THE CLEAN DEVELOPMENT MECHANISM AND TECHNOLOGY TRANSFER TO CHINA

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Abstract

In this study we analyze the role of the Clean Development Mechanism (CDM) established by the Kyoto Protocol in channeling foreign technology to China.The analysis investigates the sources and the determinants of foreign technology transfer based on the examination of 1074 registered projects. As key features, we show the prominence of German firms as technology providers and the absence of a strong relation between technology suppliers and credit buyers. We also discuss the role of leading Chinese and foreign consultants and of major credit buyers. Finally, the econometric analysis confirm that project size and cost, project location, credit buyers and consultants characteristics, as well as technology diffusion are all relevant factors in determining the probability to have a foreign supplier of technology in the project.

JEL classifications: F23, Q55, Q56

Keywords: Technology transfer, CDM, climate change, China, FDI.

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1. Introduction

The transfer of emission-saving technologies to developing countries is expected to play a major role in addressing the global environmental problem. The Clean Development Mechanism (CDM), introduced under article 12 by the Kyoto Protocol, is one of the international instruments favouring such transfer.[1] Primarily aimed at promoting cost-effective greenhouse gas emission (GHG) mitigation by Annex-I countries, the mechanism was also designed to foster sustainable development in the developing world, by channelling new financial resources towards these areas and promoting the international transfer of environmentally sound technologies (UNFCC, 2010). Notwithstanding the uncertainty on the prospects of this instrument, due to lack of clarity on the future of the Kyoto protocol (Linacre et al, 2011, Junfeng et al 2010),[2] appraising the experience of CDM remains of key importance to draw lessons for the post-2012 climate regime.

China is a particularly interesting case for analysing technology transfer in CDM projects since, after a slow start, this country has become the largest and most dynamic CDM recipient world-wide (Capoor and Ambrosi, 2008; BMU CDM-JI Initiative, 2008; Lewis, 2010). Furthermore the analysis of CDM projects may offer some insights on the complex web of technological links between Chinese and foreign firms and on the technology and industrial policies implemented by the Chinese authorities. Understanding the technological upgrading of this country, and its mechanisms, represents a central issue in the present context of economic power shift from the West to the East.

Previous studies on international technology transfer (ITT) promoted by CDM projects have mainly been conducted at global scale and directed to understand which characteristics of the projects (such as size and type) and of the hosting

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[1] The Kyoto Protocol, which became operational on 16 February 2005, introduced the CDM mechanism , an instrument that allows the countries that committed to reduce or to cap their greenhouse gas emissions under the Protocol (Annex-I parties), to comply with obligations by generating or purchasing certified emission reduction (CER) credits from project activities aimed at reducing net emissions in developing countries. Each CER equals to 1 ton of CO_2e.

[2] See also Financial Times “Towards a standstill” September 28 2011.

countries have an influence on the probability of ITT associated to CDMs (Dechezleprêtre et al., 2009; Doronova et al., 2010; Schneider et al., 2008; Haites et al., 2006; Youngman et al., 2007). Limited attention has been given instead to the different actors involved in CDM projects. Only a few studies have looked more closely to the actors involved, but at a rather aggregate level (Dechezleprêtre et al., 2008; Seres et al., 2009; Schneider et al., 2010; UNFCC, 2010). Such an aggregate multi-country approach, although offering interesting insights, does not allow to capture some essential aspects, such as the characteristics of the main technology providers (local and foreign), the role of credit buyers and project's consultants in channelling foreign technology, as well as the role of countries' institutional and regulatory framework which may vary considerably from country to country while greatly affecting the pattern of foreign technology adoption in CDM projects.

In this study we analyze the source and determinants of international technology transfer in CDMs projects in China and we offer some insights on how the characteristics of the major players and the links between them affect this phenomenon. The analysis is based on a careful examination of all relevant documentation attached to individual projects, such as the project design documents (PDDs) and the associated reports, which provide a wealth of information on both the technologies and the companies concerned. We begin with a descriptive analysis which allows us to formulate hypothesis then tested in the empirical verification.

Compared to previous empirical studies, this one looks more deeply "inside the box" of CDM projects in China using a large database and considering important characteristics so far neglected.[3] Benefiting from several recent descriptive papers on the implementation of this mechanism in China (such as Wang, 2010, Wang and Chen, 2010; Lewis, 2010),. we investigate to what extent institutional factors affected the pattern of CDM projects in China and the ITT associated to it; in doing so, we try to understand how China shaped the use of this tool to finance costly investments or to acquire foreign technology in targeted

[3] Dechezleprêtre et al. (2009) consider projects up to May 2007, with only 71 projects in China. See section 5.

sectors. We further address the question of what is the origin of technologies adopted in CDM projects in China and who are the main (domestic and foreign) actors. Also examine the main determinants of ITT in CDM projects in China and consider the role PDD consultants and credit buyers in selecting the most appropriate technology (foreign vs domestic).

The paper is organized as follows. In Section 2 we describe the data set, in Section 3 we sketch the main features of the Chinese regulatory framework and present an overview of CDM projects in China, while in Section 4 we present our empirical model and econometric strategy aimed at shedding some light on the determinants of ITT to China. Section 5 draws the main conclusions.

2. The data set

As of 2 June 2011, 1354 CDM projects have been registered in China, covering 19 out of 26 project types defined by the United Nations Environment Programme (UNEP) Riso Centre.[4] At the moment we have carefully analyzed 1074 projects (79% of the total),[5] within all the project types, collecting data on: the occurrence of international technology transfer (ITT); the identity of foreign and domestic technology providers (TP); the identity of project owners (PO) and their sector of activity (POS); the identity and sector of activity of credit buyers (CB), the identity of consultants for project design documents (PDDC); the amount of certified emission reductions (CERs) and the cost of the project (i.e. the cost of the investment measured as US$/t$CO_2$). We collected some of these information, such as those on ITT, identity of TPs and POs, through a careful examination of all the relevant documentation attached to the 1074 individual projects, such as project design documents (PDDs), validation reports, technical documentation and other internet resources.[6] With these data on hand we integrated the information available from the UNEP Riso Centre Database.

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[4] UNFCC (2010; p. 14), classifies the projects according to "greenhouse gas emission reduction actions, sectors and technologies". See also CDM Pipeline at http://cdmpipeline.org.

[5] We left out 280 hydropower projects.

[6] The participants must present a project design document that describes the proposed CDM project. The proposal goes thought a validation process, at the end of which –if approved- will be registered by the CDM Executive Board. Many players are involved, we focused on the PO (the company undertaking the project, which also owns of the carbon credits), the PDD consultant (that is the firm

Our definition of technology transfer goes beyond what is declared in the PDD or in the validation report. These two documents, in fact, often, but not always, explicitly state whether foreign technology transfer occurs or not in the project. However the statements are not always coherent across projects. For consistency purposes, in our definition technology transfer occurs any time we find explicit mention (in the PDD and/or the validation report) of a foreign firm involvement, either as pure supplier of technology (equipment, knowledge, or both), or in the form of a joint venture with domestic suppliers, or in the form of local subsidiaries of foreign firms providing technology for the project. In analyzing the relevant documentation, we adopted a strategy similar to that described in UNFCC (2010), although we do not distinguish between different types of technology transfer (equipment and/or knowledge transfers). Rather we analyze the sources (countries and firms) of technology in CDM projects and the role of global corporations in China, therefore we concentrate on identities, nationalities and sector of activities of technology providers, to uncover the pattern of technological linkages between China and foreign countries/firms.[7]

3. Descriptive analysis

Before presenting an overview of our dataset we briefly discuss some key aspect of the regulatory framework in China.

3.1 Key features of the regulatory framework

CDM projects in China are regulated by the *Measures for the Operation and Management of CDM Projects in China* (from now on Measures),[8] issued by the National Development and Reform Commission (NDCR) – China's top planning agency - and other two ministries,[9] which entered into force on October 2005 (see

that prepares the PDD and follow it through its overall development), the CB (the company buying the CERs generated by the project) and the TP (the company providing the technology).

[7] It is worth noting that the distinction of the nature of technology transfer (knowledge or equipment) often made in the CDM literature is based on shaky information, as the PDDs are usually not very accurate and clear on this point (see UNFCC, 2010).

