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The Clean Development Mechanism and the International Diffusion of Technologies: An Empirical Study

Antoine Dechezleprêtre, Matthieu Glachant
and Yann Ménière
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Antoine Dechezleprêtre, Matthieu Glachant and Yann Ménière, *CERNA, École Nationale Supérieure des Mines de Paris, France*

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The Clean Development Mechanism and the International Diffusion of Technologies: An Empirical Study

Summary

The Clean Development Mechanism (CDM) is expected to stimulate the North-South transfer of climate-friendly technologies. This paper provides an assessment of the technology transfers that take place through the CDM using a unique data set of 644 registered projects. It provides a detailed description of the transfers (frequency, type, by sector, by host country, etc.). It also includes an econometric analysis of their drivers. We show that transfer likeliness increases with the size of the projects. The transfer probability is 50% higher in projects implemented in a subsidiary of Annex 1 companies while the presence of an official credit buyer has a lower – albeit positive – impact. The analysis also yields interesting results on how technological capabilities of the host country influence technology diffusion in the CDM.

Keywords: Kyoto Protocol, Clean Development Mechanism, International Technology Transfer

JEL Classification: Q5, Q55

Address for correspondence:

Matthieu Glachant
CERNA École des mines de Paris
60, Boulevard Saint Michel
75272 Paris Cedex 06
France
Phone: + 33140 51 92 29
Fax: +33140 51 91 45
E-mail: glachant@ensmp.fr

1. Introduction

The Clean Development Mechanism (CDM) is one of the most innovative tools of the Kyoto Protocol. It allows industrialized countries which have accepted emissions reduction targets to develop or finance projects that reduce greenhouse gas (GHG) emissions in non-Annex 1 countries¹ in exchange for emission reduction credits. Since reducing GHG emissions in a less-developed country may be cheaper than doing so domestically, it helps Annex 1 countries to achieve their emission reduction target at a lower cost and it contributes to the sustainable development of the host countries (see Ellis et al., 2007, for an up-to-date discussion on the CDM).

While its primary goal is to save abatement costs, the CDM is also considered by many as a key means to boost technology transfer and diffusion. If the technology used in the project is not available in the host country and has to be imported, the project de facto leads to a technology transfer. This technology may consist of “hardware” elements, such as machinery and equipment involved in the production process, and/or “software” elements, including knowledge, skills, and know-how (OECD 2005). Note that the CDM did not have originally an explicit technology transfer requirement in the Kyoto Protocol. This was included later in the 2001 Marrakech Accords

Expecting international technology transfer through CDM projects sounds reasonable. However whether this is true in practice is an empirical question. In this paper, we use a unique dataset describing the 644 CDM projects that have been registered until May 1st, 2007 in order to explore this issue. More precisely, we address two types of questions. The first are descriptive: how often do CDM

¹ Non-Annex 1 countries have also ratified the Kyoto Protocol but do not have any emissions reduction targets. This group has 148 members and is mainly comprised of developing countries. Large GHG emitters such as China, India, Brazil or Mexico belong to this group.

projects include a transfer of technology from abroad? In which sectors? Which types of technologies are transferred? Which countries are the main recipients? Who are the technology suppliers?

The second set of questions is more analytical. Using regression analysis, we investigate what drives technology transfer in the CDM. This provides insights on questions such as: do the host country's technological capabilities influence technology transfer? Does the presence of an official credit buyer in the project's partnership promote transfer? Is a transfer more likely in projects implemented in subsidiaries of companies based in industrialised countries?

The transfer of environmentally sound technologies in the context of climate change mitigation is the subject of an extensive literature (see for example Worrell et al. 2001; Yang and Nordhaus, 2006). In contrast, only two papers deals with technology transfer through CDM projects using a quantitative approach. Based on a limited sample of 63 registered projects, De Coninck, Haake and van der Linden (2007) show that imported technologies originate mostly from the European Union and that the investments from industrialized countries associated with the CDM are small when compared to total foreign direct investments. Haites, Duan and Seres (2006) work on a larger database gathering 860 projects. They find that technology transfers occur in one third of the projects, accounting for two thirds of the annual emission reductions. Larger projects and projects with foreign participants tend to induce technology transfer.

We depart from these papers in two respects. First, our data set provides a richer description of the countries hosting the CDM projects and of the countries supplying the technologies. It also describes in more details the participants involved in the projects. Second - and this is related to the previous point- a richer set of independent variables allows to run regressions that explain the technology transfer². This gives insights on the design variables of CDM that promote technological transfer, thereby leading to potentially useful policy lessons. More generally, it helps deepening our understanding of the transfer of GHG mitigation technologies, which could be useful in the current debate surrounding post-Kyoto talks.

The article is organized as follows. In section 2, we describe the data set. Section 3 includes the descriptive results on technology transfers. The econometric analysis is carried out in Sections 4 and 5. We investigate what drives the transfer but also the type of transfer (equipment or knowledge). Section 6 concludes.

² The paper by Haites et al. (2007) also includes a regression. But its explanatory power is weak as independent variables are essentially country and sector dummies.

2. Data issues

2.1. Sources

In this section, we describe how we construct the data set. CDM projects that result in real, measurable and long-term climate mitigation benefits in non-Annex 1 countries are registered by the Executive Board of the UNFCCC. Our data describes all the 644 projects that have been registered as of May 1st, 2007. These projects amount for 888.5 expected million tons of CO₂-equivalent (MtCO₂eq) emissions reductions until the end of 2012.

