract almost the same number of non-CDM firms as their CDM counterparts. In all, we generated a sample of 320 non-CDM firms.

Finally, we used PROWESS to extract information for two groups of companies: CDM and non-CDM firms. We extracted the selected financial data of these firms for the years from

2001 to 2012 and merged the CDM database obtained from the IGES with the companies' financial database to create a panel dataset for the years 2001 to 2012 and constructed our variables.

Table 2: A comparative analysis of sample vs. census database

Project specific factors	Type of project	% Share in Sample	% Share in Census
Project category	Afforestation	0.72	0.61
	Biogas	2.17	2.11
	Biomass	22.74	16.41
	Cement	5.05	1.16
	Energy efficiency	6.14	9.33
	Fuel Switch	5.05	2.65
	HFC reduction	1.81	0.48
	Hydro power	5.05	9.87
	Methane avoidance	1.81	1.3
	N_2O decomposition	1.08	0.54
	PFC reduction and substitution	0.36	0.14
	Transportation	0.36	0.61
	Waste gas/heat utilisation	13.72	5.17
	Wind power	33.94	42.75
	Solar	-	6.74
Foreign participation	Unilateral projects	81.5	83.9
Project Size	Small projects	58	70.5

Source: Based on PROWESS database

Table 3 presents descriptive and t-test statistics to examine the relationship between CDM implementation and the outcome variables. Our preliminary observations with t-statistics show that the CDM implementation is negatively related with fuel intensity and TFPG[2]. However, its relationship with R&D intensity is ambiguous. These results need to be validated

[2] The negative TFPG in 2010 could be due to the global slow down.

after controlling the effect of other variables. The paper uses the DiD estimation approach for empirical analysis.

Table 3: Descriptive statistics of the outcome variables

	Firm	Year	Observations	Average	Standard deviation	T-statistics@
Fuel-intensity	CDM	First year of CDM project	214	0.076	0.080	
	CDM	2010	223	0.064	0.070	**-1.62***
	Non CDM	2010	196	0.176	1.086	**1.44**
R&D intensity	CDM	First year of CDM project	245	0.00131	0.0111	
	CDM	2010	282	0.00138	0.0057	0.089
	Non CDM	2010	297	0.0188	0.0176	0.465
TFPG	CDM	First year of CDM project	151	0.182	1.063	
	CDM	2010	204	-0.125	1.19	**-2.556*****
	Non CDM	2010	148	-0.559	2.95	**-1.693***

Notes: @ The t-statistics refers to that of the simple regression between the two variables. 1.The table comparatively analyses the outcome variables between the first year of initiation and 2010 for CDM implementing firms, and between implementing and non-implementing firms for 2010.
2. * = 10%, and *** = 1%; Bold with no star=just missed significance at 10%.

6. Empirical Results

R&D intensity

There is substantial literature on the determinants of inter-firm differences in R&D intensity. This literature examines the association of firm level R&D efforts with scale of operations, technological opportunities prevailing in the industry in which the firm operates, external technology acquisition, internal flows of resources, and government policy, among other factors (Kumar and Aggarwal, 2005). While using this broad framework we adapted equations 1 and 2 to incorporate the relevant variables. The results are presented in Table 4. While focusing on the main variables, we find evidence that the average R&D intensity increases in the post CDM implementation period taken as a whole (Model 1). However, it is statistically insignificant due to large variations across firms. But, while the cumulative (cdm_{it}) is insignificant $cdm*T_{i5-8}$ is significant with a positive sign in Model 2. Thus, R&D effects appear to emerge with a time lag. Since the dummy cdm_{it}×unilateral is negative, one can say that the projects involving foreign partners are more likely to incentivise domestic R&D efforts than the unilateral ones. Project size does not seem to matter.

