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Andrea Vaona

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Kiel Institute for the World Economy, Hindenburgufer 66, 24105 Kiel, Germany

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Determinants of Technology Transfer through CDM: the Case of China*

Matthias Weitzel, Wan-Hsin Liu, and Andrea Vaona

Abstract:
Technology transfer (TT) is not mandatory for Clean Development Mechanism (CDM) projects, yet proponents of CDM argue that TT in CDM can bring new technologies to developing countries and thus not only reduce emissions but also foster development. We review the quantitative literature on determinants of TT in CDM and estimate determinants for CDM projects in China. China is by far the largest host country of CDM projects and it is therefore crucial to understand the factors that drive TT there. We focus on heterogeneity within a single country and results can thus be linked to specific policies of the country for better interpretation. Our probit estimations confirm results of international cross-country studies, indicating that larger projects and more advanced technologies are more likely to involve TT. In addition, we find evidence that agglomeration effects are more pronounced on the province level rather than larger regions. We also find a positive effect of FDI on TT and a complementary role of academic R&D engagement to TT.

Keywords: Clean Development Mechanism, Technology Transfer, R&D, Agglomeration, China.

JEL classification: O33, Q55, Q58

Matthias Weitzel
Kiel Institute for the World Economy
Hindenburgufer 66
24105 Kiel, Germany
+49(0)431-8814-580
Email: Matthias.weitzel@ifw-kiel.de

Wan-Hsin Liu
Kiel Institute for the World Economy
Hindenburgufer 66
24105 Kiel, Germany
+49(0)431-8814-269
Email: wan-hsin.liu@ifw-kiel.de

Andrea Vaona
University of Verona,
Via dell'Artigliere 8
37129 Verona, Italy
+45-8028537
andrea.vaona@univr.it.

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1 Introduction

The main aim of the Clean Development Mechanism (CDM), introduced by the Kyoto protocol, is decreasing CO_2 emissions in developing countries, at the same time giving buyers in developed countries more flexibility in achieving reduction requirements. Although there is no explicit objective of transferring knowledge, technology and equipment to developing countries, it is hoped that CDM can bring them advanced low carbon technologies, by connecting partners from developing and developed countries. In addition, revenues from selling carbon credits might finance more advanced technologies that would not have been viable without this revenue stream. CDM thus reduces barriers especially with respect to finance costly foreign technology (Schneider et al., 2008).

While technology transfer (TT) in CDM projects is not well defined in international legal documents (Das, 2011), there has emerged a literature trying to find determinants of this phenomenon (see Section 2). Previous studies are mainly based on international cross-sectional datasets, i.e., they try to explain the heterogeneity between countries, thus potentially neglecting heterogeneity within countries.

The CDM has led to 7127 registered projects (as of July 30, 2013). These projects have led to the issuance of 1353 million certified emission reductions (CER), i.e., they have avoided the equivalent of 1353 Mt of CO_2 emissions. The projects are however distributed very unequally, with China and India hosting 52% and 19% of all registered CDM projects, respectively. Cross-country estimates are therefore to a large extent driven by these two countries, whose specificities are however customarily controlled by simple dummies though. As a consequence there is generally no in-depth interpretation of these country specific effects.

Providing this interpretation for China is all the more important given that the Chinese government has adopted national legislation to facilitate TT in CDM projects.[1] It is stated there that, "CDM project activities should promote the transfer of environmentally sound technology to China" (Article 10). This, however, does not mean that TT is a necessary condition for project approval and there are no direct incentives for TT. At the same time, other restrictions potentially harm the willingness of foreign firms towards TT. For example, foreign partners are eligible to conduct CDM projects in China, however the project owner can only be a Chinese (majority) owned entity (Article 11). Other legislation requires certain shares of local content in renewable energy technologies. Schroeder (2010) therefore concludes that initial hopes of Chinese project owners for TT were not entirely met.

As far as China is concerned, it is very diverse and CDM projects are carried out both in rather developed coastal regions and western regions, the latter have a per capita GDP only half that of coastal provinces. Yet, most existing international studies often do not take into account this regional heterogeneity. This paper tries to fill this gap, taking a closer look at China. On the footsteps of cross-country studies, we aim at investigating whether the determining factors they highlighted - such as different levels of development of technological capacity - also hold at a regional level. This extends recent studies on TT in Chinese CDM projects which either had a different focus or relatively few controls. In particular, we measure the agglomeration effects of existing CDM projects along different spatial scales and introduce a more detailed analysis on the role of R&D expenditures.

[1] http://cdm-en.ccchina.gov.cn/Detail.aspx?newsId=5628&TId=37.

To sum up, our paper provides a more detailed view on the drivers of TT through CDM in China, which hosts more than half of all CDM projects worldwide. We do not only investigate whether the determinants found to be important in an international context also hold for China at a sub-national level. This paper additionally analyzes agglomeration effects on TT through co-locating with similar CDM projects using different geographic contexts and explores the role of R&D from different innovators on TT. In this way, our paper both complements existing international studies and it also extends recent papers concerning Chinese projects (Luo and Ye, 2011; Marconi and Sanna-Randaccio, 2012; Zheng and Zhang, 2012).

The remainder of the paper is structured as follows. Section 2 provides an overview of the relevant literature. Section 3 describes the data and estimation strategy. Section 4 discusses our econometric results. Section 5 concludes.

2 Relation to the existing literature

There exist several quantitative studies on TT of CDM projects. In principle, all studies made use of information published in the official project design document (PDD) describing the project. This method is not perfect because the information on TT in PDDs is not standardized. However, follow-up surveys indicate that PDDs predict TT sufficiently well (Murphy et al., forthcoming). Criteria to measure TT differed slightly between studies. Most studies searched the PDDs for indications of involvement of foreign partners or suppliers. Das (2011) however differentiated between simple technology imports and "superior" TT, the latter one specifically adjusting a technology for the host country or the CDM project. Schmid (2012) analyzed different forms of TT by differentiating between transfer in equipment, knowledge, or both.