We use three main information sources to describe these projects: 1) the UNEP Risoe Center CDM Pipeline database³, 2) the so-called Project Design Documents, and 3) data from international institutions like the World Bank and the World Trade Organization for country-level economic and technological variables.

For every CDM project, the UNEP Risoe Center CDM Pipeline database includes the host country, the type of technology, the estimated amount of the annual emissions reductions, the cumulative emissions reductions to the end of the Kyoto period (31 December 2012) and the countries that will buy the carbon credits generated by the project (if already available). We have also collected the registration date and the name of all parties involved on the UNFCCC website dedicated to CDM projects⁴.

The content of the Project Design Documents (PDDs, hereafter) is our main source of information. They are mandatory standardized documents of about 50 pages submitted to the Executive Board by the project developers for registration. In the PDDs, we have collected information about the technology used, whether there is a transfer or not, the type of transfer, the project implementer (name, business sector and name of parent company) and every foreign partner involved (name, location). We have also retrieved information on the role of the projects partners: whether they are credit buyers, consulting companies, PDD consultant or equipment suppliers.

Host country characteristics, including information on GDP, trade or FDI flows have been obtained from the World Bank's World Development Indicators 2006⁵. We have completed this information with

³ The database is available at <http://cdmpipeline.org/>

⁴ <http://cdm.unfccc.int/Projects/index.html>,

⁵ Available online at <http://devdata.worldbank.org/wdi2006>

economic performance indicators from the Earth Trends database of the World Resource Institute⁶. To proxy the technological capability of a country to import and use advanced technology, we have used the composite index Arco developed by Archibugi and Coco (2004).

2.2. Information on technology transfers

Given our questions, it is worth describing carefully how we encode information on technological transfers. To begin with, we define technology transfer as the import of a technology from abroad.

We consider two forms of technology transfer. The first one is referred to as a *knowledge transfer* and takes place if the local project developer benefits from the transfer of knowledge, know-how, information or technical assistance from a foreign partner. The second form is referred to as an *equipment transfer*. It consists in importing equipments, such as wind turbines or gas burners, from a supplier located in a foreign country. Of course, a project can involve both a transfer of equipment and a transfer of knowledge.

We get this information from the PDDs. In these documents, the technology to be employed in the project activity is described in section A.4.3. The Guidelines for completing the PDD available from UNFCCC indicate that "this section should include a description of how environmentally safe and sound technology, and know-how to be used, is transferred to the host Party(ies)." Yet, this is not a compulsory requirement and no section is specifically devoted to technology transfer. Indeed, claims of technology transfer can often be found in others sections such as "Description of the project activity" (A.2) or "Barrier analysis" (B.4). Section G ("Stakeholders comments") sometimes contains interesting information on equipment suppliers. Further information on the technology employed may also be displayed in the annex. In order to get relevant information, we have read carefully all the PDDs.⁷

In order to illustrate how we have proceeded in practice, consider two examples. Project #247 involves a *knowledge transfer*. It consists in replacing fossil fuel with biomass in the production of cement at Lafarge Malayan Cement Company in Malaysia. The technology to process and use local biomass has been developed by Lafarge Malayan Cement's parent company, Blue Circle Industries. Their research centre is based in Europe. The PDD makes it clear that "knowledge and expertise have been actively transferred in the development of the project by European expert deployment in Malaysia."

⁶ <http://earthtrends.wri.org/>

⁷ For efficiency purposes, we first searched the PDDs for the words "technology", "transfer", "equipment", "supplier", "import", "manufacturer" and "training". If no information on technology transfer could be found through this search, the PDD was read.

Training of local staff and engineers has been provided by experts from Blue Circle as well as from Lafarge Europe (Blue Circle's parent company).

Project #839 is an example of *equipment transfer*. It aims at generating electricity from biogas at a landfill in Talia, Israel. The PDD informs us that "the high temperature flare, blower, gas analyzer, industrial computer are all imported from Europe" but does not give any further information on the equipment supplier's involvement beyond the sale. Technology suppliers certainly transfer some knowledge, at least in the form of an instructions leaflet. Hence an equipment transfer should be seen as a transfer of technology that comes with the minimum possible transfer of knowledge.

How reliable is this information? There are several potential problems we have tried to mitigate. In some PDDs, a transfer of technology sometimes refers to the simple adoption of a new technology. If the technology provider is clearly located within the country, the project does not involve any international technology transfer, and consequently does not appear as such in our database.

Another difficulty concerns specifically the import of equipment. From a general point of view, the import of goods does not always entail a technology transfer. For instance, importing a DVD player produced in China in the U.S. does not. The same is true for CDM projects. They might include the imports of generic devices. In this regards, we have considered that the import of equipment is associated with a technology transfer whenever the PDD claims it is so.

It remains that PDD editors have an incentive to overstate the existence of technology transfer as it helps project registration. Accordingly, type I errors are unlikely while type II errors could be frequent even if any claim of technology transfer has been justified in the PDD⁸. Therefore, descriptive statistics on the percentage of technology transfer are probably less reliable than other figures.⁹ This is a usual difficulty with this type of studies. But, one can realistically assume that this bias is randomly distributed in the population of PDD writers. Therefore, this problem probably does not damage our econometric results.

⁸ A type I error consists in wrongly describing a project as not involving any technology transfer. Conversely, a type II error occurs when a project is wrongly described as involving a technology transfer (when it does not).

⁹ Haites et al. (2006) find that 33% of the projects involve transfer, compared to 43% in our data set. One possible reason is that the datasets are slightly different. Another is the procedure that has been used in both papers for encoding tech transfer. We read the whole PDDs whereas Haites et al. (2006) have only searched for the word "technology".

