Working Paper Sustainability and Innovation
No. S 05/2015

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Factors driving international technology transfer: empirical insights from a CDM project survey

A revised version of Working Paper S 05/2015 is published as:

Gandenberger, C.; Bodenheimer, M.; Schleich, J.; Orzanna, R.; Macht, L. (2015): Factors driving international technology transfer: empirical insights from a CDM project survey, Climate Policy DOI: 10.1080/14693062.2015.1069176

Fraunhofer ISI

MERIT International transfer of climate technologies

Abstract

This study employs an original survey-based dataset to explore technology transfer in CDM projects. The findings suggest that about two-thirds of the CDM projects involve a medium to very high extent of technology transfer. The econometric analysis distinguishes between knowledge and equipment transfer and specifically allows for the influence of technological characteristics, such as novelty and complexity of a technology, as well as the use of different transfer channels. More complex technologies and the use of export as a transfer channel are found to be associated with a higher degree of technology transfer. Projects involving 2- to 5-year-old technologies seem more likely to involve technology transfer than both younger and older technologies. Energy supply and efficiency projects are correlated with a higher degree of technology transfer than non-energy projects. Unlike previous studies, our analysis did not find technology transfer to be related to project size, the length of time a country has hosted CDM projects or the host country's absorptive capacity. Our findings are similar for knowledge and equipment transfer. CDM projects are often seen as a vehicle for the transfer of climate technologies from industrialized to developing countries. Thus, a better understanding of the factors driving technology transfer in these projects may help policy makers design policies that better foster the transfer of knowledge and equipment, in addition to lowering greenhouse gas emissions. This may be achieved by including more stringent requirements with regard to international technology transfer in countries' CDM project approval processes. Based on our findings, such policies should focus particularly on energy supply and efficiency technologies. Likewise, it may be beneficial for host countries to condition project approval on the novelty and complexity of technologies and adjust these provisions over time. Since such technological characteristics are not captured systematically by PDDs, using a survey-based evaluation opens up new opportunities for a more holistic and targeted evaluation of technology transfer in CDM projects.

Keywords: Clean Development Mechanism; Technology Transfer; North-South; Energy Technology; Development and Climate

Acknowledgement: This work was supported by the German Federal Ministry of Education and Research under Grant 01LA113DA.

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1 Introduction

When the UN Framework Convention on Climate Change (UNFCCC) was established as one of the key pieces of transnational environmental governance in 1992, non-OECD countries accounted for 44% of global energy related CO_2 emissions (IEA/OECD, 2014); subsequent UN climate policy, notably the Kyoto Protocol, required most developed countries to limit their greenhouse gas (GHG) emissions, while developing countries did not face such targets. Since then, however, the share of CO_2 emissions by non-OECD countries has increased to 61.7% in 2012, and is projected to increase further to 72.7% by 2035 (IEA/OECD, 2014).

Enhancing developing countries' access to climate technologies can therefore be considered an important contribution to effectively addressing climate change at the global level. While the UN principle of 'common but differentiated responsibilities' implies that developed countries must "lead in combating climate change and the adverse effects thereof" and support developing countries in assuming their responsibilities (United Nations Framework Convention on Climate Change, 1992), global warming cannot be controlled without also limiting emissions by major non-OECD countries in the future. Article 4.5 of the UNFCCC therefore prescribes that "[t]he developed country Parties […] shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties...." (United Nations Framework Convention on Climate Change, 1992).

In particular, the Clean Development Mechanism (CDM) allows developed (Annex I) countries to meet their national emissions targets using emissions reductions achieved through specific projects in developing countries. While it is not one of its explicit goals, the CDM is frequently perceived as a vehicle for international technology transfer[1] (Dechezleprêtre, Glachant, & Ménière, 2008, 2009; Murphy, Kirkman, Seres, & Haites, 2013; Popp, 2011; Schneider, Holzer, & Hoffmann, 2008; Weitzel, Liu, & Vaona, 2014). As part of the CDM approval process, host countries may require these projects to involve technology transfer (UNFCCC, 2010), but only few countries have done so explicitly (Spalding-Fecher et al., 2012).

Previous studies have empirically explored to what extent the CDM contributes to international technology transfer, but findings differ to some degree. According to Murphy et al. (2013), about 40 % of registered CDM projects involve technology transfer. Haites, Duan, and Seres (2006) and Seres, Haites and Murphy (2009) report that about one third of CDM projects, accounting for about 60 % of the CDM's annual emissions reductions, involve technology transfer. Das (2011), on the other hand, concludes that the "contribution of the CDM to technology transfer can at best be regarded as minimal" (Das, 2011, p. 28).

