Supplementary file

Technology transfer in the CDM: An updated analysis

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Appendix A

Statistical Analysis of the Prevalence of Technology Transfer for CDM Projects

1. Introduction

Statistical analysis was used to identify the factors that explain differences in the prevalence of technology transfer for CDM projects. The analysis was based on 3,249 projects registered as of 31 March 2012. Projects were classified according to whether they expected technology transfer to occur (1,282 expected transfer of knowledge, equipment or both) or whether they did not (1,967). The 700 registered projects whose PDDs did not mention technology transfer were excluded.

A larger, richer country with a more open economy and more technology transfer via other channels was expected to have greater technological capacity leading to less frequent technology transfer for CDM projects. Other studies (Dechezleprêtre et al. 2008; Doranova et al. 2010; Schmid 2012) use population and GDP per capita (size and income), variations of imports and tariff rates (openness), FDI (openness and technology transfer via other channels). ODA (technology transfer), and various measures of technological capacity for the analysis. These variables have the same value for all project types in a host country and most change slowly over time. In an attempt to better explain the differences in the prevalence of technology transfer by project type, four variables that differ by project type and host country were added to the analysis. The data is discussed in more detail in Section 2 below.

Previous studies have conducted analyses by estimating either a single equation (Haites et al. 2006; UNFCCC 2007; Dechezleprêtre et al., 2008; UNFCCC 2008; Doranova et al., 2010; Schmid 2012; Zheng and Zhang 2012) or two equations (UNFCCC 2010; Haites et al. 2012). Both approaches are applied here. With a single equation, technology transfer for a CDM project is related to the project type, project characteristics (size, small-scale, etc.), year the project was registered, and various host country characteristics (population, per capita GDP, etc.). A project either involves technology transfer ($TT = 1$) or does not involve technology transfer ($TT = 0$). With a dependent variable that can only take the values 0 or 1 the appropriate form of regression is a binomial logit model.

With two equations, the first equation relates technology transfer to project type, project characteristics, year the project was registered and the host country, but not the host country characteristics. This is also a binomial logit model. This equation is used to predict the

probability (between 0 and 1) of technology transfer for each combination of project type, host country and year (holding the characteristics of the CDM projects constant at their sample means).¹ The predicted probabilities and data on country characteristics are then used to estimate the coefficients for the second equation – the coefficients for the country characteristics. The second equation was estimated using ordinary least squares.

2. Data

The variables used in the analysis and the data sources are shown in Table A1 below. The project characteristics – Size (estimated annual emission reductions in tCO₂e), Small scale (project that uses a small-scale methodology), Project type (a project type identifier), Number (sequential number of the project for its project type in the host country), and Year (project start year) – are unique to each project. Each project is also associated with its host country.

Table A1: Variables used in the regression analysis

Variable name	Description
Project characteristics	
Size	Estimated annual emission reduction by the project (tCO ₂ /yr)
Small scale	Dummy variable. 1 if the project uses a small-scale methodology. The size of projects eligible to use small-scale methodologies has changed over time.
Number	Number of projects of the same type in the host country. First project =1, second project of the same type in the same country = 2, etc.
Project type	Dummy variable for each project type
Year	Dummy variable for the year the project started. Variable for each year from 2000 through 2012 except 2007.
Host country characteristics	
Population ^a	Natural logarithm of the population
Per capita GDP ^a	Per capita GDP in 2005 US dollars using purchasing power parity exchange rates.
Capital formation ^a	Gross fixed capital formation as a percentage of GDP
Imports ^a	Imports as a percentage of GDP
Tariff rate ^b	Average tariff rate.
FDI ^a	Inward Foreign Direct Investment as a percent of GDP.
ODA ^c	Official Development Assistance (ODA) per capita
Renewables ^d	Percentage of electricity generated from renewable sources.
Knowledge stock ^e	Discounted stock of total patent applications – current year = previous year's stock less 10% plus new applications.
Technology base ^e	Discounted stock of patent applications relating to the technology used by the CDM project.
Transferred technology ^e	Number of applications by foreign patent holders relating to the technology used by the CDM project.
Abatement potential ^f	Estimated 2020 abatement potential for the project type (MtCO ₂ e)
Abatement cost ^f	Estimated abatement cost for the project type in the host country (US\$/tCO ₂ e)

Sources: a World Bank: 2011, World Development Indicators, Available at <http://data.worldbank.org/>

b World Trade Organization's (WTO) World Tariff Profiles 2009. Many countries report tariff rates every two

or three years, so missing values are interpolated. Available at http://www.wto.org/english/res_e/publications_e/world_tariff_profiles09_e.htm
 c Organisation for Economic Co-operation and Development (OECD), 2011. Statistics available at http://www.oecd.org/document/0,3746,en_2649_201185_46462759_1_1_1_1,00.html
 d Government of the United States of America, Energy Information Administration, 2011. Data available at <http://www.eia.doe.gov>
 e Patent application data graciously provided by Nick Johnstone and Ivan Haščič of the OECD. For a description of the data and the calculation of the discounted stock of patent applications see Johnstone et al., 2010.
 f Data prepared by ECN for the UNFCCC Secretariat, 2012.