3. Descriptive statistics on technology transfers

In this section we provide a detailed description of technology transfers occurring in CDM projects.

3.1. Frequency and nature of technology transfers

Table 1 shows that 279 projects out of 644 involve technology transfer. They represent 43% of the number of projects and 84% of the expected annual CO₂ emissions reductions. Projects with transfer are thus larger on average than those without transfer. This discrepancy is partly explained by the fact that all 13 HFC-destruction projects, representing more than 59 million tons of annual CO₂eq reductions, involve transfers.

In Table 1, we see that transfers limited to the import of equipments are much less frequent than the transfer of knowledge only (9% of the projects against 19%). The transfer of both equipment and knowledge is observed in 19% of the projects. This illustrates the key role of technical skills in the diffusion of carbon mitigation technologies.

Table 1 – Nature of technology transfer involved in the CDM projects

Nature of technology transfer	Number of projects	% of projects	% of annual emission reductions	Average reduction per project (ktCO ₂ eq/yr)
Transfer	279	43 %	84 %	403
Equipment	57	9 %	6 %	133
Knowledge	101	15 %	14 %	185
Equipment + Knowledge	121	19 %	64 %	714
No transfer	365	57 %	16 %	59
Total	644	100 %	100 %	208

3.2. Transfer by type of technology

Using the 21 technology categories established by the UNEP Risoe Center CDM pipeline, Table 2 shows that the number of projects and the transfer likeliness vary greatly across types of technology.

Table 2 – Technology transfer by type of technology

Type of technology	Number of projects	Percentage of projects involving technology transfer	Share of transfers that include equipment	Average project size (annual ktCO ₂ eq)
Biomass energy	141	19%	81%	56
Hydro power	112	22%	68%	50
Biogas recovery in agriculture (breeding farms)	104	70%	10%	43
Wind power	80	63%	96%	84
Energy efficiency measures in industry	65	25%	75%	112
Landfill gas recovery	51	80%	80%	279
Fossil fuel switch	14	43%	100%	34
Biogas recovery (other)	14	29%	75%	45
Reduction of the share of clinker in cement production	14	7%	0%	144
HFC decomposition	13	100%	92%	4612
Energy efficiency / supply side	7	14%	0%	33
N ₂ O destruction	6	100%	83%	3141
Geothermal power	5	40%	50%	293
Solar power	4	100%	100%	11
Recovery of fugitive gas	3	100%	33%	621
Power generation from coal mine methane	3	67%	100%	462
Energy efficiency measures in households (insulation)	3	67%	100%	14
Energy efficiency measures in the services sector	2	100%	100%	8
Tidal power	1	100%	100%	315
Reforestation	1	0%	–	26
Transport	1	0%	–	247

All projects aiming at the destruction of HFC-23 entail a transfer. HFC-23 is a byproduct of HCFC-22, a widely used ozone-friendly refrigerant. The global warming potential of HFC-23 gas is 12,000 times higher than that of carbon dioxide (IPCC 2001). Projects mitigating HFC thus generate very large amounts of CERs and are extremely profitable. A few companies located in Europe and in Japan have developed technologies to destroy HFC. They are key partners in any HFC decomposition CDM

project. Projects avoiding the emission of nitrous oxide (N_2O) in the chemicals industry and recovering methane (CH_4) in landfills and farms also exhibit a very high transfer rate.

In the energy sector, equipment for solar and wind power generation are usually imported from Annex 1 countries. More precisely, about 60% of wind power projects import turbines which are of higher capacity than locally produced ones. This is not surprising as local companies like Goldwind in China and Suzlon in India only produce small-capacity turbines. This explains why projects using imported turbines have an average total capacity of 53 MW in comparison with 28 MW for projects using local devices.

A large share of projects recovering biogas in breeding farms also involves technology transfer. The purpose of this type of project is to mitigate and recover biogas resulting from the decomposition process of animal effluents. Each project includes the installation of covered lagoons and a combustion system that destroys the captured biogas. Albeit the technologies are not very elaborate, knowledge transfer is frequent because these projects are mainly initiated by developers located in Annex 1 countries like AgCert. This Irish company provides farmers with turnkey solutions, including training sessions on how to operate the technology. The offered service includes specification and design of the complete technology solution, identification of appropriate technology providers, supervision of the project installation, farm staff training and ongoing monitoring.

Conversely, technology transfers are limited in certain areas. Power generation using hydro power or biomass is an example. Biomass power plants are similar to fossil-fuel fired power plants and use a very common technology. So do hydro power plants: most projects are located in Brazil, India and China, which have been mastering hydro power technology for decades.

Table 3 gives an aggregate view of these results by sector. Excepting the chemicals sector with HFC and N_2O destruction projects, the industrial sector surprisingly does not yield many technology transfers. The situation is different for the energy sector with a technology transfer rate of 39%.

Table 3 – Technology transfer by sector

Sector	Number of projects	Percentage of projects involving technology transfer	% of equipment transfer in projects with transfer
Waste	51	80%	80%
Agriculture (incl. reforestation)	105	70%	10%
Energy	264	39%	87%
Industry	223	27%	79%
Transport	1	0%	—

3.3. Transfer by mitigation mechanism

Table 4 distinguishes different mitigation mechanisms. Transfers largely concern end-of-pipe technologies that remove gaseous pollutants from effluent streams at the end of the production process. The “new units” category describes the setting up of new production units with reduced GHG emissions. It gathers biomass-fired and hydro power plants that essentially use local technology as well as wind farms that often benefit from technology transfer. In contrast, projects that modify existing production processes involve far less transfers. Input switch refers to projects involving a change of production inputs (e.g., biomass instead of coal in a power plant).

