

Technology transfer in the Clean Development Mechanism: the role of host country characteristics

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Abstract

Technology transfer is not an explicit objective of the Clean Development Mechanism (CDM). In some projects it however constitutes a valuable co-benefit as it exposes developing countries to clean technologies and helps improve local living conditions. Understanding the drivers and barriers to technology transfer in CDM projects is therefore essential to direct investment flows in host countries and promote possible enhancements of the current CDM framework. In this respect, the contribution of this paper is twofold. First, it identifies facilitating factors and barriers in host countries which are correlated with technology transfer. Trade flows and expenditure in research and development are found to be positively linked to technology transfer. A one percent increase in the latter is associated with a five percent increase in the likelihood of a technology transfer. Second, the study analyzes the correspondence of these facilitating factors and barriers with the likelihood of a transfer of the different types of technology (equipment and/or knowledge). The paper concludes with suggestions for improvements of the CDM to better assess technology transfer in offsetting projects.

JEL classification: C21, Q54, Q55

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1 Introduction

Technology transfer has attracted increasing attention over the past years in international climate negotiations. Already in the 1992 United Nations Framework Convention on Climate Change (UNFCCC), Articles 4.1 and 4.5 stress the need for cooperation between Parties to promote the transfer of environmentally sound technologies to fight climate change. The 2007 Bali Action Plan identifies technology development and transfer as one of the four "building blocks" of a future climate treaty. In the 2009 Copenhagen Accord Parties agreed upon the establishment of a technology body and further details for the implementation of Nationally Appropriate Mitigation Actions (NAMAs) by developing countries. Financial support for NAMAs would help developed countries to comply with their obligations on technology transfer.

However a missing element in current climate negotiations is the focus on improving existing flexible mechanisms such as the Clean Development Mechanism (CDM) to promote technology transfer. As an international mechanism, the CDM was designed to meet the double objective to assist developing (Non Annex I) countries in achieving sustainable development and, at the same time, to assist industrialised (Annex I) countries in achieving compliance with their quantified emission reductions under the Kyoto Protocol (Art.12, Kyoto Protocol 1997). Although technology transfer is not an explicit mandate of the CDM, it nevertheless offers a unique opportunity to channel clean technologies to developing countries.

The objective of this paper is to test the potential associations between technology transfer in the CDM and economic, human capital and environmental specific characteristics of Non Annex I countries. Identifying the role played by factors such as trade, foreign direct investment, the level of education, research and development and patterns of energy production could shed light on particular needs in host countries and potential improvements to the current CDM framework. In this spirit, the paper analyses the impact of these factors on the type of technologies transferred (knowledge, equipment or both). While exploratory, the novelty of this paper is twofold. On the one hand it introduces new country factors to the analysis of technology transfer in the CDM and, on the other, it studies the impact of these factors both on the likelihood of a transfer and on the different types of technologies transferred.

The remainder of the paper is structured as follows. Section 2 reviews the literature on the analysis of technology transfer in the CDM. Section 3 defines technology transfer and describes the methodology used to account for it in CDM projects. Section 4 presents the different patterns of technology transfer across countries. Section 5 discusses important features of the host country which are likely to influence the project developer's decision to undertake a CDM project. Section 6 presents the model and the new country factors

whose influence will be tested. Results are discussed in Section 7 and Section 8 concludes.

2 Review of the literature

Analysis of technology transfer in the CDM has been mostly based upon the review of Project Design Documents (PDDs).¹ Haites et al. (2006) were the first to analyse a set of 854 proposed projects searching for the keyword "technology" in individual PDDs. They found that technology transfer occurred in one-third of the projects, accounting for almost two-thirds of the expected annual emission reductions. Dechezleprêtre et al. (2008) analysed a sample of 644 registered projects and found that 43% of projects involved a technology transfer representing 84% of the expected annual emission reductions. These different results might come from using a slightly different methodology. Finally Seres et al. (2008) worked on a database of 3296 registered and proposed projects (which I also use in this paper). They searched for several technology-related keywords in the different PDDs and despite the large number of projects, found similar results to Haites et al. in terms of the share of projects with a technology transfer and expected emission reductions (36% and 59% respectively).

Haites et al., Dechezleprêtre et al. and Seres et al. have highlighted three 'stylized facts' on technology transfer in the CDM. First, the size of the project matters. Larger projects tend to attract more technology transfer. A higher number of expected Certified Emission Reductions (CERs) will reduce the relative fixed cost of the project, thus making a technology transfer more likely. Second, projects not involving an Annex I credit buyer are less likely to include a technology transfer (these projects are known as "unilateral" projects). Finally, having more projects of the same type in a host country is negatively correlated with the likelihood of a technology transfer in the CDM. A possible explanation might be that as the number of similar projects increases, the technology becomes available locally and the marginal benefit of imported technology falls.

These studies however do not focus on the role of host countries' economic and regulatory environment, nor do they study the impact of human capital and natural resources associated with technology transfer.² As pointed out by Schneider et al. (2008), there is a need for more detailed analysis of country characteristics and country-specific variables that might account for or be associated with the differences between countries in attracting technology through the CDM.

¹A Project Design Document (PDD) is the administrative document which project developers have to submit to the UNFCCC Secretariat in order to register their CDM project.

²A study by Pueyo Velasco (2007) was a first attempt to identify the impact of climate change, economic and natural resources variables on technology transfer. I however use a different set of country factors and find different results.

Following this last criticism this paper aims to contribute to the existing empirical literature by identifying the associations between a new set of country factors (described in Section 6) and the likelihood of a technology transfer (overall and by type of technology). Before going into more details of the analysis, a definition of technology transfer is needed.

3 A definition of technology transfer

The IPCC (2000) defines technology transfer as:

“(...) a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions.”

This definition covers all relevant flows of ‘hardware’ elements such as machinery and equipment involved in the production process, and/or ‘software’ elements, including knowledge, skills and know-how (Tébar Less et al., 2005). These flows take place between and within countries, from Annex I to Non Annex I countries and vice versa. This paper focuses on the international dimension of technology transfer, i.e. the transfer of hardware and/or software from Annex I to Non Annex I countries in the context of CDM projects.³

I follow Seres et al.’s (2008) methodology to analyse technology transfer claims in the PDDs. Because of the large amount of projects and their diversity, no standard definition was established to describe technology transfer in the CDM. However it could be inferred from the PDDs that technology transfer is broadly understood by project developers as meaning the use by the CDM project of equipment and/or knowledge not previously available in the host country (Seres et al., 2008). As the main focus of the analysis of technology transfer in the CDM is on between-country transfers, projects claiming a within-country technology transfer were not recorded in the database.

In their study Dechezleprêtre et al. (2008) used a similar methodology and pointed out the potential incentive problem for PDD writers to overstate a technology transfer in their project as it may increase the chances for the project to be approved and registered. While wrongly describing a project as not involving any technology transfer is unlikely, describing a project as involving a technology transfer when there is none could happen more often (even though any claim of technology transfer should be justified in the PDD). These ‘false technology transfers’ are problematic and could potentially mislead econometric interpretation of results. The only way to overcome this problem would be to have local experts in host countries studying a sample of projects in specific sectors and judging

³In some cases technology transfer also occurs between Non Annex I countries (3% of reviewed projects).

whether or not the technology used is actually new in the host country. Removing the share of ‘false transfers’ from all projects in each sector and in each host country would correct this potential distortion. This is however beyond the scope of this paper which assumes that the share of ‘false transfers’ is reasonably small and randomly distributed across countries so as to avoid biased results.