The country characteristics include Population, GDP per capita, Capital Formation, Imports, Tariff Rate, FDI, ODA, Renewables and Knowledge Stock. Since many CDM projects are renewable generation technologies, generation by renewables is a measure of technical capacity. Knowledge stock – the discounted stock of all patents applications for the country – is another measure of national technical capacity. Linear relationships among the variables – collinearity – are problematic for the regression analysis. Population, GDP, foreign direct investment (FDI), fossil fuel generation and renewable generation are strongly correlated. To address the collinearity we used the log of population, GDP per capita, FDI as a percentage of GDP, and the renewables share of electricity generation. For the same reason Imports as a percentage of GDP was used rather than both imports and exports or imports plus exports. Capital Formation and ODA were expressed as a percentage of GDP.

A larger, richer country with a more open economy and more technology transfer via other channels was expected to have greater technological capacity leading to less frequent technology transfer for CDM projects. Thus larger values for Population, GDP per capita, Imports, FDI, ODA, Renewables and Knowledge Stock were expected to be associated with lower frequencies of technology transfer for CDM projects. Thus they were expected to have negative coefficients. Greater demand for technology due to economic growth, as measured by more Capital Formation, and a less open economy, as measured by a higher Tariff rate, should lead to more technology transfer, so those variables were expected to have positive coefficients.

Although annual data were used for all of these country characteristics the values generally change only gradually.² Annual data allows lags to be tested – the period between a change in a variable and its impact on the prevalence of technology transfer – for these characteristics.

In an attempt to better explain the differences in the prevalence of technology transfer by project type and time the following variables were added to the analysis:

- Abatement Potential: The estimated 2020 abatement potential for the project type in the host country.
- Abatement Cost: The estimated 2020 abatement cost for the project type in the host country.
- Technology Base: The host country's discounted stock of patent applications relating to the technology used by the CDM project. This is a measure of the technological capacity of the host country for the relevant project type.
- Transferred Technology: The number of applications by foreign patent holders relating to the technology used by the CDM project. This is a measure of technology transferred to the host

country by project type.

All four vary by host country and project type while Technology Base and Transferred Technology also vary by year. Higher values for Abatement Potential and Technology Base reflect a larger existing technical capacity so less technology transfer by CDM projects, a negative coefficient, was expected. A higher Abatement cost means that projects are less attractive, so existing technical capacity is likely to be smaller thus making technology transfer more prevalent for CDM projects, i.e. a positive coefficient. The expected sign of Transferred Technology is not clear. If technology transfer via other channels is common, the technical capacity would be larger and transfer for CDM projects would be less prevalent, i.e. a negative coefficient. But if the CDM projects are a large contributor to the transfer of those technologies via all channels, the coefficient could be positive.

Use of the Technology Base and Transferred Technology variables comes at a cost. The patent data need to be matched to CDM project types and this is not possible for all project types. Biomass energy, CO₂ capture, coal bed/mine methane, geothermal, HFCs, hydro, N₂O, PFCs and SF₆, solar, tidal and wind project types match the patent technology categories closely. Patent data cover some, but not all, of the technologies used by cement, EE households, EE own generation, EE supply side, energy distribution, landfill gas and methane avoidance projects.³ Afforestation, EE industry, EE service, fossil fuel switch, fugitive and transport projects were excluded from some regression equations because related patent data were not available.

For the binomial logit regressions, observations with “perfect prediction” must be dropped. This included all host countries with a single project. If they were not dropped, the analysis would implicitly assume that all projects in that host country would fall into the same technology transfer category (i.e. transfer or no transfer) as that single project. Also dropped were host countries, project types and years where all (usually only a few) projects either involved technology transfer or did not involve technology transfer. Thus the number of observations actually used for the estimation will be less than 3,249.

3. Regression Results

The regression results are presented Table A2 below. The statistical performance was quite good. The single equation approach had a pseudo r^2 of 0.55 and correct prediction of over 88% of the observations. The two equation approach correctly predicted over 85% of the observations for the first equation and had an r^2 of 0.68 for the second equation.

