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The Clean Development Mechanism and Dynamic Capabilities of Implementing Firms: Evidence from India

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Contents

Abstract

This study assesses the impact of the Clean Development Mechanism (CDM) on the dynamic capabilities of implementing firms in India. While doing so, it uses three indicators of firms' dynamic capabilities: R&D expenditures to sales ratio, fuel consumption to sales ratio and total factor productivity growth. It moves away from the analysis of technology transfer claims made in either Project Development Documents or primary surveys to use actual information on firms' performance for the analysis. A difference-in-difference design is used by defining CDM-implementing firms as the treatment group and non-CDM firms as the control group for the pre- and post-CDM implementation periods. We control for unobserved fixed effects of firms and time periods and observed characteristics of firms and CDM projects. The analysis draws on the balance sheet data of 612 firms from India between 2001 and 2012 from the PROWESS database. Our results reveal that the CDM implementation does not have significant outcome effects on the dynamic capabilities of firms. Much depends on the type and size of the project, and size of the firm.

Keywords

CDM, Dynamic capability, R&D, Fuel efficiency, Total factor productivity, India

JEL Classification: C21, O3, Q54, Q55

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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, thus far, most of them have been developed and tested in developed countries. Developing countries, which are at a greater risk of climate change impacts due to much of their population living in physically exposed locations and 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), 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 available to them to catch up with the developed world: i) developing the technology by their own means; ii) purchasing it from developed countries; and iii) 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 the developing countries brought the issue of technology transfer in the environmental context on the international agenda as early as in 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 fora 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. The Kyoto Protocol's Clean Development Mechanism (CDM) established in 1997 is by far the most successful carbon offset market-based mechanism that incentivises the private sector to transfer low-carbon technology to developing countries (Schneider *et al*., 2008). It is a project-based mechanism in which eligible entities from developed countries are expected to finance emission reduction projects in developing countries and use carbon credits generated by them to meet a portion of their greenhouse gas (GHG) reduction commitments under the 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 and build firms' capabilities in clean technologies (OECD/ IEA, 2001; Ockwell *et al*., 2008; 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; Dechezlepretre *et al*., 2008, 2009; De Coninck *et al*., 2007; Doranova *et al*., 2009; Haites *et al*., 2006; Hansen, 2011; Sepibu, 2009; Lema and Lema, 2013; Schneider *et al*., 2008; Seres, 2007; Wang 2010; Youngman *et al*., 2007 among others). However, most studies are based on either *ex-ante* evidence (projected effects) or perceptions of managers of the CDM-implementing firms gathered through primary surveys. While this research builds on the existing literature, it also contributes in two ways. First, 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 capability,' which goes beyond a focus on the accumulation of technology assets and 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; Teece, 2007). The concept of dynamic capability is captured by using three indicators: indigenous R&D efforts, fuel efficiency and total factor productivity growth (TFPG). Second, unlike the existing studies, the present study uses the balance sheet data of host firms to establish the relationship between CDM implementation and its impact on them after controlling for other effects. 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 randomly selected CDM-implementing and non-implementing firms over 2001 to 2011.

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 policymakers 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 a 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, which has been one of the largest CDM-implementing countries in the world. According to the UNFCCC database, as of 31 December 2013, there were 7,418 projects registered worldwide; of which, India alone initiated 1,468 projects accounting for almost 20 per cent of the global share, and issued 0.19 billion tons of Certified Emission Reductions (CERs) (more than 13% of worldwide CERs). India occupies second place in terms of its share in registered CDM projects and the investment undertaken therein, after only China. Thus, the insights provided by the study may have useful implications for other developing countries as well.

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

2.1 Mechanisms of technology transfer through CDM

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 goods and services' is one. All 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 investor in CDM projects, 2) purchase of yet-to-be-generated CERs, and 3) purchase of CERs in the secondary market. These mechanisms correspond to 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 (UNCTAD, 2010; Niederberger and Saner, 2005). 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 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 (Lutken 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.

