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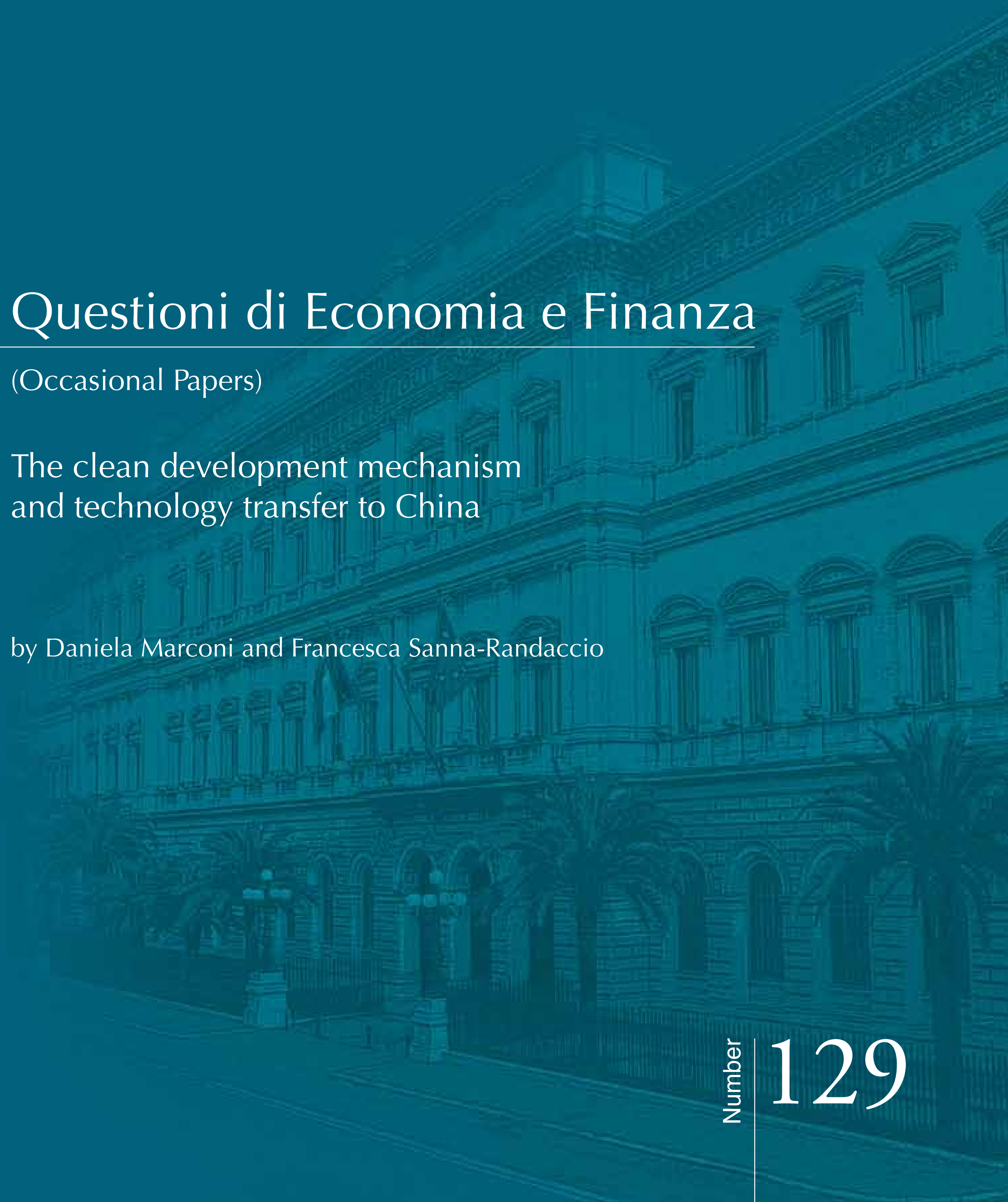

Questioni di Economia e Finanza

(Occasional Papers)

The clean development mechanism and technology transfer to China

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THE CLEAN DEVELOPMENT MECHANISM AND TECHNOLOGY TRANSFER TO CHINA

by Daniela Marconi[*] and Francesca Sanna-Randaccio[**]

Abstract

In this study we analyse the role of the Clean Development Mechanism (CDM) established by the Kyoto Protocol in channeling foreign technology to China. The descriptive analysis investigates the sources and the determinants of foreign technology transfer based on the examination of 1,355 registered projects. As key features, we show the prominence of German firms as technology providers and the absence of a strong relationship between technology suppliers and credit buyers. We also discuss the role of leading Chinese and foreign consultants and of major credit buyers. The econometric analysis finds 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 of having a foreign supplier of technology in the respective project.

JEL Classification: F23, Q55, Q56.

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

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1. Introduction[1]

The transfer of emission-saving technologies to developing countries is expected to play a major role in addressing environmental problems worldwide, and in this context it is important to assess the potential of a tool such as the Clean Development Mechanism (CDM). The CDM was introduced under Article 12 by the Kyoto Protocol and became operational in late 2004; it allows emission-reduction projects carried out in developing countries to earn certified emission reduction (CER) credits. Each CER equals one metric ton of carbon dioxide equivalent (CO_2e). CERs can be traded and sold to developed countries that have signed the Protocol (Annex-I parties) to meet part of their emission reduction targets.[2] Primarily aimed at promoting cost-effective greenhouse gas emission mitigation by Annex-I countries, the mechanism was also designed to foster sustainable development in the developing world by channelling new financial resources and encouraging the international transfer of environmentally sound technologies (UNFCC, 2010). Appraising the experience of CDM remains of key importance when drawing lessons for the post-2012 climate regime.[3]

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 worldwide (Capoor and Ambrosi, 2008; BMU

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[1] We are grateful to the attendees of the International ICCG Workshop on "Foreign Direct Investment and Climate Change" in Venice, of the 23rd CEA (UK) conference in London, and of the EAERE conference in Prague for their helpful comments and discussion. We wish to thank David Clarke and two anonymous referees for extremely valuable comments. Usual disclaimers apply. The views expressed in this paper are our own and do not necessarily reflect those of the Bank of Italy.

[2] According to the United Nations Framework Convention on Climate Change *"the purpose of the clean development mechanism is to assist Parties not included in Annex I to the Convention in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3 of the Kyoto Protocol"*. A technical description of the CDM is beyond the scope of this paper; more information on it can be found at cdm.unfccc.int/about/index.html.