Econometric (either probit or logit) estimation was usually carried out to investigate the relevance of different factors in fostering TT of CDM projects. Most studies regressed the observed flow of TT on project and host country specific characteristics. While the former included truly project specific characteristics (such as the project's abatement potential, its technology, and starting year), the latter gave information on characteristics of the host country. Earlier studies simply used host country dummies, while many later studies replaced these host country fixed effects by variables identical to all or several projects in a given host country (e.g. GDP or tariff rates). Some studies (UNFCCC, 2010; Haites et al., 2012) used country fixed effects in a first stage estimation and subsequently added a second estimation which regressed country characteristics on predicted TT probabilities from the first stage (including country dummies).

Table 1 presents determinants found to be significant in previous studies. In general, studies found that larger projects are more likely to involve TT, whereas either small-scale ones or those without a foreign partner ("unilateral") are less likely to involve TT. As a consequence, projects which either require more capital or are more complex due to their size are more likely to involve TT.

Table 1: Overview of determinants of TT in CDM projects in the quantitative literature

Study	Observations[a]	Determinants of TT [b]		Further controls	Remarks
		+	-		
De Conink et al. (2007)	63 (reg)	No regression analysis			Technology types, estimation of capital flows and investment costs
Haites et al. (2006)	854 (all)	China dummy, Size	Unilateral[c]	Technology and country dummies	
Dechezlepretre et al (2008)	644 (reg)	Size, GDP growth, Project firm is subsidiary of firm from Annex I country[d], Trade, (Technological capability)	Unilateral, Similar[e], (FDI inflow)	GDP per capita, Population, Technology and country dummies	Technological capability weakly positive, interacts positively for energy/chemicals projects and negatively with agricultural projects
Dechezlepretre et al (2009)	644 (reg)	Size, Project firm is subsidiary of firm from Annex I country, Trade, GDP growth, Tech. capability	Unilateral, Similar, FDI inflow	GDP per capita, Population, Carbon intensity, Technology and country dummies	China dummy negative, TT in China driven mainly by high growth and technological capability
Seres et al. (2009)	3296 (all)	Size	Unilateral, Time trend, China dummy	Technology and country dummies	Analyze origin of TT and credit buyers
UNFCCC (2010)	4974 (all)	Size, (business climate)	(Unilateral), Similar, Small scale, (China dummy). 2[nd] stage: (Exports), Official development assistance, Population, Tariff rates, Knowledge stock, Democracy index, Renewable energy share	Technology, country, and year effects. 2[nd] stage: per capita GDP, FDI, Fixed capital formation, Imports	Two stage estimations for country effects: Predicted TT probability based on estimations with country dummies regressed on country characteristics in a 2[nd] stage Further estimations with a subset of countries to identify specific barriers
Das (2011)	1000 (reg)	No regression analysis			More narrow definition of TT, Involvement of international consultant improves likelihood of TT
Luo and Ye (2011)	889 (reg)	EU emission allowance price, Consultant is carbon trader or from research institute, Developed regions dummy	(Price of certified emission reduction (CER)), (Buyer is financial institute)	Size, Similar	Only Chinese projects, focus on buyer/consultants, no controls for industries, instead of year dummies the average annual price of EU emission allowances or the price for CERs was included
Marconi and Sanna-Randaccio	715 (reg)	Size, Investment/CER, Project owner is consultant, Credit buyer is large	Northwest China dummy, Similar projects for wind	Technology and region dummies, Similar, Chinese PDD	Only Chinese non-hydro projects, analysis of technology providers and CER buyers, similar projects positive but significant only when

(2012)		consultant		consultant, Size of PDD consultant	controlling for interaction with technologies, declining trend over time (increasingly negative year effects)
Schmid (2012)	3296 (all)	Size, (Business climate), (duration), (Unilateral)	(Similar projects), MFN tariff rates on environmental goods, (R&D), (GDP)	Technology and country dummies	Analysis of different TT types; education, unilateral and R&D only significant in specification without technology and country dummies
Murphy et al. (forthcoming)	3530 (all)	Size, Imports, FDI, Tariff rates, Abatement cost, Transferred technology[f], 2nd stage: Official development assistance, Knowledge stock	Similar projects, Small scale, Capital formation, Abatement potential, Technology base. 2nd stage: Population, Share of renewables	Technology and country dummies	Two stage estimations for country effects, year dummies show declining effect over time, China dummy in first stage positive but not significant, some variables switch sign in one and two stage estimation (per capita GDP)
Zhang and Zheng (2012)	1509 (reg)	GDP, Size	(Patent stock), Similar projects	Technology dummies, Internal rate of return	Only Chinese projects

[a] Observations refers to number of projects, and all/reg. refer to all projects in the pipeline or only registered projects, respectively.
[b] Drivers do not include specific technologies, but technologies are often controlled for. The symbol "+" indicates that regressors have a statistically significant positive effect on TT, while "-" a statistically significant negative effect on TT. Determinants shown in parenthesis are not robust in the estimations.
[c] "Unilateral" denotes projects that started without a foreign partner.
[d] "Annex I countries" refers to countries with binding emission targets as listed in Annex I of the Kyoto protocol.
[e] "Similar" refers to the number of projects in the same country/region and the same technology.
[f] "Transferred technology" refers to the number of applications by foreign patent holders relating to the technology used by the CDM project.

International cross-section estimations with country dummies did not find a consistent coefficient for China. As many of China's initial projects included TT, the coefficient was positive in Haites et al. (2006), but negative (yet not always significant) in later studies (UNFCCC 2010, Seres 2009). Some studies also analyzed the effects of different roles that CER buyers and project consultants can fill. TT is more likely in projects where PDD consultants are more closely connected to the project (e.g. through ownership of the project) and less likely when CER buyers are coming from financial institutions and thus have less direct interest in the technology used.