The transfer of technology may help firms build their technology assets; but this may not be sufficient to confer on 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 Zawislak *et al* 2012; Kwanghui and Falk 2013). The capacity of a firm to "appropriately adapt, integrate, and reconfigure internal and external organizational 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 green technology through 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 markets. This opens new sources of knowledge and experience for the firm which facilitates its organisational learnings from others' experiences, 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 have competitiveness enhancing effects (Todeva and Knoke, 2005 for literature survey). The firm leverages these technological, organisational and managerial learnings to ensure it a superior performance. Whether it actually happens is a matter of empirical testing.

2.2 Hypotheses

To empirically assess the impact of CDM projects, 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 following testable hypotheses corresponding to these three channels.

H_1: CDM-implementing firms are likely to spend more on local R&D efforts than their non-implementing counterparts

Technological learning requires conscious allocation of funds on domestic R&D efforts (Cooper, 1994; Nelson and Winter, 1982; Lall 1992). A technology transfer results in absorption capabilities provided that the host firm accelerates its in-house technological efforts towards adapting or improving upon the imported technology and/or equipment.

H_2: CDM implementation enhances fuel efficiency of the host firms

CDM implementation may enhance a firm's technology asset but it may not yield it 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 had been 59.4% while energy efficiency/fuel switch comprised of another 17.2% projects. We thus expect CDM implementation to affect dynamic capability of implementing firms positively if it enhances their fuel efficiency by reducing fuel intensity.

H_3: CDM implementation improves TFPG of the host firms

Technology learning and its integration with production process need to be leveraged by other organizational capabilities (such as skill management, marketing and distribution) to yield it distinct competitive advantages. These competitive advantages may generate rents in terms of its performance. There are several measures of performance. But, in the literature, growth by TFPG is considered to be one of the most comprehensive measures of technical and organizational efficiency of a firm. In general, we may expect a positive relationship between TFPG growth and CDM implementation.

2.3 Caveats

Although these hypotheses are phrased as a positive relationship between CDM implementation and technological capabilities of host firms, empirically the relationship may turn out to be rather weak. 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). These costs might reduce the implementing firm's resources for R&D and other organizational changes, and, in turn its financial performance. In the first step, the project developer, identifies an opportunity for a CDM project and develops a project design document (PDD) which includes a baseline estimate and an analysis of the net carbon. 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. After registration, projects generally move forward for implementation. 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. If these reports are approved, CERs are certified and issued by the Board.

Further, a CDM project may be a small part of a firm's overall operations having little impact on its overall performance. Concerns have also been expressed that technology transfer through CDM may replace domestic R&D efforts. 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. The link between CDM implementation and technological capability is therefore a matter of empirical testing.

3. CDM and Dynamic Capabilities of Firms in India

In general, the existing studies on the relationship between CDM implementation and firms' capabilities tend to focus narrowly on technology transfers. This literature can be divided into three categories: one, those based on Project Design Documents (PDDs); two, those based on primary surveys; and three, case studies (Cox, 2010; Hansen, 2011; Lema and Lema, 2013).

The PDDs provide information on whether or not technology transfer would be involved in the implementation of the project. Most existing studies use these documents for analysing technology transfer through CDM (See Cox, 2010 for a survey). Since 2007, the UNFCCC secretariat has been compiling and publishing information contained in these documents on 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 per cent) and unilateral projects (84%) are further expected to limit the role of CDM in building capabilities to move towards clean economy in India.

The PDDs based evidence suggests that small-scale and unilateral projects involve significantly less technology transfer than their large counterparts (Aggarwal, 2011). It is also indicated that CDM projects hosted in India are found to be 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; Dechezlepretre *et al*., 2009; Seres, 2007, 2008).

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. She too finds that a mere 4.9% of the projects involved technology transfer for India against 26.5% for all 1000 projects. Her analysis shows that in most projects technological learning and capability building is confined only to the basic or operational level. In a nutshell, the analysis of growth and patterns of CDM projects, and technology transfer claims made therein and reported in PDDs indicate that 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*. (2009) 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 taken place neither in unilateral projects nor in bilateral/multilateral projects due to the lack of financial assistance.