A number of studies have also employed econometric analyses to explore the factors driving technology transfer through the CDM (e.g. Dechezleprêtre et al., 2008, 2009; Haites et al., 2006; Haščič & Johnstone, 2011; Schmid, 2012; Weitzel et al., 2014). These factors typically include project size, the technology sector, the length of a host country's experience with the CDM and its technological capabilities. The extant literature largely draws on information available from the project design documents (PDD) of CDM projects that is regularly gathered by the UNEP DTU (formerly UNEP Risø Center) and published in its CDM Pipeline (Fenhann, 2014).

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[1] Despite the prevalence of technology transfer in academic analyses and the policy arena, there is no universally accepted definition, see Popp (2008). Following the IPCC, we understand technology transfer as "a broad set of processes covering the flows of knowledge, experience and equipment...amongst different stakeholders.....The broad and inclusive term 'transfer' encompasses diffusion of technologies and technology cooperation across and within countries.... It comprises the process of learning to understand, utilise and replicate the technology, including the capacity to choose it and adapt it to local conditions" Metz, Davidson, Martens, van Rooijen, and Van Wie McGrory (2000, p. 3).

Our empirical analysis relies on new and original data collected through a survey among participants in CDM project activities listed in the PDDs. Apart from the factors already mentioned above, we also include technological characteristics (complexity and novelty) and the type of transfer channel used in our model. These factors have been identified in the general international technology transfer literature as being relevant to transfer success (Davidson & McFetridge, 1984, 1985; Hakanson, 2000; Stock & Tatikonda, 2000; Tsang, 1997), but have not been systematically examined in the context of the CDM. Moreover, the survey-based approach also allows for a more nuanced evaluation of the degree of technology transfer as compared to the assessment provided in the CDM Pipeline, which only indicates whether technology transfer is expected or not. Finally, since our data was gathered at a later stage of project implementation than the data provided in the PDDs, the survey assessment may rely on updated information about the extent of technology transfer involved in a project.

The paper is organized as follows: Section 2 specifies the theoretical background and research interests that have guided our study. Section 3 describes the data, methodology and econometric models employed. Section 4 presents the results. The final section 5 discusses the main findings and concludes.

2 Background

Several studies have recently explored factors driving technology transfer in the CDM. For example, Dechezleprêtre et al. (2008), Haites et al. (2006), Schmid (2012), and Seres et al. (2009) find that larger projects are more likely to involve technology transfer. Dechezleprêtre et al. (2008) explain this with the fact that technology transfer costs are fixed and thus represent an impediment to smaller projects. Most studies also control for the type of technology or sectors. The findings by Haites et al. (2006), Seres et al. (2009) and Weitzel et al. (2014) suggest that the likelihood of technology transfer is higher for wind power projects and lower for hydro power projects (see also Murphy et al., 2013). For technology transfer involved in CDM projects in the agricultural sector, the evidence is mixed: Haites et al. (2006) and Seres et al. (2009) find a positive correlation, but Dechezleprêtre et al. (2008) find a negative correlation between projects in the agricultural sector and technology transfer. Several studies have also taken the impact of host country characteristics into account. For example, the findings by Weitzel et al. (2014) for projects in China and by Murphy et al. (2013) for projects in Brazil, China and India suggest that the likelihood of technology transfer is lower, the longer a country has had experience with the CDM. Several studies find countries' technological capabilities and knowledge base to affect technology transfer through CDM projects. According to the World Bank (2008, p. 8), technological absorptive capacity includes "governance and the business climate", "basic technological literacy", "finance of innovative firms", and "pro-active policies". To date, empirical studies on technology transfer in the CDM have typically employed a narrower definition, focusing on a country's technological capabilities. Relying on the ArCo technology index (Archibugi & Coco, 2004), Dechezleprêtre et al. (2008) find technology transfer in CDM projects to be conditional on the host country's level of technological capabilities: On the one hand, a certain level of ability is necessary for the absorption of new technologies. On the other hand, with increasing abilities and availability of local technologies, the contribution of CDM projects to technology transfer decreases. Similarly, Doranova, Costa and Duysters (2010) find that, given a strong knowledge base in the host countries, CDM projects tend to use local technologies, or a combination of local and foreign technologies, instead of foreign technologies only. Contrary to this, Haščič and Johnstone (2011), who employ patenting activity as an indicator for the local knowledge base, find that the transfer of foreign technologies increases with a larger local knowledge base. Finally, using tertiary education and R&D as indicators of a country's absorptive capacity, Schmid (2012) does not find statistically significant effects on technology transfer.