[3] At the United Nations Climate Change Conference, held in Durban at the end of 2011, all the signatory countries of the Kyoto Protocol, with the notable exceptions of Canada, Japan and Russia, decided that *"a second commitment period under the Kyoto Protocol shall begin on 1 January 2013 and end either on 31 December 2017 or 31 December 2020, to be decided by the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at its seventeenth session"*. More recently, the importance of keeping the CDM alive was stated by the UNFCCC Executive Secretary Christiana Figueres, who said: *"Wherever the future climate talks lead, private sector engagement will be essential, and as such so will mechanisms like the CDM"*. See the press release: "CDM reaches milestone: 4000th registered project".

CDM-JI Initiative, 2008; Lewis, 2010). Furthermore, the analysis of CDM projects may offer some insights into the complex web of technological links between Chinese and foreign firms and into the technology and industrial policies implemented by the Chinese authorities. Understanding the technological progress of this country, and its mechanisms, is a central issue in the ongoing economic power shift from west to east.

Previous studies on international technology transfer (ITT) promoted by CDM projects have mainly been conducted at global level and have sought to understand the characteristics of the projects (such as size and type) and of the hosting countries that have an influence on the probability of ITT being associated with CDMs (Dechezleprêtre et al., 2009; Doranova et al., 2010; Schneider et al., 2008; Haites et al., 2006; Youngman et al., 2007). Limited attention has been given however to the different parties involved in CDM projects. A few studies have looked closely at the participants, 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 the essential aspects to be captured, such as the characteristics of the main technology providers (local and foreign), the role of credit buyers and project consultants in channelling foreign technology, as well as the role of institutional and regulatory frameworks. These frameworks may vary considerably from country to country, while greatly affecting the pattern of foreign technology adoption in CDM projects.

In this study we analyse the sources and determinants of international technology transfer in CDM projects in China and we offer some insights into 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 involved. We begin with a descriptive analysis which allows us to formulate hypotheses which in turn can be empirically tested.

Compared with previous empirical studies, this one looks more deeply "inside the box" of CDM projects in China using a large database and considering important characteristics, which hitherto have been neglected.[4] Drawing on several 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 have affected the pattern of CDM projects in China and the technology adopted; in doing so, we try to understand how China has shaped the use of this tool to finance costly investments or to acquire foreign technology in specific sectors. We further address the question of the origin of technologies adopted in CDM projects in China and the identity of the main (domestic and foreign) players. We also examine the main determinants of foreign technology adoption in CDM projects in China and consider the role of PDD consultants and credit buyers in selecting the most appropriate technology (foreign vs. domestic).

Several countries supply technology to CDM projects in China (mostly the EU, the US and Japan). Germany has a prominent position in many respects, e.g. in terms of the number of projects, number of firms involved and breadth of technology portfolio. We find a clear specialisation among EU members between "mainly credit buyer" countries (the UK and Netherlands) and "mainly technology provider" countries (Germany, Spain and Denmark). Japan, however, has an important position in both roles, and in the case of several projects one Japanese company occupies a double role.

In the econometric analysis we find that the likelihood of having 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 CO2 abated. The probability of having a foreign technology provider is lower when projects are located in the poorest provinces of China, while the probability is higher when the credit buyer is also a consultant for the project or when the consulting process is controlled directly by the project owner. We also find a growing concentration of projects in wind power over time

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

as well as a decreasing role of foreign technology as the number of these projects has expanded.

The paper is organised as follows. In Section 2 we describe the data set, in Section 3 we outline 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. Data set

As at 2 June 2011, 1,355 CDM projects were registered in China, covering 19 out of 26 project types defined by the United Nations Environment Programme (UNEP) Risø Centre.[5] We analysed these projects, collecting data on: ITT occurrence; the identity of foreign and domestic technology providers (TP); the identity of project owners (PO) and their sector of activity; the identity and sector of activity of credit buyers (CB), the identity of project consultants; the amount CERs to be issued by each project and the cost of the project (i.e. the cost of the investment measured as US$/t$CO_2$e). We collected some of this information by carefully examining all the relevant documentation attached to the 1,355 individual projects, such as PDDs, validation reports, technical documentation and other internet resources.[6] With [We merged these data with the information available from the UNEP Risø Centre Database. All project types are considered in the descriptive analysis.

In our econometric analysis on the determinants of ITT however we exclude hydropower projects, as in this field there is a disproportionate number of projects

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[5] The project participants must present a PDD compiled according to the UNFCCC CDM guidelines, i.e. which describes the proposed project. The PDD enters the CDM pipeline and is made available for public comments, going through a validation process to ensure that the project meets all the requirements. At the end of the validation process, the approved projects are registered by the CDM Executive Board. UNFCC (2010; p. 14) classifies the projects according to "greenhouse gas emission reduction actions, sectors and technologies". See also the CDM Pipeline at http://cdmpipeline.org.

[6] As many players are involved, we focused on the PO (the company undertaking the project, which also owns the carbon credits), the PDD consultant (the firm that prepares the PDD and follows it through its overall development), the CB (the company buying the CERs generated by the project) and the TP (the company providing the technology).

and a negligible rate of international technology transfer (see section 3.2). We are then left with 715 projects.

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. For consistency purposes, according to our definition, technology transfer occurs any time we find explicit mention (in the PDD and/or the validation report) of a foreign firm's involvement, either as a sole supplier of technology (equipment, knowledge, or both), or in the form of a joint venture with domestic suppliers, or as local subsidiaries of foreign firms providing technology for the project. In analysing the relevant documentation we adopt a strategy similar to that described in UNFCC (2010), but without distinguishing between different types of technology transfer (equipment and/or knowledge transfers), as such a distinction is only rarely obtainable and reliable.[7] Rather, we collect data on countries and firms providing technology in CDM projects to uncover the pattern of technological linkages between China and foreign countries/firms.

3. Descriptive analysis

Before presenting an overview of our dataset we briefly discuss some key aspects 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

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[7] It is worth noting that the distinction often made in the CDM literature between technology transfer as knowledge or as equipment is based on shaky information; the PDDs are rarely very accurate or 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 (Designated National Authority), which has the mandate to give host country approval to CDM projects (Wang and Chen , 2010, p. 1991).