Table 4: Fixed effect cluster-robust-VCE estimates of R&D intensity

	All firms		Small firms		Large firms	
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
T_{it}=1 for post cdm period; =0 otherwise	0.107		0.0606		0.0956	
	(1.284)		(0.761)		(1.022)	
T_{i1-4}=1; 1-4 years		0.0993		0.0528		0.105
		(1.183)		(0.749)		(1.169)
T_{i5-8}. 5-8 years		0.256**		0.105		0.275*
		(2.283)		(0.837)		(1.660)
CDM_{it}Xlarge project=1;=0 otherwise	-0.0454	-0.0408	0.171*	0.160*	-0.0560	-0.0527
	(-0.637)	(-0.588)	(1.762)	(1.670)	(-0.658)	(-0.633)
CDMitXunilateral project=1;=0 otherwise	-0.136*	-0.120*	0.0453	0.0495	-0.165*	-0.146*
	(-1.807)	(-1.630)	(0.913)	(1.001)	(-1.787)	(-1.647)
Constant	0.111	0.108	0.181**	0.181**	-0.487	-0.518
	(0.372)	(0.359)	(2.379)	(2.372)	(-0.502)	(-0.520)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,183	4,183	1,679	1,679	2,504	2,504
Number of firms	536	536	254	254	282	282

Robust t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

The results for small and large firms presented in Table 4 show that the positive effect of CDM on R&D efforts of firms with a time lag may largely be attributed to large firms. These firms appear to be positively affected by CDM implementation with a time lag (Model 6). Notably, the dummy for bilateral/multilateral projects is significant in the specifications for large firms underlying their role in promoting R&D. Small firms on the other hand do not appear to augment their R&D expenditures in the post CDM implementation period, in general (Model 4). The DiD estimators turn out to be insignificant in all specifications; even if they are positive throughout. It could be because they are more likely to take up small projects based on simple technologies where the scope of technology transfers is limited (Gandenberger et al., 2016; Murphy et al., 2013). It is seen that the adoption of large projects does influence their R&D efforts positively. The project size does not turn out to be significant for large firms; it is foreign collaboration that matters in their case. It is likely that foreign collaborations are associated with projects involving more complex technologies.

Fuel intensity

Table 5 shows that CDM implementation is not associated with improvement in fuel efficiency (Model 7). The DiD coefficient highlights some dynamism when the effect is broken down into two time periods: 1-4 years and 5-8 years (Model 8). There is evidence of a weak negative effect of CDM implementation on fuel intensity after some years' gap. But it is not significant statistically. The project size and foreign collaboration also emerge insignificant. This shows that the CDM projects do not impact the organisational processes. It could be because there is a disconnect between the main business of the host firms and their CDM activity. We interviewed two large energy intensive firms that have been involved in CDM activity. It was apparent that the CDM activities were not clearly embedded in their main organisational strategies.

Fuel intensity (efficiency) declines (increases) with firm size but after a threshold level it starts increasing (decreasing) with firm size (Not shown here). Thus, the large firms are under more pressure to reduce their energy intensity due to high fuel intensity. A disaggregated analysis by firm size in Table 5 however offers weak evidence that large firms benefit more from technological learning particularly when they implement large projects (Models 11 and 12). In none of the specifications presented in the table do the relevant estimators for large firms turn statistically significant. So is the case with small firms.

Table 5: Fixed effect cluster-robust-VCE estimates of fuel intensity

	All Firms		Small Firms		Large Firms	
VARIABLES	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
T_{it}=1 for post cdm period; =0 otherwise	0.0303		0.296		0.00656	
	(0.240)		(0.536)		(0.909)	
$T_{i1\text{-}4}$=1; 1-4 years		0.0384		0.332		0.00613
		(0.301)		(0.569)		(0.853)
$T_{i5\text{-}8}$. 5-8 years		-0.133		0.154		-0.00134
		(-1.076)		(0.287)		(-0.171)
cDM_{it}Xlarge project=1;=0 otherwise	-0.0992	-0.107	-0.0120	0.0290	-0.00753	-0.00778
	(-0.869)	(-0.914)	(-0.0528)	(0.118)	(-1.309)	(-1.358)
CDMitXunilateral project=1;=0 otherwise	-0.0286	-0.0475	-0.351	-0.373	-0.00732	-0.00817
	(-0.336)	(-0.561)	(-0.779)	(-0.780)	(-0.990)	(-1.102)
Constant	8.207*	8.232*	11.68*	11.69*	0.371	0.373
	(1.680)	(1.681)	(1.750)	(1.749)	(1.610)	(1.617)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,899	3,899	1,512	1,512	2,387	2,387
Number of firms	509	509	233	233	276	276