In these studies, technology transfer enters the analysis as a binary dependent variable, typically based on the nominal codes used in the CDM Pipeline

(Fenhann, 2014). To assess technology transfer, a keyword search for the word 'technology' is performed for each PDD. Technology transfer is then categorized based on eight different codes, indicating whether technology transfer was mentioned, whether it is expected to take place, and if so, its expected type (equipment, knowledge and/or joint-venture). Thus, while the coding is quite detailed, the CDM Pipeline does not differentiate between degrees of technology transfer. Dechezleprêtre et al. (2008), among others, point out that PDD editors might overstate the amount of expected technology transfer, since it could be conducive to project registration. However, using a follow-up survey, Murphy et al. (2013) instead demonstrate a tendency to underestimate technology transfer in the PDDs.

As a result of using the CDM Pipeline as the basis for empirical analysis, some of the factors that have been highlighted in the literature on international technology transfer have not been adequately included in previous studies, since they are not included in the CDM Pipeline. These include technological characteristics related to the tacitness of knowledge embodied in a technology and the choice of transfer channel (Hakanson, 2000; Stock & Tatikonda, 2000; Tsang, 1997). Knowledge tacitness refers to the fact that people know more than they can explain (Polanyi, 1966), which has important implications for the transfer of knowledge: Whereas explicit knowledge can easily be codified and transferred, tacit knowledge is difficult to codify and closely tied to individuals or teams that posses this knowledge. Building on earlier research, Tsang (1997) states that the relevance of tacit knowledge depends on the age and complexity of the technology. Mature technologies have been widely used in the industry and as a result, much of the previously tacit knowledge has been codified (Dosi, Teece, & Winter, 1992; Teece, 1977). Cutting-edge technology, on the other hand, is still subject to frequent changes, making the associated knowledge difficult to codify. But even for mature technologies, a high degree of complexity can hamper attempts to codify the underlying knowledge (Tsang, 1997).

Only few studies in the extant research on CDM projects have paid attention to technological characteristics such as novelty or complexity. Murphy et al. (2013, p. 7) conclude that the least amount of technology transfer takes place in CDM projects involving “widely available, mature technologies”. Dechezleprêtre et al. (2008) argue that CDM projects in the energy sector and chemicals industry contribute more to technology transfer than projects in agriculture, because the former involve more complex technologies than the latter.

Tsang (1997) also argues that the tacit components of the relevant technological knowledge need to be transferred through close human interactions, which often requires a joint-venture or a wholly-owned subsidiary as transfer mode. Empirical findings indicate that firms prefer foreign direct investment (FDI) to transfer newer technologies and licensing to transfer older technologies.[2] This finding may be explained by the need to protect valuable technological knowledge from imitation by local competitors. Only Dechezleprêtre et al. (2008; 2009) explore the relevance of a host country's openness to foreign knowledge stocks in the context of the CDM. They find trade openness (measured by the sum of exports and imports of merchandise relative to GDP) to increase transfer probability, but the share of FDI in GDP was not positively related to technology transfer. In addition, they find the propensity of a CDM project to contribute to technology transfer to be 50 percentage points higher when the project is developed in a subsidiary of a company headquartered in an Annex I country. These studies, however, do not specifically examine the transfer channel chosen at the project level.

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2 See Popp (2011) for further references.

3 Data and Methodology

3.1 Descriptive Statistics

Empirical data was collected through an online survey among participants in CDM projects. Contact information for participants from 4313 projects could be gathered from the project design documents (PDDs) of the 4984 CDM projects that were listed in the UNFCCC's CDM project database on June 30th 2010 (UNFCCC 2010). At that point in time, 2425 projects were at the validation stage, 2389 had been registered, and 170 projects were being considered for registration.

The online survey was conducted between 22 August 2013 and 29 September 2013 and resulted in 137 responses. About one third of the respondents were consultants (35%),[3] 28% came from small and medium enterprises and 10% represented transnational corporations. Moreover, 66% of the participants were on the receiving side of technology transfer (technology recipient or supporting party) and 31% represented technology suppliers.