Table 4 – Technology transfer by mitigation mechanism

Mechanism	Number of projects	% of technology transfer
End-of-pipe	205	69%
New unit	286	36%
Input switch	39	33%
Change in the production process	111	20%

3.4. Technology transfer by host country

CDM projects are located in 44 non-Annex 1 countries, but Brazil, China, India and Mexico host 73% of them. 35 % of the projects are located in India alone. 24 countries host 3 projects or less and among these, 12 countries host only 1 project.

Table 5 shows technology transfers in the main host countries. They appear very heterogeneous in their capability to attract technology transfers.

Table 5 – Technology transfer for selected host countries

Country	Number of projects	% of technology transfer
India	225	12%
Brazil	99	40%
Mexico	78	68%
China	71	59%
Chile	17	35%
Malaysia	15	87%
South Korea	13	77%
Honduras	10	30%

3.5. Technology suppliers

Among the 154 projects that explicitly mention the origin of the imported equipment, 71% originate from a European supplier. Within Europe, the main exporting countries are Germany, Spain and Denmark, which accounted for 45% of the exported machinery. Non European suppliers are mainly located in the USA (19%) and Japan (10%).

This means that the money spent by Annex 1 countries to finance CDM projects – through the purchase of carbon credits – is only marginally used to buy machinery from countries that have not ratified the Kyoto Protocol. Does it mean that each country subsidizes its own technologies through the Clean Development Mechanism? This argument has been widely used by CDM opponents. A closer look at our data invalidates this assertion: an Annex 1 country hosts both the credit buyer and the equipment supplier in only 2% of the projects.

Table 6 reports the main countries of origin and of destination by technology. Spain mainly exports wind turbines manufactured by Gamesa Eolica. Other wind turbines exporters include Vestas from Denmark and Enercon from Germany. The French company Vichem is the main technology provider for HFC decomposition projects. Technologies for N₂O destruction are provided by Japanese companies or by UHDE (a ThyssenKrupp company).

Table 6 – Main countries of origin and of destination by type of technology

Type of technology	Main countries of origin	Main countries of destination
Biomass energy	Belgium, Denmark, Japan	Malaysia, India, Brazil, Indonesia
Wind power	Denmark, Germany, Spain, USA	China, India, Brazil, Mexico
Landfill gas	Italy, UK, France, USA, Ireland, Netherlands	Brazil, Mexico, Argentina, Chile, China
HFC decomposition	France, Germany, Japan	China, India
Hydro power	France, Germany, UK, Spain	Ecuador, Panama, Honduras, South Korea, Mongolia
Agriculture	Ireland, Canada, UK	Mexico, Brazil, Philippines, Ecuador
Energy efficiency in industry	Japan, Italy, USA	India, China, Malaysia
N ₂ O destruction	Germany, Japan, France	South Korea

3.6. Partnerships

Initially, it was thought that CDM could be initiated by companies from Annex 1 countries to cut emissions at a lower cost through technological partnerships that would also benefit developing countries. An example in line with these expectations is Project # 526. The Heidelberg group - a German cement company - has developed this project to cut carbon emissions in its Indonesian subsidiary, Indocement. The project aims at producing a new type of blended cement which reduces CO₂ emissions reductions. It has benefited from research and development activities conducted in Europe by Heidelberg Cement.

However, if we look at the data, a limited number of projects follow a similar pattern. Only 8% are implemented in subsidiaries of companies located in an Annex 1 country. Among these projects, only 21 parent companies offered technical assistance to their local subsidiary. This means that in total, less than 5% of all CDM projects involve a transfer from an Annex 1 country company to its subsidiary. Instead, the CDM business has generated unexpected forms of technological partnership. Companies such as AgCert, EcoSecurities, Carbon Resource Management, Agrinergy or Carbon Asset Services Sweden are now key players in the production and sale of carbon credits. We refer to these companies as CDM project designers. They manage the whole CDM project cycle, from PDD writing to credit sale. Their diversified portfolio of CDM projects allows to minimize risk and to exploit

economies of scale in administrative tasks. Some of them directly transfer the technology to local project developers. For example, AgCert transfers know-how in Animal Waste Management Systems to livestock farms in Brazil and Mexico. Others simply help local firms finding technology suppliers and assessing their technologies.

As shown by Table 7, nearly 50% of the credit buyers are CDM project designers. Carbon traders - either banks like ABN AMRO or companies involved in commodity trading like Nuon Energy or EDF Trading - are not very active on the primary market, although the Noble group has created a dedicated subsidiary, Noble Carbon Credits. Private companies also frequently buy credits.

Table 7 – Types of credit buyer

Type of credit purchaser	Number of projects (percentage)
CDM project designer	179 (47%)
Carbon trader (mostly banks)	18 (4.7%)
Private company	96 (25.1%)
Private fund	5 (1.3%)
Government fund	45 (11.8%)
Public-private fund	9 (2.4%)
World Bank fund	29 (7.6%)
TOTAL	381 (100%)
Note: a project may have more than one credit buyer involved.	

4. The determinants of technology transfers: an econometric analysis

In the previous section, we have presented statistics describing technology transfers through the CDM. They give a detailed view on these issues but do not help us to understand what drives the transfer. For instance, we know from Table 5 that 69% of the Chinese projects involve a transfer while the percentage is only 12% in India. Why is it so? Is it because the technological capability of India is less than that of China? Or is it due to sector composition effect – Indian projects may take place in economic sectors where a transfer is less likely? Is it due to project characteristics? For instance, is it because Chinese projects are implemented more frequently in subsidiaries of Annex 1 companies, assuming that this type of partnership increases the likeliness of transfer?

