Technology transfer in the CDM: an updated analysis

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The prevalence of technology transfer (TT) for Clean Development Mechanism (CDM) projects is analysed, based on information in the project design documents (PDDs) of 3949 projects registered as of 31 March 2012. Responses to a follow-up survey indicate that the PDD statements that concern TT are reasonably accurate and at least 39% of the related projects are expected to involve it. Technology transfer is very heterogeneous across project types and is more common for larger projects. It also usually involves both knowledge and equipment and differs significantly by host country. Technology transfer has declined over time in China, India, and Brazil, the countries that host most of the CDM projects, but it has remained high for other host countries. A host country’s existing capacity specific to the technology, the scope for economic deployment of the technology, and complementary policies to build capacity and promote TT, increase the frequency of TT by CDM projects. The technology used by CDM projects originates mostly from Germany, the US, Japan, Denmark, and China, with multiple suppliers of the technology for all project types.

Policy relevance
The results suggest that a developing-country government that wishes to develop technological capacity related to a specific technology should consider whether there is potential for domestic commercial application. It should then develop a strategy for building capacity relevant to the technology, facilitate transfer via one or more channels, including CDM projects, and implement complementary policies for deployment of the technology.

Keywords: Clean Development Mechanism; technology; technology transfer

1. Background

The Clean Development Mechanism (CDM), established by the Kyoto Protocol, enables projects that reduce GHG emissions in developing countries to earn credits that can be used by developed-country (Annex I) Parties to help meet their national emissions limitation commitments. The CDM does not have an explicit technology transfer (TT) objective, but some projects import knowledge and/or equipment, thus contributing to TT. Some host-country governments also impose technology requirements on CDM projects, which may affect TT.

The prevalence of TT in CDM projects is analysed and the factors that influence it are identified relative to technology and host country. The principal data source is the project design documents (PDDs)
of the CDM projects, which are provided by project participants. The PDD describes the proposed project, is validated by an independent entity, and forms the basis for registration of the project by the CDM Executive Board. A total of 3949 CDM projects registered as of 31 March 2012 are analysed here.

Several articles have already analysed the TT claims made in the PDDs for registered projects (Das, 2011; de Coninck, Haake, & van der Linden, 2007; Dechezlepretre, Glachant, & Meniere, 2008; Zheng & Zhang, 2011) or projects in the pipeline (Haites, Duan, & Seres, 2006; Haites, Kirkman, Murphy, & Seres, 2012; Schmid, 2012; Seres, Haites, & Murphy, 2009; UNFCCC, 2007, 2008, 2010). This article extends this literature in several ways. First, it uses responses to a follow-up survey for a sample of registered projects to confirm the results based on statements contained in the PDDs. Most previous studies understate the frequency of TT because they have not addressed issues identified by the follow-up survey. Second, previous efforts to identify the factors that explain the pattern of TT are enhanced by incorporating explanatory variables that differ by project type and host country. Third, a more thorough analysis of how TT by CDM projects has evolved over time is provided. Finally, the contribution of the CDM to the transfer of technology to developing countries is discussed.

In Section 2 the definition of ‘technology transfer’ is discussed, while Section 3 compares the PDD statements that relate to TT and the responses to a follow-up survey for a sample of projects. Some methodological issues in relation to the analysis of the PDDs are addressed in Section 4. A summary of the prevalence of TT by CDM projects, is given in Section 5, while the origins of the imported technology are reviewed in Section 6. Section 7 presents the results of statistical analyses to identify host-country characteristics that influence TT by CDM projects. The contribution of the CDM to the transfer of technology to developing countries is discussed in Section 8. In Section 9, a summary of the results of the analysis, including their policy implications, is provided.

2. What is technology transfer?

There is no accepted definition of ‘technology transfer’ (Cools, 2007; Das, 2011; Popp, 2011). The Intergovernmental Panel on Climate Change (IPCC) defines it as:

a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private-sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions. (IPCC, 2000, p. 3)

This definition covers every relevant flow of hardware, software, information, and knowledge between and within countries. The IPCC (2000) admits that this definition is much broader than that used by the United Nations Framework Convention on Climate Change (UNFCCC).