Our sample is not representative for the population of CDM projects. In the CDM database, the share of projects from Asia is higher (78.9 % vs. 58.4 % in our sample) and the shares of projects in Africa (2.6 % vs. 13.1 %) and South America (13.8 % vs. 20.4 %) are lower than in our sample. As the survey was conducted in English, language barriers may explain the low representation of Asian countries in the sample, particularly China. Likewise, the share of projects in the CDM database that focus on energy supply is higher (75.7 % vs. 52.6 %)

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3 CDM projects have to go through a complex project cycle, involving not only project design, validation, registration and implementation, but also monitoring, verification, certification and the issuance of emission reduction units (Michaelowa, 2005; Olsen, 2010). Consequently, specialized CDM consultants play a key role at various steps of the CDM project cycle.

than in our sample,[4] while the share of waste management projects (6 % vs. 13.9 %) and reforestation (1 % vs. 9.5 %) is lower. For energy efficiency/GHG avoidance and transport projects, our sample is close to being representative.

To assess to what extent CDM projects involved technology transfer, respondents were asked to what extent equipment and technical components/knowledge and experience were transferred to the receiving parties for the technology in question. As can be seen in Figure 1, about two-thirds of the respondents thought that a medium to very high extent of equipment and knowledge transfer had taken place in their project. Nevertheless, 23% (equipment) and 16% (knowledge) of participants stated that their project did not involve any technology transfer. We also compared the survey-based assessments of technology transfer with the corresponding PDD-based assessments provided in the CDM Pipeline. Accordingly, for 7% of the projects in our sample, the survey-based equipment transfer is lower than the PDD-based transfer. For 35% of the projects the survey-based assessment is higher than the PDD-based assessment. Similarly, for 10% (38%) of the projects the survey-based assessment of knowledge transfer is lower (higher) than the PDD-based assessment.[5] This leads to the conclusion that technology transfer tends to be underestimated in PDDs.

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4 As CDM projects in energy supply account for 77 % of the projects in China and for 73 % in India, the low representation of Asian countries largely explains that energy supply projects are underrepresented in our sample.

5 To compare our survey data with the codes from the CDM Pipeline, we created a variable *CDM_TT* from the pipeline that took on a value of 0 if the PDDs indicated either no technology transfer or made no mention of transfer, 1 if equipment transfer was expected, 2 if knowledge transfer was expected and 3 for an expectation of both transfer types. We then compared this variable with the assessments we received from the survey. If *CDM_TT* = 1, 2 or 3 and the survey response was 0 or 1 (no or very low transfer) for the respective category, we concluded that technology transfer had been overestimated in the PDD. If CDM_TT = 0 and the survey response for either knowledge or equipment was between 2 and 5 (low to very high transfer), transfer was assumed to have been underestimated.