[8] See http://cdm.ccchina.gov.cn/english/

[9] NDRC, MOST (Ministry of Science and Technology) and MFA (Ministry of Foreign Affairs) are co-chairs and vice chair of the National CDM Board. NDRC has also been selected as China's DNA

Wang, 2010; Schroeder, 2009; BMU CDM-JI Initiative, 2008). Below we will call attention on some key points:

- Three priority areas have been set for CDM in China, in line with the more general national strategy for sustainable development: energy efficiency improvement, development and utilization of new and renewable energy, methane recovery and utilisation (article 4).
- Differentiated project fees are established. Projects in the priority areas are subjected to a 2% tax on their CER revenue. The tax raises to 65% for Hydrofluorocarbon (HFC) and Perfluorocarbon (PCF) projects and to 30% for Nitrous Oxide (N_2O) projects (Article 24).
- Eligibility requirements for project ownership are set, by introducing a 51% Chinese ownership rule. Article 11 provides that only "Chinese funded or Chinese-holding enterprises within the territory of China are eligible to conduct CDM projects with foreign partners."[10] For this reason a foreign company cannot directly benefit from the CER revenue since it cannot act as Project Owner, while it can participate as PDD Consultant and/or Credit Buyer and/or Technology Provider.
- Technology transfer. The Chinese Government expects that CDM projects should promote the transfer of environmentally sound technology to China (Article 10).

The CDM Measures are part of a complex set of (climate, industrial, trade and technology) policies implemented to promote sustainable development and more specifically to foster Renewable Energy and energy efficiency. These policies, even when not focused specifically on CDM projects, have played a critical role in shaping the strategies of foreign and local firms involved in these projects. This may be illustrated by considering the case of wind power, an area in which several measures were explicitly directed to develop local equipment

(Designated National Authority), which has the mandate to give host country approval to CDM projects (Wang and Chen , 2010, p.1991).

[10] These are enterprises with at least 51% of the equity share owned by Chinese entities or citizens (see BMU CDM-JI Initiative, 2008, p. 11).

manufacturing industry.[11] Local content requirements were introduced by NDRC with the "Wind Farm Concession Program" in 2003, establishing that wind farm projects of a relatively large scale should be selected through public tendering. An important criterion to win the bid was the share of domestic components utilized in the wind farm. The local content requirement initially set to 50% was raised to 70% in 2005.[12] This policy favoured the rapid expansion of Chinese-owned wind turbine producers and compelled foreign manufacturers to open local production units (section 3.3). Domestic production was also supported by setting in 2007 import tariffs which basically reserved the Chinese market for smaller turbines to domestic producers.[13] In addition various measures have been introduced to support R&D in the wind power sector, promoting the domestic industry (Liu and Kokko, 2010; Wang, Q., 2010; Wang, 2010; Wu, 2010; Zhang et al., 2009; Zhao et al., 2011; Zhao et al., 2012).

3.2 Overview of CDM projects in China

Taking stock of the key features of the regulatory framework in China, we are now ready to look at CDM projects registered so far in this country. When considering the composition by <u>number</u> and type (Figure 1), CDM projects in China are indeed heavily concentrated in areas related to renewable energy[14] (82.4% of the total number of registered projects), while the share of projects implementing energy efficiency actions in industry (EE own generation) is equal

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[11] China's grid connected wind power started to develop in the 1980's. The first on-shore wind power farm was constructed in 1988 , funded by the Danish government. However only after the landmark Renewable Energy Law promulgated in 2005 the investment in wind power generation and in the domestic turbine manufacturing industry started to grow dramatically in the country. (Liu and Kokko, 2010; He and Chen, 2009; Wang, 2010). Renewable Energy remains a top priority area in the 12th Five-Year Plan (2011-2016).

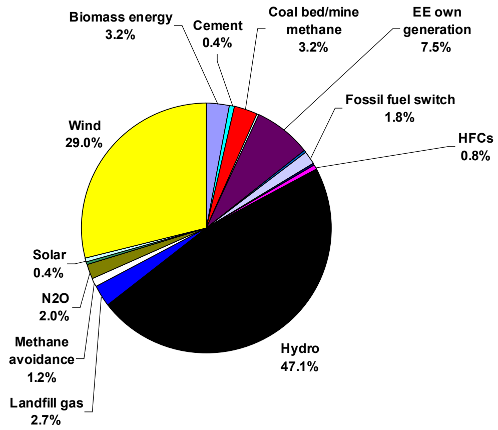
[12] Although setting content requirements was a violation of the WTO rules, foreign MNEs did not complain with their home government fearing to loose access to the booming Chinese wind farm business. In the period from 2005 to 2010, due to the extremely rapid growth of the Chinese market, the volume of sales of these foreign companies in China has increased, even though their market share has shrunk relative to Chinese firms. Only in the summer 2009 officials from the Obama administration began pressing China to repeal the wind turbine content requirements, and the Chinese government revoked this measure on 25 December 2009 (see , *"To conquer wind power, China writes the rules"*,.New York Times, December 14, 2010.

[13] The Ministry of Finance issued the "Guidelines on Adjusting Import Taxes on High Voltage Wind Turbines and Components"(Liu and Kokko, 2010).

[14] Here renewable energies include: Hydro power, Wind power, Biomass Energy, Landfill Gas and Solar power.

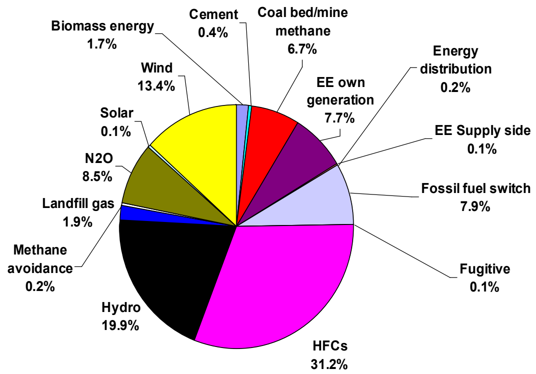
to 7.5%; methane coal bed and methane avoidance projects jointly make up for 6.9%. Such an high concentration in renewable energy is peculiar to China.[15] At the level of individual types, hydro projects are dominant (47.1%), followed by wind power projects (29%). The dominance of hydropower reflects the important role of this form of generation in China.[16]

Figure 1a. Share of CDM projects in China by type and number of projects.



Source: based on UNEP Riso Centre database. (1354 projects)

Fig. 1b Share of expected CERs (2012 ktCO_2e) by CDM type



Source: based on UNEP Riso Centre database. (1354 projects)

However, in terms of expected certified emission reductions (CERs), the picture is rather different (Figure 1b).[17] The share of projects involving the destruction of HFC-23 and N_2O[18] raises to almost 40% of the total, notwithstanding the higher tax on CER revenues, while renewable energy projects account for only 37% of expected CERs. The dominance of HFCs and N_2O projects emerges also at a global scale, and it is due to the high global warming potential of these greenhouse gases. For instance, one ton of HFC-23 is equivalent to 11,700

[15] See http://cdmpipeline.org/ CDM pipeline overview, Regions. Renewable account for 52% of the projects in Latin America, and for 42% in Africa.
[16] By the end of 2010 hydropower was the second most important form of generation in China, accounting for 22.4% of the total cumulative installed capacity (966 GW). The major form of generation, coal-fired plants, accounted for 66.9%, while wind for 3.1%. See Jiang et al. (2011).
[17] Expected CERs are measured as the amount of certified emission reduction expected to be issued by the end of first commitment period in 2012; see http://cdm.unfcc.int.
[18] Hydro fluorocarbon 23 (HFC-23) is a by-product of HFC-22 which is used as a refrigerant and as feedstock for the production of polytetrafluoroethylene. As to N_2O see section 3.3.

tons of CO_2.[19] Thus these projects generate large numbers of CERs for relatively low initial investments and represent the "low-hanging fruits" of CDM initiatives (see European Commission, 2010, p.10).[20] It appears therefore that Chinese authorities have been rather successful in channeling a large number of projects in the priority areas, although have not been able (or willing) to discourage those undertaken by industrial gases producers.

Table 1. China: Registered CDM by type and international technology transfer

Type of greenhouse gas emission reduction actions	Number of projects	Percentage of projects involving foreign technology	Average abatement (annual ktCO2eq)	
		(%)	*Foreign tech*	*Domestic tech*
Biomass energy	43	37	174	131
Cement	5	0	0	240
Coal bed/mine methane	44	52	671	266
EE Households	2	0	0	26
EE own generation	102	51	345	107
Fossil fuel switch	24	100	1017	0
Fugitive	1	0	0	291
HFCs	11	91	6359	2066
Hydro	359	1	517	103
Landfill gas	36	72	169	73
Methane avoidance	16	31	50	59
N2O	27	100	778	0
Reforestation	3	0	0	45
Solar	5	20	103	36
Transport	1	0	0	218
Wind	391	43	130	131
EE Supply side	1	0	0	306
Energy distribution	2	50	230	1971
PFCs and SF6	1	0	0	155
Total	1074	33	487	123

Source: based on UNEP Riso Centre database. (1074 projects)

We now turn our attention to the role of foreign technology in these projects (Table 1). By inspecting PDDs and sometimes also validation reports (VRs) for

[19] See CDM Executive Board "Revision of the approved baseline methodology AM0001", available on line.