Robust t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.1

TFPG

The productivity effects are negative throughout but remain insignificant. These negative effects are larger in the initial years (the coefficient just missed significance) but decline somewhat without changing the sign over time. These results notwithstanding, it is interesting to note that unilateral projects have positive and statistically significant effects on TFPG. It could be that the unilateral projects involve 'learning by doing'. Implementation of CDM projects involves considerable risks, preparations, networking, alliances, collaborations and guidance. This process shapes the learning outcomes of the implementing firms.

Table 6: Fixed effect cluster-robust-VCE estimates of total factor productivity growth: Small vs. Large firms

	All Firms		Small Firms		Large Firms	
VARIABLES	Model 13	Model 14	Model 15	Model 16	Model 17	Model 18
T_{it}=1 for post cdm period; =0 otherwise	-0.717		-1.405		-0.702	
	(-1.595)		(-1.340)		(-1.504)	
T_{i1-4}=1; 1-4 years		-0.717		-1.398		-0.708
		(-1.594)		(-1.325)		(-1.525)
T_{i5-8}. 5-8 years		-0.705		-1.238		-0.766*
		(-1.504)		(-1.000)		(-1.682)
CDM_{it}Xlarge project=1;=0 otherwise	0.214	0.212	0.801	0.744	0.420**	0.417**
	(0.953)	(0.959)	(1.083)	(0.920)	(2.307)	(2.265)
CDMitXunilateral project=1;=0 otherwise	1.004**	1.002**	2.474*	2.455*	0.773*	0.765*
	(2.280)	(2.238)	(1.766)	(1.790)	(1.863)	(1.819)
Constant	1.886	1.897	5.536	5.493	-5.213*	-5.145*
	(0.824)	(0.825)	(1.604)	(1.583)	(-1.762)	(-1.728)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,601	2,601	839	839	1,762	1,762
Number of firms	448	448	188	188	260	260

Robust t-statistics in parentheses; *** p<0.01, ** p<0.05, * p<0.10

It may be seen that TFPG is affected adversely for both small and large firms (Table 6). In the initial years, this could be due to a high cost of implementing these projects. But, in later years, the negative TFPG effects appear counterintuitive. This could partly be due to the global slow down in the post 2008 period, which led to a dramatic fall in carbon prices and severely affected the CDM firms. These results notwithstanding, it is interesting to note that unilateral projects have positive and statistically significant effects on TFPG for both small and large firms.

Overall, the effects of CDM appear insignificant. This could be attributed to the design and use of this mechanism. One reason is that project implementation under CDM involves a multi-stage process, with costs almost at each step of the process: search costs, negotiation costs, PDD costs, approval costs, validation costs, registration costs, monitoring costs, verification and certification costs, and costs accruing from the adaptation fee (Krey, 2004). In the first step, the project developer identifies an opportunity for a CDM project and develops a project design document (PDD). Once a PDD is completed, it is submitted to the host country's Designated National Authority (DNA), which reviews the proposed project and assesses whether it will contribute to national sustainable development goals. If it is satisfied, it issues a "Letter of Approval". The completed PDD is then validated by an accredited auditor, known as a Designated Operational Entity (DOE). After validation, it is submitted to the Executive Board of CDM. The Board assesses the proposal and validation report, and can 1) reject the project; 2) call for it to be improved and re-submitted; or 3) approve it for registration. If it is approved, the project participant is responsible for monitoring actual emissions according to approved methodology. After a certain period of time (typically one year), the project developer is required to hire another accredited auditor (different from the one hired for the validation phase) to verify the amount of emission reductions achieved. The auditor's verification reports are submitted to the CDM Executive Board for approval. Only if these reports are approved then CERs are certified and issued by the Board. These costs might reduce the implementing firm's resources for R&D and other organisational changes, and, in turn its financial performance (Griffith-Jones et al., 2009). Further, a CDM project may be a small part of a firm's overall operations having little impact on its overall performance. In addition, it is argued that the core objective of a project participant in a CDM project is only to generate carbon credits in a cost-effective manner; s/he is not expected to look for knowledge elements beyond the extent necessary for successful operation of the project concerned. Finally, it is argued that CDM may be a small constituent of a broader strategy and may be inconsequential in the absorption of clean technologies. It must however be observed that the type and size of the projects matter.