Finally, in their case study 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.

The existing literature on CDM technological capability thus depicts a passive role that CDM can play shifting developing countries to clean technologies. 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 the actual and is found to understate the latter. UNFCCC (2011, 2012) reports that in post-CDM implementation surveys many of those projects were found to involve technology transfers that were not anticipated when the PDD was prepared.

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 a gap by using a large secondary database of firms to retrospectively assess the impact of CDM projects.

4. The Model and Methodology

We use the panel data based DiD technique for the 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. A standard DiD model is

$$Y_{it} = \alpha_1 + \alpha_2 D_i + \alpha_3 T_t + \alpha_4 D_i * T_t + bX'_{it} + \varepsilon_{it} \cdot \quad (1)$$

where D is a group dummy that captures possible differences between the treatment and control groups prior to the treatment and T is a dummy for the post treatment period that controls for factors that would cause changes in Y over time even in the absence of the treatment. The coefficient of interest, i.e. the DiD estimator, is $\alpha 4$, the coefficient on the interaction of D and T.

In our data, the CDM implementation year differs across firms, and so, there is no single time dummy "T" that represents the common year of treatment. A general model in this case is

$$Y_{it} = \alpha_1 + \alpha_2 \mathrm{CDM}_{it}.*T'_{it} + bX'_{it} + T_t + v_i + \varepsilon_{it} \cdot \quad (2)$$

In this specification, $CDM_{it}*T_{it}$ 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. For robustness check, we use two alternative specifications of this variable. The second specification thus allows the effect of CDM participation to change over time (e.g., to become stronger or weaker later in the project). In this specification we have used an alternative specification for this variable ($CDM_{it}*T_{ig}$). where T_{ig} represents two broad periods: first 4 years of implementation and thereafter.

$$Y_{it} = \alpha_1 + \alpha_2 CDM_{it}.*T'_{ig} + bX'_{it} + T_t + v_i + \varepsilon_{it} \cdot \quad (2a)$$

We conducted regressions with the 4th, and 5th year as the cut off and finally reported results with the former as the cut off points points with T_{ig} broken down into two dummies: T_{i1-4},T_{i5-9}),. The third specification replaces T'_{ig} by $T´_{it}$ where the latter is a vector of annual time dummies after the start of a given CDM project.

$$Y_{it} = \alpha_1 + \alpha_2 CDM_{it}.*T'_{it} + bX'_{it} + T_t + v_i + \varepsilon_{it} \cdot \quad (2b)$$

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

Finally, we identify four sets of control variables capturing project-, firm-,sector- and time specific effects. The controls are drawn on the relevant literature. Table 1 provides a summary list of variables with their definitions. Three sets of regression equations were estimated one for each dependent variable.

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, 2002), we cluster standard errors by firm.

In addition to estimating the models with 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 dividing the observations fairly into two categories.

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 the structure of the projects implemented by sample and 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 selected 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 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. However, its relationships with R&D intensity and TFPG are ambiguous. These results need to be validated after controlling the effect of other variables. The DiD based results are presented in Tables 4 to 9.

6. Empirical Results

R&D intensity

There has been a vast 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 equation 2 to incorporate the relevant variables in the model. The results are presented in Table 4. The variables come up with expected signs in all specifications *albeit* weakly, after controlling for the year- and firm- specific fixed effects. While focusing on the main variables, we find evidence that R&D intensity increases in the post CDM implementation period with a time lag. While the cumulative (cdm_{it}) and yearly effects are insignificant, $D*T_{i5-10}$ comes up significant with a positive sign (Model 2). Since the dummy cdmit×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. But, the t-statistics misses significance in some cases at 10% level. Project size does not appear to matter.