[20] In January 2011 the EC established that from January 2013 the use of CERs from projects involving the destruction of HFC-23 from HCFC-22 production and N_2O from adipic acid production is prohibited in the EU ETS. There has been widespread accusation that host countries have expanded HCFC-22 output primarily to profit from CER revenues and that the current incentives for HFC-23 destruction undermine attempts under the Montreal Protocol to phase out HCFC-22 production. See European Commission (2010).

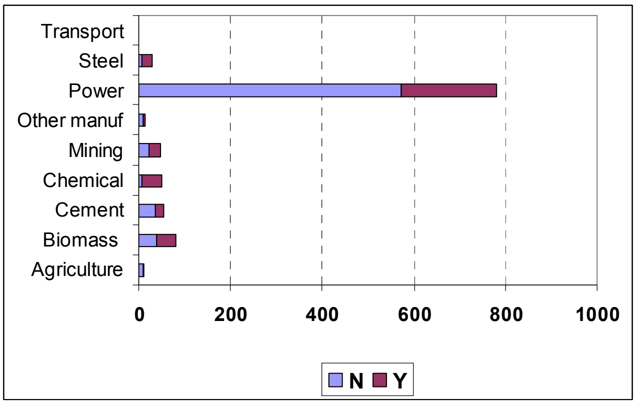
1074[21] registered projects we find out that 34 per cent of the projects involves foreign technology, accounting for 80% of expected annual emissions reduction. The likelihood of technology transfer varies considerably across technology types, confirming the result obtained by Dechezleprêtre et al. (2008) at the global level. Hydro projects, with few exceptions, do not involve technology transfer. This is not surprising, since only small-hydro projects are eligible for CDM funding, [22] and small-hydro turbine manufacture represent the low margin segment of the market which is dominated by Chinese producers.[23] Furthermore in recent years China has become quite advanced in hydro-power technologies. In fact, when considering CDM projects at global level, China is a major supplier of technology for hydro projects (UNFCC, 2010, p. 26). It thus seems that the large number of projects in this area is motivated by the desire to benefit from the financial opportunities created by the CDM instrument, rather than by technological considerations. On the other hand, almost all projects directed to destroy HFC-23 and nitrous oxide (N_2O) and to fossil fuel switch claim technology transfer. Moreover, in terms of average abatement, data shown in Table 1 confirm that in general technology transfer occurs more often in larger projects (see also Dechezleprêtre et al., 2008, 2009; Doranova et al., 2010; UNFCC, 2010). Wind power generation, methane avoidance and energy distribution constitute notable exceptions.

3.3 Project owners and technology providers

When considering the sector of activity of the project owners, we see in Figures 2a and 2b that power companies are the most involved in CDM projects. The large state-owned power generator companies (Huaneng, Datang, Guodian, Huadian and to a lower extent China Power Investment Corporation) are very active, particularly in wind power projects.[24]

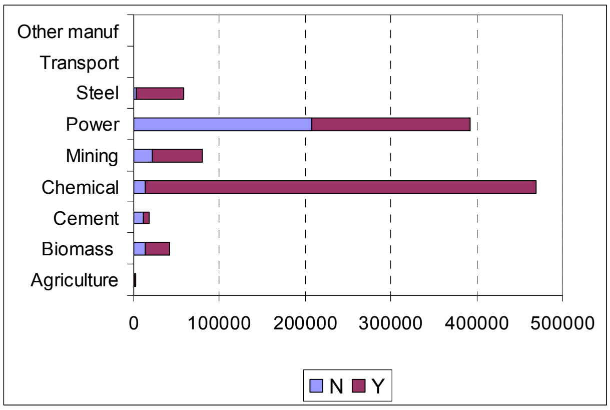
[21] The projects here considered are the total number (1354) less the 280 hydro projects left out.
[22] Large hydropower projects, nuclear projects and carbon capture and storage projects are not eligible.
[23] Foreign companies and major Chinese producers compete instead in the large hydro project segment of the market. Here too Chinese competition has become considerably stronger from the beginning of the century.
[24] The main players in the power sector emerged in 2002, when the State Power Corporation was broken up to form five power generation companies and two grid companies (Musu, 2011, p. 161).

Fig.2a International technology transfer by sector of activity: number of projects.



Source: based on UNEP Riso Centre database. (1074 projects)

Fig.2b International technology transfer by sector of activity: expected CERs from start to 2012



Source: based on UNEP Riso Centre database. (1074 projects)

The large number and the characteristics of wind power projects is one aspect of the dramatic growth of both wind power and wind turbine manufacturing in China, which took place after the Renewable Energy Law was promulgated in 2005 (Liu and Kokko, 2010; He and Chen, 2009; Wang, 2010). Due to a consistent policy framework,[25] by the end of 2010 China has become the world leader in terms of installed wind capacity (WWEA,2011). Local wind turbine manufacturing and the development of Chinese-owned producers was also actively promoted by measures such as those discussed in section 3.1. This policy framework, coupled with the size and growth potential of the Chinese market, stimulated the main foreign producers such as Vestas (Denmark), Gamesa (Spain), REpower (Germany), GE(USA), Suzlon (India) and Nordex (Germany), to create local subsidiaries. These foreign companies have been important technology providers in wind power projects in China, at first exporting equipment and providing training, and then, more recently, setting up their Chinese subsidiaries. At the same time powerful Chinese-owned manufacturers emerged. Sinovel, Xinjiang

[25] For instance, obligations were set for both grid companies and power generators. Grid companies were initially obliged to purchase all the electricity generated by wind projects, while after the 2009 amendments to the Renewable Energy Law a renewable power quota was introduced. Power generation companies are obliged to ensure that by 2020 at least 5% of their total energy output will be accounted for by wind power (Liu and Kokko, 2010).

Golwind and Dongfang, which entered the market by acquiring technology and intellectual property rights from European firms, rapidly gained a dominant position in the Chinese market.[26] In recent years these Chinese producers have taken an increasingly important role as technology providers in wind CDM projects in China.

Leading Chinese firms operating in emission intensive industries such as cement, steel and chemical production have also played an important role. In the cement industry, the top Chinese cement producer, the State-owned firm Anhui Conch, in several CDM projects adopted waste heat recovery power generation systems for cement plants provided by the Japanese company Kawasaki (Wang, 2010).[27] In iron and steel, some major Chinese state-owned producers (such as Baosteel, Wuhan Iron and Steel, Anshan Iron and Steel) have been involved as project owner in several CDM projects and the Japanese companies, such as Nippon Steel Corporation and Mitsubishi Heavy Industry played a major role as technology providers.[28]

Projects by chemical companies are mainly directed to abatement of HFC-23 and N_2O. In the case of N_2O, for instance, which is an unwanted by-product of adipic and nitric acid production we find that the major Chinese producer of adipic acid, PetroChina , and the third Chinese producer, Henan Shenma Nylon Chemical, are both active as project owners. In the first case, technology is provided by the German BASF, while in the second by INVISTA Technologies (Switzerland), a fully owned subsidiary of the US company Koch Industries, the world largest adipic acid producer. As to nitric acid, the largest Chinese

[26] Sinovel acquired production licences from Fuhrländer of Germany; Dogfang and Xinjiang Golwind acquired production licences from REpower of Germany (He and Chen, 2009). As a consequence, the share of foreign companies in newly installed wind power capacity in China decreased form 75% in 2004 to 13% in 2009 (Junfeng et al., 2010).

[27] In 1996 the Conch group was awarded a grant from the Japanese public agency NEDO (New Energy and Industrial Technology Development Organization) to deploy the Japanese cement waste heat recovery system in a demonstration project. In 2006 Conch implemented again the same Kawasaki technology through its first CDM project. (see for instance the PDD for CDM project 3613). Subsequently a paretitec joint venture, Anhui Conch Kawasaki Engineering was formed.

[28] With these projects, for instance, the coke dry quenching (CDQ) system, developed to recover waste heat during the quenching process, was transferred to China.

companies,[29] operate as project owners deploying technology provided by the Norwegian firm YARA, the world leading manufacturer of nitrous fertilizer.

The overview of project owners and technology providers presented above allows us to grasp an important insight. In many areas top Chinese companies have used CDM projects to adopt foreign technology provided by leading foreign firms. In the case of wind power, CDM projects have probably played a more complex role, contributing to carry out the national priority of building a Chinese owned turbine manufacturing industry.

3.4 Geography of technology supply and credit buying

Going through the relevant documentation we recorded all the foreign countries/firms involved as technology providers whenever such an information was made available.[30] In conducting our analysis we decided to exclude hydropower projects as their inclusion would probably distort the picture since, as shown in Table 1, in this field there is a disproportionate number of projects and a negligible rate of international technology transfer. Excluding hydropower we are left with 715 projects. Foreign technology is involved in 364 projects, belonging to 11 classes of project types, out of 18.