Another issue is how to measure technology transfer. In this paper I follow Seres’ methodology and measure technology transfer in the CDM by accounting for the number of projects with a technology transfer claim in their PDD. This method is imperfect since a technology claim does not necessarily mean that the technology will be fully assimilated and replicated in the host country. Nevertheless it gives an indication on where and in which sector international technology transfer in the CDM is taking place.

4 Patterns of technology transfer

The data set used in this paper comes from Seres et al. (2008). It covers a sample of 3296 CDM proposed and registered projects (until 29 April 2008) in 67 Non Annex 1 countries. I dropped rejected and withdrawn projects as they do not represent a potential technology transfer and only account for 3% of the overall number of projects. The individual PDDs were searched for several keywords related to technology transfer⁴ and claims were coded as follows:

Table 1: Coding of technology transfer in CDM projects.

Code	Description	# projects	%
-1	No technology transfer is occurring.	1179	36%
0	No clear indication of technology transfer in the PDD	934	28%
1	Technology transfer of equipment only	383	12%
2	Technology transfer of knowledge only	173	5%
3	Technology transfer of equipment and knowledge	622	19%
4	Joint venture (unclear if it is technology transfer)	5	0%
Total		3296	100%

Source: Seres et al. (2008)

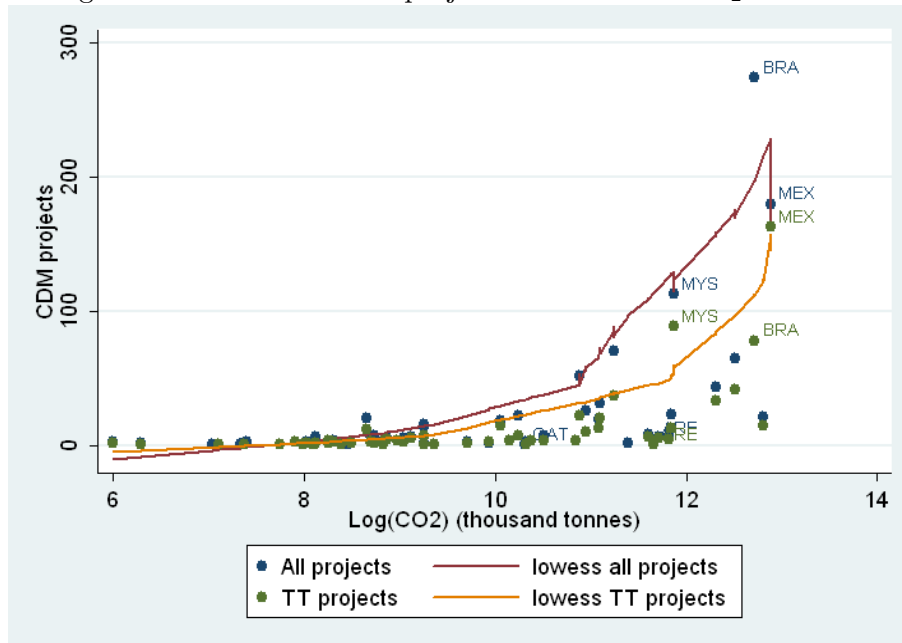
Note: For 27 projects, the PDDs were not available (they were dropped).

1178 projects out of 3296 claimed to have a technology transfer of knowledge, equipment or both (almost 36% of total projects). The five Non Annex I countries hosting the most CDM projects and the most projects with a technology transfer (TT projects) are

⁴Keywords included: technology, transfer, import, foreign, abroad, overseas, domestic, indigenous, etc. (Seres et al., 2008)

China, India, Brazil, Mexico and Malaysia. Figure 1 shows a positive correlation between the number of CDM projects taking place in a host country and its absolute number of CO₂ emissions. This correlation does not disappear when removing China, India and South Korea from the sample (the three biggest emitters in absolute value). As expected economies that release more CO₂ emissions also attract more CDM projects, both overall and with a technology transfer.

Figure 1: Number of CDM projects and absolute CO₂ emissions



Note: TT=technology transfer. For more smoothing, China (all projects: 1168; TT projects: 325; CO₂ : 3'734'650 kt), India (all projects: 902; TT projects: 141; CO₂: 1'233'809 kt) and South Korea (all projects: 43; TT projects: 21; CO₂: 464'918.6 kt) were dropped.

Correlation calculated using a locally-weighted scatter plot smoothing procedure - *lowess* in Stata, which stands for 'locally weighted least squares'. The smoothing parameter (bandwidth) is 0.8.

Source: World Bank Development Indicators (average 2000-2003), Seres (2008)

When looking at CDM project intensity and emission intensity, a positive correlation is still visible (Figure 2). However this association is not perfectly linear as Qatar (QAT) and the United Arab Emirates (ARE), which are the most CO₂/capita intensive countries in the sample, do not attract the highest number of CDM projects and technology transfer (Qatar has only got one project and it does not have a technology transfer).

Figure 3 relates the rate of technology transfer⁵ to the amount of absolute emissions of CO₂. A slight negative correlation can be observed which is rather an encouraging sign.

⁵TT rate = (number of projects with a TT/overall number of CDM projects)