Table 5, which presents the results for small and large firms separately, shows 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. This is particularly evident in Model 8 which breaks down the post CDM period into two broad periods: first to fourth year of initiation and thereafter. In other models for large firms (Models 7 and 9) the DiD estimators miss significance. Notably, however, the dummy for bilateral/multilateral projects is significant in all specifications for large firm underlying their role in promoting R&D by them. Small firms on the other hand do not appear to augment their R&D expenditures in the post CDM implementation period, in general. The DiD estimators turn insignificant in all specifications; even if they are positive throughout. But, large projects do influence their have R&D efforts positively.

A careful scrutiny of the results pertaining to control variables presented in Models 4-9 indicates that the firm size-R&D intensity relationship is horizontal S-shaped. Very small firms appear to have a very high R&D intensity which declines with firm size up to a threshold level, beyond which it rises to another threshold before falling again with size. This result is consistent with Kumar and Aggarwal (2005). The dummy variable for engineering and chemical industries d_rd emerges positive but remains insignificant in all models. This means that engineering and chemicals industries do not have a higher R&D intensity than the other industries. This is contrary to our expectation. It may be that there is diffusion of R&D activity across various sectors. Finally, R&D spending decisions of firms, in particular those of large firms seem to be significantly guided by the exporting activity, which expose them to severe technological competition.

Fuel intensity

It turns out that the CDM implementation is negatively (positively) related with fuel intensity (efficiency) (SeeTable 6). But these effects become visible after a long gestation period. In Model 12 (See Table 6), they become significant after 6 years of gestation. Other models could not fully capture the positive effects of CDM on fuel efficiency. It may also be seen that fuel intensity (efficiency) declines (increases) with firm size but after a threshold level it starts increasing (decreasing) with firm size. Thus, the large firms have a greater pressure to reduce their energy intensity due to high fuel intensity. A disaggregated analysis by firm size in Table 7 offers weak evidence that the large firms may be more benefitted by technological learning in particular when they implement large projects. However, 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. The CDM based fuel efficiency gains are positive for small firms also but they come with a time lag and miss statistical significance irrespective of the size and type of projects. A comparative analysis of the results in Table 6 and 7 reveals that fuel intensity declines across firms of different sizes producing a positive effect on fuel efficiency in general; but, the size and type of the projects have a statistically insignificant effect on it.

Productivity effects

The productivity effects, as presented in Tables 8 and 9, are negative throughout but remain insignificant/ weakly significant. These negative effects are larger in the initial years but decline somewhat without changing the sign over time. The negative effects in the initial years are relatively more pronounced for the small firms (See Table 9). This could be due to the cost of implementing these projects which affect them more seriously. 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. 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. It must also be noted that the effect of large projects is also positive and turns significant for large firms. .

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 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 in this direction. While moving away from claim-based technology transfers or even technological capability, it uses the paradigm of dynamic capability and estimates reliable effects of CDM implementation on dynamic capability of implementing firms using a unique dataset. In an impact assessment 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 dynamic capability. The impact of CDM on domestic R&D turns out to be positive particularly for large firms. But it remains statistically weak. There is also evidence of improvement in fuel efficiency but it remains statistically weak. Productivity, on the other hand, 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 large 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 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 it is not effective in its current form. 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 alone may not address the issues involved in technological upgrading of the host firms. Further, we suggest governments and firms to invest in building local absorptive capacity which would further ensure better appropriation of new knowledge and technologies. This is particularly becoming important for the clean technologies niche as the trend in demand for these technologies is lately 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 minimum. This will benefit the small firms. Finally, there is a need for more attractive environment for investors and greater funding 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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Tables

Table 1: List of variables with definition

Variable name	Variable Definition
	Dependent variables
R&D Intensity	RD expenditure to sales ratio
Fuel intensity	Fuel expenditure to sales ratio
TFPG	Total factor productivity growth calculated using the Solow method
	Main 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 $_i$
$T_i1....T_i10$	T_i1=1 for the first year of implementation of the project, T_i2=1second year after the project is implemented, and so on for firm $_i$
T_i1-4 and T_i5-10	T_i1-4=1 for the first 4 years of CDM implementation and T_i5-10 =1 for the later years for firm $_i$
	Project specific controls
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.
	Firm specific controls
Firm size	Log of sales
Export intensity	exports to sales ratio
Profit margins	Profits to sales ratio
vi	Firm specific dummies/fixed effects
	Sector specific controls
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
	Time specific controls
Tt	Year dummies