Three EU countries play a prominent role as technology providers (Table 2). German firms supply technology in 26% of the 364 non-hydro CDM projects in which foreign companies participate as technology providers, Danish companies in 20% and firms from Spain in 12% of the cases. The EU total amounts to 68%. An important role is also played by US (18%) and Japanese firms (13%).

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[29] These companies are: Tianji Group (number 1), and Sichuan Golden Elephant Chemical Company (number 3), Shandong Huayang Dier Chemical Co. (number 9), Shijiazhuang Jinshi Chemical Fertilizer Co. (number 14). See Research and Markets, Research Report on the Chinese Nitric Acid Industry, 2010-2011 from http://www.researchandmarkets.com/reports/1236227

[30] Most of the times foreign and domestic technology providers are explicitly named; however, in a number of cases only the country of origin is known. In few other occasions, instead, even though technology transfer from abroad is claimed no further information is provided.

Table 2. Technology providers (TP) by country of origin

Country	Total number of projects as TP (a)	Average % of projects with foreign technology (b)	Number of project types in which TP	Largest project type (as % of the country total number of projects)	Number of firms involved as TP
Austria	7	2%	2	Landfill gas (86%)	1
Canada	2	1%	1	Landfill gas (100%)	1
Denmark	72	20%	3	Wind (76%)	7
France	7	2%	2	HFCs (71%)	2
Germany	96	26%	8	Wind (63%)	18
Italy	2	1%	1	Landfill gas (100%)	1
Japan	48	13%	6	EE own generation (67%)	10
Netherlands	2	1%	2	Methane Avoidance (50%)	2
Norway	10	3%	1	N2O (100%)	1
Spain	45	12%	2	Wind (96%)	4
Switzerland	8	2%	3	EE own generation (50%)	3
UK	16	4%	5	N2O (44%)	8
USA	65	18%	8	Fossil Fuel Swithch (25%)	15
Other or Unknown	21	6%			

Source: based on UNEP Riso Centre database. (715 non-hydro projects)
(a) The column does not add to 364 (number of projects with foreign technology) as there are projects with multiple technology providers from different countries.
(b) First column divided by total number of non-hydro projects with foreign technology (364)..

When considering also the breadth of the technology portfolio and the number of firms involved (columns 3 to 5 in Table 2), it clearly emerges that Germany, US and to a somewhat lesser extent Japan are the main players. A large number of German firms (18) are active as technology providers, operating in a wide range of project types (8 out of 11), being however mainly concentrated in wind power (this type accounts for 63% of the projects involving German firms as technology providers). The US is also present with a large number of firms (15), mastering an even more diversified range of technologies. Japanese producers, in turn, play a dominant role in the provision of technologies for energy efficiency in industry and in industrial gas reduction projects. These results are consistent with finding in Dechezleprêtre et al. (2011) that Japan, US and Germany are the three top inventor countries for a wide range of climate-change mitigation technologies, with Germany in leading position as for high-value inventions (Dechezleprêtre et al., 2011).

Danish and Spanish firms are involved in a narrower range of technologies. Spain is present almost exclusively in wind power, thanks to Gamesa and a few other producers; Denmark has a key role in wind, due to the leading turbine manufacturer Vestas, but also in biomass energy with BWE. Although being present in only one typology of projects, Norway too is quite relevant as technology provider. The Norwegian producer Yara, the world leading manufacturer of nitrous fertilizers, is the main supplier of catalyst technology to reduce N_2O emission from nitric acid plants (see section 3.4). It is worth noting the difference between Germany and other large EU countries. France accounts for only 2% of the total number of CDM projects with a foreign technology provider and the UK for 4%. Italy, which is quite active as credit buyer, has only a very marginal role as technology provider.

Indeed, several policies adopted by the German government may have contributed to the prominence of German firms as technology providers in CDM projects in China. On the one hand, the German government, via restrictive measures and incentives, has implemented measures aimed at fostering the development and implementation of low-carbon technologies. Our evidence thus may be suggesting a sort of "Porter Hypothesis" effect. Secondly, from an early start this country has created stronger links with China compared to other EU members. Thirdly, several measures have been employed to facilitate German firms in taking advantage of the possibilities generated by the CDM instrument. For instance, the German Ministry of the Environment, Nature Conservation and Nuclear Safety has undertaken a well structured CDM initiative. As part of this action, it has published a series of studies on the opportunities for the German know-how in CDM projects in different sectors in China (e.g. see BMU CDM-JI Initiative, 2008).

Turning our attention to the relationship between technology providers and CER buyers, we learned that only in few occasions the same firm plays both roles. For instance, this is the case of Nippon Steel (CDM project 909, 2516), Mitsubishi

(CDM project 1859) and Toyo (CDM project 2327). However, here we are interested in assessing to what extent the technology supply from one country is linked to credit buying from the same country. Such an analysis will offer some indications on whether companies with the same nationality but different specialization, cooperate in the Chinese market.[31] Having not signed the Kyoto Protocol, the United States cannot be considered here, even though its firms are quite important as technology providers in Chinese CDM projects.

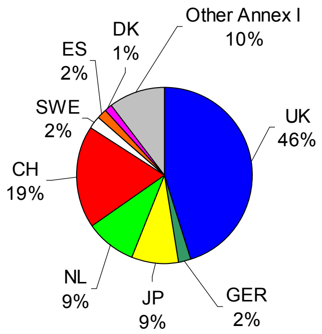
A first inspection of the data in Figure 3a does not support the hypothesis of "national systems", since the role of countries as credit buyers and technology suppliers differ considerably. To start with, when considering the number of CDM projects by buyer's nationality, the UK emerges as the most important CER buyer while its firms have only a minor role as technology providers. Figure 4a shows that UK firms participate as credit buyers in 46% of the 364 projects with international technology transfer, while provide technology only in 4% of these projects (Table 2). On the contrary, Germany plays only a minor role as credit buyer (2% of the projects with ITT), notwithstanding its prominent position as technology provider (26% of the projects with ITT). The picture is not altered in a major way when considering the role of buyers in terms of the share of total expected CERs (Figure 3b).

Our evidence for China seems in line with that reported in Dechezleprêtre et al (2008), while it differs sensibly to that of UNFCC (2010) and Seres et al. (2009), as both find a close relationship between credit buyers and technology suppliers in worldwide CDM projects.

Three groups of countries can be singled out. The "*mainly credit buyers*" countries (UK, Netherlands and Switzerland), whose role seems more related to their importance as financial centers than to national abatement objectives; the "*mainly technology providers*" countries (Germany, Spain and Denmark) which operate as direct credit buyers only to a very limited extent, and Japan which has an important role in both positions, credit buyer and technology supplier.

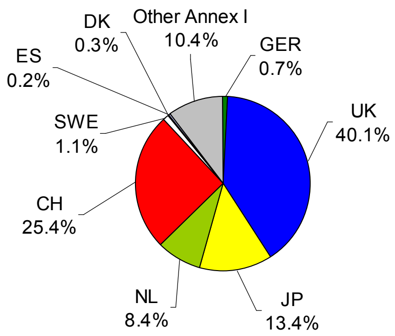
[31] We want to capture cases such as CDM project 2135 in which the German power company RWE is credit buyer and the German Nordex (wind turbine manufacturer) is the technology provider. Similarly in the CDM projects 238 and 1090 the Spanish ENDESA (power company) is the credit buyer and the Spanish Gamesa Eolica (turbine manufacturer) the technology provider.

Figure 3a. Buyers of CERs by buyer's nationality: share of total number in projects with foreign technology providers.



Source: based on UNEP Riso Centre database (364 non-hydro projects with ITT)

Figure 3b. Buyers of CERs by buyer's nationality: share of total CERs in projects with foreign technology providers.

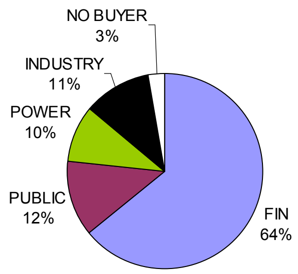


Source: based on UNEP Riso Centre database (364 non-hydro projects with ITT)

In line with previous evidence in the literature, examining the identity of credit buyers for 715 no-hydro CDM projects in China (Figures 4a and 4b) we find that 'primary' CERs are mainly bought by financial intermediaries (either banks, financial institutions or carbon market funds).[32] In terms of project number, financial entities are buyers in 64% of the cases, accounting for 58% of expected CERs to be issued by these projects; manufacturing firms, in turn, buy CERs in 11% of the cases. Annex-I power companies, such as Electrabel (Belgium), Endesa (Spain), Enel (Italy), RWE (Germany) and TEPCO (Japan),[33] are also an important presence in the primary CER market acting as buyers in 10% of the cases, equivalent to 14% in terms of CERs volume, indicating that power companies are directly involved as CER buyers in large projects and are willing to bear the financial risks associated to them. It is worth noting also that, in the case of China, the percentage of projects with no credit buyers indicated in the PDD at the moment of registration (the "no buyer" projects also called "unilateral" projects) is negligible (3% of the projects, with almost no impact in terms of expected CERs).[34]

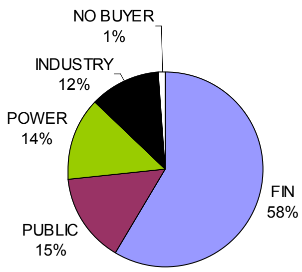
[32] In the primary market the project developer and the CER buyer agree on a price for the expected credits which depends on the characteristics of the projects and its risks. In the secondary market, instead, are traded only credits already issued, or with a guarantee of delivery from the seller (Green, 2008).
[33] On the increasing involvement of power companies with carbon trading see Kolk and Mulder (2011).
[34] The distribution does not substantially change when considering the 364 projects with ITT.