Figure 2: Number of per capita CDM projects and per capita CO₂ emissions

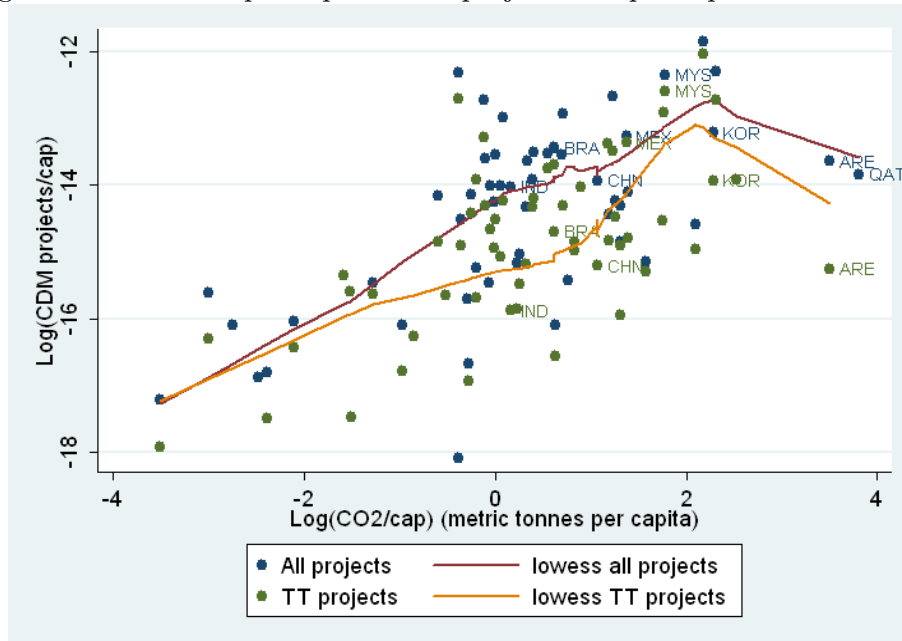
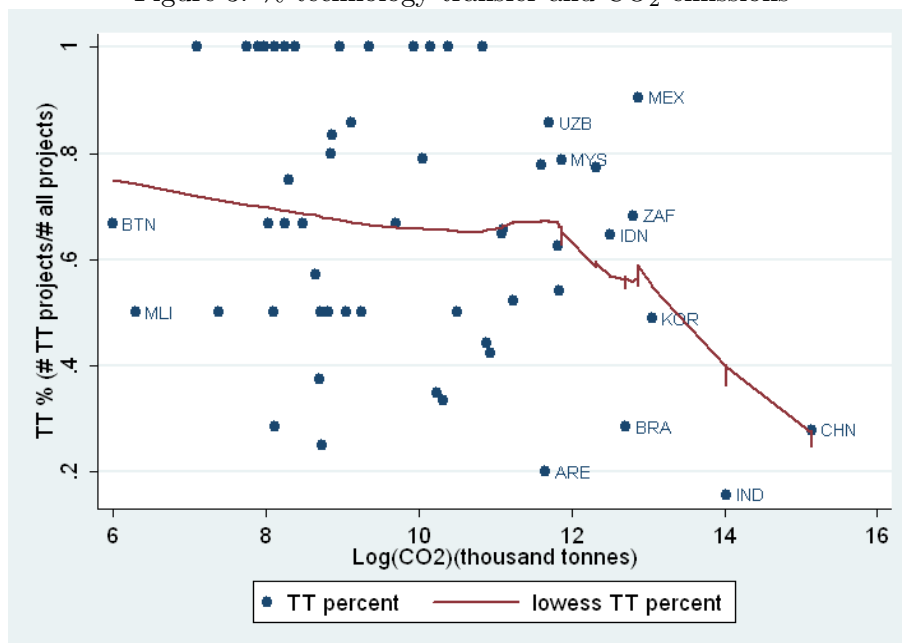


Figure 3: % technology transfer and CO₂ emissions



Note: TT=technology transfer.

Correlation calculated using a locally-weighted scatter plot smoothing procedure (*lowess* in Stata), which stands for 'locally weighted least squares'. The smoothing parameter (bandwidth) is 0.8.

Source: World Bank Development Indicators (average 2000-2003), Seres (2008)

The most polluting countries happen to be the ones attracting less technology transfer and for the least emitting ones (like Bhutan (BTN)) the rate of technology transfer is higher.

Mexico (MEX) and Malaysia (MYS) both host a large number of TT projects per capita (see Figure 2) and have a high technology transfer rate (78% and 90% respectively), whereas India (IND), which is the second largest host country in terms of number of projects (and TT projects) after China, has a lower CDM project intensity and the lowest rate of technology transfer (15.6%) of the sample.

Why are some countries attracting more technology transfer in their CDM projects? To attempt to answer this question the next section discusses the role of host country (including CDM specific) characteristics in influencing the investment choice of a CDM project and, by extension, of a potential technology transfer.

5 Decision drivers for a CDM project

Among the different factors important for creating a favourable environment for technology transfer, trade and foreign direct investment are recognized as particularly influential (Saggi, 1999; Barton, 2007). Trade in goods can help transmit knowledge internationally. A recent report from the World Bank (World Bank, 2008) suggests that liberalizing trade can significantly increase the diffusion of clean technologies in developing countries. Hence a country trading a high share of goods and services in its GDP may be more likely to attract new technologies in its CDM as local conditions may be improved for technology assimilation, thus lowering the risk for the project developer.

As an additional vehicle for FDI, the CDM will be influenced by FDI policies (Cosbey et al., 2005). Evidence suggests that licensing and investment flows will respond to an adequate business environment. Key factors include an effective infrastructure and transparency and stability of the government (Maskus, 2004). Non Annex I countries thus have incentives to work on removing burdensome regulations and fight corruption.

Besides trade and FDI policies, project developers are also likely to be influenced by the level of gross domestic capital formation in the host country. A high level of investment signals a favourable business environment in which CDM projects also take place. Other aspects such as fiscal policies could also play an important role.

Adequate environmental regulation is one of the most important factors influencing the transfer of technologies from developed to developing countries (Tébar Less et al., 2005). This includes access to information as well as intellectual property rights (IPR) protection. IPR protection plays an important role for channeling technology transfer (Maskus, 2004). Two forces work in opposite directions. On one hand, it is reasonable to assume that firms will be less willing to provide their new technology on open technology markets without the guarantee of a minimum protection from leakage of their new technical information. This reasoning also applies to CDM projects and suggests that minimum IPR protection

should encourage CDM investors to import their new technologies and ideas. On the other hand, this might not be so much of an issue if the technology is not patented, but still new to the host country. Nevertheless IPR protection will play an important role if state-of-the-art technologies are to be transferred or developed through research and development (R&D) programs in host countries.

The quality of CDM institutions is also likely to influence the choice of a project developer. A high number of registered projects in a host country could be perceived as a token of experience and effectiveness of the host country's Designated National Authority (DNA). The DNA is the authority responsible for the approval of a CDM project in the host country. According to its guidelines, it will decide whether a project is in line with its appreciation of sustainable development. Trained employees, sufficient capacity and knowledge of potential local climate change consequences as well as previous experience with the CDM are key elements to save time in the approval procedure of the submitted project. In this respect institutional and financing capacity will play a crucial role.

6 Empirical analysis

Building on the previous discussion I introduce the model which aims to test the association between three sets of variables and the probability of an international transfer of knowledge and/or equipment in CDM projects. These sets include variables related to 1) the economic and regulatory environment, 2) human capital and 3) natural resources. To do so I use a binary choice model, a probit,⁶ to analyse technology transfer claims for registered and proposed CDM projects between November 2004 and April 2008.

In the first step I estimate the coefficients of the probit model to test my hypotheses on the likelihood of a technology transfer regardless of its type. I run several regressions to differentiate between the effects on the coefficients when controlling for the clustering of errors and for large host country characteristics. I also analyse the relevant marginal effects.

In the second step I use a nested logit model and base upon my results from the probit model to analyse the influence of country factors on the different types of technology transfer (equipment, knowledge or both). The nested logit has the advantage to break decision into groups into a hierarchical manner. In the context of the CDM the project

⁶The criterion used to discriminate between a probit and a logit model is empirical: the model specification yielding the highest fitted log-likelihood was chosen. A heteroscedastic probit has the advantage over the logit to allow the variance to be non constant (the variance of a logit is equal to $\sigma^2 = \pi^2/3$). Another motivation for using a non-linear model is to avoid the problem of aggregating project-specific variables, such as the average number of expected emission reductions or the presence of a foreign credit buyer.

developer is likely to first decide whether or not to transfer technology and, if so, which type of technology to transfer. If this is indeed the decision structure of the project developer, then using a nested logit model to analyse the particular choice of a technology to transfer is appropriate.