Table A2: Regression Results

Variable	Lag	One equation		Two equation		
		Binomial Logit	Marginal Effects	Step 1		Step 2 OLS Regression Coefficients
				Binomial Logit	Marginal Effects	
Size		4.18×,10 ^{-7.} ** (1.83×,10 ^{-7.})	4.66×,10 ^{-8.} ** (1.90×,10 ^{-8.})	8.58×,10 ^{-7.} ** (3.37×,10 ^{-7.})	1.49×,10 ^{-7.} ** (5.21×,10 ^{-8.})	
Small scale (d)		-1.482*** (0.269)	-0.1495*** (0.0269)	-0.9950*** (0.3283)	-0.1638*** (0.0567)	
Number		-0.00377*** (0.00135)	-0.00042*** (0.00016)	-0.0035*** (0.00033)	-0.00061*** (5.82×,10 ^{-5.})	
Population	3	-0.742 (0.713)	-0.0827 (0.07996)			
	1					-0.115*** (0.0232)
Per capita GDP	1	-0.000342** (0.000157)	-0.000038** (0.0000178)			
	3					0.0000386* (0.000018)
Capital formation	1	-0.0965*** (0.0204)	-0.0108*** (0.0023)			-0.00943 (0.00742)
Imports	3	0.0683*** (0.024)	0.00761*** (0.00285)			-0.00189 (0.00648)
Tariff rate	3	0.0436* (0.0254)	0.00486* (0.00278)			0.00282 (0.00694)
FDI	3	0.321*** (0.1165)	0.0358*** (0.0135)			
	2					-0.0184 (0.0248)
ODA	1	-0.312 (0.302)	-0.0347 (0.0337)			
	3					0.189** (0.0729)
Renewables	1	-0.00408 (0.0297)	-0.000455 (0.0033)			-0.00655** (0.00217)
Knowledge stock						1.00 x10 ⁻⁶ ** (3.54 x 10 ⁻⁷)
Abatement potential		-0.01295** (0.0062)	-0.00144** (0.00066)			-.00181*** (.000153)
Abatement cost		0.0137** (0.0061)	0.00153** (0.0007)			0.00101* (0.00053)
Technology base	1	-0.00595*** (0.00041)	-0.00066*** (0.000044)			-.000377*** (0.000039)

Transferred technology	2	0.0124*** (0.0014)	0.00138*** (0.00018)	
	1			0.00238*** (0.000198)
Brazil (d)		-1.135 (2.311)	-0.0872 (0.114)	
China (d)		0.656 (1.408)	0.0669 (0.1317)	
India (d)		-3.069*** (1.020)	-0.1726*** (0.02997)	
Mexico (d)		2.704** (1.133)	0.5411** (0.2484)	
Constant		18.233 (14.152)		1.51249 (.78181)
N		2,186		182
Pseudo R ²		.5455		.6803

Notes:

Binomial logit coefficients describe the effects of the independent variables on the predicted logarithmic odds of technology transfers.

The marginal effect is the effect of a one unit change in the variable on the predicted probability of technology transfer. This is the same as the coefficient estimated using the ordinary least squares method. Thus the marginal effects for the single equation can be compared with the coefficient for equation 2. For example, the marginal effect of Tariff rate .00486 compares with the regression coefficient of .00282 for equation 2.

The pseudo R² is an indicator of the explanatory power of the equation. A value of 0 indicates no explanatory power while a perfect explanation would have an R² = 1.

(d) Marginal effect for discrete change of dummy variable from 0 to 1.

All specifications control for year and project type fixed effects.

Standard errors in parentheses are robust to cluster heteroskedasticity.

* p<0.10 ** p<0.05 *** p<0.01

Larger projects were more likely to have involved technology transfer. This is reflected in the positive coefficient for Size and the negative coefficient for Small scale, both of which were statistically significant.

The negative coefficient for Number indicates that the prevalence of technology transfer declined as the number of projects of the same type in a host country increased. The effect of an additional project was small (-0.00042 to -0.00061), but highly significant. This suggests that as the number of projects of a given type grew some technological capacity beyond the requirements of the individual projects was created. Because the effect for a single project was small it may take a large number of projects to observe a project's influence.

The variables that reflect both the host country and project type were all statistically significant. Abatement Potential and Technology Base both had the expected negative sign and Abatement Cost had the expected positive sign. This means technology transfer for CDM projects was less prevalent for a host country with a larger and more economic abatement potential and a larger

technical capacity for that project type. Transferred technology had a positive sign, which was interpreted as indicating that CDM projects increased overall transfer of the relevant technologies to the host countries.