Table 2: A comparative analysis of sample vs census database

Project specific factors	Type of project	% Share in Sample	% Share in Census
	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
	N2O 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
Size	Small projects	58	70.5

Source:Based on PROWESS

Table 3: Descriptive statistics of the outcome variables

	Firm	Year	Observations	Average	Standard deviation	t- statistics1
Fuel-intensity	CDM	First year of initiation	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 initiation	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 initiation	151	0.182	1.063	
	CDM	2010	204	-0.125	1.19	**-2.556*****
	Non CDM	2010	148	-.559	2.95	**-1.693***

Notes: 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%, ** = 5%, and *** = 1%; Bold with no star=just missed significance at 10%.

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

VARIABLES	(1) Model 1	(2) Model 2	(3) Model 3
T_{it}=1 for post cdm period; =0 otherwise	0.107		
	(1.284)		
T_i1-4=1; 1-4 years		0.0993	
		(1.183)	
T_i5-10. 5-9 years		0.256**	
		(2.283)	
T_i1=1 for initial year of cdm			0.127
			(1.159)
T_i2=1 for post 1 year			0.0290
			(0.289)
T_i3=1 Post 2 years			0.125
			(1.436)
T_i4=1 Post 3 years			0.0443
			(0.344)
T_i5=1 Post 4 years			0.373*
			(1.709)
T_i6=1 Post 5 years			0.0585
			(0.372)
T_i7=1 Post 6 years			0.175
			(1.269)
T_i8=1 Post 7 years			0.230
			(1.446)
T_i9=1 Post 8 years			0.126
			(0.634)
T_i10=1 Post 9 years			0.221
			(1.251)
CDMitXlarge project=1;=0 otherwise	-0.0454	-0.0408	-0.0447
	(-0.637)	(-0.588)	(-0.625)
CDMitXunilateral project=1;=0 otherwise	-0.136*	-0.120	-0.120
	(-1.807)	(-1.630)	(-1.607)
Sales in log	0.0305	0.0421	0.0383
	(1.153)	(1.436)	(1.452)
Sales square in log	0.00177	0.000281	0.000754
	(0.347)	(0.0671)	(0.159)
d_rd=1 for technology intensive sectors	0.161	0.166	0.159
	(1.156)	(1.193)	(1.155)
Exports to sales ratio	0.00677	0.00604	0.00783
	(1.070)	(0.992)	(1.120)
Profit sales ratio	-4.23e-05	-4.31e-05	-5.31e-05
	(-0.184)	(-0.170)	(-0.212)
Constant	0.111	0.108	0.107
	(0.372)	(0.359)	(0.370)
Time effects	Yes	Yes	Yes
Observations	4,183	4,183	4,183
Number of code	536	536	536

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

Table 5: Fixed effect cluster-robust-VCE estimates of R&D intensity: Small vs large firms