In both steps I control for project type and host country specific effects by adding dummies for project types and host countries including a significant share of observations (>5%).⁷

6.1 The model

The dependent variable is technology transfer (TT). TT is a binary variable which takes the value of 1 if a PDD involves an international technology transfer claim (of any kind - of equipment only, of knowledge only or both) and 0 otherwise. I estimate the following heteroscedastic probit equation:

$$p_i = Pr(TT_i = 1|\mathbf{X}) = \Phi\left(\frac{\mathbf{X}'_i\boldsymbol{\beta}}{\exp(Z_i\gamma)}\right)$$

where \mathbf{X} is a $K \times 1$ regressor vector (for each project), Z is the variable *Similar*⁸ associated with its estimated coefficient γ . $\boldsymbol{\beta}$ is a $K \times 1$ vector of coefficients to be estimated and Φ is the standard normal cumulative distribution function. The arguments of the \mathbf{X} vector include:

$$\begin{aligned} \mathbf{X}'_{i,jk}\boldsymbol{\beta} = & \beta_0 + \beta_1(Size_{i,jk}) + \beta_2(Unilateral_{i,jk}) + \beta_3(Similar_{i,jk}) \\ & + \beta_4(Trade_j) + \beta_5(FDI_j) + \beta_6(Education_j) \\ & + \beta_7(R\&D_j) + \beta_8(Fossil\ fuels_j) \\ & + \beta_k(Type_k) + \beta_j(Country_j) + \varepsilon_{i,jk} \end{aligned}$$

where $i = 1, \dots, 3296$ (project index), $j = 1, \dots, 67$ (host country index) and $k = 1, \dots, 26$ (project type index). ε is the error term which is assumed to be distributed $N(0, [\exp(Z_i\gamma)]^2)$. $Type_k$ and $Country_j$ are respectively project type and country dummies.

As most of the explanatory variables vary by host country, I must control for the clustering of errors.⁹ In other terms, it is likely that projects may be correlated within a

⁷Host countries include China, Brazil, India and Mexico. Project types are in agriculture, biogas, biomass energy, energy efficiency (own generation), hydro, landfill gas and wind. I do not add dummies for all countries and all project types because of the incidental parameter problem (this issue was not always addressed in previous studies).

⁸An iterative 'trial and error' procedure was performed to select the best model according to the value of the pseudo log-likelihood. To keep things simple, only one variable was included in the variance function.

⁹To do so I use a clustered sandwich estimator of the variance. See Rogers (1993) for details on how

host country (a cluster) owing to the presence of a common unobserved host-specific term. This important issue seems to have been omitted in previous studies.

The model includes two types of variables: variables which vary by project and variables which vary by country.¹⁰ A major difficulty when working in cross section is to ensure exogeneity of the regressors. To overcome this problem I have taken average values prior to the 2004-2008 period of the sample (whenever possible). Gathering information to identify variables which are specific to technology transfer for each type of project is difficult. I thus focus my study on factors likely to be associated with the motivation of transferring technology as a subdecision of investing in a CDM project.

6.1.1 Project variables

I first look at the association with technology transfer of the three project specific variables (*Size*, *Unilateral* and *Similar*). These variables were also included in previous studies (Haïtes et al. (2006); Dechezleprêtre et al. (2008); Seres et al. (2008)) and will serve as a baseline scenario (expected correlations are given in parentheses).

- *Size* (+) is the log of the project size measured by the expected average annual emission reductions. The underlying assumption is that CDM projects entail fixed transaction costs. When a technology transfer is involved, these costs are likely to be higher due to costs related to identification of technologies and identification of technology holders, patent status of technologies and information about licensing terms (CIEL, 2008). Higher transaction costs prevent small scale projects from taking place and thus I expect, as in previous studies, that large projects will be more likely to involve a technology transfer.
- *Unilateral* (-) denotes unilateral projects, i.e. projects which do not involve an Annex I credit buyer. Although 30% of unilateral projects include a technology transfer I assume, like in previous studies, that the absence of a foreign credit buyer will decrease the probability of a technology transfer.
- *Similar* (-) denotes the number of projects of the same type in the host country. As the number of similar projects increases, this could generate a learning effect and might even favour the gradual development of the needed technology in the host country. Therefore having more projects of the same type should decrease the likelihood of an international transfer of technology.

the calculation is actually performed in Stata.

¹⁰The selection of the country variables was made according to economic intuition and according to low pairwise cross correlations (see Table 8, Section 10).

I then formulate three hypotheses to test the association between technology transfer and economic and regulatory, human capital and natural resources country-varying variables.

6.1.2 Hypothesis 1: Openness to trade and favourable FDI policies are positively associated with TT

1. *Trade* (+) measures the average amount of merchandise trade measured as the sum of merchandise exports and imports divided by the value of GDP (in current U.S. dollars) over the period 2000-2003.¹¹ A recent report from the World Bank (World Bank, 2008) suggests that liberalizing trade can significantly increase the diffusion of clean technologies in developing countries. Trade in goods (and services) is recognised as playing a crucial role in helping the transfer of technologies globally, in particular through imitation and reverse engineering (Saggi, 1999). A high openness to trade signals a business friendly environment and is therefore anticipated to be positively correlated with technology transfer.
2. *FDI* (+) is the average ratio of net FDI inflows divided by GDP over the period 2000-2003. FDI net inflows are measured as the net inflows of investment (new investment inflows less disinvestment) in the reporting economy from foreign investors¹² divided by GDP.¹³ As one of the main channels for technology transfer (Maskus, 2004), high values of the FDI/GDP ratio reflect favourable FDI policies in the host country and should thus be positively associated with the probability of technology transfer.

6.1.3 Hypothesis 2: There is a positive link between human capital and TT

1. *Education* (+) measures the average percentage of tertiary school enrollment (%gross) over 2000-2003.¹⁴ Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level. Hascic and Johnstone (2009) found the absorptive capacity of a country (proxied by the number of patents for climate change technology invented in the recipient country) to be a significant positive factor in their empirical study on the transfer of climate change technologies. The intuition

¹¹Source: World Trade Organization, and World Bank GDP estimates. <http://data.worldbank.org/indicator>

¹²Source: International Monetary Fund, International Financial Statistics and Balance of Payments databases, and World Bank, Global Development Finance. <http://data.worldbank.org/indicator>

¹³Source: World Bank national accounts data, and OECD National Accounts data files. <http://data.worldbank.org/indicator>

¹⁴Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics. <http://data.worldbank.org/indicator>

for including the percentage of tertiary schooling is an alternative to measure the absorptive capacity. Hence the percentage of skilled labour in the population might be positively correlated with the likelihood of a technology transfer if e.g. project developers require trained staff to operate their project.

2. *R&D (+)* measures average research and development expenditure (%GDP) over 2000-2003.¹⁵ According to the definition of this variable, expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development. The intuition is that a higher share of R&D expenditure signals a more effective environment for the protection and development of new technologies in which project developers might even find potential synergies. Hence the correlation between R&D and technology transfer is expected to be positive.