Wang, 2010; Schroeder, 2009; BMU CDM-JI Initiative, 2008). Below we will focus on some essential 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 utilization (Article 4).
- Differentiated project fees are established. Projects in the priority areas are subject to a 2 per cent tax on their CER revenue. The tax rises to 30 per cent for Nitrous Oxide (N_2O) projects and up to 65 per cent for Hydrofluorocarbon (HFC) and Perfluorocarbon (PCF) projects (Article 24).
- Eligibility requirements for project ownership are set by introducing a 51 per cent 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 be a project owner. This restriction is peculiar to China, as in other developing countries very often projects are implemented by subsidiaries of companies located in Annex-I countries. Still, foreign firms can participate as PDD consultants and TPs.
- Technology transfer. The Chinese Government is expecting CDM projects to 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 have been explicitly aimed at developing the local equipment manufacturing industry.[11] Local content requirements were introduced by the

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

[11] China's grid-connected wind power started to develop in the 1980s. The first onshore wind power farm was constructed in 1988, funded by the Danish government. However, only after the landmark Renewable Energy Law promulgated in 2005 did investment in wind power generation and in the

NDRC with the "Wind Farm Concession Program" in 2003, establishing that wind farm projects of a relatively large scale should be subject to a public tender process. An important criterion for the success of a bid is the share of domestic components utilized in the wind farms. The local content requirement, initially set at 50 per cent, was raised to 70 per cent 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 [restricted] 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 and to promote 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

Having taken stock of the key features of the regulatory framework in China, we now look at CDM projects registered so far in this country. When considering the composition by number and type (Figure 1), CDM projects in China are heavily concentrated in areas related to renewable energy[14] (82.4 per cent of the total number of registered projects), while the share of projects implementing energy efficiency in industry (EE own generation) is equal to 7.5 per cent; methane coal bed and methane avoidance projects jointly make up 6.9 per cent. Such a high

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domestic turbine manufacturing industry start 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).

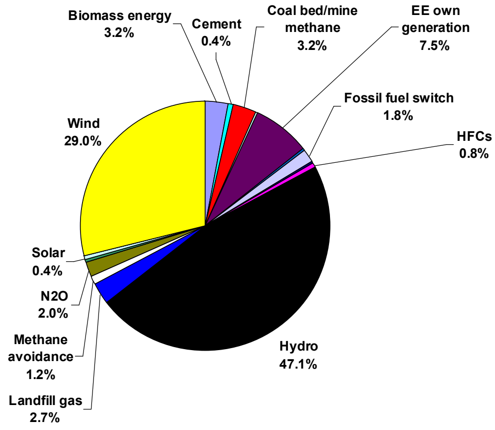
[12] Although setting content requirements was a violation of the WTO rules, foreign multinationals did not complain to their home government, as they feared losing access to the booming Chinese wind farm market. Between 2005 and 2010, due to the extremely rapid growth of the Chinese market, the volume of sales of these foreign companies in China increased, even though their market share was shrinking relative to Chinese firms. Only in the summer 2009 did officials from the Obama administration begin 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, 14 December 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] Including hydro power, wind power, biomass energy, landfill gas and solar power.

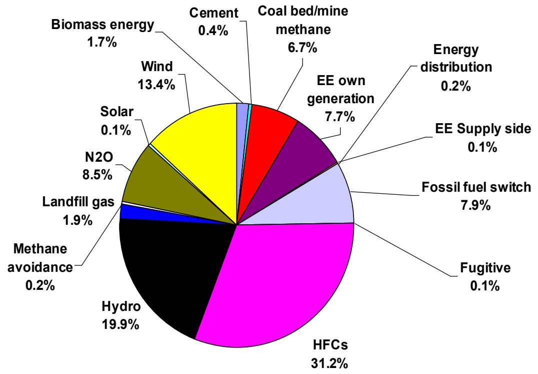
concentration in renewable energy is specific to China.[15] At the level of individual types, hydro projects are dominant (47.1 per cent), followed by wind power projects (29 per cent). The dominance of hydropower reflects the important role of this form of power generation in China.[16]

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



Source: Based on UNEP Risø Centre database (1,355 projects)

Fig. 1b Share of expected CERs (2012 ktCO$_2$e) by CDM type



Source: Based on UNEP Risø Centre database (1,355 projects)

However, in terms of expected CERs, the picture is rather different (Figure 1b).[17] The share of projects involving the destruction of HFC-23 and N_2O[18] rises to almost 40 per cent of the total, notwithstanding the higher tax on CER revenues, while renewable energy projects account for only 37 per cent of expected CERs. Indeed, the dominance of HFCs and N_2O projects emerges worldwide, due to the high global warming potential of these greenhouse gases. For instance, one ton of HFC-23 is equivalent to 11,700 tons of CO_2.[19] Thus, these projects generate large

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[15] See http://cdmpipeline.org/ CDM pipeline overview, Regions. Renewables account for 52 per cent of the projects in Latin America and 42 per cent in Africa.

[16] By the end of 2010 hydropower was the second most important form of generation in China, accounting for 22.4 per cent of the total cumulative installed capacity (966 GW). The major form of generation, coal-fired plants, accounted for 66.9 per cent and wind for 3.1 per cent. 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.unfccc.int

[18] Hydrofluorocarbon 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.

[19] See CDM Executive Board "Revision to the approved baseline and monitoring methodology AM0001" .

numbers of CERs for relatively low initial investments and represent the "low-hanging fruits" of CDM initiatives (see the European Commission, 2010, p.10).[20] It appears therefore that the Chinese authorities have been quite successful in channelling a large number of projects into the priority areas, although they have been unable (or unwilling) to discourage those undertaken by producers of industrial gases.

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
EE Supply side	1	0	0	306
Energy distribution	2	50	230	1971
Fossil fuel switch	24	100	1017	0
Fugitive	1	0	0	291
HFCs	11	91	6359	2066
Hydro	640	2	546	111
Landfill gas	36	72	169	73
Methane avoidance	16	31	50	59
N2O	27	100	778	0
PFCs and SF6	1	0	0	155
Reforestation	3	0	0	45
Solar	5	20	103	36
Transport	1	0	0	218
Wind	391	46	128	132
Total	1355	28	477	123

Source: Based on UNEP Risø Centre database

We now turn our attention to the role of foreign technology in these projects (Table 1). By inspecting PDDs and sometimes also validation reports we find out that 28 per cent of the projects involve foreign technology, accounting for 80 per cent of expected annual emissions reduction. The likelihood of technology transfer

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[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. It has been widely claimed 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).

varies considerably across technology types, confirming the result obtained by Dechezleprêtre et al. (2008) at 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, [21] and small-hydro turbine manufacture represent the low margin segment of the market, which is dominated by Chinese producers.[22] Furthermore, in recent years China has become quite advanced in hydropower technologies. In fact, when considering CDM projects worldwide, 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, rather than by technological considerations. On the contrary, almost all projects aimed at destroying HFC-23 and nitrous oxide (N_2O) as well as those concerning fossil fuel switch technologies adopt foreign equipments and expertise. Moreover, in terms of average abatement, the 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 project owners' sectors of activity, we see in Figures 2a and 2b that power companies are the most involved in CDM projects. The large state-owned power generation companies (Huaneng, Datang, Guodian, Huadian and to a lesser extent China Power Investment Corporation) are very active, particularly in wind power projects.[23]