Understanding the rationale underlying the technology transfer through CDM projects is necessary to derive policy implications and, more generally, to give more general insights on the diffusion of GHG mitigation technologies. In this section, we rely on econometric analysis to do so.

4.1. The econometric model

Let $TECH_TRANSFER$ denote a binary variable equal to 1 if a project involves a technology transfer (regardless of the nature of this transfer) and 0 otherwise. To examine the relationship between $TECH_TRANSFER$ and a set of explanatory variables, the following logit equation is estimated:

$$\Pr(TECH_TRANSFER = 1) = \frac{e^\Omega}{1 + e^\Omega}$$

with:

$$\begin{aligned} \Omega = & \alpha_0 + \alpha_1(LOGSIZE) + \alpha_2(CREDIT_BUYER) + \alpha_3(SUBSIDIARY) \\ & + \alpha_4(SIMILAR_PROJECTS) + \alpha_5(TRADE) + \alpha_6(FDI_INFLOWS) \\ & + \alpha_7(GDP_GROWTH) + \alpha_8(TECH_CAPACITY) \\ & + \alpha_9(LOG_POPULATION) + \alpha_{10}(GDP_PERCAPITA) + \alpha_i SECTOR_i + \alpha_j COUNTRY_j + \varepsilon \end{aligned}$$

α_i is a vector of coefficients to be estimated and ε is a random term identically independently distributed following a Gumbel extreme distribution.

We now discuss in depth the different explanatory variables. $LOGSIZE^{10}$ is the log of the project size, as measured by its annual emissions reduction. The underlying hypothesis is that CDM projects entail transaction costs that are fixed and that are likely to be higher when some technology transfer is involved (Maskus, 2004). Such transaction costs are an impediment to small projects. Assumedly, the larger a project, the higher its probability to involve technology transfer.

$CREDIT_BUYER$ is a dummy variable indicating the participation of one or more credit buyers in the project. Before the project developer can sell the credits, the UNFCCC must first certify, issue and register the emission reduction and this administrative process takes time. Selling credits through a forward contract can be of great help. It reduces the risk surrounding the investments by adding a guaranteed revenue stream. Most credit buyers are not pure financial actors as shown in Table 7.¹¹ One can assume that they also give advice and bring expertise that may ease technology transfer.

¹⁰ Using the logarithm of the size ensures that the few very large HFC projects do not have a disproportionate influence on the results

¹¹ Only 18 credit buyers are banks.

SUBSIDIARY is a dummy variable indicating whether the project is implemented in the subsidiary of a company located in an Annex 1 country. In this case, the local project developer can probably benefit from the expertise or from the technology of the parent company (Jahn *et alii* 2004).

The number of other CDM projects using the same technology within the host country is described by the variable SIMILAR_PROJECTS. We see this variable as a proxy for the local availability of the technology in the country. Accordingly, the higher the number of similar projects, the lower the probability of transfer.

We also include country variables. In this regard, there is empirical evidence in the general economic literature that international trade and Foreign Direct Investments (FDI) promote the transfer of technology across countries (Coe, Helpman, and Hoffmaister 1997). Accordingly, we use the variable TRADE which is the ratio of the sum of exports and imports of merchandise on GDP and FDI_INFLOWS which is the level of incoming FDI in the host country.

As richer and larger countries are likely to have more technologies already available locally, we include the country size (LOG_POPULATION) and the per capita GDP (GDP_PERCAPITA) as control variables. In order to take into account the possible influence of economic dynamism, we also use GDP_GROWTH which is the average annual rate of GDP growth from 2000 to 2004.

Furthermore, empirical evidence indicates that the adoption of a new technology is strongly associated with human capital, supporting infrastructure and research and development activities (Blackman 1997). In order to measure this technological capability (TECH_CAPABILITY), we use the ArCo technology index developed by Archibugi and Coco (2004). This composite indicator captures three aspects determining technological capabilities: the creation of technology (number of patents and number of scientific articles), the technological infrastructures (internet penetration, telephone penetration and electricity consumption) and the development of human skills (percentage of tertiary science and engineering enrolment, mean years of schooling and literacy rate).

TECH_CAPABILITY may have contrasting effects on technology transfers. On the one hand, the influence may be positive as the establishment of a new technology in a country may require technical competencies and a skilled workforce. On the other hand, high technological capabilities mean that many technologies are already available locally, thereby reducing the probability of transfers through CDM projects. These antagonistic effects may have different weights across sectors. This leads us to estimate two variants of the model:

- In Model A, we simply use the index TECH_CAPABILITY, thereby assuming that the effect of technological capability does not vary across sectors.
- In Model B, the variable TECH_CAPABILITY interacts with 11 sector dummies allowing differentiated effects across sectors. We use AGRICULTURE, ENERGY, WASTE¹² and 8 other dummies describing industrial sectors.

Finally, SECTOR_i and COUNTRY_i are vectors of sector dummies and country dummies, respectively.

They control for sector- and country-specific characteristics that are not captured by the other variables.

Table 8 yields precise definitions, summary statistics and the expected signs of the coefficients.