Unlike all other quantitative studies mentioned above which measured determinants for TT in CDM, Haščič and Johnstone (2011) focused on the effect of CDM (among other channels) on bilateral TT in the wind energy sector.[2] They found that wind energy patents first registered in Annex I countries are more likely to be also registered in countries with more wind energy CDM projects. For China, this effect is larger than for other important CDM host countries. They also found a negative stock effect, i.e., with more CERs already issued, the propensity to transfer wind energy patents to CDM host countries declines.

Three studies analyzed CDM projects in China only (Luo and Ye, 2011; Marconi and Sanna-Randaccio, 2012; Zheng and Zhang, 2012). Luo and Ye (2011) as well as Marconi and Sanna-Randaccio (2012) emphasized the role of participants in the market. For the likelihood of TT in a CDM project it matters who acts as a project consultant and CER buyer. This confirms Das (2011) and Schroeder (2010) pointing out that there are several distinct segments in the market for CDM projects. Zheng and Zhang (2012) emphasized the role of the existing knowledge stock which has a negative effect on TT. As domestic renewable technologies in China approach the global technological frontier, the potential for TT decreases. Also among the three studies on China, only Zheng and Zhang (2012) found a robust negative agglomeration effect from similar projects at the national level. In general, findings from international cross-country studies seem to hold for the relatively few included variables describing province characteristics.

This paper therefore aims at extending the analysis of Chinese projects by looking at agglomeration effects at the sub-national level and by investigating the role of province-specific capacity and capability in R&D activities on TT in more detail than in previous studies. Compared to cross-country studies, which rely on cross-country variability, this paper looks at within-country differences. Thus, determinants found significant in an international context might not apply here because all provinces are subject to the same policies, e.g. tariff rates. However, there remain differences between provinces in characteristics, e.g. FDI flows and their technological capabilities.

3 Data description and Estimation Strategy

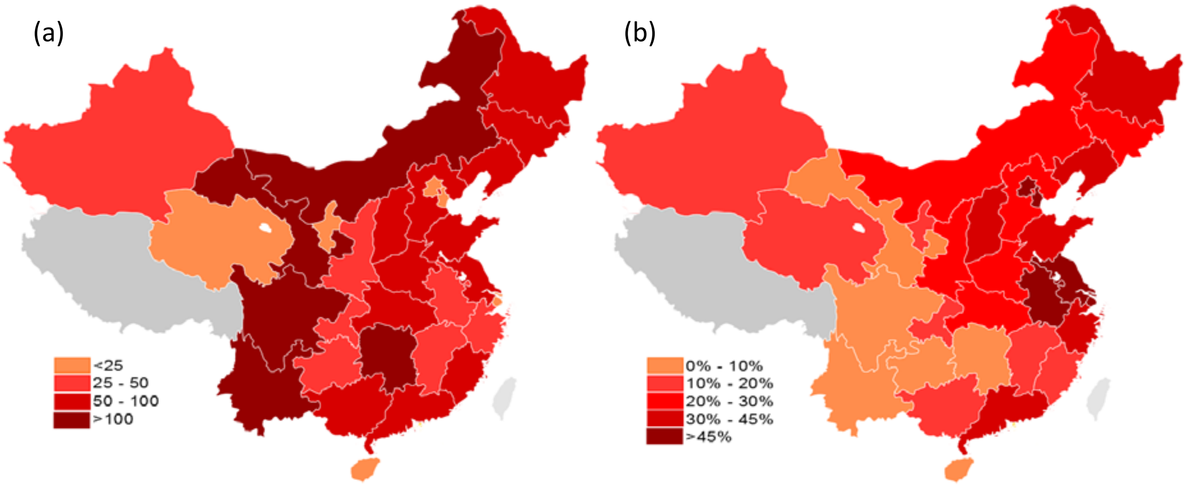
The information of whether a given CDM project encompasses TT is taken from the database underlying UNFCCC (2010). PDD data has some limitations as this is an ex-ante description of the planned project. Furthermore mentioning TT in the PDD is not required and there exists no standard way of doing so. Therefore there is some potential of measurement error. The most pronounced error arises from projects that do not mention TT at all, namely, neither its presence nor its absence in a given project. Previous studies have either interpreted these as absence of TT or excluded the projects from the sample. Murphy et al. (forthcoming) carry out a follow-up survey to check for the accuracy of TT coding. While the coding for TT from PDD performs well for projects that either state

[2] Because of this difference to the other studies, we do not include this study in Table 1.

presence or absence of TT, the results of the other group is mixed as many projects that do not mention TT in fact involve some form of TT. In this study we opt for excluding projects with unclear information on TT. For China, this exclusion does not matter much because only about 10% of projects are coded as unknown TT. Results quantitatively and qualitatively hardly change when using all observations, with one major exception that we comment when illustrating our results. The TT data is merged with CDM project specific information taken from the UNEP Risø CDM/JI Pipeline Database (UNEP Risø Centre, 2012). For China, we have 1799 matched projects that have entered the pipeline between January 1, 2005 and June 30, 2010.[3]

Data on province characteristics include provincial GDP per capita, population size, FDI engagement as proxy for openness, and R&D activities of different innovators. Provincial data are collected from the annual China Statistical Yearbook and annual Chinese Yearbook of Science and Technology for the research period corresponding to the CDM database.

Figure 1: Number of CDM projects in different provinces (a) and share of TT in CDM projects (b)



Data source: authors' compilation based on data from UNEP Risø Centre (2012), and UNFCCC (2010).