Finally I test the relationship between fossil fuel resources and technology transfer.

6.1.4 Hypothesis 3: TT will take place in countries with more substitution potential for fossil fuels

1. *Fossil fuels (+)* measures the percentage of energy production from fossil fuels in total energy production in tonnes of oil equivalent (average for 2006-2007).¹⁶ I anticipate that the higher the share of fossil fuels in the total energy production mix, the higher the possibilities for CO_2 mitigation, the higher the number of potential CDM projects and therefore the higher the likelihood of a technology transfer. The estimated coefficient on this variable should thus be positive.

7 Results

7.1 Heteroscedastic probit regressions

Tables 2 to 6 show the results for the estimated coefficients of the heteroscedastic probit regressions for technology transfer regardless of its type. In order to evaluate the role of host country specific effects I proceed in three steps in each table. In the first column I run the regression with country dummies (D_j) but do not control for the clustering of errors. In the second column I leave out the country dummies and control for the clustering

¹⁵Source: United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics. <http://data.worldbank.org/indicator>

¹⁶IEA (2009).

of errors. Finally, in the third column, I control for the largest host countries and the clustering of errors and compare results.¹⁷

Table 2 looks at the effect of the project variables *Size*, *Unilateral* and *Similar* on the likelihood of a technology transfer and serves as a baseline scenario. In all three columns the signs are the ones expected and the coefficients are significant for *Size* and *Unilateral*. Higher transaction costs of transferring a technology are decreased in large scale projects and thus are more likely to have a technology transfer. Moreover not having an Annex I credit buyer involved in the project does seem to be associated with a lower likelihood of a technology transfer.

Adding the country dummies helps increase the percentage correct prediction of the model, but the clustering of the errors does not increase accuracy of the estimated coefficients. As the level of significance decreases on *Unilateral* and disappears on *Similar* between column 2 and 3, there must be unobserved host-specific characteristic which are partly captured by the country dummies and which might be identified when I test my hypotheses.

Table 3 shows the results for the first hypothesis testing the link between technology transfer and the role of a favourable economic and regulatory environment for investment. I anticipated both trade and FDI would have a positive estimated coefficient. It turns out only the past volume of trade measured as the sum of exports and imports divided by GDP is highly positively correlated with a likelihood of technology transfer in the CDM whereas results on FDI are not significant. Combining *Trade* and *Unilateral* in the third column cancels the significance of the coefficient on the latter variable.

All other things being equal host countries importing more capital goods also have a higher probability of using foreign technologies in their CDM projects. This positive correlation might also be explained by the fact that developing countries with a high share of exports also offer more possibilities of substitution in their production process through the CDM. This result might also suggest that lower tariffs on technological capital could help transfer clean technologies (as was found by Dechezleprêtre et al.(2009) when measuring technology transfer with patent data).

Table 4 tests the second hypothesis ("There is a positive link between human capital and TT") by introducing a measure of education (the percentage of tertiary school enrollment) and of the amount of research and development (percentage of R&D expenditure to GDP). Surprisingly the sign on *Education* is significant and negative in the first and third columns, but positive and significant in the second. Not controlling for the effect of large host countries leads to an opposite conclusion on the role of education, as countries

¹⁷Regressions are performed separately to check for the stability of the estimated coefficients. In addition for each regression I control for the effect of the main project type categories.

Table 2: Project variables only (Baseline)

β	D_j & no clustering	No D_j & clustering	D_j & clustering
$Size_{i,jk}$	0.144***	0.171***	0.144***
(+)	(0.0208)	(0.0341)	(0.0350)
$Unilateral_{i,jk}$	-0.117*	-0.436***	-0.117*
(-)	(0.0596)	(0.0850)	(0.0598)
$Similar_{i,jk}$	0.000172	-0.00348*	0.000172
(-)	(0.000423)	(0.00179)	(0.000685)
Constant	-0.160	-0.575**	-0.160
	(0.109)	(0.225)	(0.205)
γ			
$Similar_{i,jk}$	-0.00250***	-0.000290	-0.00250***
	(0.000564)	(0.000749)	(0.000775)
Observations	3296	3296	3296
% correct prediction	78.33%	76.33%	78.33%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Significance on the γ coefficient indicates that as the number of similar projects increases, the variance decreases. D_j = host country dummy for *China, India, Brazil* and *Mexico*.

Table 3: Hypothesis 1: Openness to trade and favourable FDI policies are positively associated with TT

β	D_j & no clustering	No D_j & clustering	D_j & clustering
$Size_{i,jk}$ (+)	0.154*** (0.0212)	0.157*** (0.0408)	0.154*** (0.0344)
$Unilateral_{i,jk}$ (-)	-0.0954 (0.059)	-0.106** (0.0739)	-0.0954 (0.0594)
$Similar_{i,jk}$ (-)	-0.000126 (0.000522)	-0.000502 (0.000874)	-0.000126 (0.000704)
$Trade_j$ (+)	0.00429*** (0.00102)	0.00863*** (0.00240)	0.00429*** (0.00110)
FDI_j (+)	-0.0044 (0.0211)	0.0277 (0.0405)	-0.0044 (0.0300)
$Constant$	-0.490*** (0.141)	-1.092*** (0.222)	-0.490** (0.225)
γ			
$Similar_{i,jk}$	-0.00216*** (0.000595)	-0.00233* (0.00123)	-0.00216*** (0.000714)
Observations	3286	3286	3286
% correct prediction	79.09%	77.57%	79.09%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Significance on the γ coefficients indicates that as the number of similar projects increases, the variance decreases. D_j = host country dummy for *China*, *India*, *Brazil* and *Mexico*. Project type dummies included in all regressions.

like China and India have rather low rates of tertiary school enrollment compared to other countries but attract many CDM projects with a technology transfer. So contrarily as to what was expected, education is negatively correlated with technology transfer and this might be due to the fact that technologies used in the CDM are not necessarily complex and thus do not necessarily always need skilled labour. This result might indicate that the technologies used in CDM projects are not highly complex and thus, if skilled labor is available in the host country, these technologies might already have been developed without the help of an Annex I country.

The result on the amount of expenditure on research and development is interesting. Although the estimated coefficient is not significant in columns 1 and 2, clustering the errors increases the accuracy of the estimation. The estimated coefficient is positive and significant. A high value of the ratio R&D/GDP might be a positive signal for the private sector. Countries who invest more in research and development may protect (intellectual) property rights more strongly and more effectively. This should also be relevant for CDM project developers' decision to transfer technology for which they fear imitation (like high-tech technologies). Moreover Hoel and de Zeeuw (2009) have shown that cooperation in R&D can increase global abatement by reducing the costs of adopting new technology. This result should also apply to the CDM and calls for more cooperation in R&D between countries.

The link between education and R&D and technology transfer is thus sensitive to country characteristics which are partly captured by introducing country dummies and by controlling for other omitted factors. This emphasizes the importance of controlling these parameters when studying the influence of specific host country environments.