7. Conclusion and Policy Implications

There is a concern that technology transfer via the CDM has been analysed mainly on the basis of claims made either in project design documents (PDDs) or primary surveys and that there is a little understanding of the actual technology related benefits of CDM (UNFCCC, 2012). The present study is an attempt to better understand the actual benefits. While moving away from claim-based technology transfers or even technological capability, it uses the paradigm of dynamic capability. It estimates reliable effects of CDM implementation on the capability of implementing firms to upgrade their technological assets and assimilate new technologies into their processes to upgrade their performance, using a unique dataset. In an impact assessment analysis based on DiD designs, this study makes the following observations.

One, the CDM implementation does not appear to benefit the implementing firms in terms of building their capability by absorbing the technologies, improving organisational learning, and enhancing their performance. The impact of CDM on domestic R&D turns out to be weakly positive with a time lag particularly for large firms. But, there is little evidence of CDM influencing organisational processes and learning to upgrade dynamic capabilities of firms. Productivity appears to suffer possibly due to high cost of implementing the projects.

Two, even if the positive effects of CDM turn out to be insignificant, the size and type of projects and the size of firms can have important implications. In general, large and multilateral projects are associated with R&D and fuel-efficiency enhancing effects, *albeit* weakly while unilateral projects have productivity enhancing effects. Small firms are more likely to augment R&D expenditures while implementing large projects but learn more from the implementation of unilateral projects (significant productivity effects). Large firms are more likely to improve their R&D while implementing multilateral/bilateral projects. Their productivity growth is positively affected by the implementation of large and unilateral projects.

Clearly, unilateral CDM implementation offers host firms an opportunity of 'learning by doing' in building dynamic capabilities.

In sum, our analysis shows that CDM has the potential of laying a foundation for capability building in the developing countries but in its current form it is not effective. We suggest that there is a need to give the CDM a more explicit agenda of technology transfers. In its current form, its mission is not technology transfer but the generation of low-cost CERs to assist Annex I parties to meet their Kyoto commitments. But this may not address the issues involved in technological upgrading of developing countries. Further, we suggest that the government should arrange for technical, financial and consultancy services on CDM projects to promote large and multilateral projects. We also suggest governments and firms invest in building local absorptive capacity which would further ensure better appropriation of new knowledge and technologies. This in particular is becoming important for the clean technologies niche, as lately, the trend in demand for these technologies is increasing due to increasing environmental concerns. To realise its potential it is also important to introduce institutional reforms in the system so that the transaction costs associated with administering the programme can be kept to a minimum. This will benefit the small firms. Finally, there is a need for a more attractive environment for investors and for greater funding to be made available for CDM implementation. Through appropriate reforms both, in CDM and institutional policies of the host country, CDM can be turned into a valuable instrument to promote diffusion of green technologies in the developing countries.

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REFERENCES

Aggarwal, A. (2011), "South-South Cooperation in Technology Transfers and the Clean Development Mechanism: Some Explorations." *Tech Monitor,* May-June: 37–47.

Bertrand, M., E. Duflo, and S. Mullainathan (2004), "How Much Should We Trust Differences-in-Differences Estimates?" *The Quarterly Journal of Economics,* 119(1): 249-275.

Biorn E. (2004) Regression system for unbalanced panel data: a stepwise maximum likelihood procedure. *Journal of Econometrics* 122: 281-91.

Blackman, A. (1999), "The Economics of Technology Diffusion: Implications for Climate Policy in Developing Countries." *Discussion Paper 99-42,* Resources for the Future, Washington, D.C.