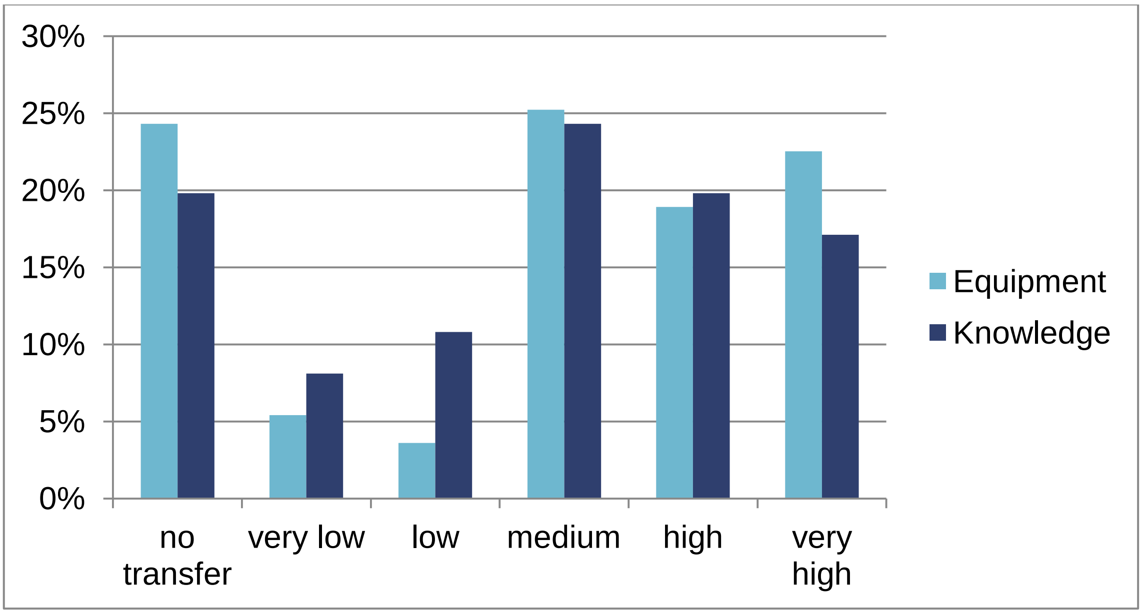

Figure 1: Assessment of the degree to which equipment/knowledge were transferred to the receiving parties in the project (N=111)

3.2 Econometric Model

Econometric analysis is used to empirically assess the relationship between knowledge/equipment transfer and a set of explanatory variables based on our survey, including information on technology complexity, novelty, and choice of transfer channel. The explanatory variables also include variables that have typically been employed in the literature, such as project size, sector dummies, time dummies, and absorptive capacity.

Dependent variables

The dependent variables used are *knowledge* transfer and *equipment* transfer, which we assume to be influenced by characteristics of the technology, the choice of transfer channel and the host countries' absorptive capacity. To narrow down the scope of our analysis, we examine only the transfer of knowledge pertaining to the production, replication, adaptation and usage of equipment, which excludes knowledge that is transferred in the form of services. In the context of our survey, *knowledge* stands for respondents' perception of the technological knowledge and experience that was transferred to the receiving parties of the CDM project. Similarly, *equipment* reflects the extent to which equipment and technical components were transferred. For both variables, responses are coded from 1 (‘no transfer’ or ‘very low’) to 5 (‘very high’). This allows for a more nuanced assessment of the degree of technology transfer involved than the binary classification of technology transfer in CDM projects employed in previous analyses.

Explanatory variables

Because knowledge tacitness is difficult to capture empirically, we use technological complexity and novelty as proxies. In the survey, respondents were asked to assess the complexity of the technologies employed in their project. The original answers were scaled from 1 (‘very low complexity’) to 5 (‘very high complexity’). The responses were used to create *complexity,* a binary variable, which takes on the value of 1 if respondents answered ‘very high complexity’ and 0 otherwise.[6]

Similarly, the questionnaire asked respondents to assess the novelty of technologies. They were asked how old the version, type or model of the technology utilized in the project was at the time that the project started. The five answer categories were 0-2 years, 3-5 years, 6-10 years, 11-15 years and > 15 years. To save degrees of freedom but allow for nonlinearity in the marginal effects, we created three dummy variables, *novelty1* (‘0-2 years’), *novelty2* (‘3-5 years’) and *novelty3* (‘>5 years’).

We further differentiate between four transfer channels: *export* and *licensing*, which are market-based and therefore exhibit a low degree of organisational interaction, and transfers to *jointventures* and *affiliated* companies or subsidiar-

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6 To save degrees of freedom, we do not include dummies for all five response categories as explanatory variables. The final specification of complexity was chosen based on Wald tests, which imply that there is no difference between the parameter values of the four lowest response categories for complexity. Also note that based on these tests, treating the original responses as a continuous variable would not be correct.

ies, which are both characterized by closer interactions. Respondents were asked to which extent these channels were used for transferring technical equipment and/or knowledge to the recipient parties. The response categories ranged from 1 (‘very low’) to 5 (‘very high’). Since the responses are ordinal and to save degrees of freedom, binary variables are included in the analysis. The dummy variables *export, licensing, jointventure,* and *affiliated* take on the value of 1 if the transfer channel is used to a ‘high’, or ‘very high’ degree, and 0 if it is used to a ‘very low’, ‘low’ or ‘medium’ degree.

To capture differences in countries’ abilities to incorporate new knowledge and technologies, a dummy variable for countries’ absorptive capacity was used: We gathered country data for the years 2012-2013 from the World Economic Forum's (WEF) Global Competitiveness Report (Schwab & Sala-i-Martin, 2013) to construct the variable *absorptivecap.* The following five indicators were used from the WEF database: public institutions, infrastructure, higher education and training, technological readiness, and innovation. For each indicator, countries are ranked on a scale between 1 and 7. An exploratory factor analysis showed that these five items all loaded on a single factor. After checking reliability (Cronbach’s α = 0.91), *absorptivecap* was calculated as the average ranking of the five indicators.