	Small firms			Large Firms		
VARIABLES	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
T_{it}=1 for post cdm period; =0 otherwise	0.0606			0.0956		
	(0.761)			(1.022)		
T_i1-4=1; 1-4 years		0.0528			0.105	
		(0.749)			(1.169)	
T_i5-10. 5-9 years		0.105			0.275*	
		(0.837)			(1.660)	
T_i1=1 for initial year of cdm			0.0286			0.126
			(0.723)			(1.008)
T_i2=1 for post 1 year			0.0500			0.00448
			(0.807)			(0.0408)
T_i3=1 Post 2 years			0.0547			0.124
			(0.669)			(1.293)
T_i4=1 Post 3 years			0.0741			0.0105
			(0.730)			(0.0784)
T_i5=1 Post 4 years			0.0966			0.405
			(0.814)			(1.348)
T_i6=1 Post 5 years			0.0944			0.0107
			(0.772)			(0.0664)
T_i7=1 Post 6 years			0.131			0.134
			(0.853)			(0.909)
T_i8=1 Post 7 years			0.148			0.191
			(0.921)			(1.093)
T_i9=1 Post 8 years			0.147			0.0506
			(0.876)			(0.233)
T_i10=1 Post 9 years			0.162			0.193
			(0.911)			(0.865)
CDMitXlarge project=1;=0 otherwise	0.171*	0.160*	0.162*	-0.0560	-0.0527	-0.0562
	(1.762)	(1.670)	(1.689)	(-0.658)	(-0.633)	(-0.660)
CDMitXunilateral project=1;=0 otherwise	0.0453	0.0495	0.0566	-0.165*	-0.146*	-0.148*
	(0.913)	(1.001)	(1.057)	(-1.787)	(-1.647)	(-1.648)
Sales in log	0.0507	0.0512	0.0514	0.185	0.197	0.193
	(1.296)	(1.290)	(1.282)	(1.190)	(1.197)	(1.197)
Sales square in log	-0.00934	-0.00945	-0.00948	-0.00668	-0.00762	-0.00737
	(-1.345)	(-1.338)	(-1.323)	(-0.974)	(-1.086)	(-1.044)
Export to sales ratio	0.00254	0.00217	0.00175	0.0419***	0.0408***	0.0462***
	(0.941)	(0.882)	(0.739)	(4.438)	(4.637)	(4.507)
Profit-sales ratio	4.44e-05	4.08e-05	3.79e-05	-0.0156	-0.0174	-0.0152
	(0.500)	(0.470)	(0.445)	(-0.730)	(-0.770)	(-0.697)
d_rd=1 for technology intensive sectors				0.209	0.210	0.200
				(0.990)	(0.993)	(0.960)
Constant	0.181**	0.181**	0.181**	-0.487	-0.518	-0.507
	(2.379)	(2.372)	(2.324)	(-0.502)	(-0.520)	(-0.521)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,679	1,679	1,679	2,504	2,504	2,504
Number of code	254	254	254	282	282	282

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

Table 6: Fixed effect cluster-robust-VCE estimates of fuel intensity

VARIABLES	Model 10	Model 11	Model 12
T_{it}=1 for post cdm period; =0 otherwise	0.0303		
	(0.240)		
T_i1-4=1; 1-4 years		0.0384	
		(0.301)	
T_i5-10. 5-9 years		-0.133	
		(-1.076)	
T_i1=1 for initial year of cdm			0.0334
			(0.289)
T_i2=1 for post 1 year			0.0434
			(0.314)
T_i3=1 Post 2 years			-0.0207
			(-0.165)
T_i4=1 Post 3 years			-0.0437
			(-0.363)
T_i5=1 Post 4 years			-0.0982
			(-0.782)
T_i6=1 Post 5 years			-0.170
			(-1.259)
T_i7=1 Post 6 years			-0.253*
			(-1.655)
T_i8=1 Post 7 years			-0.364*
			(-1.886)
T_i9=1 Post 8 years			-0.348*
			(-1.803)
T_i10=1 Post 9 years			-0.529*
			(-1.925)
CDMit Xlarge project=1;=0 otherwise	-0.0992	-0.107	-0.114
	(-0.869)	(-0.914)	(-0.957)
CDMit X unilateral project=1;=0 otherwise	-0.0286	-0.0475	-0.0545
	(-0.336)	(-0.561)	(-0.640)
Sales in log	-2.059*	-2.077*	-2.095*
	(-1.721)	(-1.724)	(-1.726)
Sales square in log	0.125*	0.127*	0.129*
	(1.764)	(1.768)	(1.771)
d_proj=1 for energy efficiency project	-0.202	-0.185	-0.172
	(-1.239)	(-1.109)	(-1.020)
Export to sales ratio	-0.0613	-0.0608	-0.0598
	(-1.138)	(-1.134)	(-1.124)
Constant	8.207*	8.232*	8.267*
	(1.680)	(1.681)	(1.681)
Time effects	Yes	Yes	Yes
Observations	3,899	3,899	3,899
R-squared	0.089	0.089	0.090
Number of code	509	509	509

