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

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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.

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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 countries[1] 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 but must be imported, the project leads, de facto, 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 originally have 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 registered up to 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 projects

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[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 and Mexico belong to this group.

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 into a range of questions. 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 deal with technology transfer through CDM projects using a quantitative approach. Based on a limited sample of 63 registered projects, De Coninck et al. (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 et al. (2006) work on a larger database involving 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 those 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 greater detail 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 transfer[2]. This gives insights into the design variables of the CDM that promote technological transfer, thereby leading to potentially useful policy lessons. More generally, it helps deepen 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 regarding technology transfers. The econometric analysis is carried out in Sections 4 and 5. We investigate what drives not only the transfer but also the type of transfer (equipment or knowledge). Section 6 concludes.

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 registered as of May 1st, 2007. These projects account for an expected 888.5 million tons of CO_2-equivalent ($MtCO_2eq$) emissions reductions by the end of 2012.

We use three main information sources to describe these projects: 1) the UNEP Risoe Center CDM Pipeline database[3], 2) the so-called Project Design Documents, and 3) data from international institutions such as 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 dates of each project and the name of every country involved, on the UNFCCC website dedicated to CDM projects[4].

The content of the Project Design Documents (PDD) 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 project partners: are they credit buyers, consulting companies, PDD consultants 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 2006[5]. We have completed this information with

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[2] The paper by Haites et al. (2006) also includes a regression. But its explanatory power is weak as independent variables are essentially country and sector dummies.
[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 Institute[6]. 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, which we call a *knowledge transfer*, 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 an *equipment transfer*. It consists in importing equipment, 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)." But 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 other[s] 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."

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 which we have tried to mitigate. In some PDDs, a transfer of technology may refer to the simple adoption of a new technology. If the technology provider is clearly located within the country, the project involves no international transfer; consequently our database records no international transfer for that project in that country.

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 made in China and imported into the U.S. does not. The same is true for CDM projects which might include the import of generic devices. In this regard, we have considered that the import of equipment is associated with a technology transfer whenever the PDD claims that it is.

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 PDD[8]. Therefore, descriptive statistics regarding technology transfer percentages are probably less reliable than other figures.[9] This is a usual difficulty with this type of study. But one can realistically assume that this bias is randomly distributed over the PDD-writing population. Therefore, this problem probably does not damage our econometric results.

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[8] A type I error consists of 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 used in both papers for encoding

3. Descriptive statistics regarding 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 projects and 84% of the expected annual CO_2 emissions reductions. Projects with transfer are thus larger-scale on average than those without. This discrepancy is partly explained by the fact that all 13 HFC-destruction projects, representing more than 59 million tons of annual CO_2eq reductions, involve technology transfer.

In Table 1, we see that transfers limited to the import of equipment are much less frequent than the transfer of knowledge alone (9% of the projects as opposed to 15%).

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

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technology transfer. We read the entire PDDs whereas Haites et al. (2006) only searched for the word

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 likelihood of transfer 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 $ktCO_2eq$)
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_2O 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 by-product 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

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"technology".

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. Although 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

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

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

In 71% of the 154 projects that explicitly mention the origin of imported equipment, it comes from European suppliers. Within Europe, the main exporting countries are Germany, Spain and Denmark, which accounted for 45% of the exported machinery. Non-European suppliers are mostly 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. But 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 turbine exporters include Vestas in Denmark and Enercon in Germany. The French company Vichem is the main technology provider for HFC decomposition projects. Technologies for N_2O 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_2O destruction	Germany, Japan, France	South Korea

3.6 Partnerships

Initially, it was thought that CDM projects 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 CO_2 emissions. 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 Annex 1 countries. 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 risk minimization and exploitation of 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 with 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 this? 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 a clearer view of the diffusion of GHG mitigation technologies. In this section, we rely for this on econometric analysis.

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 to 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. It may be assumed that 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.

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 al., 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

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

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 et al., 1997). Accordingly, we use the variable TRADE, which is the sum of exports and imports of merchandise divided by GDP. FDI_INFLOWS is the level of incoming FDI divided, again, by the host country's GDP.

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, the average annual rate of GDP growth 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.

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[11] Only 18 credit buyers are banks.

- In Model B, the variable TECH_CAPABILITY interacts with 11 sector dummies allowing differentiated effects across sectors. We use AGRICULTURE, ENERGY, WASTE[12] 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	–

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[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 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 all that surprising, since capital links are already captured by the variable SUBSIDIARY.

Results regarding technological capabilities are very interesting. First, Model A tells us that technological capability has a positive overall effect on technology transfer. However, introducing the possibility of differentiated effects across sectors (Model B) modifies this finding. 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 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 $\overline{x}_i$ 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 $\beta_i \overline{x}_i$ represents the average impact of x_i on the linear predictor Ω. Calculating the value of $\beta_i \overline{x}_i$ for every variable allows setting the average weight of each variable against 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 increases 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 is a very significant finding because it 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.		