To control for a possible decrease in the amount of technology transfer over time, *CDM_age* is calculated on a country-level as the difference between the year each project was registered and the year in which the first CDM project was registered in that country.[7] Following the literature, we use the amount of expected greenhouse gas emissions savings (i.e. certified emission reductions, CERs) of a project per year (in tCO_2/yr) as an indicator for project size and employ its natural log in the actual implementation (*lnsize*). Finally, to capture sector effects, we include *energy* to reflect whether a project involves energy sup-

[7] For the nine projects in our sample where the project status was ‘at validation’ or ‘replaced at validation’ we assumed 2015 as the year of registration.

ply or energy efficiency technologies. Apart from energy supply projects like wind or hydro power, energy also includes some projects labeled as 'landfill gas', 'methane recovery' (based on references to energy production in the project title), 'fuel switch', and energy efficiency projects in industry and residential sectors.[8] Table 1 provides descriptive statistics of the independent and explanatory variables.

8 To save degrees of freedom and since other sectors did not contain sufficient observations, we did not include additional sector dummies.

Table 1: Descriptive statistics (N=70)

Variable		Mean	Std. Dev.	Min.	Max.
complexity	Dummy for technology associated with 'very high complexity'	0.07	0.26	0	1
novelty1	Dummy if technology is 0 to 2 years old	0.39	0.49	0	1
novelty2	Dummy if technology is 3 to 5 years old	0.21	0.41	0	1
novelty3	Dummy if technology is older than 5 years	0.40	0.49	0	1
export	Dummy if export is used to a 'high', or 'very high' degree as a transfer channel	0.46	0.50	0	1
licensing	Dummy if licensing is used to a 'high', or 'very high' degree as a transfer channel	0.17	0.38	0	1
jointventure	Dummy if a joint venture is used to a 'high', or 'very high' degree as a transfer channel	0.23	0.42	0	1
affiliated	Dummy if an affiliated company/subsidiary is used to a 'high', or 'very high' degree as a transfer channel	0.23	0.42	0	1
absorptive-cap	Average country ranking for five indicators of absorptive capacity	3.83	0.53	2.89	5.99
CDM_age	Difference between project registration year and year of first CDM project registration in host country	4.46	2.48	0	11
lnsize	Logarithm of expected CERs in tons per year	10.88	1.48	7.85	13.86
energy	Dummy for energy supply or energy efficiency projects	0.64	0.48	0	1

Econometric model

Since the dependent variables are ordinal, we estimate ordered response models, specifically, ordered logit models.[9]

4 Results

We use STATA13 to run the ordered logit models for *knowledge* and *equipment*.[10] To prevent singularity of the regressor matrix, *novelty1 is not included in* the set of explanatory variables. Thus, *novelty1* serves as the base for *novelty2* and *novelty3*. Results for both equations are shown in Table 2. Robust standard errors appear in parentheses.

The Wald test statistics on the combined statistical significance of all parameters imply that the null hypothesis that all parameters of the explanatory variables are zero can be rejected at $p<0.01$ for both equations.

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9 We also tested the so-called parallel lines assumption, which implies that coefficients are identical across all categories of the dependent variables, and found no evidence that it is violated. Thus, we estimated simple ordered logit models rather than generalized ordered logit models.

10 Based on Wald tests, we combined the answers for the response categories 2 ('very low) and 3 ('low") for *equipment*.

Table 2: Results of ordered response models

	knowledge		equipment	
complexity	1.579	**	3.485	***
	(0.716)		(1.103)	
novelty2	1.297	**	0.296	
	(0.630)		(0.693)	
novelty3	-1.121	*	-1.201	*
	(0.577)		(0.626)	
export	1.732	***	2.415	***
	(0.528)		(0.656)	
licensing	0.569		0.738	
	(0.885)		(0.802)	
jointventure	-0.852		-1.072	
	(0.983)		(0.811)	
affiliated	1.037		0.246	
	(1.040)		(0.882)	
absorptivecap	0.0426		-0.235	
	(0.508)		(0.482)	
CDM_age	0.0241		0.0819	
	(0.0852)		(0.0925)	
lnsize	0.0693		0.0734	
	(0.191)		(0.198)	
energy	1.440	**	0.803	
	(0.719)		(0.793)	
Sample size	70		70	
Wald χ^2	37.07	***	40.65	***
Pseudo R^2 (McFadden)	0.1423		0.1843	