Table 8 – Definition of variables and summary statistics

Variable	Definition	Number of obs.	Mean	Standard deviation	Expected impact
LOGSIZE	Log of the size of the project (expected annual reductions in ktCO ₂ eq).	644	3.716	1.532	+
CREDIT_BUYER	= 1 if the project has one or more credit buyer, 0 otherwise	644	0.607	0.489	+
SUBSIDIARY	= 1 if the project developer is the subsidiary of a company from an Annex 1 country, 0 otherwise	644	0.171	0.377	+
SIMILAR_PROJECTS	= log (N) where N is the number of projects already using the same type of technology within the host country	644	1.959	1.386	–
GDP_GROWTH	Average annual growth of GDP from 2000 to 2004	644	4.688	2.560	+
TRADE	Sum of exports and imports of merchandise divided by the value of GDP. Average for 2000-2004	644	25.62	17.06	+
FDI_INFLOWS	Sum of net inflows of FDI divided by GDP. Average for 2000-2004	644	2.374	1.534	+
TECH_CAPABILITY	Index of technological capability * 100 (source: Archibugi and Coco 2004)	644	30.05	8.80	?
GDP_PERCAPITA	GDP per capita 2004	644	3779	3871	–
LOG_POPULATION	Log of total population in million (2004)	644	5.38	1.80	–

¹² We have excluded the transport sector which only concerns one project.

4.2. Results

Empirical results are displayed in Table 9. The overall quality of the estimations is reasonably good.

The McFadden pseudo R-squared is around 0.35-0.4 depending on the model. The model correctly predicts 80 % of the observations and the results are robust across the two specifications (models A and B).

We now interpret the influence of the different variables. To begin with, technology transfer positively depends on the size of the project (LOGSIZE). This is in line with the expectation that larger projects are better able to exploit economies of scale in technology transfer.

Having a credit buyer also increases the likelihood that the project involves technology transfer. But calculations show that the marginal effect of CREDIT_BUYER is low: a project with a credit buyer has only a 16% higher probability of involving a technology transfer.

Being the subsidiary of a company from an Annex 1 country (SUBSIDIARY) clearly favors the transfer of technology. The coefficient is highly significant in all specifications and much larger than that of CREDIT_BUYER. In marginal terms, the transfer likeliness of a project located in the subsidiary of an Annex 1 company is 50% higher. This confirms the conjecture that pre-existing capital links strongly promote the import of a new technology.

As expected, the probability of technology transfer decreases with the number of projects using the same type of technology in the country (SIMILAR_PROJECTS).

Turning next to country variables, we confirm that, all other things being equal, the openness of the economy positively influences transfer probability. In contrast, the share of FDI inflows in GDP does not have any significant impact. This is not that surprising as capital links are already captured by the variable SUBSIDIARY.

Results on technological capabilities are very interesting. First, Model A tells us that the technological capability has a positive overall effect on technology transfer. However, introducing the possibility of differentiated effects across sectors (Model B) modifies this statement. In fact, TECH_CAPABILITY has a positive influence only in the energy sector and in the chemicals industry. The effect is strongly negative in agriculture and not significant in most industry sectors and in waste management.

Recall the two antagonistic effects of technological capabilities. One the one hand, they promote transfer as local implementers have skills to use the technology. On the other hand, high technological capabilities increase the local availability of technologies. Our results suggest that the latter effect

dominates the former in agriculture while the opposite is true in the energy sector and in the chemicals industry. The interpretation is that technologies transferred in the agriculture sector are not very elaborate, implying that they might be introduced without high technical skills. In contrast with this, wind turbines, solar panels in the energy sector or abatement devices in the chemicals industry would require technically qualified manpower to be built and operated. In the other sectors in which coefficients are not significant, the two effects might compensate each other.

In order to compare the size of the effects of different explanatory variables, we draw Figure 1 using model B's results. Using the same metric, each bar measures the impacts of the variable on an average CDM project.

Figure 1 is based on the following calculation. Let \bar{x}_i be the average value of the variable x_i in the data set and let β_i denote the value of its coefficient. Then, the product $\beta_i \bar{x}_i$ represents the average impact of x_i on the linear predictor Ω . Calculating the value of $\beta_i \bar{x}_i$ for every variable allows to compare the average weight of each variable on the decision to transfer technology. Figure 1 represents these weights.