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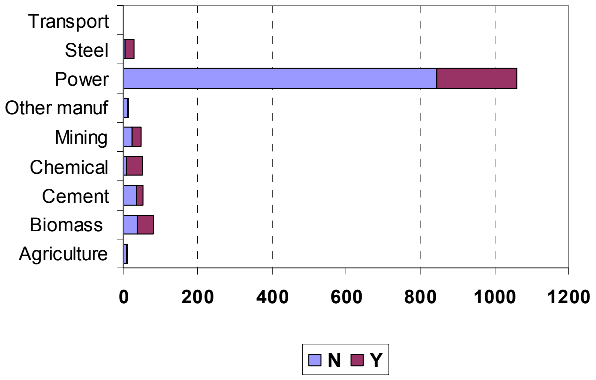
[21] Large hydropower projects, nuclear projects and carbon capture and storage projects are not eligible.

[22] 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 since the beginning of the century.

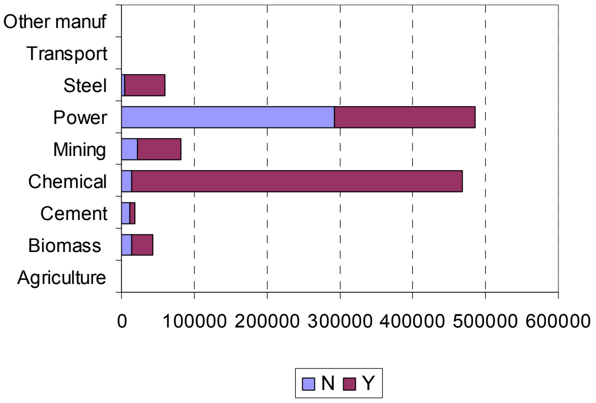
[23] The main players in the power sector emerged in 2002, when the State Power Corporation was broken up to form five power generation companies and two grid companies (Musu, 2011, p. 161).

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



Source: Based on UNEP Risø Centre database. (1,355 projects)

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



Source: Based on UNEP Risø Centre database. (1,355 projects)

The large number and the characteristics of wind power projects represent 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). Thanks to its consistent policy framework,[24] China had become the world leader in terms of installed wind capacity by the end of 2010 (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, encouraged 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 Chinese subsidiaries. At the same time, powerful Chinese-owned manufacturers

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[24] For instance, certain conditions were imposed on 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 per cent of their total energy output will be accounted for by wind power (Liu and Kokko, 2010).

emerged. Sinovel, Xinjiang 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.[25] In recent years, these Chinese producers have occupied 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 a significant role. In the cement industry, the top Chinese producer, the state-owned firm Anhui Conch, adopted waste heat recovery power generation systems in several CDM projects for cement plants provided by the Japanese company Kawasaki (Wang, 2010).[26] 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 owners in several CDM projects and Japanese companies, such as Nippon Steel Corporation and Mitsubishi Heavy Industry, have played a major role as technology providers.[27]

Projects by chemical companies are mainly aimed at the 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 main 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 for nitric acid, the largest Chinese

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[25] 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 from 75 per cent in 2004 to 13 per cent in 2009 (Junfeng et al., 2010).

[26] 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 the same Kawasaki technology through its first CDM project. (See, for instance, the PDD for CDM project 3613). Subsequently, a 50:50 joint venture, Anhui Conch Kawasaki Engineering was formed.

[27] 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[28] 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, helping to achieve 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 information was available.[29] This analysis was conducted excluding hydropower projects, as their inclusion would probably distort the picture since, as Table 1 shows, 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 project classes out of 18.

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

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[28] 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 at http://www.researchandmarkets.com/reports/1236227

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

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

Country	Number of projects (a)	Share as TP (% of total) (b)	Number of different project types	Largest project type (as % of country's 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
US	65	18%	8	Fossil Fuel Switch (25%)	15
Other or Unknown	21	6%			

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

When considering the breadth of the technology portfolio and the number of firms involved (columns 3 to 5 in Table 2), it clearly emerges that Germany, the 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 per cent of the projects involving German firms as technology providers). The US is also present with a large number of firms (15), managing 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 the findings of Dechezleprêtre et al. (2011) that Japan, the US and Germany are the three top inventor countries for a wide range of climate-change mitigation technologies, with Germany in leading position 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 present in only one class of projects, Norway too is quite important as a 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 per cent of the total number of CDM projects with a foreign technology provider and the UK for 4 per cent. Italy, which is quite active as credit buyer, has a very marginal role as a 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 suggest a sort of "Porter Hypothesis" effect.[30] Secondly, Germany's links with China go back to the 1970s and are stronger than those of other EU members. Thirdly, several measures have been taken to help German firms take advantage of the possibilities generated by the CDM. For instance, the German Ministry for 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 German know-how in CDM projects in different sectors in China (e.g. see BMU CDM-JI Initiative, 2008).

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[30] Porter (1991), challenging conventional wisdom, maintained that "Strict environmental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed they often enhance it". More stringent measures may stimulate innovation and upgrading, encouraging companies to re-engineer their technology, with the result being less pollution, lower costs or better quality. This idea, known as the "Porter Hypothesis", contradicts the so-called "Pollution Haven Hypothesis" which predicts that more restrictive environmental policies will have negative repercussions on the competitiveness of local producers.

Turning our attention to the relationship between technology providers and CER buyers, we learned that only on a few occasions did the same firm play 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 as to whether companies with the same "nationality" but different specializations 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 roles 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 per cent of the 364 projects with international technology transfer, while they provide technology only in 4 per cent of these projects (Table 2). By contrast, Germany plays only a minor role as a credit buyer (2 per cent of the projects with ITT), notwithstanding its prominent position as a technology provider (26 per cent of the projects with ITT). The picture does not change significantly when considering the role of buyers in terms of the share of total expected CERs (Figure 3b).