Figure 4a. Buyers of CERs by buyer's organization type: share of total number of projects with foreign technology providers.



Source: based on UNEP Riso Centre database (715 non-hydro projects)

Figure 4b. Buyers of CERs by buyers's organization type: share of total expected CERs to be issued in project with foreign technology providers.



Source: based on UNEP Riso Centre database (715 non-hydro projects)

3.5 PDD Consultants and Technology Transfer

In order to gain some initial understanding on the role of individual actors, we look more in depth at the major PDD consultants. Project consultants are engaged in the overall development of the project.[35] The first thing to note is that, since the adoption of the CDM instrument, the PDD consultancy industry has flourished in China. Today there are about 260 PDD consultants headquartered in China.

Chinese PDD consultants are very active, being engaged in 62% of the 715 non-hydro projects considered here. Table 3 lists the largest among them (i.e. those active in at least 10 projects). We may identify two groups. The first is composed of CWEME, Longyuan and China Fulin which are subsidiaries of two top state-owned power companies, DATANG and China Guodian Co. The second group is composed of five consulting companies unrelated to a specific industrial entity, namely Tsinghua University, that with the Global Climate Change Institute/INET (GCCI/NET), has been the earliest institution in China engaging in CDM consulting activities; Easy Carbon, an independent consultancy located in Bejing; CREIA (China Renewable Energy Industries Association), a business association; Green Capital Consulting, a private company consulting mainly for top Chinese

[35] For a detailed description of the different stages see Wang (2010), BMU (2008).

power companies; Caspervandertak, the Chinese branch of Caspervandertak Consulting based in the Netherlands.[36]

Table 3 Top Chinese PDD Consultants (at least 10 registered projects in China

	Number of projects	% of which also PO	% of which ITT	Largest type (as % total)
CWEME (**DATANG**)	51	82%	49%	Wind (90%)
Tsinghua University	48	0%	73%	Wind (42%)
Easy Carbon	41	1%	41%	Wind (76%)
Longyuan (Beijing) Carbon Asset Management Technology Co.(**China Guodiang Co.**)	32	78%	41%	Wind (97%)
China Fulin Windpower Development Corporation (**China Guodian Co.**)	25	68%	64%	Wind (100%)
CREIA	16	0%	37%	Wind) (81%)
CasperVanderTak	11	0%	36%	Wind (64%)
Green Capital Consulting	11	0%	73%	Wind (54%)

Source: based on UNEP Riso Centre database. (715 non-hydro projects)

Many differences emerge between these two groups. The three PDD consultants owned by power companies have entered almost exclusively in wind power projects, i.e. in an area connected with the operations of the controlling company. Furthermore, these companies generally act at the same time as PDDC and PO (see second column Table 3). In contrast to that, the "purely" consulting companies while operating on a wider range of project types (especially in the case of Tsinghua University) are never involved as POs.[37]

No clear indication emerges from the above evidence on whether being PO and PDDC at the same time stimulates a larger uptake of foreign technology. Prior expectation is that the capability of performing multiple roles, and thus dealing with complexity, might be expected to stimulate a greater uptake of foreign

[36] In the CDM Pipeline classification by country of world PDD consultants, Caspervandertak is listed as Chinese.

[37] There are only two exceptions in which Easy Carbon act jointly with another consultant.

technology. We will try to shed some light on this issue in our empirical investigation.

As to foreign PDDCs, three UK carbon trading companies (Carbon Resource Management, CAMCO and EcoSecurities) have a dominant role (Table 4). All of them are also important credit buyers. It is interesting to note that each of these UK companies specializes in different project types. Carbon Resource Management operates almost exclusively in wind. It is the main PDDC for the largest Chinese state-owned power company, China Huaneng Group. The latter, while operating in a large number of projects as PO, has not created its own PDD consulting subsidiary, as opposed to other important power companies such as Datang and Guodian. CAMCO's main area of operation is energy efficiency for industry, with several projects owned by cement and by iron and steel producers. An example of project owner collaborating with CAMCO is Conch, the top Chinese cement company. EcoSecurities has had an important role in the case of N_2O abatement, in association with major Chinese producers of adipic and nitric acid.

It is interesting to note that in projects in which these large UK carbon traders are involved, the rate of ITT is above the average. This finding is in line with Wang (2010) who suggests that international carbon traders engaging in the overall development of the CDM process by being also PDDC are more likely to adopt well developed foreign technologies, in order to obtain a larger and more secure volume of CERs, as the *additionality* requirement will be more easily proven and project risks reduced. At the same time international traders have the financial and technological capabilities to adopt foreign technology, being also in the position to negotiate more favourable economic conditions with foreign suppliers.

Table 4 Top Foreign PDD Consultants (PDDC) (at least 10 registered projects in China)

	Number of projects	% of which also CB	% of which ITT	Largest type (as % total)
Carbon Resource Management (UK)	76	96%	59%	Wind (97%)
CAMCO (UK)	52	90%	60%	EE own generation (40%)
EcoSecurities (UK)	37	95%	59%	N2O (41%)
Millennium Capital Services (Ukraine)	24	0%	42%	Wind (50%)
Arreon Carbon (UK)	16	94%	25%	Coal bed/mine methane (25%)
Climate Experts (Japan)	11	0%	82%	N20 (73%)
KOE Environmental Consultancy (Japan)	10	0%	30%	EE own generation (40%)
WB-CF (US)	10	0% (a)	70%	HFCs (20%)

Source: based on UNEP Riso Centre database. (715 non-hydro projects)

Note: (a) The World Bank acts as trustee of the Community Development Carbon Fund (partnership of different governments and companies) and of various national Carbon Funds.

Two Japanese companies, Climate Experts and KOE, rank amongst the main PDDC in China. Differently from their UK counterparts, these two firms do not operate as credit buyers, however almost always in their projects the CER buyer is a Japanese firm. This is the case in 73% of the projects which see Climate Experts as PDD consultant and in 90% of the cases for KOE. In the group of the largest PDDC in China we find also the World Bank Carbon Finance (WB-CF) which manages several carbon funds initiatives (such as the Community Development Carbon Fund, the Bio Carbon funds).

Tacking stock of all the evidence discussed so far, in the next section we propose an econometric analysis to test the determinants of technology transfer in CDM projects in China.

4. CDM and International Technology transfer to China: an econometric analysis

In recent years, as the implementation of CDM projects grew larger and a considerable amount of data became available, an empirical literature started to flourish, enquiring whether CDM projects effectively promote the transfer of environmental friendly technology from developed to developing countries and searching for project and country-specific characteristics favoring such a technology transfer.

Table 5 summarizes the main contributions appeared on this topic. All the reviewed papers consider more than one hosting country, use similar estimation strategies (logistic models) and consider similar independent variables. Some of these variables control for project-specific characteristics, others for country-specific ones. Among project-specific controls there is the size of the project, measured by the total amount of CER expected by the project. Such a variable indicates the estimated income from the project; larger projects, therefore, should facilitate the acquisition of state-of-the-art foreign technology. Another important characteristic usually taken into account is the distinction between unilateral and non-unilateral projects. The former consist of projects for which the credit buyer was not indicated or not found yet, while the latter consist of projects with at least one credit buyer already indicated in the project. Intuitively, having a credit buyer from the very beginning should relax the financial constraint eventually faced by the project owner, and therefore facilitate the acquisition of more efficient, though more expensive, foreign technology. Another important control often considered (Dechezleprêtre et al., 2008 and Doronova et al., 2010) is given by a dummy variable that signal whether the project in the host country is carried out within a subsidiary of a company headquartered in an Annex-I country. The hypothesis is that when the project is developed within a subsidiary technology transfer from abroad should be easier. Finally, another important project-specific characteristic to control for is the number of previous projects of the same type in the same host country. The hypothesis here is that when the number of similar projects grow larger, the rate of technology transfer decreases since the technology is likely to have already diffused in the host country. As for country-specific factors considered, some of the reviewed studies (such as Dechezleprêtre et al., 2008, and Doronova, 2010) include indicators of absorption capacity or technological ability in the host countries (such as R&D expenditures, patent filling activity and so on), as well as other country controls such as population, GDP, trade and FDI openness.