CDM Policy Dialogue (2012), "Climate Change, Carbon Markets and the CDM: A Call to Action." *Report of the High-Level Panel on the CDM Policy Dialogue.* CDM Policy Dialogue.

Chatterjee, B. (2011), "Technology Transfer through the Clean Development Mechanism (CDM)." *Briefing Paper, ED56638,* Centre for European Policy Studies.

Chaudhaya, A., A.D. Sagara, and A. Mathur (2012), "Innovating for Energy Efficiency: A Perspective from India". *Innovation and Development*, 2 (1): 45-66.

Clampet-Lundquist S., M. Douglas S. (2008) "Neighborhood Effects on Economic Self-Sufficiency: A Reconsideration of the Moving to Opportunity Experiment". *American Journal of Sociology* 2008

Cohen, W. M., and D.A. Levinthal (1989), "Innovation and Learning: The Two Faces of R & D." *Economic Journal*, 99: 569–596.

Cohen, W. M., and D. A. Levinthal (1990), "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly*, 35(1): 128-152.

Cooper, C. (1994), "Relevance of Innovation Studies to Developing Countries". In: *Cooper, C.(Ed.), Technology and Innovation in International Economy*. Edward Elgar: UN University Press, 1–37.

Cox, G. (2010), "The Clean Development Mechanism as a Vehicle for Technology Transfer and Sustainable Development – Myth or Reality?" *Law, Environment and Development Journal*, 6 (2): 179–199. Available at http://www.lead-journal.org/content/10179.pdf

Das, K. (2011), "Technology Transfer under the Clean Development Mechanism: An Empirical Study of 1000 CDM Projects." *Working Paper* 014, The Governance of Clean Development, Economic and Social Council Research.

Dechezlepretre, A., M. Glachant, and Y. Meniere (2008), "The Clean Development Mechanism and the International Diffusion of Technologies: An Empirical Study." *Energy Policy*, 36 (4): 1273–1283.

Dechezlepretre, A., M. Glachant, and Y. Meniere (2009), "Technology Transfer by CDM Projects: A Comparison of Brazil, China, India and Mexico." *Energy Policy*, 37 (2): 703–711.

de Coninck, H.C., F. Haake, and N. van der Linden (2007), "Technology Transfer in the Clean Development Mechanism." *Climate Policy*, 7 (5): 444–456.

Doranova, A., I. Costa, and G. Duysters (2011), “The Role of Absorptive Capacity in Technological Learning in CDM Projects: Evidences from Survey in Brazil, China, India and Mexico.” *International Journal of Technology and Globalisation,* 5: 230–254.

Dunning, J.H.(1993), *Multinational Enterprises and the Global Economy.* Addison-Wesley, Reading.

FICCI (2012), “Impacts, Governance and Future of CDM (Indian Industry Perspective).” *Report,* Federation of Indian Chambers of Commerce and Industry, New Delhi, India.

Gandenberger, C., M. Bodenheimer, J.Schleich, R. Orzanna, and L. Macht (2016), “Factors Driving International Technology Transfer: Empirical Insights from a CDM Project Survey.” *Climate Policy,* 16 (8): 1065-1084 DOI: 10.1080/14693062.2015.1069176

Griffith-Jones, S., M. Hedger and L.Stokes (2009, “The Role of Private Investment in Increasing Climate Friendly Technologies in Developing Countries”. Background Paper prepared for *World Economic and Social Survey*.

Haites, E., M. Duan, and S. Seres (2006), “Technology Transfer by CDM Projects”. *Climate Policy,* 6 (3): 327-344.

Hansen, U.E.(2011), “An Empirical Case Study of the Transfer of GHG Mitigation Technologies from Annex 1 Countries to Malaysia under the Kyoto Protocol's Clean Development Mechanism (CDM)”. *International Journal of Technology Transfer and Commercialisation*, 10 (1): 1-20.

Johnstone, N., I. Haščič, and F. Watson (2010), *Climate Policy and Technological Innovation and Transfer: An Overview of Trends and Recent Empirical Results, No.30, OECD Environment Working Papers, OECD Publishing,* OECD, Paris.