Our evidence for China seems to be in line with that reported in Dechezleprêtre et al. (2008), while it differs sharply from 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 buyer*" countries (the UK, Netherlands and Switzerland), whose role seems more related to their importance as financial centres than to national abatement objectives; the

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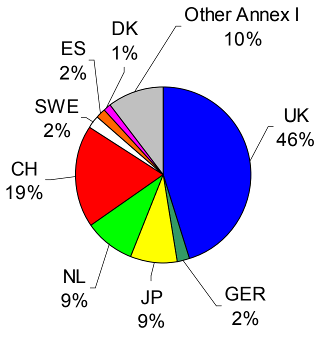
[31] We want to capture cases such as CDM project 2135 in which the German power company RWE is credit buyer and the German Nordex (wind turbine manufacturer) is the technology provider. Similarly in the CDM projects 238 and 1090 the Spanish ENDESA (power company) is the credit buyer and the Spanish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

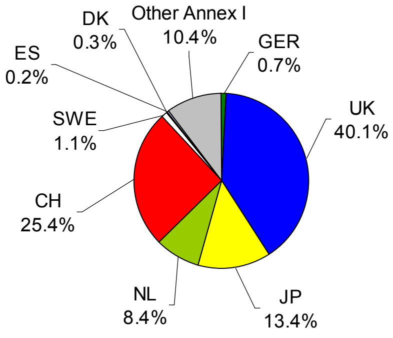
"*mainly technology provider*" countries (Germany, Spain and Denmark) which operate as direct credit buyers only to a very limited extent, and Japan, which has an important role in both positions, credit buyer and technology supplier.

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



Source: Based on UNEP Risø 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 Risø Centre database (364 non-hydro projects with ITT)

In line with previous evidence in the literature and 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 numbers, financial entities are buyers in 64 per cent of the cases, accounting for 58 per cent of expected CERs to be issued by these projects; manufacturing firms, in turn, buy CERs in 11 per cent 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 per cent of the cases, equivalent to 14 per cent in terms of volume of CERs, indicating that power companies are directly involved as CER buyers in large projects and are willing to bear the financial risks associated with them. It is also worth noting 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" or "unilateral"

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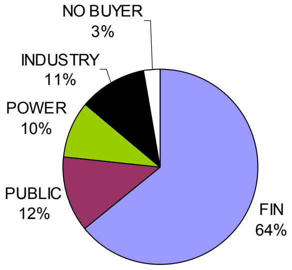
[32] In the primary market the project developer and the CER buyer agree on a price for the expected credits which depends on the characteristics of the project and its risks. In the secondary market, however, only credits already issued are traded, as are those with a guarantee of delivery from the seller (Green, 2008).

[33] Regarding the increasing involvement of power companies with carbon trading, see Kolk and Mulder (2011).

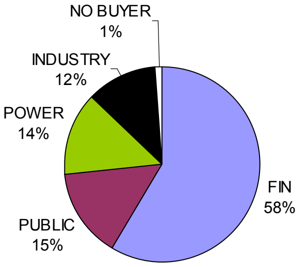
projects) is negligible (3 per cent of the projects, with almost no impact in terms of expected CERs).[34]

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



Source: Based on UNEP Risø 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 projects with foreign technology providers



Source: Based on UNEP Risø Centre database (715 non-hydro projects)

3.5 *Project design document consultants and technology transfer*

In order to gain some initial understanding of the role of individual players, 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 based in China.

Chinese PDD consultants are very active, being involved in 62 per cent 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 can identify two groups. The first is composed of CWEME, Longyuan and China Fulin, which are subsidiaries of two leading 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 which, together with the Global Climate Change Institute/INET (GCCI/NET), was the earliest institution in China

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[34] The distribution does not substantially change when considering the 364 projects with ITT.

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

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 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 Risø Centre database (715 non-hydro projects).

There are many differences between these two groups. The three PDD consultants owned by power companies have almost exclusively joined wind power projects, i.e. in an area related to the operations of the controlling company. Furthermore, these companies generally act at the same time as PDDC and PO (see second column of 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 as to whether being a? PO and PDDC at the same time fosters a larger uptake of foreign technology. The

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[36] In the classification provided by the UNEP Risø Centre, Caspervandertak is listed as a Chinese consultant.

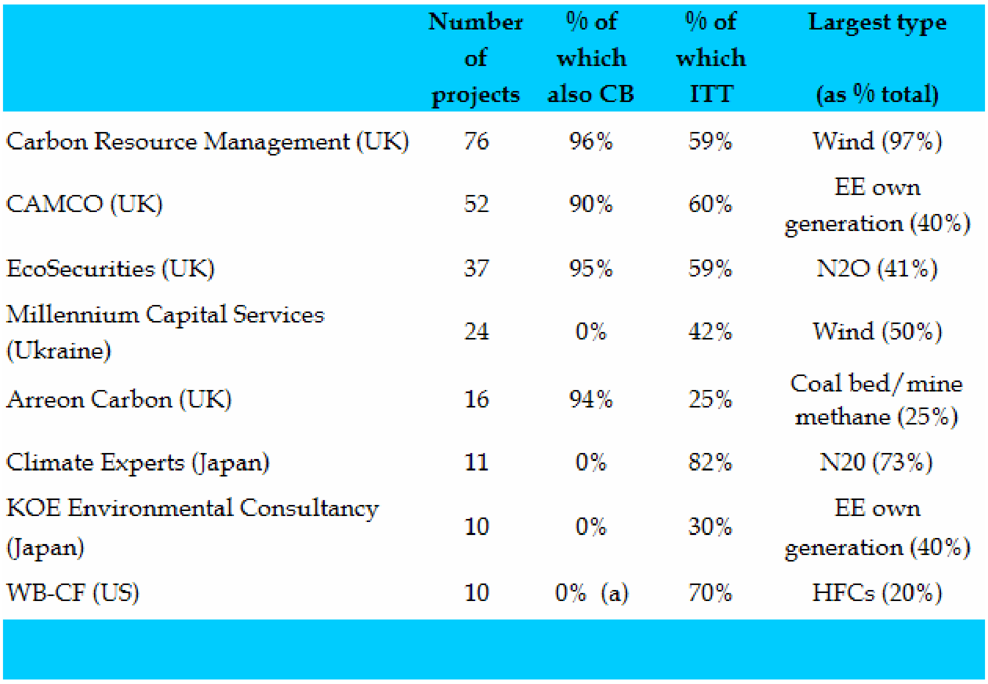
[37] There are only two exceptions, in which Easy Carbon acts jointly with another consultant.

capability of performing multiple roles, and thus dealing with complexity, might be expected to facilitate the adoption of foreign 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, unlike 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 a 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 the rate of ITT is above average in projects in which these large UK carbon traders are involved. This finding is in line with Wang (2010) who suggests that international carbon traders engaging in the overall development of the CDM process 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 a position to negotiate more favourable terms 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 Risø 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 among the main PDDC in China. Unlike 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 per cent of the projects which see Climate Experts as PDD consultant and in 90 per cent of the cases for KOE. In the group of the largest PDDCs in China we also find the World Bank Carbon Finance (WB-CF), which manages several carbon fund initiatives (such as the Community Development Carbon Fund, the BioCarbon Fund).