CDM projects are not evenly distributed among provinces (see Figure 1a). More than 100 projects are implemented or projected in each Inner Mongolia, Hunan, Sichuan, Yunnan, and Gansu. These provinces have large potential for renewable energy projects like hydro energy (Hunan, Sichuan, Yunnan, and Gansu) or wind energy (Inner Mongolia and Gansu). Projects related to hydro and wind energy constitute the majority of CDM projects in these provinces and China in total. Because of different geographical features, different provinces are more likely to engage in different technologies which in turn unevenly involve TT. The share of CDM projects with TT is thus very different between provinces (Figure 1b). Overall about 21% of the projects involve TT, but the share is higher in coastal provinces, especially in the municipalities of Beijing, Tianjin, and Shanghai (although they do not host many CDM projects). Part of the differences might be due to geographical characteristics which make different project types more suitable for different provinces, which is of

[3]We exclude two projects which started in 2004 because these rather have to be judged as pilot projects prior to the entering into force of the Kyoto protocol and the set-up of CDM related administrative structures. Out of the 1799 projects, we further exclude 5 projects implemented in more than one province and can thus not be used in our econometric strategy. By including technology effects in the estimations, 47 observations must be dropped because all geothermal and N_2O abatement projects contain TT, while all afforestation, reforestation, solar energy, household energy efficiency, industry energy efficiency, and oil flaring reduction projects contain no TT. We are left with 1752 observations.

policy relevance in itself. However it is also interesting to gain more insights into whether different policies have a direct effect on the likelihood of TT in CDM projects. We adopt an econometric approach to highlight such information.

In order to investigate the determinants of the TT of CDM projects, we construct a baseline model consisting of four groups of potential determinants for estimation. The TT variable is binary, therefore we apply a non-linear approach and carry out probit estimates. The basic idea of our empirical models can be presented as follows:

$$y_i^* = x_i\beta + \varepsilon_i \qquad (1)$$

where *i* denotes individual CDM projects, y_i^* is a latent variable that is related to the dependent variable of interest – TT, x_i refers to the exogenous variables that are expected to affect the TT of CDM projects (Section 2) and ε_i represents a random error term.

The latent variable y_i^* is unobserved but is linked to TT in CDM projects. More concretely, the dummy variable TT_i is equal to 1 (indicating the implicit occurrence of TT in the *i-th* CDM project) if the latent variable is larger than zero and it is equal to 0 (no technology transfer) otherwise. Assuming a standard normal distribution of the error term ε_i, we end up with probit models as follows for estimation:

$$\Pr(TT = 1 \mid x) = \Pr(y^* > 0 \mid x) = \Phi(x\beta) \qquad (2)$$

with $\Phi(.)$ referring to a standard normal cumulative distribution function.

The dependent variable is equal to 1 when technology transfer was explicitly documented to be carried out in the CDM application documents and 0 otherwise. This variable and the explanatory variables discussed below are described in Table 2. Some basic statistics are provided there as well.

In our baseline models we focus on the following four groups of project-specific determinants.

$$x_i = (x_i^{basic} \quad x_i^{yr} \quad x_i^{ind} \quad x_i^{agg}) \qquad (3)$$

x_i^{basic} consists of three basic project characteristics – project size in log (*lnsize*), whether it is a small-scale project which is characterized with more simple documentation procedures (*smallscale*) and whether it is a unilateral project, i.e., started without foreign partners (*unilateral*). These three basic project characteristics were in the previous literature found of significant relevance for determining the probability of TT of the CDM projects.

The second group of project-specific determinants, x_i^{yr}, considers the time effect. The starting year of the CDM projects is codified in five year dummy variables (*year2006, year2007, year2008, year2009, and year2010*), assuming the year of 2005 as reference year. We expect a larger TT probability in earlier CDM projects. Table 2 gives us some first support for this expectation, where the share of TT is generally larger for the projects started in earlier years. Considering the fast development experienced by China, it is likely that the potential for technology catch-up in receiving provinces diminished over time as these provinces reduced their gap to the technological frontier.

Table 2: Summary statistics and variable description based on the observations from 2005 to 2010

Variable	Description	Mean	Std. Dev.	Min/Max	%TT
TT	Dummy for TT	0.19	0.40	0/1	19.46
lnsize	Project size in log for expected 1000 CERs annually	4.49	1.02	1.79/9.25	-
smallscale	Projects applying simplified modalities and procedures for small scale	0.29	0.46	0/1	2.92
unilateral	Projects without an Annex I Party letter of approval at the time of registration	0.05	0.22	0/1	19.77
year2006	Year dummy for 2006	0.09	0.28	0/1	52.32
year2007	Year dummy for 2007	0.27	0.44	0/1	24.84
year2008	Year dummy for 2008	0.26	0.44	0/1	13.22
year2009	Year dummy for 2009	0.25	0.44	0/1	9.66
year2010	Year dummy for 2010	0.12	0.32	0/1	10.24
hydro	Hydro energy projects	0.47	0.50	0/1	0.61
wind	Wind energy projects	0.23	0.42	0/1	30.30
eeown	Energy efficiency in own generation projects	0.13	0.34	0/1	35.34
eesupply	Energy efficiency in supply projects	0.005	0.07	0/1	62.50
distribution	Energy distribution projects	0.01	0.08	0/1	27.27
switch	Fuel switch projects	0.02	0.13	0/1	89.66
minemethane	Mine methane projects	0.03	0.17	0/1	51.85
methaneavoid	Methane avoid projects	0.02	0.14	0/1	17.65
landfill	Landfill gas projects	0.03	0.18	0/1	64.29
hfcs	HFC-23 destruction projects	0.01	0.08	0/1	90.91
cement	Cement sector projects	0.01	0.08	0/1	10.00
provcount	Number of projects already in the pipeline with same technology and in the same province at project start	35.19	44.94	1/195	-
regcount	Number of projects already in the pipeline with same technology and in the same region (geographically defined) at project start	144.85	172.04	1/634	-
natcount	Number of projects already in the pipeline with same technology in China at project start	289.43	251.15	1/882	-
techregcount	Number of projects already in the pipeline with same technology and in the same region (technologically oriented) at project start	236.46	250.06	1/839	-
gdp_pc	real per capita GDP in RMB (in prices of 2000)	13826.73	6740.23	4019.17/ 56261.62	-
lnpopulation	Log of Population (population in 10,000)	8.39	0.55	6.30/ 9.17	-
trcf	Total investment of (partially) foreign funded companies in stock relative to GDP	2.33	2.03	0.43/ 11.82	-
rd_ml	R&D expenditure of companies as percentage of GDP	0.50	0.26	0.03/1.32	-
rd_uniri	R&D expenditure of universities and research institutes as percentage of GDP	0.31	0.31	0.06/2.96	-

Data source: authors' calculation based on data from NBSC (2004a – 2010a), NBSC (2004b – 2010b), UNEP Risø Centre (2012), and UNFCCC (2010). Note: Each variable has 1752 observations (confined by the validity of TT variable).