IPCC (2000), *Methodological and Technological Issues in Technology Transfer.* Cambridge University Press, Cambridge.

Krey, M. (2004), “Transaction Costs of CDM Projects in India – An Empirical Survey,” *HWWA-Report 238* Hamburgisches Welt-Wirtschafts-Archiv (HWWA), Hamburg Institute of International Economics.

Kumar, N., and A. Aggarwal (2005),"Liberalization, Outward Orientation and In-house R&D Activity of Multinational and Local Firms: A Quantitative Exploration for Indian Manufacturing". *Research Policy,* 34 (4): 441–40.

Lema, A., and R. Lema (2013), "Technology Transfer in the Clean Development Mechanism: Insights from Wind Power". *Global Environmental Change*, 23 (1): 301–313.

Liang, K-Yee., and S.L. Zeger (1986), "Longitudinal Data Analysis Using Generalized Linear Models". *Biometrika,* 73 (1): 13-22.

Lim, K., and Michael R. Falk (2013), "Absorptive Capacity". In Mie Augier and David J. Teece (Eds.), *The Palgrave Encyclopedia of Strategic Management.* Palgrave Macmillan Publishers Ltd. New York.

Lütken, S., and A. Michaelowa (2008), *Corporate Strategies and the Clean Development Mechanism: Developing Country Financing for Developed Country Commitments?* Edward Elgar, UK.

Markusen, J.(1995), "The Boundaries of Multinational Enterprises and the Theory of International Trade". *Journal of Economic Perspectives,* 9 (2): 169–189.

Maskus, K. E. (2004), "Encouraging International Technology Transfer". *Issue Paper No. 7,* UNCTAD/ICTSD, Geneva.

Murphy K., G.A. Kirkman, S. Seres and E. Haite (2013), Technology Transfer in the CDM: An Updated Analysis". *Climate Policy,* 15(1):127-145.

Nelson, R. R., and S.J. Winter (1982), *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge.

Niederberger, A.A., and R. Saner (2005), "Exploring the Relationship between FDI Flows and CDM Potential". *Transnational Corporations,* 14 (1): 1–41.

Ockwell, D. G., J. Watson, G. MacKerron, P. Pal, and F. Yamin (2008), "Key Policy Considerations for Facilitating Low Carbon Technology Transfer to Developing Countries". *Energy Policy,* 36 (11): 4104-4115.

OECD/IEA (2001), *Technology without Borders: Case Studies in Successful Technology Transfer*. OECD/IEA, Paris.

Olsen, K. H. (2007), "The Clean Development Mechanism's Contribution to Sustainable Development: A Review of the Literature". *Climatic Change,* 84 (1): 59–73.

Schneider, M., A. Holzer, and V. H. Hoffmann (2008), "Understanding the CDM's Contribution to Technology Transfer". *Energy Policy,* 36 (8): 2930– 2938.

Schneider, M., V. H. Hoffmann, and B. R. Gurjar (2009), "Corporate Responses to the CDM: the Indian Pulp and Paper Industry". *Climate Policy,* 9(3), 255-272.

Sepibu, J.D. (2009), "Reforming the Clean Development Mechanism to Accelerate Technology Transfer". *Working Paper No 2009/42,* Swiss National Centre for Competency in Research.

Seres, S. (2007), *Analysis of Technology Transfer in CDM Projects.* UNFCCC Secretariat, Bonn.

Seres, S., and E. Haites (2008), "*Analysis of Technology Transfer in CDM Projects".* UNFCCC Registration & Issuance Unit CDM/SDM, Bonn.

Sterk, W. et al. (2009), "Further Development of the Project-Based Mechanisms in a Post-2012 Regime". Wuppertal Institute for Climate, Environment and Energy, Wuppertal.

Teece, D.J. (1977), "Technology Transfer by Multinational Firms: The Resource Cost of Transferring Technological Know-how". *Economic Journal,* 87 (346): 242–261.

Teece, D. J., and G. Pisano (1994), "The Dynamic Capabilities of Firms: An Introduction". *Industrial and Corporate Change,* 3(3): 537–556.