In any case these results point out a need for improvement: further details and description of the technologies transferred in projects would be necessary to assess technology transfer more accurately. Development in host countries will likely depend on a mix of high-tech and low-tech technologies. It is therefore important to create a favourable environment for private sector investors in countries with low resources and weak effective intellectual property rights protection. One possible solution would be to implement a compensation or insurance mechanism for the additional financial risk of investing in some countries (such as least developed countries). Access to information will also play a crucial role. Provided there is internet access in the host country, knowledge of market conditions should be improved through e.g. online platforms where investors could share experiences. In addition, cooperation in research and development should be improved so as to create more complex and more efficient technologies to adapt to and mitigate climate change.

Table 5 tests the hypothesis concerning the link between technology transfer and the

Table 4: Hypothesis 2: There is a positive link between human capital and TT

β	D_j & no clustering	No D_j & clustering	D_j & clustering
$Size_{i,jk}$ (+)	0.143*** (0.0213)	0.163*** (0.0401)	0.143*** (0.0347)
$Unilateral_{i,jk}$ (-)	-0.127** (0.0634)	-0.290*** (0.0552)	-0.127** (0.0637)
$Similar_{i,jk}$ (-)	0.000249 (0.000412)	0.0002 (0.000783)	0.000249 (0.000657)
$Education_j$ (+)	-0.0104*** (0.0039)	0.0137** (0.00636)	-0.0104*** (0.0036)
$R\&D_j$ (+)	0.105 (0.0698)	-0.161 (0.135)	0.105** (0.0517)
$Constant$	0.0744 (0.153)	-0.822*** (0.198)	0.0744 (0.230)
γ			
$Similar_{i,jk}$	-0.00250*** (0.000542)	-0.00282*** (0.00107)	-0.00250*** (0.000746)
$Observations$	3119	3119	3119
% correct prediction	79.41%	76.92%	79.41%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Significance on the γ coefficients indicates that as the number of similar projects increases, the variance decreases. D_j = host country dummy for *China, India, Brazil* and *Mexico*.

amount of fossil fuels in the energy production mix. A higher number of opportunities for CO_2 mitigation could be positively linked with more CDM projects and therefore more technology transfer. The sign on the estimated coefficient is significant and is the one expected, however, significance vanishes when adding country dummies and clustering the errors. This again highlights the importance of controlling for these parameters. Even though figures 1 and 2 showed a positive correlation between CO_2 emissions and CDM projects and CDM projects per capita, this correlation is not statistically significant when associated with the likelihood of a technology transfer.

Table 5: Hypothesis 3: TT will take place in countries with more substitution potential for fossil fuels

β	D_j & no clustering	No D_j & clustering	D_j & clustering
$Size_{i,jk}$ (+)	0.138*** (0.0209)	0.160*** (0.0359)	0.138*** (0.0356)
$Unilateral_{i,jk}$ (-)	-0.115* (0.0606)	-0.410*** (0.0781)	-0.115* (0.0596)
$Similar_{i,jk}$ (-)	0.000105 (0.000454)	-0.00447*** (0.00163)	0.000105 (0.00069)
$Fossil\ fuels_j$ (+)	0.00252* (0.00129)	0.00536** (0.00235)	0.00252 (0.00198)
$Constant$	-0.283** (0.128)	-0.827*** (0.258)	-0.283 (0.219)
γ			
$Similar_{i,jk}$	-0.00250*** (0.000608)	2.91e-06 (0.000571)	-0.00250*** (0.000791)
$Observations$	3283	3283	3283
% correct prediction	78.25%	76.7%%	78.25%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Significance on the γ coefficients indicates that as the number of similar projects increases, the variance decreases. D_j = host country dummy for *China, India, Brazil* and *Mexico*.

Finally Table 6 includes all the previous variables to test if interactions between these could yield different results. As can be seen the signs on the project variables, *Size* and *Unilateral*, conserve their significance and their expected direction. The positive association between trade and the likelihood of a technology transfer is still robust and highly significant. Clustering the errors increases the accuracy of the estimation of the

coefficients on *Education* and *R&D*.

Table 6: Including project variables and hypotheses variables

β	D_j & no clustering	No D_j & clustering	D_j & clustering
<i>Size</i> _{<i>i,jk</i>}	0.149***	0.143***	0.149***
(+)	(0.0217)	(0.0381)	(0.0346)
<i>Unilateral</i> _{<i>i,jk</i>}	-0.115*	-0.146**	-0.115*
(-)	(0.0633)	(0.0701)	(0.0643)
<i>Similar</i> _{<i>i,jk</i>}	-3.96e-05	-0.000230	-3.96e-05
(-)	(0.000497)	(0.000614)	(0.000681)
<i>Trade</i> _{<i>j</i>}	0.00403***	0.00663***	0.00403***
(+)	(0.00116)	(0.00228)	(0.00096)
<i>FDI</i> _{<i>j</i>}	-0.00391	0.0301	-0.00391
(+)	(0.0240)	(0.0339)	(0.0258)
<i>Education</i> _{<i>j</i>}	-0.00744*	0.00993**	-0.00744**
(+)	(0.00408)	(0.00430)	(0.00335)
<i>R&D</i> _{<i>j</i>}	0.0901	-0.119	0.0901**
(+)	(0.0689)	(0.106)	(0.041)
<i>Fossil fuels</i> _{<i>j</i>}	0.000824	0.00513**	0.000824
(+)	(0.00162)	(0.00261)	(0.00165)
<i>Constant</i>	-0.387*	-1.411***	-0.387
	(0.222)	(0.227)	(0.257)
γ			
<i>Similar</i> _{<i>i,jk</i>}	-0.00223***	-0.00236***	-0.00223***
	(0.000582)	(0.000614)	(0.000707)
Observations	3110	3110	3110
% correct prediction	79.58%	78.9%	79.58%

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Significance on the γ coefficients indicates that as the number of similar projects increases, the variance decreases. D_j = host country dummy for *China*, *India*, *Brazil* and *Mexico*.

These results show the importance of controlling for the effect of large host countries and other omitted factors captured through the clustering of errors. These issues were not clearly treated in previous studies and may have led to biased result interpretation.

7.1.1 Marginal effects

Interest lies in determining the marginal effect of a change in a regressor on the conditional probability that $TT = 1$. In a linear setting the estimated coefficient has a direct interpretation as the marginal effect. For non-linear models, this interpretation is no longer possible as the marginal effect is a function of both parameters and regressors, and the size of the marginal effect depends on x in addition to β .