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

4. Econometric analysis

In recent years, as a growing number of CDM projects have been implemented and a considerable amount of data have become available, an empirical literature has started to flourish, examining whether CDM projects effectively promote the transfer of environmentally friendly technology from developed to developing countries and searching for project and country-specific characteristics favouring such a transfer.

Table 5 summarizes the main contributions that have 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 from the project. Such a variable indicates the estimated income from the project; larger projects, by making available greater financial resources, 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 is not indicated or has not been 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 ease the financial constraints 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 signals whether the project in the host country is carried out by 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 host country. The hypothesis here is that when the number of similar projects grows larger, the rate of technology transfer decreases since the technology might have already been diffused in the host country. As for country-specific factors considered, some of the reviewed studies (such as Dechezleprêtre et al., 2008, and Doranova, 2010) include indicators of absorption capacity or technological ability in the host countries (such as R&D expenditures, patent filing activity and so on), as well as other country controls such as population, GDP, trade and FDI openness that can explain the likelihood of ITT.

Findings are quite similar across the papers: the likelihood of ITT is greater 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; however, 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 the host country favours ITT, Doranova et al. (2010) find instead that more technologically advanced countries show a preference for local or mixed (domestic and foreign) technologies over foreign technology alone.[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.

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[38] Doranova et al. (2010) analyses 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. They consider, as key independent variables, 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 a 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 analysing the relevant documentation, there is no effort to take into account the relationships between the main actors in CDM projects, such as credit buyers, PDD consultants and project owners, and their role, if any, in favouring 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 up-to-date 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 adoption in China, the single largest host country, accounting for 46 per cent of world total CDM projects. Second, in our analysis we explore the relevance of all the information available on credit buyers, project owners and PDD consultant characteristics. The next section describes our estimation strategy.

4.1 Estimation strategy and variable description

In this section we use regression analysis to explore 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 explained ? in section 3.2.

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

$$\begin{aligned}\Pr(ITT_i = 1) = G(&\alpha_s + \beta_1 \log(projectsize_i) + \beta_2 \log(investment_i) + \beta_3 inland_i + \beta_4 northwest_i \\ &+ \beta_5 southwest_i + \beta_6 (Nfrac) + \beta_y ycomm_i + \beta_7 (CB\_PDDC_i) + \beta_8 (CB\_PDDC_i * Large) \\ &+ \beta_9 (PO\_PDDC_i) + \beta_{10} (CHI\_PDDC_i) + \beta_{11} (lPDDC_i) + \beta_{12} (mPDDC_i))\end{aligned}$$

Where G is a function that maps the model into the response probability.[39] The explanatory variables considered here are the following:

- α_s : project type dummy variable;
- ***logprojectsize:*** log of total emission abatement expected by the project;
- ***loginvestment:*** measured as the log of US$ per unit of abatement, i.e. ton of CO_2 e);
- ***Inland, Northwest* and *Southwest:*** dummy variables for project location.

The location dummies are intended to capture the differential effect in the rate of technology transfer between less developed and more developed provinces (with the east coast as the control group). We expect that in the poorer provinces the likelihood of technology transfer is lower due to a lower absorption capacity, other things being equal.

- ***Nfrac:*** number of previous projects using the same abatement methodology.

Contrary to what is usually done in the literature, we do not consider the number *per se*, rather we normalise 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.

- ***Ycomm***: time dummies to capture year-specific effects; each project is dated according to the year in which it entered the pipeline, which coincides with the beginning of the validation stage.[40]

As the main novelties, we consider the relationships between the main participants in the project and their effects on the likelihood of having ITT:

- ***CB_PDDC***: dummy variable that takes value 1 if the credit buyer is also a PDD consultant for the project and 0 otherwise;
- ***PO_PDDC*** a dummy variable that takes value 1 if the project owner is also a consultant for the project and 0 otherwise;

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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-day public comment period. See “Guidance to the CDM & JI Pipelines” available at http://cdmpipeline.org/publications/GuidanceCDMpipeline.pdf).

- ***CHI_PDDC***: a dummy variable that takes value 1 if there is at least one Chinese project consultant for the project; zero otherwise.
- ***sizePDDC****:* size of PDD consultant *(size=m,l);* we classify PDD consultants as small, medium or large, according to the number of CDM projects developed in China; the small group is taken as the control one.

Unlike other studies, we do not distinguish between unilateral and non-unilateral projects because for China such a characteristic is irrelevant, since only a tiny percentage of all the registered projects hosted in China can be classified as unilateral (about 3 per cent). Table A1 in the appendix describes our variables in more detail.

Our investigation is driven by the following hypotheses: controlling for project type-specific effects, the probability of having a foreign technology supplier should be higher for larger and costly projects; it should also be higher in the richest provinces due to their greater absorption capacity and openness to foreign investment; the probability should decrease as the number of previous projects of the same type increases. This latter effect would reflect technology diffusion to Chinese firms and also the government's 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 also acts as a PDD consultant, due to larger incentives, as well as greater financial resources, to obtain foreign technology (see section 3.5); in the same vein, we expect that when the project owner develops its own project (as a PDD consultant) it might be more interested in acquiring foreign technology. Finally, we presume that the probability of having a foreign technology supplier is higher the larger the PDD consultant for the project. The idea is that larger consultants might enjoy a better knowledge of the most effective foreign technologies available and can facilitate the process of acquisition of those technologies; moreover, larger consultants, by having a better knowledge of CDM procedures in the host country, might facilitate project approval by claiming foreign technology transfer.[41]

We estimate and compare three models: linear probability, logit and probit models. As the results are very similar we report only those for the linear probability model (LPM). We run three different regressions. The first one includes only the variables already considered in the existing literature; in the second regression we add our "relationship" variables; and in the third regression we add a further control for wind power to capture differential effects in the absorption of foreign technologies in this sector (key priority area for the Chinese government, also in terms of technological development).

4.2 Base regression results

The results of the LPM are reported in Table 6. As expected, regression I reveals that 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 of having 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] The rate of 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 relative position of a project within its group 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

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[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 also have different interpretations, such as the existence of an environmental *Kutzenet's curve* within China, by which in the richest provinces producers are keen to use cleaner technologies in response to higher environmental standards. Under the assumption that foreign technology is more advanced and environmentally friendly, the Kutzenet's curve hypothesis would induce a higher propensity to adopt foreign technology in the richest provinces.