Industry dummies, x_i^{ind}, are thus considered as our third group of determinants, to investigate possible industry effects on the presence of TT in CDMs. The reference group used in the estimations is biomass energy, a category with medium TT intensity. As shown in Table 2, share of TT differs strongly among projects from different industries.

Last but not least, we consider a potential agglomeration effect of CDM projects on TT probability by controlling for the amount of CDM projects which were already in place in the same area and industry at the timing as the CDM project of focus started (x_i^{agg}). We expect that the greater the number of already existing projects in the same industry in the same area (agglomeration), the more is the experience with new technology and the smaller the potential for further TT (under the very likely assumption for China of on-going technological catching-up). In order to investigate whether the provincial boundary is too limited for analyzing the agglomeration effect, we replace the province-level count variable (*provcount*) by a region-level count variable (*regcount*) which is constructed in the same way as its province-level counterpart. For this we classify the 31 provinces in China into four regions following the official classification defined for regional economic policy: north-eastern, coastal, central, and western region. As an alternative regional classification we also aggregate the provinces into four regions according to their dominant technology in the observation period (wind, hydro, energy efficiency in own generation, other). For comparison with previous studies, we also consider the nation-wide agglomeration variable (*natcount*). We consider the four groups of independent variables in sequence for estimation.

In order to control for the robustness of our results, we further extend our model by including two groups of province-specific characteristics, while sticking to our estimation strategy above. In this way we can better take into consideration whether the considered province-specific characteristics strengthen or weaken the probability of TT in CDM projects, taking as given the project-specific characteristics.

$$x_i^{prov} = (x_i^{gen} \quad x_i^{rd}) \tag{4}$$

The group of general provincial characteristics (x_i^{gen}) consists of three variables: the development level of provinces (real GDP per capita, *gdp_pc*), their population size in log (*lnpopulation*) and their openness to foreign investors in the world (*trcf*).[4]

The second group of province specific characteristics (x_i^{rd}) takes into account the technological capabilities of the province considered. It consists of two variables, namely the R&D expenditure of companies (*rd_mle*) and of universities and research institutes (*rd_uniri*) as percentages of GDP. Different types of innovators may have different strengths and focuses regarding innovation. Thus, their innovation behavior might affect the TT probability in CDM projects to varying extents. All six province-specific characteristics are calculated as two-year moving averages. In other terms we use data at times *t*-2 and *t*-1 to calculate the average for the CDM project *i* which started at the year *t*. We do so in order to smooth out short-term fluctuations and to deal with potential endogeneity issues. It is often customary in fact to use past lags of variables as instruments of current variables in many field of economics on the basis of a weak exogeneity argument. However, here there is no theoretical exclusion restriction not to insert past variables directly into the model. Therefore we believe we offer the best model specification possible. For estimations we consider first the group of general provincial characteristics and we later add in our empirical models the R&D-related province-specific characteristics.

All models are estimated using the province-clustered sandwich estimator. This relaxes the usual requirement that the observations are independent and standard errors allow for intra-group

[4] *Trcf* refers to the total investment of (partially) foreign funded companies in stock relative to GDP. We consider *trcf* as a proxy for a province's relative openness to the world investors in our estimations.

correlations. Since the probit models are non-linear models, the estimated coefficients in the results should not be interpreted as marginal effects on the probability directly. They show us instead the general direction of the effects of certain explanatory variables on the TT probability of the CDM projects.[5]

4 Estimation Results

Estimation results for the baseline models are presented in Table 3, while we will add province specific factors in Table 4. We illustrate our results accordingly. In the appendix we report the same estimations using all observations, coding unclear TT as no TT.

Table 3: Project-specific determinants of TT probability of CDM projects (Baseline models)

	(1)	(2)	(3)	(4)	(5)
lnsize	0.425***	0.445***	0.432***	0.440***	0.445***
smallscale	-0.135	-0.151	-0.142	-0.174	-0.169
unilateral	0.080	0.085	0.078	0.113	0.140
year2006	-1.522***	-1.465***	-1.488***	-1.390***	-1.402***
year2007	-1.886***	-1.795***	-1.835***	-1.676***	-1.710***
year2008	-2.682***	-2.540***	-2.604***	-2.349***	-2.428***
year2009	-3.033***	-2.839***	-2.930***	-2.579***	-2.707***
year2010	-3.115***	-2.854***	-2.992***	-2.570***	-2.715***
hydro	-1.830***	-1.675***	-1.704***	-1.458***	-1.459***
wind	0.439*	0.574**	0.489*	0.687**	0.643**
eeown	0.661**	0.683**	0.684**	0.784***	0.707**
eesupply	1.328***	1.253***	1.290***	1.157**	1.223***
distribution	0.451	0.368	0.410	0.266	0.338
switch	2.049***	1.979***	2.019***	1.912***	1.959***
minemethane	0.511*	0.501*	0.504*	0.483*	0.481*
methaneavoid	0.762*	0.745*	0.751*	0.694*	0.741*
landfill	1.676***	1.646***	1.664***	1.615***	1.637***
hfcs	-0.301	-0.304	-0.296	-0.233	-0.273
cement	-0.829	-0.833	-0.830	-0.838	-0.832
provcount		-0.005***			
regcount			-0.001		
natcount				-0.002	
techregcount					-0.002
_cons	-0.535	-0.740	-0.630	-0.858	-0.845
Wald Chi2	2907.73***	2994.64***	3737.01***	3101.34***	3791.85***
obs	1752	1752	1752	1752	1752

Data source: authors' estimation based on data from NBSC (2004a – 2010a), NBSC (2004b – 2010b), UNEP Risø Centre (2012), and UNFCCC (2010). Note: ***/**/* significant at 1%/5%/10% (two-tailed tests).