In the case of a heteroscedastic probit model, the effect of a change in the j -th regressor, assumed to be continuous, evaluated at x_{ij} would be:

$$\frac{\partial Pr(TT_i = 1|x_i)}{\partial x_{ij}} = \phi\left(\frac{\mathbf{X}'_i\boldsymbol{\beta}}{\exp(Z_i\boldsymbol{\gamma})}\right)\beta_j$$

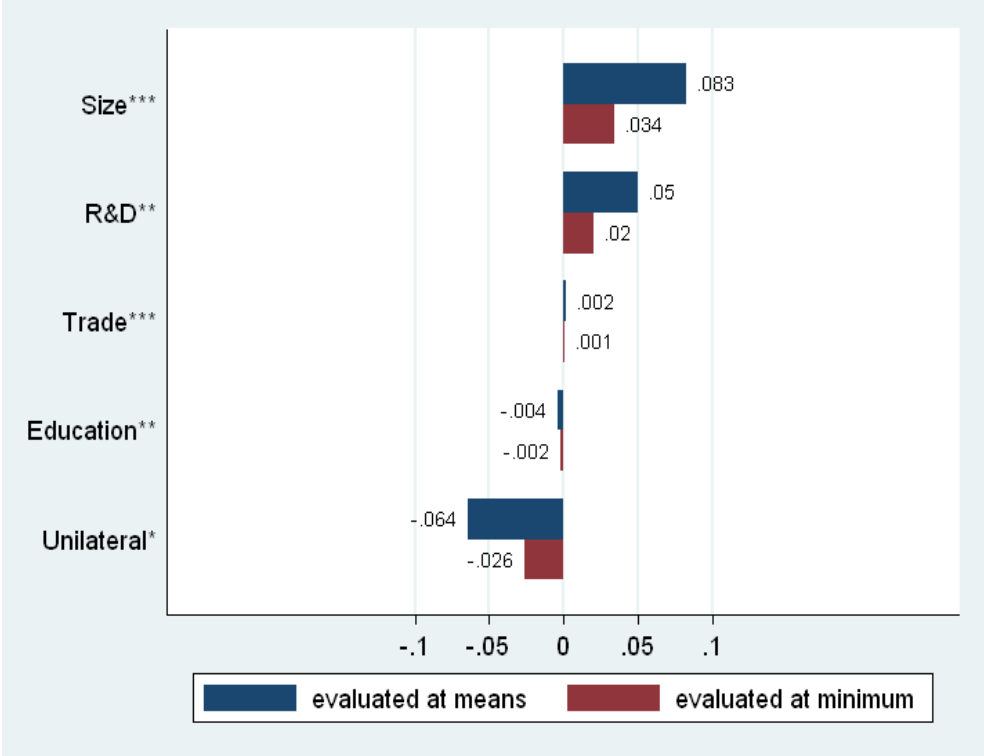
where $\phi(z) = \frac{\partial\Phi(z)}{\partial z}$. The marginal effect gives the change in the likelihood of a technology transfer when regressor x changes by one percentage point.

As the third column of Table 6 yields good results in terms of the percentage of correct prediction, I use this specification to calculate and illustrate the marginal effects of the significant regressors.¹⁸

When evaluated at means, a 1 percentage change in the size of the project will increase the likelihood of a technology transfer by 8 percentage points (Figure 4), whereas a 1 percent increase in R&D expenditure will increase it by 5 percentage points. This last result is rather encouraging and should help promote more cooperation in research and development between Annex I and Non Annex I countries. The effect of openness to trade and the negative effect of education are very small. Absence of an Annex i credit buyer reduces the likelihood of a technology transfer by 6 percentage points. However this result is not highly significant. When evaluated at minimum values, no regressor showed a marginal effect higher than the one evaluated at means. These results highlight potential improvements of the current CDM framework which will be discussed in the conclusion.

¹⁸Marginal effects are evaluated at means and at minimum values.

Figure 4: Marginal effects of significant regressors on the likelihood of a technology transfer

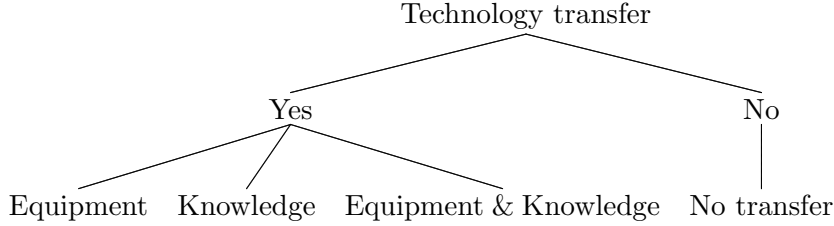


Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Marginal effects for *Unilateral* are for discrete change of dummy variable from 0 to 1 (evaluated at mean). Other dummies evaluated at means.

7.2 Nested logit regression

The second step of my analysis is to look at the impact of the previous country factors on the choice of transferring either knowledge, equipment or both. For this purpose I use a nested logit model which has the advantage to break decision into groups into a hierarchical manner. In the context of the CDM the project developer will first decide whether or not to transfer technology and, if so, which type of technology to transfer. The decision structure is depicted in the following tree:



This model groups the three technology type alternatives into two subgroups ("Yes" and "No")¹⁹ and allows the variance to differ across the groups while maintaining the assumption of the *independence of irrelevant alternatives (IIA)* within the groups.²⁰ Suppose that $\mathbf{x}'_{ik|j}$ is the vector containing the attributes of the choices and \mathbf{z}'_{ij} is the vector containing the attributes on the choice sets (limbs), then $Pr(Choice_{jk})$, the joint probability of being on limb j (with $j = Yes; No$) and branch k (with $k = Equipment; Knowledge; Equipment \& Knowledge; No transfer$) can be written as:

$$Pr(Choice_{ijk}) = P_{ijk} = \frac{\exp(\mathbf{x}'_{ik|j}\boldsymbol{\beta} + \mathbf{z}'_{ij}\boldsymbol{\gamma})}{\sum_{k=1}^K \sum_{j=1}^J \exp(\mathbf{x}'_{ik|j}\boldsymbol{\beta} + \mathbf{z}'_{ij}\boldsymbol{\gamma})} + \varepsilon_{i,jk}$$

which is also equivalent to $P_{i,jk} = P_{i,k|j} \times P_j$,²¹ i.e. the probability of choosing limb j , times the probability of choosing branch k conditional on being on limb j . Thus the probability of choosing, e.g. a technology transfer of equipment only, would be:

$$Pr(TTequ = 1 \cap TT = 1) = Pr(TT = 1) \times Pr(TTequ = 1 | TT = 1)$$

I run a nested logit regression to test my hypotheses on the likelihood of the different types of technology transfer. I restrict the independent variables of the top equation ($Pr(TT = 1)$) to include the three project variables (*Size*, *Similar* and *Unilateral*). The bottom equation uses the variables of the last regression in Table 6 to see if they have a particular association with the different types of technology transfer. I again make sure to

¹⁹The branch of level two will be degenerate as there is only one alternative ("No transfer")

²⁰The IIA assumption implies that adding another alternative or changing the characteristics of a third alternative does not affect the relative odds between alternatives "Yes" and "No".

²¹The error terms $\varepsilon_{i,jk}$ are assumed to have a generalized extreme value (GEV) distribution (for more information on nested logit models, see Cameron and Trivedi (2005), p.507)

control for the clustering of errors and the effect of large host countries.²² The reference case is no technology transfer. Results are presented in Table 7.