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

request). In terms of goodness of fit, the models perform quite well, the R-squared is 0.22 and the percentage of correct predictions is 71 per cent. The latter measure is calculated at the 50 per cent threshold, which coincides with the average value of the dependent variable.[44]

In regression II we added our "relationship" variables and we find that the probability of ITT is larger when the credit buyer is also a (large) consultant for the project; the same is true when the consulting process is controlled directly by the project owner. The latter finding confirms the importance of major consultants, whether foreign or Chinese, as only major Chinese consultants are project owners as well. The goodness of fit of our model improves both in terms of R-squared (up to 0.26) and in terms of correctly predicted outcomes (up to 71.8 per cent).

Compared with 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, though not significant, coefficient when we control for the year of entry into the pipeline. Our results differ from UNFCC (2010), which 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. Finally, we show the importance of considering the relationship between the main participants in channelling foreign technology into the project; the relationship between credit buyers and PDD consultants as well as that between project owners and PDD consultants is particularly important. This finding suggests that the availability of financial resources from the very beginning, secured by large PDD consultants, is fundamental in accessing foreign technology.

We perform a robustness check to explore further the negative time trend and the ***Nfrac*** variable and the differences in our findings compared with the existing literature in the next sub-section.

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[44] Running the regressions, all the observations belonging to sectors with a rate of ITT equal to 0 or 1 are automatically deleted. Hence, we are left with 646 observations (out of 715), with an average rate of ITT equal to 0.49.

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), it is worth considering 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 number of projects in the wind power sector increases. In our database we have 391 wind power projects (out of 715), with an average probability of ITT of 0.45, compared with an average probability of 0.57 elsewhere. One way to capture such a differential effect is by making the ***wind*** dummy interact with the number of previous projects of the same type variable and see whether it makes a difference. We do so in regressions III reported in Table 6.

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 for foreign technology declines. In particular, given the estimated marginal effect, 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 66 per cent threshold of the total number of projects of the same type.[45]

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, in which, controlling for all the relevant characteristics, the adoption of foreign technology tends to increase as the number of projects of the same type increases.[46] Overall, we still find a decreasing rate of foreign technology over time, as the ***ycomm(i)*** coefficients retain their negative sign, although their magnitude is now slightly lower. In the case of China, this effect is mainly driven by the increasing number of projects in wind power and a decreasing number of

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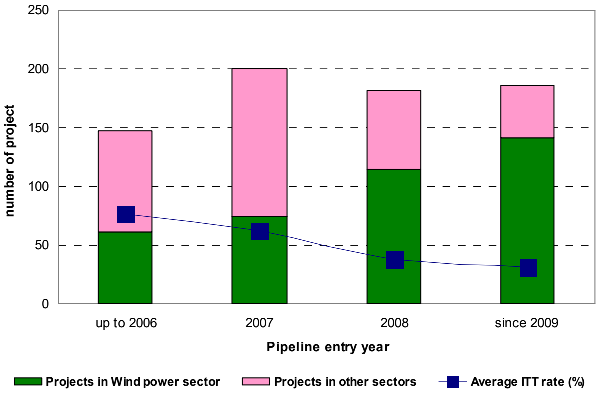
[45] $\frac{dy}{dWind} = 0.316 - 0.478 * Nfrac > 0 \ if \ \ Nfrac < 0.66.$

[46] 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.

projects elsewhere (Fig. 5), however, even excluding wind power projects from our sample we are still observing a decreasing rate of foreign technology adoption over time in CDM projects in China, indicating that the CDM tool has been increasingly used as a purely financial mechanism, possibly also reflecting the country's technological progress. All the other explanatory variables retain their previous sign and degree of significance.

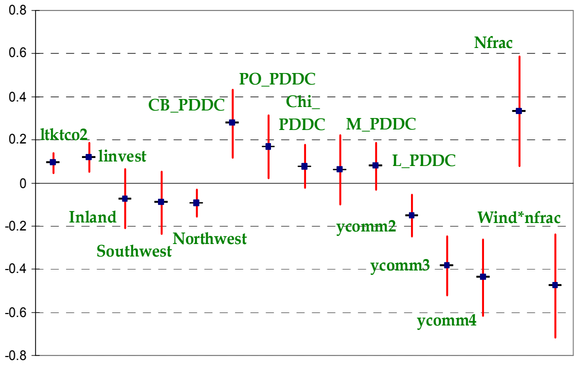
In terms of goodness of fit, the model performs slightly better, both in terms of pseudo-R squared (now up to 0.27) and in terms of the overall percentage of correctly predicted outcomes (72 per cent). In all the regressions the model performs better in predicting no technology transfer than it does in predicting a positive transfer (see Table A2 in the appendix). The likelihood-ratio test confirms the significance of all slope coefficients in regression II and III.

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



Source: Authors' elaborations on UNEP Risø Centre Database (715 projects).

Fig. 6. Marginal effects from LPM estimates
(point estimate and 5 per cent confidence interval)



Source: Authors' elaborations on UNEP Risø Centre Database (715 projects).

Table 6. Probability of foreign technology transfers in CDM projects in China: results from LPM regressions

Dependent variable: y= pr(ITT=1)	LPM (OLS)		
Independent variable	**I**	**II**	**III**
Log(tot_KtCO2)	0.110***	0.084***	0.093***
Log(investment)	0.136***	0.130***	0.119***
Inland_dummy	-0.052	-0.073	-0.074
Southwest_dummy	-0.127*	-0.097	-0.090
Northwest_dummy	-0.094***	-0.102**	-0.096***
ycomm2 (2007)	-0.167**	-0.176**	-0.153***
ycomm3 (2008)	-0.388***	-0.400***	-0.384***
ycomm4 (>2008)	-0.488***	-0.511***	-0.440***
Nfrac	0.081	0.104	0.339**
CB_PDDC		0.030	-0.006
CB_PDDC*Large		0.261***	0.276***
PO_PDDC		0.181**	0.169**
Chi_PDDC		0.088*	0.076
L_PDDC		0.076	0.078
M_PDDC		0.053	0.059
Wind			0.316**
Wind*Nfrac			-0.478***
Const	-0.881***	-0.847***	-0.983***
Type_dummies	YES	YES	YES
Cluster CB	YES	YES	YES
Number obs	648	646	646
% correctly predicted	**71.0%**	**71.8%**	**72.0%**
R2	**0.22**	**0.26**	**0.27**

Likelihood-ratio test

	Regression I	**Regression II**	**Regression III**
Log likelihood	-387.218	-373.6387	-367.0153
LR satistic (Restr. Reg I)	:	27.1586	40.4054
Probability (LR stat)	:	**Pr> Chi2(6)= 0.000**	**Pr> Chi2(7)=0.0000**
LR satistic (Restr. Reg II)	:	:	13.2468
Probability (LR stat)	:	:	**Pr> Chi2(1)=0.0003**

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

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 with 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 aimed at CDM projects (such as the 51 per cent Chinese ownership requirement discussed in section 3.1) but also at several measures intended to achieve the planned targets on renewable energy development and energy efficiency improvement. The distinguishing feature of Chinese CDM projects is that the process seems almost completely under the control of domestic entities and policies.