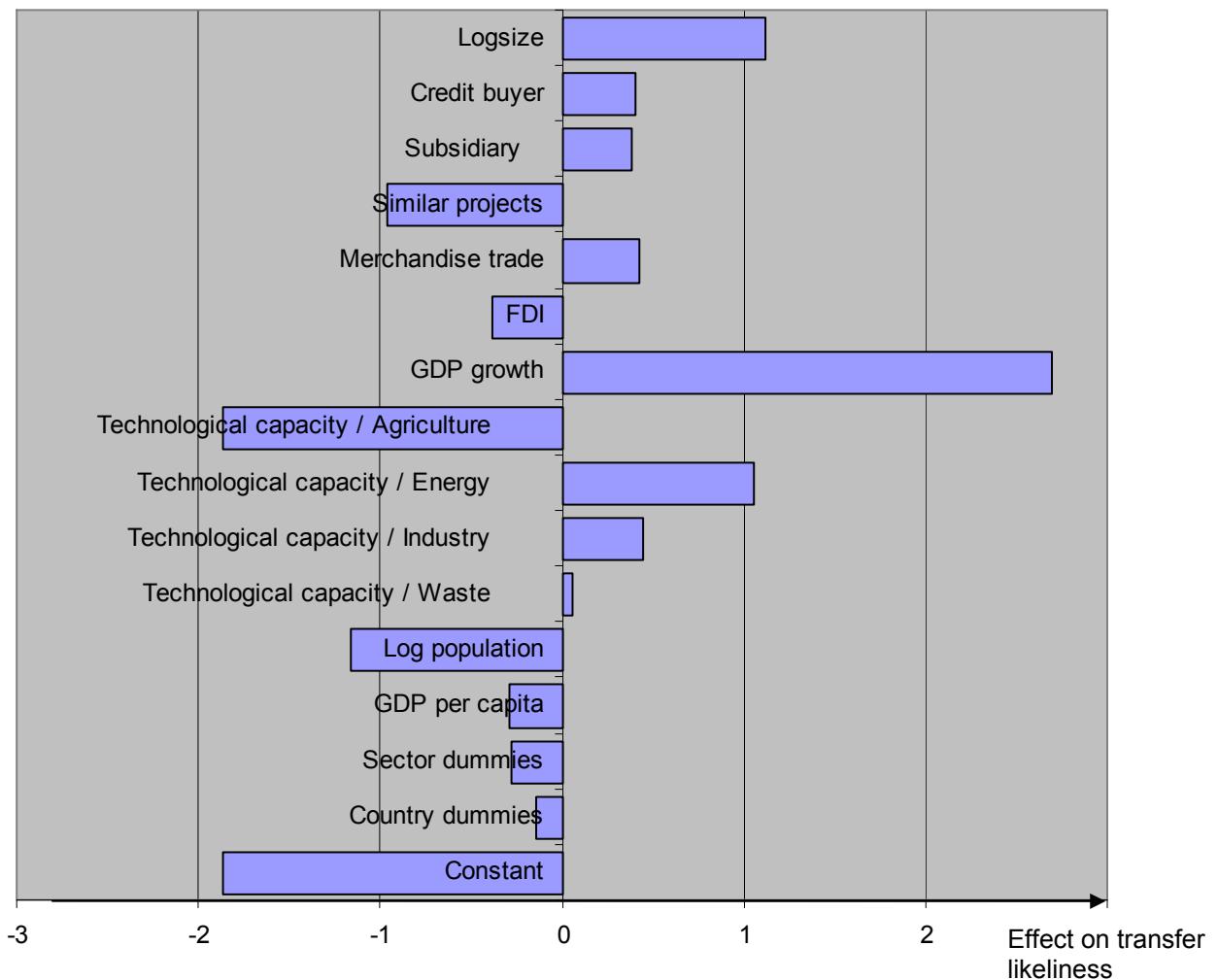
This representation shows that, among project variables, the size of the project and the number of similar projects within the host country have the most important impact on technology transfer. CREDIT_BUYER and SUBSIDIARY have similar effects but for different reasons. SUBSIDIARY increase the transfer probability by 50% but only 8% of the projects are implemented in subsidiaries of Annex 1 companies. CREDIT_BUYER has a weaker marginal effect (+16%) but credit buyers participate in 61% of the projects.

At the country level, GDP growth exerts a stronger influence than economic openness. The technological capability has a strong effect - either negative in agriculture or positive in the energy sector. We also find that the overall impact of project-level variables is smaller than that of country-level variables. This result is very important and suggests that the incentives to transfer technology given specifically by the CDM are low compared to usual economic and infrastructure-related incentives.

Table 9 – Regression results of models explaining *TECH_TRANSFER*

Dependant variables	Model A	Model B
LOGSIZE	0.2792 *** (0.0842)	0.2590 *** (0.0929)
CREDIT BUYER	0.5122 ** (0.2504)	0.6282 *** (0.2635)
SUBSIDIARY	2.3508 *** (0.3578)	2.2463 *** (0.3621)
SIMILAR_PROJECTS	-0.4192 *** (0.1204)	-0.2782 ** (0.1310)
TRADE	0.0104 * (0.0056)	0.0103 * (0.0060)
FDI_INFLOWS	-0.2587 * (0.1368)	-0.1045 (0.1452)
GDP_GROWTH	0.6153 *** (0.2219)	0.5124 ** (0.2184)
TECH_CAPABILITY	0.0686 * (0.0395)	
TECH_CAPABILITY * AGRICULTURE		-0.3474 ** (0.1730)
TECH_CAPABILITY * ENERGY		0.0825 * (0.0471)
TECH_CAPABILITY * WASTE		0.0134 (0.0508)
TECH_CAPABILITY * CHEMICALS		0.1088 ** (0.0522)
TECH_CAPABILITY * CEMENT		0.0428 (0.0485)
TECH_CAPABILITY * FOOD		0.0497 (0.0475)
TECH_CAPABILITY * IRON & STEEL		0.0392 (0.0542)
TECH_CAPABILITY * PAPER		0.0089 (0.0617)
TECH_CAPABILITY * TEXTILE		0.0538 (0.0690)
TECH_CAPABILITY * WOOD		0.0209 (0.0576)
TECH_CAPABILITY * OTHER INDUSTRY		0.0553 (0.0574)
GDP_PERCAPITA	-0.0001 (0.0001)	-0.0001 (0.0001)
LOG_POPULATION	-0.2546 (0.2645)	-0.1614 (0.2643)
SECTOR _i	-	-
COUNTRY _i	-	-
# observations	643	643
Pseudo-R2	0.3568	0.3861
Percent correct prediction	80.1 %	79.9 %
Notes:	Standard error in parentheses; * denotes significance at 10% level, ** denotes significance at 5% level, and *** denotes significance at 1% level.	