Note: *** indicates significance at p<0.01, ** indicates significance at p<0.05 and * indicates significance at p<0.1 in an individual two-tailed t-test

The findings suggest that knowledge and equipment transfers both increase with rising *complexity*. That is, for the technologies which are perceived to be very complex, the transfer of knowledge and equipment is higher than for technologies perceived to be less complex. For technologies which were older than five years at the time the project started (*novelty3*), knowledge and equipment transfers are found to be lower than for technologies that had been on the market for less than two years, while our results suggest that technologies which are between three and five years old are associated with higher knowledge transfer than the newest technologies (0-2 years). Using export or – in more general terms – arm's length market transfer as a channel for technology transfer in CDM projects is associated with a higher transfer of knowledge and equipment than projects that do not use export. Apart from *export,* no other transfer channel was found to be statistically significant.

The parameter estimates associated with the variables reflecting a host country's absorptive capacity (*absorptivecap*), the length of time it has hosted CDM projects (*CDM_age)* and the size of the project (*lnsize*) are not statistically significant in either equation. Finally, energy supply and energy efficiency projects are positively correlated with knowledge and equipment transfer, but the p-value of *energy* in the equipment equation (p=0.311) is above the conventional levels of significance.[11]

To provide additional insight and allow for further interpretation of the econometric findings, Table 3 and Table 4 display the average marginal probability effects of *complexity* and *export* for all categories, ranging from 1 ('no or very low transfer') to 5 ('very high transfer'), of *knowledge* and *equipment*.

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[11] We also estimated a model without the explanatory variables from our survey, to allow for comparisons with analyses based primarily on explanatory variables taken from the PDD, i.e. *absorptivecap*, *CDM_age*, *lnsize* and *energy*. None of the coefficients in this model turned out to be statistically significant, and the explanatory power is very weak. In addition we ran regressions including selected regional dummies (e.g. for China) but results did not provide any additional insights. All findings are available upon request.

Table 3: Average marginal effect of *complexity* and *export* on *knowledge*

Category	complexity	export
1	-0.07	-0.06
2	-0.05	-0.05
3	-0.01	-0.01
4	0.09	0.08
5	0.20	0.19

Table 4: Average marginal effect of *complexity* and *export* on *equipment*

Category	complexity	export
1	-0.06	-0.09
2&3	-0.05	-0.07
4	0.08	0.12
5	0.31	0.44

For example, using a technology that is considered highly complex as opposed to not highly complex decreases the probability of involving ‘low’ knowledge transfer (i.e. category 1) by 7 percentage points, and increases the probability of involving ‘very high’ knowledge transfer (i.e. category 5) by 20 percentage points. Similarly, using technologies that are considered highly complex as opposed to not highly complex decreases the probability of involving ‘low’ equipment transfer by 6 percentage points, and increases the probability of involving ‘very high’ knowledge transfer by 31 percentage points.

Likewise, employing export as a transfer channel decreases the probability of ‘low’ knowledge transfer by 6 percentage points, and increases the probability of ‘very high’ equipment transfer by about 19 percentage points. Similarly, employing export as a transfer channel decreases the probability of ‘low’ equipment transfer by 9 percentage points, and increases the probability of ‘very high’ knowledge transfer by about 44 percentage points.

5 Discussion and conclusions

Our findings based on a survey of CDM participants suggest that about two-thirds of those projects involve a medium to very high extent of equipment and knowledge transfer. Similar to Murphy et al. (2013), we find that respondents tend to perceive the technology transfer to be higher than they had originally stated in their PDDs. Hence, for the projects included in our survey we do not find support for the notion that editors of PDDs overstate the technology transfer of the project. The differences in the assessment of technology transfer between our survey and the PDD-based CDM pipeline may be due to information update since the survey was conducted after the PDD had been submitted. Likewise, the differences may be due to a more direct focus on the issue of technology transfer and/or a more nuanced scale in the survey.