Teece, D., G. Pisano, and A. Shuen (1997), "Dynamic Capabilities and Strategic Management ". *Strategic Management Journal,* 18(7): 509–533.

Altenburg,T., and Anna Pegels (2012), "Sustainability-oriented Innovation Systems – Managing the Green Transformation". *Innovation and Development,* 2(1): 5-22, DOI: 10.1080/2157930X.2012.664037

Todeva, E., and David Knoke (2005), “Strategic Alliances and Models of Collaboration”. *Management Decision*, 43(1): 123-148.

UN (1972), *Declaration of the United Nations Conference on the Human Environment*

UNCTAD (2010), “Investing in a Low-Carbon Economy”. *World Investment Report,* United Nations.

UNFCCC (2010), “The Contribution of the Clean Development Mechanism under the Kyoto Protocol to Technology Transfer”. Available at http://cdm.unfccc.int/about/CDM_TT/index.html

United Nations Framework Convention on Climate Change (UNFCCC) (2011), “Benefits of the Clean Development Mechanism 2011”. Available at: https://cdm.unfccc.int/about/dev_ben/pg1.pdf

UNFCCC (2012), Benefits of the Clean Development Mechanism, United Nations Framework Convention on Climate Change downloaded on 20 December, 2014 https://cdm.unfccc.int/about/dev_ben/ABC_2012.pdf downloaded on 22 December 2014

Walz, R., and J.N. Delgado (2012), ‘Different Routes to Technology Acquisition and Innovation System Building? China’s and India’s Wind Turbine Industries”. *Innovation and Development*, 2 (1):87-109, DOI: 10.1080/2157930X.2012.667209

Wang, B (2009), “Can the CDM Bring Technology Transfer to Developing Countries? An Empirical Study of Technology Transfer in China’s CDM Projects”. *Working Paper 002,* The Governance of Clean Development, University of East Anglia.

Weitzel, M., W-H. Liu, and A. Vaona (2014), “Determinants of Technology Transfer through the CDM: A within-country Analysis for China, *Climate Policy*, 15 (5): 626-646.

World Bank (2010), *World Development Indicators 2010*, World Bank Publications, Washington, D.C.

Xie, L., S. Zeng, H. Zou, V.W.Y.Tam, and Z. Wu (2013), “Technology Transfer in Clean Development Mechanism (CDM) Projects: Lessons from China”. *Technological and Economic Development of Economy*, 19 (Suppl.1): S471-S495.

Yang, Z (1999), "Should the North Make Unilateral Technology Transfers to the South? North–South Cooperation and Conflicts in Responses to Global Climate Change". *Resource and Energy Economics*, 21 (1): 67–87.

Youngman, R., J. Schmidt, J. Lee, and H. de Coninck (2007), "Evaluating Technology Transfer in the Clean Development Mechanism and Joint Implementation". *Climate Policy*, 7 (6): 488-499.

Zahra, S.A., and G. George (2002), "Absorptive Capacity: A Review, Reconceptualization, and Extension". *Academy of Management Review*, 27 (2): 185-203.

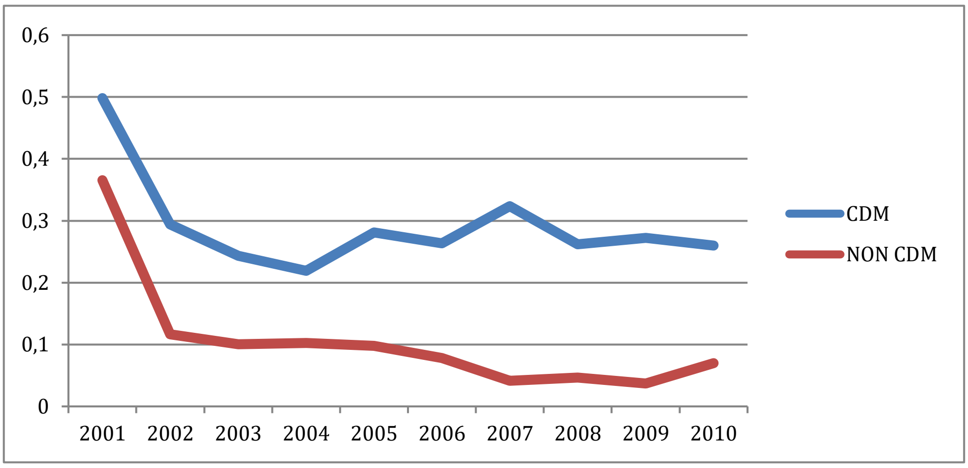
Zawislak, P.A. et al, (2012), "Innovation Capability: From Technology Development to Transaction Capability". *Journal of Technology Management and Innovation*, 7 (2): 14-27.