The performance of the country characteristics was mixed. In the two equation approach only Population, GDP per capita, ODA, and Renewables were significant and two – Per capita GDP and ODA – had the wrong signs. Almost all (except Population, ODA, and Renewables) were significant in the one equation approach, but only GDP per capita and Tariff Rate had the expected sign. The positive sign for FDI may indicate that instead of serving as an alternative channel to CDM projects for technology transfer, foreign investment and technology transfer were stimulated by CDM projects. This would be consistent with the finding by Dechezleprêtre et al. (2008) that technology transfer has been more prevalent for CDM projects with foreign participation.

The time lags often differ between the one and two equation approaches for the same variable. They are the same for four variables but differ for six variables. Statistical results for different lags – e.g., 1 vs 2 years – were usually similar. Since almost all of the variables only change slowly over time this is not surprising.

In summary, the prevalence of technology transfer by CDM projects exhibited major differences by project type and host country. Technology transfer for CDM projects was less frequent for a host country with a larger and more economic abatement potential and a larger technical capacity for that project type. The host country's characteristics related to the specific technology at the time the project was being planned appear to have affected the technology choice of, and hence technology transfer by, a CDM project.

The statistical results suggest that CDM projects may stimulate foreign direct investment and increase technology transfer for those technologies via all channels. If the number of CDM projects of a given type in a host country were sufficiently large it may catalyze the development of domestic capacity sufficient to lower the prevalence of technology transfer for future projects.

Notes:

- 1 We thank an anonymous referee for this suggestion.
- 2 Some developing countries have reported tariff rates every two or three years. Missing values were interpolated because the rates were quite stable.
- 3 The regression results obtained if the project types with a partial match were excluded were similar to those when these project types were included. All results reported included the project types with a partial match.

Appendix B

Comparison of Statistical Results using the PDD Statements and Survey Responses for the 408 Projects Covered by the Follow-up Survey

This Appendix compares the statistical results obtained for the 408 projects when they are classified based on their PDD statements and the survey responses. The 408 projects are not a representative sample of the 3,949 registered projects; rather they are all of the projects whose participants responded to a voluntary follow-up survey. Based on the PDD statements, the expected rate of technology transfer for the 408 projects is somewhat higher than the rate for all 3,949 registered projects.

The one equation model described in Appendix A was estimated using both the PDD statements and the survey responses to classify whether projects involved or did not involve technology transfer. Although the same 408 projects were used in both cases, projects with no statements relating to technology transfer were excluded. Using the survey responses to classify the projects lead to the exclusion of fewer projects, thus leaving more projects for the statistical analysis.

The results are presented in Table B1. The signs of the coefficients were in general agreement. Where they were not in agreement, it was always the case that at least one (if not both) of the coefficients was insignificant. Based on this broad similarity of the results for the two classifications of the projects we conclude that the PDD statements were sufficiently accurate for an aggregate analysis of technology transfer.

Table B1: Statistical analysis of aggregate technology transfer for registered CDM projects covered by the follow-up survey

Variable	Lag	One equation approach Binomial logit coefficients	
		Technology transfer based on PDD	Technology transfer based on survey response
Size		2.41×,10 ⁻⁶ .** (9.53×,10 ⁻⁷ .)	6.08×,10 ⁻⁷ *** (2.33×,10 ⁻⁷ .)
Small scale (d)		-2.266*** (0.711)	-1.369*** (0.105)
Number		0.0183*** (0.00571)	0.00971*** (0.00307)
Population	1	15.87 (13.67)	5.143 (3.549)
Per capita GDP	1	0.00317*** (0.00123)	0.00215*8* (0.000447)
Capital formation	1	0.376 (0.544)	-0.293 (0.254)
Imports	1	-0.459 (0.798)	0.166 (0.180)
Tariff rate	1	0.240 (0.187)	0.124 (0.138)
FDI	1	1.406** (0.641)	-0.0216 (0.427)
ODA	1	6.435 (5.936)	-3.822 (3.136)
Renewables	1	-0.305 (0.296)	0.356*** (0.125)
Abatement potential		-1.214*** (0.181)	-0.0726*** (0.0161)
Abatement cost		0.0970*** (0.0335)	0.0155 (0.0124)
Technology base	1	-0.0742*** (0.0154)	-0.00800*** (0.00268)

Transferred technology	2	0.0759*** (0.0289)	0.00773 (0.0140)
Brazil (d)		-30.26 (38.69)	-41.64*** (10.37)
China (d)		-18.70 (64.33)	-11.06 (6.744)
India (d)		-38.72 (64.32)	-8.559 (5.882)
Mexico (d)		-23.59 (30.96)	-19.26*** (2.938)
Constant		-271.0 (216.0)	-100.3 (63.56)
N		166	185
Pseudo R ²		.7581	.3033

Notes:

See notes to Table A2. Projects that do not mention technology transfer were excluded.

* p<0.10 ** p<0.05 *** p<0.01