Findings are quite similar across the papers: the likelihood of ITT is larger for larger projects and for projects with at least one credit buyer. ITT occurs more often when the project is developed within a subsidiary of a foreign company; on the contrary, it tends to decrease as the number of similar projects in the hosting country increases. As for absorption capacity, while Dechezleprêtre et al. (2008 and 2009) find that higher technological capacity in hosting countries favors ITT, Doronova et al. (2010) find instead that more technologically advanced countries show a stronger preference for local or combined technology over foreign technology in CDM projects.[38]

Table 5. Empirical literature on international technology transfer in CDM projects

Authors	**DGM (2008)**	**Seres et al. (2009)**	**UNFCC(2010)**	**Doronova et al (2010)**
Dependent variable **model**	**ITT** **logit (yes=1; no=0)**	**ITT** **logit (yes=1; no=0)**	**ITT** **logit (yes=1; no=0)**	**Technology origin: local over foreign; combined over foreign** **multinomial logit (local = 1; combined= 2; foreign=3)**
Independent variable	**Effect on ITT likelihood**			
Size	+	+	+	+
Unilateral	-	No effect	No effect	Not included
Subsidiary	+	Not included	Not included	+
Number of previous projects	-	-	-	-
Absorption capacity / technological ability	+	Not included	Not included	-
Country controls	YES	YES	YES	YES
Type dummy	YES	YES	YES	YES
Countries considered	8 developing countries	World (26 developing countries)	World	36 countries
Period / Number of projects	registered projects as of May 2007 / 644 projects	CDM pipeline June 2008 / 3296 projects (registered + at validation)	Registered projects as of June 2010 / 3530 projects	Registered projects up to 2007 / 497 projects
% correctly predicted	80	81	86.7	n.a.

[38] Doranova et al. (2010) analyzes the pattern of technology sourcing in a sample of 460 CDM projects registered during the first two years after the Kyoto protocol enforcement. They estimate the preference for local or combined (local and foreign) technology source over foreign technology alone, using a multinomial logit model. As key independent variables they consider the number of scientific publications in carbon friendly technologies (CFT), the number of patents in CFT, the export volume of CFT and the share of renewable energy in total power generation. They also control for usual project-specific variables, such as size, subsidiary, number of similar projects and country-specific variables, such as trade, population, GDP per capita. They find that a better knowledge base is positively associated with preference for local technologies.

Despite the good level of fit generally shown, some important limitations emerge from the existing empirical literature. First of all, the number of projects considered for each country appears to be very low. For instance, Dechezleprêtre et al. (2008) consider only 71 projects in China. Also, despite the extensive work carried out in analyzing the relevant documentation, there is no effort to take into account the relationships established among the main actors in CDM projects, such as credit buyers, PDD consultants and project owners, and their role, if any, in favoring foreign technology transfer. In light of the evidence discussed in section 3, we deem these aspects very important, hence, our aim is to improve upon the existing empirical literature in at least two directions: first, we concentrate on China, using a very updated database, encompassing a longer time span, ranging from 2005 to 2011. This allows us to cover almost entirely the enforcement period of the Kyoto Protocol, deepening the analysis of the pattern of foreign technology in China, the most relevant hosting country of CDM projects. Second, in our analysis we explore the relevance of all the information available on credit buyers, project owners and PDD consultant characteristics.

Next section describes our estimation strategy

4.1 Estimation strategy and variable description

In this section we use regression analysis to explore more in depth the pattern of technology transfer in CDM projects in China. Our analysis is carried out on a sample of 715 registered projects, excluding hydropower projects, as motivated in section 3.2.

Our dependent variable is a binary variable, called *ITT*, that takes value 1 if a foreign firm is involved as technology provider and zero otherwise. We model the probability to have a foreign supplier of technology in a CDM project as:

$$\Pr(ITT_i = 1) = G(\alpha_s + \beta_1 \log(projectsize_i) + \beta_2 \log(investment_i) + \beta_3 inland_i + \beta_4 northwest_i + \beta_5 southwest_i \\ + \beta_6 (CB\_PDDC_i) + \beta_7 (PO\_PDDC_i) + \beta_8 (CHI\_PDDC_i) + \beta_9 (mPDDC_i) + \beta_{10} (lPDDC_i) + \beta_{11} (Nfrac) \\ + \beta_y ycomm_i)$$

Where G is a function that maps the model into the response probability.[39] The explanatory variables considered here are the following: project type class (α_s); *project size* (measured as the log of total emission abatement expected by the project); cost of the project (*loginvestment*, measured as the log of US$ per unit of abatement, i.e. ton of CO_2 equivalent); dummy variables for project location, to capture the differential effect in the rate of technology transfer for projects developed in *inland*, *northwest* or *southwest* provinces, as compared to those developed in provinces along the *eastern coast*, the most developed region in China. Such a differential effect is intended to capture the absorption capacity of the Chinese provinces; we expect that in the poorer western provinces as the absorption capacity is lower the likelihood of technology transfer should be lower. As main novelties, we consider the relationship between credit buyers and project consultants (*CB_PDDC*); the relationship between project owners and project consultants (*PO_PDDC*); the nationality of consultants (Chinese vs foreign; *CHI_PDDC*); the size of PDD consultants (*sizePDDC; size*=*m,l*); we classify PDD consultants in small, medium and large, according to the number of CDM projects developed in China, the small group is taken as the control one. We control also for the number of previous projects using the same abatement methodology, but contrary to what is usually done in the literature, we do not consider the number *per se*, rather we normalize it by the total amount of projects within the same type class, to better capture the relative position of a project within its type class (*Nfrac);* finally we introduce time dummies to capture year-specific effects *(ycomm)*: we date each project according to the year in which the project entered the pipeline, that coincides with the beginning of the validation stage.[40]

In comparison to other studies, we do not distinguish between unilateral and non-unilateral projects because for China such characteristic is irrelevant: only a tiny percentage of all the registered projects hosted in China can be classified as unilateral (about 3%). Table 6 describes our variables in more detail.

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[39] In the linear probability model G(.) is the identity function, hence G(z)=z, in the probit model $G(z) \equiv \Phi(z) \equiv \int_{-\infty}^{z} (2\pi)^{-1/2} \exp(-v^2/2)dv$; in the logit model $G(z) \equiv \Lambda(z) \equiv \exp(z)/[1+\exp(z)]$.

[40] The validation stage starts with a 30 days public comment period. See "Guidance to the CDM & JI Pipelines" available at http://cdmpipeline.org/publications/GuidanceCDMpipeline.pdf).

Table 6. Variable definitions and source

ITT= 1 if there is at least one foreign technology supplier in the project; 0 otherwise	Based on inspection of relevant documentation available at http://cdm.unfccc.int/Projects/projsearch.html
Abatement size = log(Ktco2e)	Based on UNEP Riso Centre database (715 projects)
Investment = log(US$/tco2e)	Based on UNEP Riso Centre database (715 projects)
Inland =1 if the project is located in Anhui; Henan; Hubei; Hunan; Jiangxi; Shanxi. 0 otherwise.	Based on UNEP Riso Centre database (715 projects)
Northwest = 1 if the project is located in Gansu; Inner Mongolia; Ningxia; Quinghai; Shaanxi; Tibet; Xinjiang. 0 otherwise	Based on UNEP Riso Centre database (715 projects)
Southwest =1 if the project is located in Guangxi; Guizhou; Sichuan; Yunnan. 0 otherwise.	Based on UNEP Riso Centre database (715 projects)
CB_PDDC = 1 if at least one credit buyer is among PDDCs; 0 otherwise	Based on UNEP Riso Centre database (715 projects)
PO_PDDC =1 if PO among PDDCs; 0 otherwise	Based on UNEP Riso Centre database (715 projects)
Chi_PDDC =1 if there at least one Chinese PDDC in the project (excluding POs); 0 otherwise	Based on UNEP Riso Centre database (715 projects)
M_PDDC = 1 if PDDC shows up in at least 10 projects and up to 47 (excluding PDDC_CB); 0 otherwise	Based on UNEP Riso Centre database (715 projects)
L_PDDC = 1 if PDDC shows up in at least 48 projects (excluding PDDC_CB); 0 otherwise	Based on UNEP Riso Centre database (715 projects)
ycomm2 =1 if project entered in the pipeline in 2007; 0 otherwise	Based on UNEP Riso Centre database (715 projects)
ycomm3 =1 if project entered in the pipeline in 2008; 0 otherwise	Based on UNEP Riso Centre database (715 projects)
ycomm4=1 if project entered the pipeline from 2009 onwards; 0 otherwise	Based on UNEP Riso Centre database (715 projects)
Nfrac = number of previous projects of the same type/total number of project in same type class	Based on UNEP Riso Centre database (715 projects)
Wind*Nfrac = Nfrac if Wind=1; 0 otherwise	Based on UNEP Riso Centre database (715 projects)