In Table 3, we start our estimation with a simple model (1) only including basic project characteristics, time, and industry effects. We find a positive and highly significant coefficient for the project size which is commonly found in the literature (see Table 1). The coefficient of “small scale” is negative but not significant. Some earlier studies (see Table 1) found that unilateral projects (i.e., without a known buyer for CERs) were less likely to include TT. We cannot confirm this, as a likely result of project consultants' action, who nowadays can also serve as technology brokers (Das, 2011). Therefore, the lack of statistical significance of the "unilateral" variable can descend from the fact that the absence of a direct connection with foreign CER buyers does not necessarily preclude TT.

[5] We additionally compute marginal effects (elasticities) for the variables of main concern for our analysis, namely significant agglomeration variables and those regarding provincial characteristics (End of Section 4).

In the simple specification as well as in all the extensions we find a highly significant declining trend of TT over time. This trend cannot be explained by a possible shift in CDM composition towards projects with either less or no TT, because this would be captured in the technology effects. The coefficients on the time dummies should instead be better interpreted as a *general* decline in TT in CDM in China. The increasingly negative year dummies (relative to the 2005 projects) show a pronounced drop already for 2006 projects. Various factors can explain this trend over time. When CDM was introduced, the Chinese government did not promptly promote it. However, foreign firms, looking for CO_2 reduction opportunities, were more active in the sector and they also fostered TT. Later the Chinese government became more proactive by building institutions and spreading relevant information, which led to the entrance of many inexperienced project consultants of lesser quality and with little experience in international TT in 2007 (Schroeder, 2010). As a consequence, the declining time trend continued. Marconi and Sanna-Randaccio (2012) attribute this finding to a general trend of technological progress in China - not limited to CDM projects - which made TT less likely over time. However, an alternative explanation cannot be ruled out based on our estimations. Consultants might have learnt that TT is not a necessary condition for acceptance of CDM projects. They need to demonstrate that a project would not have been carried out without the CDM. However, when overcoming financial and administrative barriers to adopt foreign technology is not necessary to demonstrate this additionality, consultants might prefer less bureaucratic projects relying on domestic technology.

As expected, different technologies are not equally likely to include TT. As our reference technology for the analysis we use biomass. Hydro energy projects rarely include TT, as this is a mature technology used in China for a long time. China even exports this technology to be used in CDM projects in other countries (Murphy et al., forthcoming). Contrary to hydro energy, the other widely used renewable energy technology in the CDM, wind energy, has a higher likelihood of TT.

The likelihood for TT in energy distribution, destruction of hydrofluorocarbons (HFCs), and cement projects is not statistically different from biomass energy. Partly this is due to the small number of projects in the bespoken categories. The coefficient of cement projects is negative but not significant as a possible result of the fact that cement technology, now widely used in China, was imported from Japan before CDM projects came into existence (Wang, 2010). This technology, therefore, is likely to be close to the technological frontier nowadays in China.

Capturing methane from landfills, mines, or waste water (most projects in the category "methane avoidance") on the other hand is likely to involve TT; this is also a priority area as specified by the government. Schneider et al. (2008) report that in these projects mostly end-of-pipe technologies are used and projects are often initiated by international partners. Fuel switch projects mainly consist of gas fired power plants which were built instead of coal fired plants. As these power plants are relatively large, it is likely that at least in some areas there is TT. This also holds for improvements of energy efficiency in own use (eeown) and supply (eesupply). Energy efficiency is also defined as priority area as specified by the government.

In general, there is evidence that more advanced technologies and some technologies that are supported by the government (this is not the case for all energy technologies) are more likely to involve TT. This broadly confirms the conclusions by Dechezleprêtre et al. (2008), stating that high technological capability favors TT in energy sector and chemical industry.

We can confirm negative agglomeration effects from similar – either already planned or existing – close-by projects in the same province (2). While this finding is robust in international cross-country studies, Zhang and Zheng (2012) also find this for China but Marconi and Sanna-Randaccio (2012) observe this only for wind energy projects. However, both studies consider the national level, while our variable *provcount* captures the sub-national level.

When we move from the provincial level to the regional level (3), we do not find evidence for significant agglomeration effects anymore. The same happens when either considering the national level (4) or when not using the administrative regions, but regions constructed on the basis of the suitability for different technologies (5).[6] Here, we group a province into one of four (wind, hydro, eeown or other) regions according to the technology with the most projects. Therefore we can conclude that local agglomeration effects can be better captured at the province level, which is plausible given the size of Chinese provinces.

Table 4: Extended models considering province-level determinants of TT probability of CDM projects

	(1)	(2)	(3)	(4)
lnsize	0.442***	0.427***	0.442***	0.454***
smallscale	-0.108	-0.126	-0.083	-0.093
unilateral	0.054	0.060	0.040	0.043
year2006	-1.507***	-1.506***	-1.485***	-1.457***
year2007	-1.851***	-1.896***	-1.847***	-1.801***
year2008	-2.660***	-2.702***	-2.636***	-2.560***
year2009	-2.959***	-3.058***	-2.944***	-2.845***
year2010	-3.014***	-3.199***	-3.039***	-2.894***
hydro	-1.775***	-1.816***	-1.840***	-1.713***
wind	0.514**	0.510**	0.554**	0.610**
eeown	0.678**	0.656**	0.652**	0.666**
eesupply	1.262***	1.228**	1.224**	1.184**
distribution	0.517	0.485	0.555	0.463
switch	1.986***	2.053***	2.029***	1.982***
minemethane	0.578*	0.499	0.572*	0.577*
methaneavoid	0.750*	0.675	0.653	0.625
landfill	1.687***	1.691***	1.711***	1.676***
hfcs	-0.384	-0.357	-0.431	-0.434
cement	-0.757	-0.754	-0.742	-0.773
provcount				-0.004**
gdp_pc	-0.000		-0.000	0.000
lnpopulation	0.078		0.156	0.145
trcf	0.066**		0.076**	0.062**
rd_mle		0.251	-0.243	-0.372
rd_uniri		0.380***	0.418***	0.368***
_cons	-1.427	-0.792	-2.141	-2.148
Wald Chi2	3102.06***	3970.85***	5283.28***	5180.29***
obs	1752	1752	1752	1752