Figure 1 – Comparative impacts of the independent variables in a representative project



5. Explaining the type of transfer

In this section, we concentrate on the projects involving a technology transfer and we seek to identify what drives the type of transfer project developers engage in: the transfer of equipment or the transfer of knowledge.

Let $HARD_TRANSFER$ denote the binary variable that indicates whether or not the technology transfer concerns equipments. A straightforward solution would be to estimate a standard logit model on the sub-sample of projects involving transfers. But results would be biased because this sub-sample is not random. In technical terms, there is a so-called sample selection bias. The reason is that

unobserved factors may influence both the probability of transfer – and thus the probability for a project to belong to the sub-sample – and the type of transfer.

A solution to this problem has been suggested by Heckman (1976). This is a two-step estimation procedure. In a first stage, the probability that a project leads to technology transfer is estimated. This is the sample selection equation. This allows recovering a selection hazard index which is included as a regressor to estimate the type of transfer in the second stage (for more details on the Heckman model, see for instance Greene, 2003).

We have implemented the Heckman procedure and Table 10 reports the results of the second stage. In comparison with the previous models, we have excluded some dependent variables, either because there was no reason to assume they would influence the type of transfer (for example, GDP_GROWTH) or because they were not significant.

Results show interesting patterns. First of all, the probability that the transfer concerns equipment decreases with the number of projects using the same type of technology in the country (SIMILAR_PROJECTS). A possible interpretation is the following. A developer who needs a technology has two options: either to buy it locally or to import it. In the economic literature, the first refers to *horizontal diffusion* while the second refers to *vertical diffusion*. Our results suggest that *horizontal diffusion* dominates when the technology is equipment.

As regards technological capabilities, Models C and D show that the pro-transfer effect dominates for equipment in the energy and the waste management sectors. The agriculture is still specific confirming that the equipments used in agricultural projects do not require significant technological skills.

Table 10 – Estimation results of the Heckman model's for HARD_TRANSFER

Dependant variables	C	D
LOGSIZE	0.0132 (0.0638)	0.0021 (0.0667)
SIMILAR_PROJECTS	-0.3108 *** (0.0982)	-0.2417 ** (0.1136)
TRADE	0.0030 (0.0028)	0.0031 (0.0030)
TECH_CAPABILITY	0.0227 ** 0.0114	
TECH_CAPABILITY * AGRICULTURE		-0.9387 * (0.5051)
TECH_CAPABILITY * ENERGY		0.0427 ** (0.0197)
TECH_CAPABILITY * INDUSTRY		-0.0018 (0.0142)
TECH_CAPABILITY * WASTE		0.0510 * (0.0283)
SECTOR _i	-	-
COUNTRY _i	-	-
Uncensored observations	279	279
Standard error in parentheses; * denotes significance at 10% level, ** denotes significance at 5% level, and *** denotes significance at 1% level.		

6. Conclusion

This paper focuses on transfers of GHG mitigation technologies induced by the Clean Development Mechanism. We have examined technology transfers in the 644 CDM projects registered until May 2007.

From a descriptive point of view, the data shows that technology transfers take place in more than 40% of the CDM projects. Very few projects involve the transfer of equipment only. Instead, projects often include the transfer of knowledge and operating skills, allowing project implementers to appropriate the technology.

Technology transfer mainly concern two areas. The first one is the end-of-pipe destruction of non-CO₂ greenhouse gas with high global warming potentials, such as HFCs, CH₄ and N₂O. This concerns the chemicals industry, the agricultural sector and the waste management sector. The second one is wind power. Other projects, such as electricity production from biomass or energy efficiency measures in

the industry sector, mainly rely on local technologies. Moreover, Mexican and Chinese projects more frequently attract technology transfers while European countries are the main technology suppliers. We have also developed econometric models in order to characterize the factors underlying these patterns. They show that there are economies of scale in technology transfer: all other things being equal, transfers in large projects – in terms of emissions reductions – are more likely. Furthermore, the probability of transfer is 50% higher when the project is developed in a subsidiary of Annex 1 companies. Having an official credit buyer in the project also exerts a positive influence on transfer likeliness, albeit much smaller (+16%).

As regards the host countries' features, the most interesting econometric results deal with technological capabilities. In theory, this factor has ambiguous effects. On the one hand, high capabilities may be necessary to adopt a new technology. On the other hand, high capabilities imply that many technologies are already available locally, thereby reducing transfer likeliness. Our estimations show that the first effect strongly dominates in the energy sector and in the chemicals industry. By contrast, the second effect is stronger for agricultural projects. This suggests that the agricultural technologies transferred in these projects tend to be simple.

What are the policy implications? First, these results suggest policy lessons on CDM design. Encouraging large projects – or project bundling – allows to exploit increasing returns in technology transfer. Promoting projects in subsidiaries of Annex 1 companies could also be of great use to foster technology transfer. In practice, one could imagine different ways of providing incentives for companies to do so (e.g., additional credits, simplified administrative procedures). To a lesser extent, credit buyers, which are generally not pure financial actors, can also play a positive role.

Our analysis may also give lessons on general measures. In particular, the study suggests that programs of technological capacity building would be particularly profitable in the energy sector and in the chemicals industry.

Last, let us pinpoint some limits of this exercise. First, the data describes projects registered during a very short period of time (about 2 years). This prevents using this information to characterize the dynamic aspects of diffusion. Second, the data does not allow investigating the diffusion of technology within host countries, which may be as important as international transfers. Other methodological weaknesses are the lack of sector-specific variables in comparison with project design variables and

country-specific variables and the fact that information on technology transfer may be biased as it is self reported by the project developers in the PDD.

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