APPENDIX

Validity of parallel trend assumption

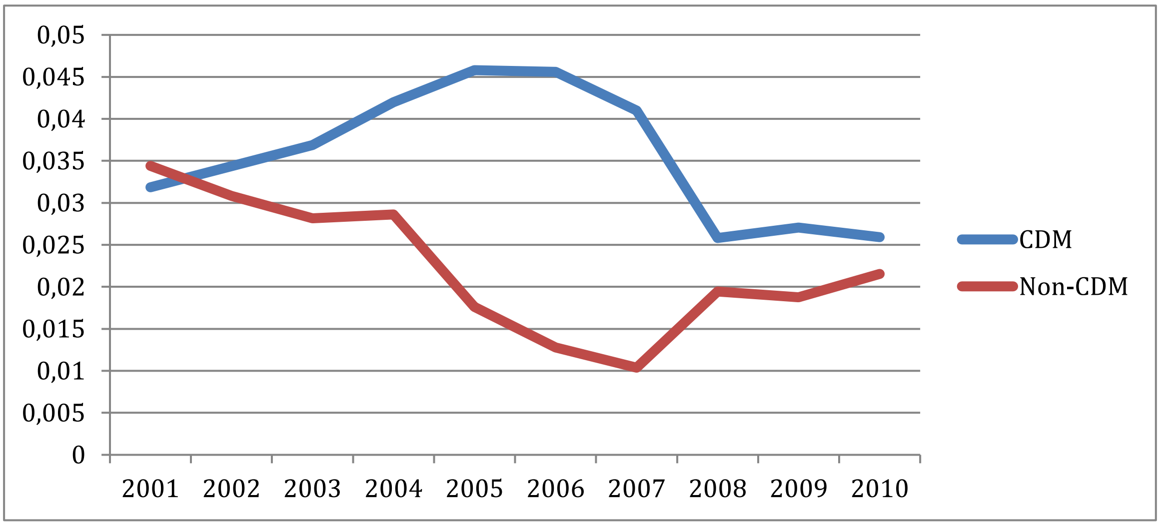
R&D intensity: Figure A1 presents trends in R&D intensity for the CDM and non-CDM firms. It shows that the assumption of parallel trend assumption is satisfied here. While the R&D intensity of non CDM firms continues to decline until 2007 when it stabilised, that of CDM firms improved after 2004.

Figure A1: Average annual R&D to sales ratio of CDM and Non-CDM firms



Fuel Intensity: Figure A2 shows the common trend assumption is satisfied by fuel intensity as well over a short period. While the fuel intensity has risen for CDM firms, it was declining for non-CDM firms. The gap between the two enlarged in the post CDM period. After 2006, however, fuel intensity started declining for CDM firms and it declined sharply. It was partly because of the fact that low fuel intensity firms also started initiating the CDM projects. After controlling the firms' specific effects, it turned out to be insignificant in the DiD analysis.

Figure 2: Average annual fuel expenses to sales ratio of CDM and Non-CDM firms



Productivity growth: Productivity growth patterns before 2003 cannot be discerned from the data that we have. However, it may be seen that productivity growth has been declining in both CDM and non-CDM firms, and that the gap between the two seems to be reducing (Figure A3). However, for the validity of these results, there is need for a longer time series.

Figure A3: Average annual productivity growth rates of CDM and Non-CDM firms