Fig. 1. Comparative impacts of the independent variables in a representative project
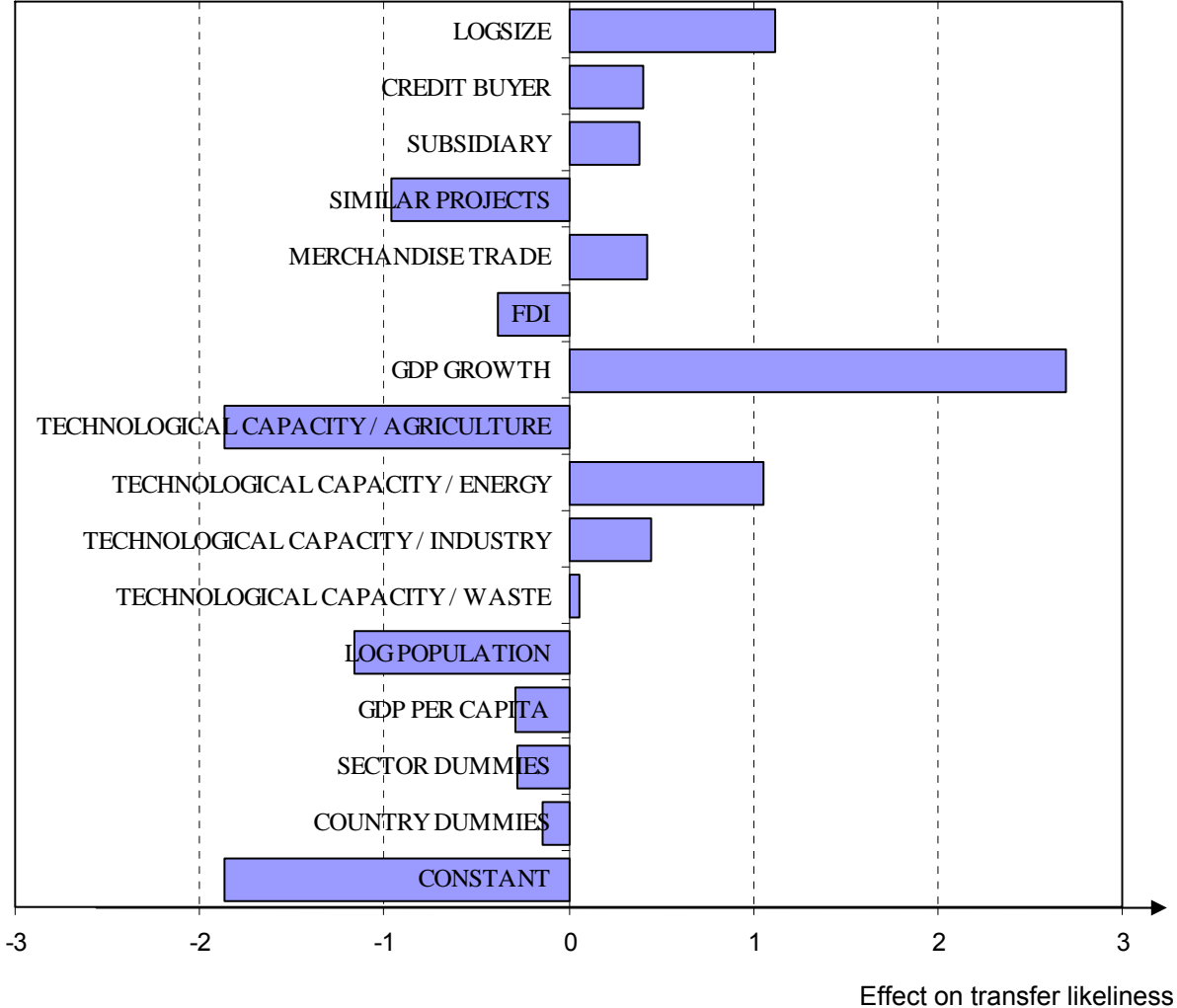
5. Explaining the type of transfer

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 equipment. 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 phase, the probability that a project leads to technology transfer is estimated. This is the sample selection equation: it allows us to set up a selection hazard index which is included as a regressor to estimate the type of transfer in the second phase (for more details on the Heckman model, see for instance Greene, 2003).

We have implemented the Heckman procedure: 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 developer who needs a technology has two options: either to buy it locally or to import it. In the economic literature, the first is termed *horizontal diffusion* and the second *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 waste management sectors. Agriculture is still specific, confirming that the equipment 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 up to May 2007.

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

Technology transfers mainly concern two areas. The first is end-of-pipe destruction of non-CO_2 greenhouse gas with high global warming potentials, such as HFCs, CH_4 and N_2O. This concerns the chemicals industry, the agricultural sector and the waste management sector. The second 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 an Annex 1 company. 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 findings involve 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 likelihood. 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 for CDM design. Encouraging large projects – or project bundling – allows exploitation of 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 regarding 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 limitations of this exercise. First, the data describes projects registered during a very short period (about 2 years). This prevents using this information to characterize the dynamic aspects of diffusion. Second, the data does not permit investigation of the diffusion of technology within host countries, which may be as significant 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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