Our investigation is driven by the following hypotheses: controlling for project type-specific effects, the probability to have a foreign technology supplier should be higher for larger and costly projects; should be higher in richest provinces due to their greater absorption capacity and openness to foreign investment; the probability should instead decrease as the number of previous projects of the same type increases, reflecting also technology diffusion to Chinese firms and the Government requirement to increase the domestic technology content over time (see section 3.1 above). As for our special variables, we expect that the likelihood of technology transfer increases when a credit buyer acts also as PDD consultant, due to larger incentives, as well as greater financial means, to obtain foreign technology (see section 3.5); on the same vein, we expect that when the project owner develops its own project (as PDDC) it might be more interested in acquiring foreign technology. Finally, we presume that the probability to have a foreign technology supplier is higher the larger is the PDD consultant for the project. The intuition is that larger consultants might enjoy a better knowledge of most effective foreign technologies available and can facilitate the process of acquisition of those technologies; moreover larger consultants, by having better knowledge of CDM procedures in the host country, might facilitate project approval claiming foreign technology transfer.[41]

We estimate and compare three models: linear probability, logit and probit models. Results are reported in Table 7. In Table 8 we collect the marginal effects. In the first three columns we report our base regressions, while in columns IV to VI we perform a robustness check, introducing an interaction term ***Wind*Nfrac*** to capture differential effect in the absorption of foreign technologies in the wind power sector (key priority area for the Chinese government in terms of local content rules). Finally, in Fig. 6 reports graphically the marginal effects and their confidence intervals for the logit estimations, the most commonly used in the literature.

4.2 Base regression results

Results are quite similar using the three methodologies. The inspection of the first three columns of table 7 and 8 revels that, as expected, the likelihood of having a foreign technology provider increases with the total number of CER issued by the project (***abatement size***) and with the cost of the project in terms of dollar per unit of abatement (***investment***). The probability to have a foreign technology provider is lower when projects are located in the poorest provinces (***Southwest*** and ***Northwest***), confirming our intuition of a lower absorption capacity there.[42] Such a probability is larger when the credit buyer is also a consultant for the project; the same is true when the consulting process is controlled directly by the project owner. Large PDD consultants too tend to improve the likelihood of foreign technology suppliers into a project. Finally,

[41] The knowledge of the regulatory framework for CDM approval is particularly important in the case of China, where country-specific "measures" have been issued (see section 3.1).

[42] Of course, this result may have also different interpretations, such as the existence of an environmental *Kutzenet's curve* within China, by which in richest provinces producers would use cleaner technologies in response to higher environmental demand. Under the assumption that foreign technology is more advanced and environmental friendly, the Kutzenet's curve hypothesis would induce higher ITT probability in richest provinces.

international technology transfer decreases over time as indicated by year dummies, suggesting domestic diffusion and absorption of foreign technology through time.[43] Contrary to previous findings in the literature, the coefficient on the variable that measure the number of projects of the same type (***Nfrac***) has a positive sign, although it is not statistically significant. Indeed the diffusion effect is already captured by the year dummies, in fact, if we exclude these dummies, *Nfrac* becomes negative and highly significant (results are unreported but available from the authors upon request). In terms of goodness of fit, the models perform quite well. In regressions I to III, the pseudo R-squared ranges between 0.20 (in LPM regression) and 0.16 (in probit and logit estimation) and the percentage of correctly predicted outcome is always above 70%, with the linear model performing slightly better at 71.5%.

Compared to other studies, our results confirm the positive effect of size and cost variable; the coefficients, although not completely comparable are reasonable in magnitude. As for the number of previous projects of the same type, we find that such a variable has a positive coefficient, though not significant, when we control for the year of entry in the pipeline. Our result differ from UNFCC (2010), that finds instead a negative coefficient on the "number" variable and positive ones on the year dummies. However, our results are not strictly comparable, since we have no cross-country variability to explore. Also, many of the variables considered in this study are not considered elsewhere. In the next sub-section we perform a robustness check.

4.3 Robustness check: The wind power sector

Given the relevance of wind power projects in China both in terms of number and in terms of CERs expected to be issued (Fig. 1a and 1b), and given the strategic role of this sector (see section 3.3), revealed also by the *local technology content requirement* imposed by the Chinese government (see section 3.1), one may wonder whether the technology diffusion effect is driven by projects of this type. If so, we expect to find a faster rate of decay of foreign technology transfer as the

[43] Projects posted before 2007 are taken as the control group. Year thresholds are set such that each sub-period contains a similar number of projects.

number of projects in the wind power sector increases. In our database we count 391 wind power projects (out of 715), with an average probability of ITT of 0.45, as compared to an average probability of 0.57 elsewhere. One way to capture such a differential effect is to interact the ***wind*** dummy with the number of previous projects of the same type and see whether it makes a difference. We do so in regressions from IV to VI in table 7 and 8.

As expected, we find a significant difference in absorption capacity in the wind power sector: the interaction term is negative and highly significant, therefore as the number of projects of this type increases, the need of foreign technology reduces. In particular, given the marginal effect reported in table 8, if we consider for example the logit estimates, we find that an additional project in the wind power sector improves (reduces) the overall likelihood of international technology transfer if the project is below (above) the 56% threshold of the total number of projects of the same type.[44]

Since the coefficient on ***Nfrac*** by itself is now positive and statistically significant, we might conclude that the same effect does not hold true for other types of projects, where, controlling for all the relevant characteristics, the adoption of foreign technology tend to increase as the number of project of the same type increases.[45] Overall, we still find a decreasing rate of foreign technology use over time, as the ***ycomm(i)*** coefficients retain their negative sign, although their magnitude is now slightly lower, this is also due to the fact that in recent years we observed an increasing number of projects in wind power and a decreasing number of projects elsewhere (fig. 5). All other explanatory variables retain their previous sign and degree of significance.

In terms of goodness of fit, the improvement looks sensibly, both in terms of pseudo-R squared (now ranging between 0.25 and 0.17) and in terms of predictive power (the percentage of correctly predicted improved by more than 1 percentage point in all regressions, reaching 73% in the LPM regression; column IV). All the

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44 $\frac{dy}{dWind} = 0.241 - 0.427 * Nfrac > 0 \ \ if \ \ Nfrac < 0.56.$

45 We confirmed this finding by interacting each type dummy with the *Nfrac* variable, we find that in all other typologies of CDM the effect is either always positive or non significant. Results are available from the authors upon request.

marginal effects, along with their confidence interval, are visually summarized in figure 6.

Table 7. Probability of foreign technology transfer in CDM projects in China: results from LPM, Probit and Logit regressions

Dependent variable: y= pr(ITT=1)

Independent variable	LPM (OLS)	Probit (MLE)	Logit (MLE)	LPM (OLS)	Probit (MLE)	Logit (MLE)
	I	**II**	**III**	**IV**	**V**	**VI**
Log(tot_KtCO2)	0.094***	0.335***	0.552***	0.103***	0.349***	0582***
Log(investment)	0.140***	0.528***	0.911***	0.131***	0.507***	0.556***
Inland_dummy	-0.058	-0.183	-0.307	-0.058	-0.181	-0.320
Southwest_dummy	-0.141*	-0.561**	-0.913**	-0.137**	-0.537**	-0.893**
Northwest_dummy	-0.099***	-0.291***	-0.474***	-0.093***	-0.285***	-0.472***
CB_PDDC	0.176**	0.633***	1.023***	0.162**	0.602***	0.971***
PO_PDDC	0.148*	0.486**	0.787**	0.133	0.458*	0.734*
Chi_PDDC	0.057	0.231	0.409	0.044	0.224	0.353
M_PDDC	0.047	0.197	0.313	0.051	0.200	0.322
L_PDDC	0.073	0.294*	0.472*	0.075	0.297*	0.485*
ycomm2 (2007)	-0.168**	-0.586***	-0.978***	-0.146**	-0.526***	-0.893***
ycomm3 (2008)	-0.394***	-1.228***	-2.022***	-0.379***	-1.203***	-1.990***
ycomm4 (>2008)	-0.495***	-1.535***	-2.544***	-0.428***	-1.376***	-2.281***
Nfrac	0.081	0.292	0.500	0.300**	0.990**	1.707**
Wind				0.293**	0.763**	1.238**
Wind*Nfrac				-0.449***	-1.275***	-2.192***
Const	-0.798***	-5.314***	-8.966***	-1.065**	-6.671	-9.65***
Type_dummies	YES	YES	YES	YES	YES	YES
Cluster CB	YES	YES	YES	YES	YES	YES
Number obs	646	607	607	646	607	607
% correctly predicted	71.50%	70.51%	70.35%	72.80%	71.20%	71.50%
Log-likelihood value	--	-352.604	-352.75	--	-348.2	-348.2
R2 and Pseudo-R2	0.20	0.16	0.16	0.25	0.17	0.17

Note: asterisks indicate the significance level: * 10%, ** 5%, *** 1%. Standard errors are robust to heteroskedasticity and adjusted for 32 clusters in credit buyers.