Consistent with the above-mentioned government priority areas, CDM projects in China are heavily concentrated on types related to renewable energy and to energy efficiency in industry. Examining 1,355 registered projects, we find that in 34 per cent 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 the local development of wind turbine manufacturing through various channels. It has promoted direct technology transfer via import and training, and has favoured the setting-up of local production facilities by 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 at any time between several potential partners.

Several countries supply technology to CDM projects in China (mostly the EU, the US and Japan). Germany has a prominent position in many respects, in terms of the number of projects, the number of firms involved and breadth of technology portfolio. This is presumably linked to Germany's sustained attempt to take the lead in green technologies.[47] When assessing to what extent the technology supply from one country is linked to credit buying from the same country, we found a clear specialisation among EU members between "mainly credit buyers" countries (the UK and Netherlands) and "mainly technology providers" countries (Germany, Spain and Denmark). Japan, however, 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; few of them though 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 dominant role is played by three UK carbon trading companies, which are also important credit buyers.

Our econometric analysis confirms some of the insights that emerged from the descriptive analysis. We find that the likelihood of having 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 of having a foreign technology provider is lower when projects are located in the poorest provinces of

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

China, supporting the idea of a lower absorption capacity there. Such a probability is greater 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 tend to encourage the adoption of foreign technology too.

Finally, we find a significant difference in the 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 for foreign technology declines and domestic suppliers become predominant, while the same effect does not hold true for projects developed in other sectors, such as chemicals or steel. This suggests that the absorption of foreign technology has been stimulated successfully by the Chinese policymakers in strategic sectors with high growth potential, such as 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. However, even excluding wind power projects from our sample, we are still observing a decreasing rate of foreign technology adoption over time, indicating that the CDM tool is being increasingly used as a purely financial mechanism, presumably also reflecting China's technological progress.

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Appendix tables

Table A1

Variable description

ITT= 1 if there is at least one foreign technology supplier in the project; 0 otherwise

Abatement size = log(Ktco2e)

Investment =log(US$/tco2e)

inland=1 if the project is located in Anhui; Henan; Hubei; Hunan; Jiangxi; Shanxi. 0 otherwise.

Northwest = 1 if the project is located in Gansu; Inner Mongolia; Ningxia; Quinghai; Shaanxi; Tibet; Xinjiang. 0 otherwise

Southwest =1 if the project is located in Guangxi; Guizhou; Sichuan; Yunnan. 0 otherwise.

M_PDDC = 1 if PDDC shows up in at least 10 projects and up to 47 (excluding PDDC_CB); 0 otherwise

L_PDDC = 1 if PDDC shows up in at least 48 projects (excluding PDDC_CB); 0 otherwise

CB_PDDC= 1 if at least one credit buyer among PDDCs; 0 otherwise

CB_PDDC*Large= 1 if at least one credit buyer among PDDCs & PDDC= L_PDDC; 0 otherwise

PO_PDDC =1 if PO among PDDCs; 0 otherwise

Chi_PDDC =1 if there at least one Chinese PDDC in the project (excluding POs); 0 otherwise

ycomm2 =1 if project entered in the pipeline in 2007; 0 otherwise

ycomm3 =1 if project entered the pipeline in 2008; 0 otherwise

ycomm4=1 if project entered pipeline from 2009 onwards; 0 otherwise

Wind= 1 if CDM is developed within the wind sector; 0 otherwise

Nfrac = number of previous projects of the same type/total number of project in same type class

Wind*Nfrac= Nfrac if Wind=1; 0 otherwise

Source: Based on inspection of relevant documentation available at http://cdm.unfccc.int/Projects/projsearch.html and UNEP Risø Centre database (715 projects).

Table A2

Percentage of correctly classified outcomes

Classified + if predicted Pr(D) >= .5
True D defined as tt ~=0

<table>
<tr><th></th><th colspan="3">Regression I</th><th colspan="3">Regression II</th><th colspan="3">Regression III</th></tr>
<tr><th>Classified</th><th>D</th><th>~D</th><th>total</th><th>D</th><th>~D</th><th>total</th><th>D</th><th>~D</th><th>total</th></tr>
<tr><td>+</td><td>207</td><td>78</td><td>285</td><td>210</td><td>76</td><td>286</td><td>206</td><td>71</td><td>277</td></tr>
<tr><td>-</td><td>110</td><td>253</td><td>363</td><td>106</td><td>254</td><td>360</td><td>110</td><td>259</td><td>369</td></tr>
<tr><td>total</td><td>317</td><td>331</td><td>648</td><td>316</td><td>330</td><td>646</td><td>316</td><td>330</td><td>646</td></tr>
<tr><td>Sensitivity Pr(+|D)</td><td>65%</td><td></td><td></td><td>66%</td><td></td><td></td><td>65%</td><td></td><td></td></tr>
<tr><td>Specificity Pr(-|~D)</td><td>76%</td><td></td><td></td><td>77%</td><td></td><td></td><td>78%</td><td></td><td></td></tr>
<tr><td>Positive predictive value Pr(D|+)</td><td>44%</td><td></td><td></td><td>44%</td><td></td><td></td><td>43%</td><td></td><td></td></tr>
<tr><td>Negative predictive value Pr(~D|-)</td><td>56%</td><td></td><td></td><td>56%</td><td></td><td></td><td>57%</td><td></td><td></td></tr>
<tr><td>False + rate for true ~D Pr(+|~D)</td><td>24%</td><td></td><td></td><td>23%</td><td></td><td></td><td>22%</td><td></td><td></td></tr>
<tr><td>False - rate for true D Pr(-|D)</td><td>35%</td><td></td><td></td><td>34%</td><td></td><td></td><td>35%</td><td></td><td></td></tr>
<tr><td>False + rate for classified + Pr(~D|+)</td><td>27%</td><td></td><td></td><td>27%</td><td></td><td></td><td>26%</td><td></td><td></td></tr>
<tr><td>False - rate for classified - Pr(D|-)</td><td>30%</td><td></td><td></td><td>29%</td><td></td><td></td><td>30%</td><td></td><td></td></tr>
<tr><td>Correctly classified</td><td>71.0%</td><td></td><td></td><td>71.8%</td><td></td><td></td><td>72.0%</td><td></td><td></td></tr>
</table>