Table 7: Nested logit results

Variables	Yes	Equipment	Knowledge	Both
	γ	β		
<i>Size</i> _{<i>i,jk</i>}	0.227***			
(+)	(0.0602)			
<i>Unilateral</i> _{<i>i,jk</i>}	-0.285**			
(-)	(0.120)			
<i>Similar</i> _{<i>i,jk</i>}	-0.00726***			
(-)	(0.00104)			
<i>Trade</i> _{<i>j</i>}		0.00949***	0.00976***	0.01000***
(+)		(0.00244)	(0.00230)	(0.00185)
<i>FDI</i> _{<i>j</i>}		-0.0293	0.0298	-0.0681**
(+)		(0.0436)	(0.0956)	(0.0324)
<i>Education</i> _{<i>j</i>}		-0.0229***	-0.00280	-0.0160**
(+)		(0.00659)	(0.0128)	(0.00813)
<i>R&D</i> _{<i>j</i>}		0.345**	0.0597	0.206**
(+)		(0.136)	(0.150)	(0.0871)
<i>Fossil fuels</i> _{<i>j</i>}		0.00701	0.00276	-0.00334
(+)		(0.00631)	(0.00399)	(0.00320)
Observations	12440	12440	12440	12440

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Project type dummies *Hydro* and *Agriculture* were dropped because of within-group collinearity.

The two project variables *Size* and *Unilateral* are significant and have the expected sign like in the heteroscedastic probit regressions. The variable measuring the number of projects of the same type (*Similar*) is now also significant and has the expected sign (negative). As the number of projects increases, there might be a learning effect which translates into less technology transfer occurring. However to test if a negative trend really exists, the data would have to be analyzed over time (and not in cross section).

The estimated coefficients on *Trade* is positive and highly significant regardless of the type of technology transferred compared with no technology transfer. The sign on *FDI* is significant and negatively associated with the likelihood of transferring both equipment

²²Host country dummies included for *China*, *India*, *Brazil* and *Mexico*. Project type dummies included for *Agriculture*, *Biogas*, *Biomass_energy*, *EEowngeneration*, *Hydro*, *Landfillgas* and *Wind*.

and knowledge. This could indicate a "crowding out" effect of *FDI* on the CDM as a channel to transfer technology to host countries. However further research is needed to interpret this result. The sign on *Education* remains negative and significant, but only for projects transferring either equipment or equipment and knowledge. Taking the level of tertiary school enrollment as a measure of absorptive capacity appears to be negatively associated with technology transfer contrarily to what Hascic and Johnstone (2009) found in their paper. However this absorptive capacity might in fact be reflected by the positive association between the level of expenditure on research and development and the likelihood of transferring either equipment or equipment and knowledge relative to no transfer of technology.

These results are quite encouraging. However the country characteristics used in this study are very aggregated. Further research at a more disaggregated level is needed to identify for which climate-friendly technologies higher trade liberalization would be most effective in helping technology transfer in the CDM. This conclusion applies in a similar manner to research and development expenditures. Further, if causality could be established from trade liberalization and research and development policies towards technology transfer in the CDM, this would be a strong signal to promote and further support such policies in Non Annex i countries.

8 Conclusion

This paper has emphasized the associations between host country characteristics and the likelihood of a technology transfer in the CDM. Results show that there is a positive relationship between the likelihood of a technology transfer and economies which had a high trade/GDP ratio and which invested a high share of their GDP in research and development activities. I find that a 1 percent increase in research and development expenditure could yield a 5 percent increase in the likelihood of a technology transfer. This interesting result advocates increased cooperation and financing between Annex I and Non Annex I countries to promote the development and assimilation of climate friendly technologies. On the contrary, the study has also showed a negative relationship between the likelihood of a technology transfer and countries having a high share of skilled labour in their population.

Previous findings on stylized facts are partly confirmed in this study. Results show that large projects do seem to be positively associated with the likelihood of a technology transfer. The lack of participation of an Annex I country in the project (effect of the variable *Unilateral*) is negatively associated with the likelihood of a technology transfer. However the data used is mainly coding transfers from Annex I countries to Non Annex

I countries. It does not take into account that an increasing number of CDM projects is experiencing cooperation between Non Annex I countries in which technology transfer is also occurring. The significant negative sign on the variable counting the number of similar projects is only significant in the nested logit regression. To be able to interpret this negative correlation as the result of a learning effect in a particular project type, the study should have to be extended to include variations over time.

From a methodological point of view this study has emphasized the importance of taking into account the effect of large host countries and controlling for the clustering of the errors. These aspects were not clearly treated in previous studies or mentioned incompletely. An important drawback of analyzing data in cross-section is that it does not allow to determine the direction of causality between the country variables and the likelihood of a technology transfer in a CDM project. A future study could look at trends in technology transfer overall or by project type using panel data. However continuing this type of analysis on the basis of PDD review will highly depend on the quality of available information.

Information on technology transfer in CDM projects varies largely across PDDs. As there is no common definition among projects developers as to what technology transfer actually means, the technology description provided is contingent on their good will. If technology transfer is to be assessed more accurately on the basis of PDDs, an official UNFCCC definition should be approved. Improving the description of the technology should also be addressed, as it is sometimes very difficult to know which parts of the technology have been manufactured locally or why these have been imported from one country rather than another.

More information on the type of technology and whether it is patented or not would also help distinguish between the likelihood of a technology transfer and its negative correlation with a higher share of skilled labour and its positive correlation with the amount of expenditure in research and development. If technologies transferred turn out to be mostly obsolete, a financial mechanism should be designed to incentivize the private sector to bring a balanced mix between state-of-the-art and basic technologies to meet developing countries' needs through CDM projects.

Another important barrier which was not directly treated in this paper is the lack of information on market opportunities in host countries. Some progress is being made to connect potential CDM developers and facilitate the exchange of information, such as the China Greentech Initiative,²³ but many efforts are still needed to help the project developer decision process.

Although the CDM will not be able to achieve technology transfer along the scale

²³<http://www.china-greentech.com>

required to fulfil bold GHG emission reduction targets (Mani, 2010), it will nevertheless remain a channel through which the private sector will bring clean technologies to Non Annex I countries. Besides new policy initiatives such as NAMAs, which are viewed as an opportunity for developing countries to attract technology transfer, and the setting up of a Technology Mechanism promised in the Copenhagen Accord, improving technology transfer in existing flexible mechanisms is essential and should be better considered in ongoing climate negotiations.

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10 Annexes

10.1 Annex I

Table 8: Cross-correlation table

Variables	Size	Similar	Unilateral	Trade	FDI	Education	R&D	Fossil fuels
Size	1.000							
Similar	0.063	1.000						
Unilateral	-0.265	-0.227	1.000					
Trade	0.025	-0.159	-0.254	1.000				
FDI	0.171	0.112	-0.272	0.260	1.000			
Education	-0.079	-0.341	0.033	0.323	0.138	1.000		
R&D	0.129	0.187	0.020	-0.115	0.126	0.334	1.000	
Fossil fuels	0.253	0.369	-0.280	0.101	0.141	-0.313	0.050	1.000

10.2 Annex II

Table 9: Summary statistics

Variable	Mean	Std. Dev.	N
Size	3.906	1.328	3296
Similar	175.956	198.586	3296
Unilateral	0.387	0.487	3296
Trade	44.59	33.23	3292
FDI	2.468	1.485	3286
Education	16.256	11.872	3187
R&D	0.819	0.518	3225
Fossil fuels	68.596	23.742	3283

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