Data source: authors' estimation based on data from NBSC (2004a – 2010a), NBSC (2004b – 2010b), UNEP Risø Centre (2012), and UNFCCC (2010). Note: ***/**/* significant at 1%/5%/10% (two-tailed tests).

Going beyond project specific characteristics, we add some province specific drivers in Table 4. Estimations with province fixed effects were less informative because just a few province dummies

[6] When using all observations including unclear TT, the count variables in models (4) and (5) are significant at the 5% level (see Table A1). This is however not our preferred specification because TT is measured with more uncertainty.

were significant.[7] While this indicates that provinces are, in general, relatively similar when accounting for CDM project characteristics, it might not be so when considering specific aspects of theirs. Furthermore, in this way, we can offer comparison with international studies that considered similar variables.

Model (1) includes macro variables at the province level. Openness, measured by *trcf*, has a positive coefficient, confirming earlier studies concluding that interaction with foreign firms via FDI fosters TT. Model (2) extends the existing literature by adding different types of R&D to GDP ratios. In the existing literature only Schmid (2012) used R&D to GDP ratios in a cross-country sample. Not using a differentiated measure for R&D as this paper does, she found insignificant coefficients with varying signs. When adding the R&D variables to the equations, only R&D activities of universities and research institutes have a positive and highly significant coefficient. This kind of research, which is often basic and not applied research, could very well be a complement to TT because these activities foster higher education and a general level of technological understanding. Other types of R&D (in firms) on the other hand yield negative, yet insignificant coefficients. In our view this means that a higher level of general-purpose knowledge can foster TT, while more applied kinds of it can rather substitute for TT. The latter finding is common in the literature, for instance UNFCCC (2010) and Zhang and Zheng (2012) find a negative effect of knowledge stocks on TT. In these studies, the knowledge stock was approximated by a patent stock in renewable energy technologies, i.e., much closer towards the technology in question. Thus the negative coefficient there (similar to the negative but not significant coefficient for R&D in firms) can be seen as an indicator for substitution between existing specific knowledge and TT.

The coefficients for the variables in x_i^{basic}, x_i^{yr}, and x_i^{ind} are robust to the inclusion of additional variables in the extended models. In particular, model (4) captures all the aspect we stressed in our analysis: agglomeration, FDI and R&D effects. Putting focus on the role of province-specific variables, we compute for this model the three corresponding elasticities at mean values. *Provcount* has an elasticity of -0.29, *trcf* of 0.31 and *rd_uniri* of 0.24. The first two are statistically significant at the 5% level, while the third at the 1% level.[8]

5 Conclusions

Our estimations on the determinants of TT in Chinese CDM projects largely confirm the existing literature, yet also bring attention to new aspects, such as the role of agglomeration effects and specific types of R&D. These variables are of particular policy relevance because they could be influenced by policy makers more than other determinants of TT.

With regard to “standard” determinants like project size or technology categories, we can confirm results from previous cross-country studies and studies for China. More advanced technologies and larger projects are more likely to involve TT. This is very intuitive given an extra fixed cost of

[7] This hampers a two-stage-estimation strategy as in UNFCCC (2010) or Haites et al. (2012).

[8] For this specification of ours we also carried out a Lagrange multiplier normality test of the residuals after Diallo (2010) obtaining a statistic of 0.07 with a p-value of 0.97. Normality was therefore not rejected. Furthermore, we implemented for Model (4) also a semi-nonparametric (SNP) estimator after Gallant and Nychka (1987) and De Luca (2008). Results hardly changed. What is more important is that a likelihood ratio test of the probit model against SNP reported a statistic of 0.27 with a p-value of 0.67, favoring the former over the latter one. Skewness and kurtosis of the distribution of the residuals were very close to the Gaussian values 0 and 3, being 0.17 and 3.06 respectively.

implementing TT that only pays off when the project is sufficiently large. We also find a declining trend of TT probability over time. The specific pattern of changes in the likelihood of TT in certain years can be well explained by policy developments that affected the participants in the markets for CDM projects in the affected years. While the trend can also be observed in international studies, the particular values can best be explained on a country level, taking into account policy developments specific to the country.

Regarding the macro-economic factors, we find that FDI stocks and R&D at universities and research institutes can foster TT. The analysis of different types of R&D rather suggests that basic R&D instead of applied R&D is complementary to TT of CDM projects. When looking at the macroeconomic determinants of international TT, the provinces along the coast generally have better prerequisites for TT. Improving the conditions for TT in other provinces by fostering e.g. R&D at universities and FDI can encourage more TT to support knowledge-based economic growth in these provinces in the future.

The negative agglomeration effect provides evidence for the presence of an externality, because the likelihood of TT of a given project is influenced by previous projects applying the same technology. This agglomeration effect is found on the provincial rather than on the national level. The presence of an externality could serve as justification for policy intervention. With the present dataset we can however not clearly determine the channel of the agglomeration effect. It is likely that the channel is through learning from TT in previous projects. In other words, local stakeholders may already learn quite a lot through obtaining technologies transferred from the existing CDM projects. The room for CDM latecomers for further TT is then restricted. It is, however, also possible that carrying out CDM projects in a province where a large pool of technologically similar CDM projects exists may intensify competition among the project holders which makes it difficult for transparent cooperation with local stakeholders, thus reducing the TT likelihood. In both cases, policy intervention may be justified to encourage especially the technologically diversified CDM projects and project holders' cooperation with local stakeholders.