Our results from the econometric analysis suggest that the type of transfer channel used affects both knowledge and equipment transfer, but only the channel *export* was found to be statistically significant. This finding may be explained by the benefits resulting from a general openness of CDM projects to trade, which facilitates access to the global pool of technologies. In this sense, the finding for *export* is consistent with the result of Dechezleprêtre et al. (2009) who find that a country's openness to trade increases the likelihood of technology transfer in CDM projects. Further, our findings on export channels do not suggest that technology transfer through CDM projects requires a high degree of organisational interaction between project partners.[12] Given the institutional structure of the CDM, the incentives for technology suppliers from Annex I countries to engage in more intensive forms of organisational interaction, such as joint-ventures, seem to be quite low, since CDM projects are limited in time

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12 At first glance, this result seems to differ from Dechezleprêtre et al. (2008), who find that when technology recipients are subsidiaries of Annex I country companies, there is a higher likelihood of technology transfer. However, they do not control for other transfer channels and the transfer examined does not necessarily take place between a parent company and its subsidiary.

and geared to emissions reductions rather than market entry. Therefore, export or market transactions, as a form of temporary, one-time interaction between supplier and customer seem to have a better institutional fit with the CDM than the other transfer channels. Another possible explanation for this result might be that most CDM projects are closely accompanied by CDM consultants with whom there is a high degree of interaction and who, in the process of their consultation, may provide some of the necessary tacit knowledge (Wang, 2010).

With regard to technological characteristics, the results of our analysis suggests that for technologies that are perceived to be highly complex, the transfer of knowledge and equipment is indeed higher than for less complex technologies. Our findings for knowledge transfer (but not for equipment transfer) suggest that technologies that are between two and five years old are associated with higher technology transfer than technologies which are either newer than two years or older than five years. There is also weak evidence that the use of technologies that were younger than two years at the time the project started are related to greater knowledge and equipment transfer than the use of those that were older than five years.

Since novelty and complexity were used as proxies for the degree of tacit knowledge contained in a technology, the results suggest that the transfer of tacit knowledge components contributes to the success of technology transfer in the CDM. Less complex technologies may have already been transferred to the host countries in the past and are thus not perceived to contribute much to technology transfer. This finding is generally consistent with Murphy et al. (2013, p. 7), who conclude that CDM projects involving widely available, mature technologies are associated with little technology transfer. Therefore, countries that host a large number of CDM projects, such as China, India and Brazil, could encourage an increase in technology transfer via CDM projects by mandating technology standards (e.g. in the project approval process) that dynamically adapt to progress in their technological capabilities and to advances at the technological frontier.

Unlike in most previous analyses, project size and the age of the CDM in a country were not statistically significant in our survey-based analysis. This may be due to the relatively small and non-representative sample size or systematic differences in the assessment of technology transfer. Likewise, the additional regressors included in our analysis may explain some of the variation in technology transfer that is otherwise (erroneously) attributed to project size or the age of the CDM. Consistent with the findings by Dechezleprêtre et al. (2008), we find that energy supply and energy efficiency projects are associated with higher technology transfer for knowledge (but not for equipment).

Similar to Schmid (2012), our results fail to exhibit a statistically significant relationship between technology transfer and the absorptive capacity of the CDM host country. Arguably, the country-level indicators that were chosen to construct the variable *absorptivecap* may have been too coarse to predict the extent of knowledge and equipment transfer on the project-level. The lack of significance, however, may also result from two countervailing effects that were previously described by Dechezleprêtre et al. (2008). On the one hand, technology transfer requires some minimum level of absorptive capability, implying a positive correlation of absorptive capacity and technology transfer. On the other hand, high absorptive capacity reflects that technologies are already available in a country, implying a negative correlation of absorptive capacity and technology transfer. Therefore, ideally, the relationship between absorptive capacity of a country and technology transfer for a particular technology should be analysed over time.

Our analysis also distinguishes between two types of technology transfer, knowledge and equipment transfer. The sign of all coefficients is the same for both transfer types, and the levels of significance are also quite similar. Our findings suggest, though, that projects which involve highly complex technologies or which employ export as transfer channels increase the probability of involving very high technology transfer more for equipment than for knowledge.

While our survey-based analysis of the factors driving technology transfer in CDM projects provides additional insights compared to the extant literature, ideally, a large and representative study should corroborate our findings. This could also allow for a more detailed consideration of differences between technologies and countries. Future analyses on technology transfer could focus on the function of international CDM project consultants as knowledge brokers and on measures to foster technology transfer via adequate provisions in the approval process. Finally, a more in-depth analysis of country-specific characteristics could be performed, employing indicators of technology-specific capability over time, rather than cross-sectional information on general indicators like education and the quality of institutions and infrastructure.

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Karlsruhe 2015