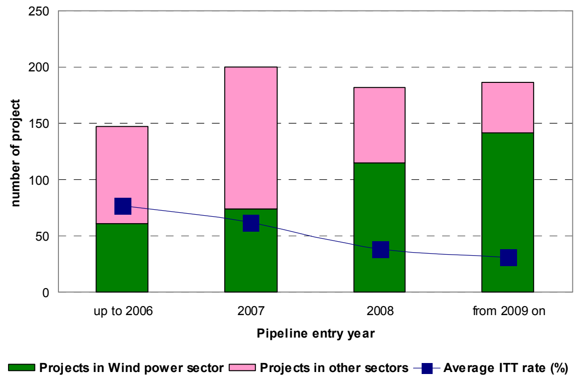
Table 8. Probability of foreign technology transfer in CDM projects in China: Average marginal effects from LPM, Probit and Logit Estimates

Dependent variable: y= pr(ITT=1)

Independent variable (x)	LPM (OLS)	Probit (MLE)	Logit (MLE)	LPM (OLS)	Probit (MLE)	Logit (MLE)
	I	**II**	**III**	**IV**	**V**	**VI**
	dy/dx					
Log(totalKtCO2)	0.094***	0.110***	0.109***	0.103***	0.114***	0.113***
Log(investment)	0.140***	0.174***	0.181***	0.131***	0.165***	0.172***
Inland_dummy	-0.058	-0,06	-0.061	-0.058	-0.059	-0.062
Southwest_dummy	-0.141*	-0.185**	-0.181**	-0.137**	-0.175***	-0.174**
Northwest_dummy	-0.099***	-0.096***	-0.094***	-0.093***	-0.093***	-0.092***
CB_PDDC	0.176**	0.209***	0.203***	0.162**	0.196***	0.189***
PO_PDDC	0.148*	0.160**	0.156*	0.133	0.149*	0.143*
Chi_PDDC	0.057	0.086	0.081	0.044	0.073	0.069
M_PDDC	0.047	0.065	0.062	0.051	0.065	0.063
L_PDDC	0.073	0.097*	0.094*	0.075	0.097*	0.095*
ycomm2 (2007)	-0.168**	-0.193***	-0.194***	-0.146**	-0.171***	-0.174***
ycomm3 (2008)	-0.394***	-0.405***	-0.401***	-0.379***	-0.392***	-0.388***
ycomm4 (>2008)	-0.495***	-0.506***	-0.505***	-0.428***	-0.448***	-0.445***
Nfrac	0,081	0.096	0.099	0.300**	0.322**	0.333**
Wind				0.293**	0.248**	0.241**
Wind*Nfrac				-0.449***	-0.415***	-0.427***
Type_dummies	YES	YES	YES	YES	YES	YES
Cluster CB	YES	YES	YES	YES	YES	YES
Number obs	646	607	607	646	607	607
% correctly predicted	71,50%	70,51%	70,35%	72,80%	71,20%	71,50%
Log-likelihood value	--	-352,604	-352,75	--	-348,2	-348,2
R2 and Pseudo-R2	0,20	0,16	0,16	0,25	0,17	0,17

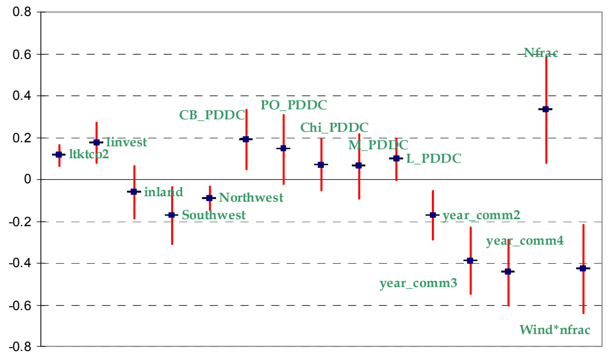
Note: asterisks indicate the significance level: * 10%, ** 5%, *** 1%. Standard errors are robust to heteroskedasticity and adjusted for 32 clusters in credit buyers.

Fig. 5 CDM projects by type and average technology transfer rate in pipeline entry year



Source: authors' elaborations on UNEP Riso Centre Database (715 projects).

Fig. 6. Average marginal effects from logit estimates *(point estimate and 5% confidence interval)*



Source: authors' elaborations on UNEP Riso Centre Database (715 projects).

5. Concluding remarks

In this paper we examine the characteristics of CDM projects in China, looking also at the main players involved, and then testing the determinants of international technology transfer associated to these projects.

A key consideration in the case of China is that domestic regulations and policies have had a major impact on the development and characteristics of CDM projects. This influence can be traced back not only to regulations specifically directed to CDM projects (such as the 51% Chinese ownership requirement discussed in section 3.1) but also to several measures aimed at achieving the planned targets on renewable energy development and energy efficiency improvement. The main peculiarity of Chinese CDM projects is that the process seems almost completely under control of domestic entities and policies.

Consistently with the above mentioned government priority areas, CDM projects in China are heavily concentrated in types related to renewable energy and to energy efficiency in industry. Examining 1074 registered projects we find out that in 34% of the cases foreign technology is adopted and that the likelihood of technology transfer is unevenly distributed across project types. For instance hydro projects, by far the largest group, implement almost exclusively domestic technology, indicating that the CDM instrument in China has also played an important role as a purely financing mechanism. In wind power, the second largest type, CDM has been conducive to local technology development of wind turbine manufacturing through various channels. It has promoted direct technology transfer via import and training and has favoured localization of production of foreign manufacturers. Moreover it has contributed significantly to renewable energy investment, and thus to the expansion of the local market which has stimulated the rise of Chinese owned turbine producers.

As to the Chinese industries involved, a small group of emission intensive sectors plays a major role. The leading Chinese power companies use CDM projects to expand in wind power and other renewable energy sources. The major iron and steel producers as well as cement companies implement projects to improve energy efficiency. Chemical firms undertake large projects to abate industrial gases. Our analysis shows that in different sectors a number of leading Chinese companies have been very active as project owners deploying technologies provided by leading international firms. It is interesting to note that in each type of project we find a number of different technology providers, indicating that Chinese firms can choose each time among several potential partners.

Several countries supply technology to CDM projects in China (mostly EU, US and Japan). Germany has a prominent position in many respects, in terms of number of projects, number of firms involved and breadth of technology portfolio. This is presumably linked with Germany's long lasting attempt to take the lead in green technologies.[46] When assessing to what extent the technology supply of one country is linked to credit buying from the same country, we found a clear specialization amongst EU members between "mainly credit buyers" countries (UK and Netherlands) and "mainly technology providers" countries (Germany Spain and Denmark). Japan, on the contrary, has an important position in both roles, and in several projects the same Japanese company acts in this double role.

As to individual companies, we examined the main Chinese and foreign PDD consultants, and found that Chinese consultants are very active and few of them have a leading position. Among the largest consultants, three are owned by two major state-owned power producers. In the case of foreign PDD consultants, a

[46] In July 2011 the Chinese premier Wen Jiabao said green technologies made Germany "a very important strategic partner". See Financial Times July 4th 2011 "Betting the wind farm".

dominant role is played by three UK carbon trading companies which are also important credit buyers.

Our econometric investigation confirm some of the intuitions emerged from the descriptive analysis. We find that the likelihood to have foreign technology providers in Chinese CDM projects increases with the total number of CERs issued by the project (abatement size) and with the cost of the project in terms of dollar per unit of abatement (investment). The probability to have a foreign technology provider is lower when projects are located in the poorest provinces of China, supporting the idea of a lower absorption capacity there. Such a probability is larger when the credit buyer is also a consultant for the project; the same is true when the consulting process is controlled directly by the project owner. Large PDD consultants too tend to encourage the adoption of foreign technology.

Finally, we find a significant difference in absorption capacity between the wind power sector and other sectors. In the former, as the number of projects of the same type increases the need of foreign technology reduces and domestic suppliers become predominant, while the same effect does not hold true for projects developed in other sectors, such as chemical or steel. This seems to suggest that the absorption of foreign technology has been stimulated successfully by the Chinese policymakers in strategic sectors with high growth potential, such as the wind power, while in other sectors, where the goal is simply to reduce greenhouse gas emissions, it seems more convenient for China to import end-of-pipe technologies from abroad.

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