But before calling for support of TT, it is important to note that fostering TT as such is not necessarily an economic goal that should be strived for at any cost. TT can be more costly than developing local technologies. If the costs of TT exceed the benefits, it might be inefficient to artificially foster TT. To measure the benefits and costs of TT, one would need to carefully take into account the potential positive/negative externalities resulting from the agglomeration of CDM projects. A complete analysis is beyond the scope of this study.

While we assess determinants for TT in CDM projects in China up to 2010, it is difficult to make projections for the future. Most of the emission reductions from Chinese CDM projects in the sample were intended for use in the EU emission trading scheme (ETS). Starting from 2013, CERs from new projects to be used in the EU ETS have to come from least developing countries (Directive 2003/87/EC, Article 11a (4)). This led to a collapse in the number of new Chinese projects after 2012. While 1812 projects were registered in 2012, only 42 new projects were registered in the first half of 2013. It is more likely that Chinese emission reduction certificates will be used in the new Chinese emission trading systems. Without the direct incentives from foreign firms to gain access to CERs, it is also likely that TT will decline. On the other hand, domestic TT could increase, at least in some technologies. A reason for this is that the pilot emission trading schemes are located in the more advanced provinces and there is a technological gap to the inland provinces.

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Appendix:

Table A1: Baseline models (observations with unclear TT included in the estimation and coded as no TT)

	(1)	(2)	(3)	(4)	(5)
lnsize	0.362***	0.381***	0.373***	0.383***	0.384***
smallscale	-0.121	-0.140	-0.131	-0.164	-0.159
unilateral	0.087	0.078	0.085	0.124	0.143
year2006	-1.184***	-1.130***	-1.138***	-1.038***	-1.069***
year2007	-1.447***	-1.354***	-1.372***	-1.195***	-1.264***
year2008	-2.262***	-2.118***	-2.150***	-1.871***	-2.000***
year2009	-2.492***	-2.295***	-2.342***	-1.948***	-2.149***
year2010	-2.595***	-2.338***	-2.416***	-1.947***	-2.182***
hydro	-1.850***	-1.686***	-1.664***	-1.399***	-1.445***
wind	0.329	0.478**	0.410*	0.652**	0.567**
eeown	0.538**	0.565**	0.575**	0.702**	0.595**
eesupply	0.877**	0.798**	0.820**	0.666*	0.761**
distribution	0.464	0.384	0.405	0.243	0.347
switch	1.255***	1.224***	1.239***	1.195***	1.217***
minemethane	0.341	0.343	0.339	0.332	0.326
methaneavoid	0.573	0.565	0.561	0.511	0.564
landfill	1.441***	1.421***	1.429***	1.390***	1.415***
hfcs	0.025	0.032	0.037	0.113	0.066
n2o	1.790***	1.785***	1.783***	1.775***	1.780***
cement	-0.805	-0.811	-0.811	-0.834	-0.814
provcount		-0.006***			
regcount			-0.001		
natcount				-0.002**	
techregcount					-0.002**
_cons	-0.688	-0.894	-0.827	-1.089**	-1.017**
Wald Chi2	2975.91***	2842.82***	3125.87***	2956.93***	4098.78***
obs	1953	1953	1953	1953	1953

Source: authors' estimation based on data from NBSC (2004a – 2010a), NBSC (2004b – 2010b), UNEP Risø CDM/JI Pipeline Database, and UNFCCC (2010). Notes: ***/**/* significant at 1%/5%/10% (two-tailed tests). Not our preferred specification because TT is measured with more uncertainty.

Table A2: Extended model (observations with unclear TT included in the estimation and coded as no TT)

	(1)	(2)	(3)	(4)
lnsize	0.370***	0.363***	0.371***	0.385***
smallscale	-0.103	-0.123	-0.094	-0.104
unilateral	0.070	0.061	0.052	0.050
year2006	-1.155**	-1.170***	-1.154**	-1.130**
year2007	-1.394***	-1.456***	-1.406***	-1.355***
year2008	-2.202***	-2.277***	-2.198***	-2.118***
year2009	-2.391***	-2.503***	-2.385***	-2.276***
year2010	-2.459***	-2.644***	-2.478***	-2.321***
hydro	-1.822***	-1.840***	-1.867***	-1.721***
wind	0.377*	0.373*	0.406*	0.486**
eeown	0.543**	0.535**	0.529**	0.550**
eesupply	0.802*	0.808**	0.788*	0.729*
distribution	0.511	0.484	0.538	0.439
switch	1.164***	1.180***	1.122***	1.111***
minemethane	0.382	0.333	0.378	0.394
methaneavoid	0.561	0.498	0.479	0.464
landfill	1.437***	1.452***	1.455***	1.429***
hfcs	-0.006	-0.014	-0.043	-0.042
n2o	1.836***	1.774***	1.805***	1.804***
cement	-0.750	-0.749	-0.735	-0.775
provcount				-0.005***
gdp_pc	-0.000		-0.000	0.000
lnpopulation	0.045		0.107	0.097
trcf	0.060**		0.068**	0.054**
rd_mle		0.171	-0.178	-0.335
rd_uniri		0.262***	0.289***	0.233**
_cons	-1.205	-0.859	-1.759	-1.784
Wald Chi2	3963.91***	3326.25***	6718.83***	5505.45***
obs	1953	1953	1953	1953

Source: authors' estimation based on data from NBSC (2004a – 2010a), NBSC (2004b – 2010b), UNEP Risø CDM/JI Pipeline Database, and UNFCCC (2010). Notes: ***/**/* significant at 1%/5%/10% (two-tailed tests). Not our preferred specification because TT is measured with more uncertainty.