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

Table 7: Fixed effect cluster-robust-VCE estimates of fuel intensity: Small vs large 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	0.296			0.00656		
	(0.536)			(0.909)		
T_i1-4=1; 1-4 years		0.332			0.00613	
		(0.569)			(0.853)	
T_i5-10. 5-9 years		0.154			-0.00134	
		(0.287)			(-0.171)	
T_i1=1 for initial year of cdm			0.314			0.00730
			(0.543)			(1.022)
T_i2=1 for post 1 year			0.355			0.00699
			(0.579)			(0.902)
T_i3=1 Post 2 years			0.357			0.00291
			(0.570)			(0.397)
T_i4=1 Post 3 years			0.360			-0.00144
			(0.587)			(-0.187)
T_i5=1 Post 4 years			0.312			-0.00325
			(0.509)			(-0.387)
T_i6=1 Post 5 years			0.150			-0.00510
			(0.276)			(-0.601)
T_i7=1 Post 6 years			0.102			-0.00680
			(0.181)			(-0.719)
T_i8=1 Post 7 years			-0.00668			-0.0101
			(-0.0126)			(-0.912)
T_i9=1 Post 8 years			-0.133			-0.00605
			(-0.240)			(-0.496)
T_i10=1 Post 9 years			-0.643			-0.0120
			(-0.891)			(-0.928)
cDMitXlarge project=1;=0 otherwise	-0.0120	0.0290	0.00592	-0.00753	-0.00778	-0.00788
	(-0.0528)	(0.118)	(0.0240)	(-1.309)	(-1.358)	(-1.379)
CDMitXunilateral project=1;=0 otherwise	-0.351	-0.373	-0.403	-0.00732	-0.00817	-0.00856
	(-0.779)	(-0.780)	(-0.812)	(-0.990)	(-1.102)	(-1.149)
Sales in log	-3.773*	-3.778*	-3.779*	-0.0557	-0.0564	-0.0572
	(-1.939)	(-1.938)	(-1.933)	(-1.130)	(-1.141)	(-1.151)
Sales square in log	0.309**	0.310**	0.309**	0.00225	0.00229	0.00235
	(2.127)	(2.126)	(2.121)	(0.897)	(0.913)	(0.930)
Export to sales ratio	-0.101	-0.100	-0.0974	0.0269	0.0276	0.0280
	(-1.326)	(-1.322)	(-1.301)	(1.150)	(1.206)	(1.228)
d_proj=1 for energy efficiency project				-0.0200	-0.0193	-0.0186
				(-0.838)	(-0.812)	(-0.781)
Constant	11.68*	11.69*	11.71*	0.371	0.373	0.375
	(1.750)	(1.749)	(1.744)	(1.610)	(1.617)	(1.620)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,512	1,512	1,512	2,387	2,387	2,387
Number of code	233	233	233	276	276	276

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

Table 8: Fixed effect cluster-robust-VCE estimates of TFPG

VARIABLES	Model 19	Model 20	Model 21
T_{it}=1 for post cdm period; =0 otherwise	-0.717		
	(-1.595)		
T_i1-4=1; 1-4 years		-0.717	
		(-1.594)	
T_i1=1 for initial year of cdm		-0.735	
		(-1.504)	
T_i2=1 for post 1 year			-0.631
			(-1.415)
T_i3=1 Post 2 years			-0.845*
			(-1.790)
T_i4=1 Post 3 years			-0.785
			(-1.497)
T_i5=1 Post 4 years			-0.435
			(-0.824)
T_i6=1 Post 5 years			-0.653
			(-1.276)
T_i7=1 Post 6 years			-0.684
			(-1.200)
T_i8=1 Post 7 years			-0.668
			(-1.179)
T_i9=1 Post 8 years			-0.447
			(-0.730)
T_i10=1 Post 9 years			-0.606
T_i1=1 for initial year of cdm			(-0.950)
			-0.487
			(-0.716)
CDMitXlarge project=1;=0 otherwise	0.214	0.212	0.224
	(0.953)	(0.959)	(1.023)
CDMitXunilateral project=1;=0 otherwise	1.004**	1.002**	1.018**
	(2.280)	(2.238)	(2.284)
Sales in log	-0.523	-0.526	-0.495
	(-1.001)	(-1.002)	(-0.935)
Sales square in log	0.0400	0.0403	0.0374
	(1.336)	(1.331)	(1.228)
Export to sales ratio	0.0332	0.0335	0.0400
	(1.028)	(1.019)	(1.125)
Constant	1.886	1.897	1.796
	(0.824)	(0.825)	(0.773)
Time effects	Yes	Yes	Yes
Observations	2,601	2,601	2,601
Number of code	448	448	448

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

Table 9: Fixed effect cluster-robust-VCE estimates of TFPG: Small vs large firms

	Small firms			Large Firms		
VARIABLES	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27
T_{it}=1 for post cdm period; =0 otherwise	-1.405			-0.702		
	(-1.340)			(-1.504)		
T_i1-4=1; 1-4 years		-1.398			-0.708	
		(-1.325)			(-1.525)	
T_i5-10. 5-9 years		-1.238			-0.766*	
		(-1.000)			(-1.682)	
T_i1=1 for initial year of cdm			-1.559			-0.599
			(-1.387)			(-1.283)
T_i2=1 for post 1 year			-2.503*			-0.682
			(-1.719)			(-1.459)
T_i3=1 Post 2 years			-1.318			-0.770
			(-1.195)			(-1.427)
T_i4=1 Post 3 years			0.211			-0.626
			(0.172)			(-1.203)
T_i5=1 Post 4 years			-0.908			-0.701
			(-0.736)			(-1.467)
T_i6=1 Post 5 years			-0.726			-0.791
			(-0.525)			(-1.504)
T_i7=1 Post 6 years			-0.795			-0.732
			(-0.609)			(-1.436)
T_i8=1 Post 7 years			-1.403			-0.403
			(-0.950)			(-0.757)
T_i9=1 Post 8 years			-1.492			-0.562
			(-1.076)			(-1.001)
T_i10=1 Post 9 years			-2.332			-0.279
			(-1.365)			(-0.502)
CDMitXlarge project=1;=0 otherwise	0.801	0.744	0.616	0.420**	0.417**	0.420**
	(1.083)	(0.920)	(0.749)	(2.307)	(2.265)	(2.295)
CDMitXunilateral project=1;=0 otherwise	2.474*	2.455*	2.513*	0.773*	0.765*	0.773*
	(1.766)	(1.790)	(1.867)	(1.863)	(1.819)	(1.853)
Sales in log	-2.110*	-2.098*	-1.944	1.054*	1.041*	1.075*
	(-1.712)	(-1.692)	(-1.559)	(1.731)	(1.699)	(1.751)
Sales square in log	0.175	0.174	0.152	-0.0419	-0.0411	-0.0430
	(1.500)	(1.476)	(1.280)	(-1.382)	(-1.344)	(-1.408)
Export to sales ratio	0.549	0.541	0.505	-0.00862	-0.00802	-0.00942
	(0.514)	(0.501)	(0.444)	(-0.305)	(-0.283)	(-0.314)
Constant	5.536	5.493	5.3001	-5.213*	-5.145*	-5.318*
	(1.604)	(1.583)	(1.527)	(-1.762)	(-1.728)	(-1.779)
Time effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	839	839	839	1,762	1,762	1,762
R-squared	0.049	0.049	0.058	0.030	0.030	0.033
Number of code	188	188	188	260	260	260

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

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