Transfer of knowledge, not just equipment, is an important aspect of TT (Lall, 1993; Popp, 2011). The United Nations Conference on Trade and Development (UNCTAD, 1985) excludes the simple sale or lease of goods from TT. Equipment that embodies a technology new to a country must be accompanied by the transfer of sufficient knowledge to successfully install, operate, and maintain the equipment. An issue that is debated in the literature is whether TT should also include the requirement that the
recipient country is able to adapt the technology to local conditions, produce similar equipment domestically, or further develop the technology.

The CDM, as an international mechanism, implies international transfers of technology. Technology transfer induced by the CDM will naturally focus on meeting the technology needs of the projects. In most cases these needs can be met with imported equipment and/or knowledge. Thus the definition of TT adopted here is the import of knowledge and/or equipment for the purposes of the CDM project. Equipment imports are assumed to be supported with sufficient training for successful installation, operation, and maintenance. Although this is a narrow definition of TT, it reflects the information available from the PDDs.

The creation of capacity by CDM projects, in a recipient country, to adapt, produce, or further develop the technology is likely to be rare (Das, 2011). Statistical analysis of the PDD data indicates that, as the number of projects of a given type in a host country increases, the frequency of TT declines. This suggests that, with enough projects, some technological capacity beyond the requirements of the individual projects is created. Survey responses also indicate that some CDM projects have not involved TT because technology adopted by earlier projects was used.

The mitigation technologies used by CDM projects can also be transferred to developing countries by licensing, foreign direct investment (FDI), trade, establishment of global research and development networks, acquisition of firms in developed countries, and recruitment of experts from developed countries (Peterson, 2008). This raises the issue of the contributions of these channels to any TT that has occurred (see Section 8).

3. PDD statements concerning technology transfer

Project participants are asked to provide details of the technology to be used by the project in the PDD. The CDM Executive Board does not define TT, so statements in the PDDs reflect the definitions implicitly adopted by the project participants. It is clear from the PDDs that the vast majority of project participants interpret TT as meaning the use by the CDM project of equipment and/or knowledge that has not previously been available in the host country.

The PDDs for each of the 3949 projects registered as of 31 March 2012 were thoroughly reviewed and searched for a number of keywords relating to TT. Based on the information in the PDD, each project was placed into one of the following categories:

- The project expects to use imported equipment
- The project expects to use imported knowledge
- The project expects to use imported equipment and knowledge
- The project does not expect to involve TT
- There are no statements with respect to TT

Since the focus is on international transfers of technology, projects that claim TT within a country are classified as those that do not expect to involve TT.

A summary of the results is given in Table 1. Many PDDs (1967) explicitly state that the project does not expect to involve a transfer of technology. Another 700 PDDs make no mention of TT. This leaves
1282 projects that expect some form of TT (knowledge, equipment, or both). Of these projects, 54% expect that both imported knowledge and equipment will be used.

A PDD reflects the expectations of the project participants when the project is being planned. Table 1 compares the PDD statements for 408 of the projects with the responses to a follow-up survey conducted by the UNFCCC Secretariat after the project was registered (when better information on what actually happened is available). The survey responses indicate that a larger percentage of the projects than indicated by the PDD statements have involved TT (68% vs. 49%).\(^4\) Transfer of both knowledge and equipment has also been more common than indicated by the PDD statements (69% vs. 60% of projects that involve TT).\(^5\) In short, it is likely that the PDD statements have understated the actual extent of TT by CDM projects.

### 4. Methodological issues related to analysis of the TT statements in the PDDs

Three issues need to be addressed before undertaking an analysis of statements in the PDDs that pertain to TT: (1) whether TT should be analysed in aggregate (i.e. transfer or no transfer) or by type of transfer (i.e. knowledge, equipment, or both); (2) how projects that make no statements in their PDD that relate to TT should be treated; (3) whether the PDD statements are sufficiently accurate to allow a sound analysis of TT by CDM projects.

An aggregate analysis (i.e. whether a transfer occurs or not) is preferred for three reasons. First, a comparison of the PDD statements with the survey responses indicates that the classification by type of TT is not consistent for individual projects. For example, although the overall percentages of projects classified by type of TT for equipment only are similar – on the basis of the PDDs equal to 12% and on the basis of the survey responses equal to 15% (see Table 1) – over half (56%) of the projects changed categories. Second, the number of projects for some types of TT, especially for the category of knowledge only, is relatively small for the purposes of statistical analysis. The dataset for an aggregate analysis permits the statistical analysis of more host country/project type combinations than a TT-type analysis. Third, statistical analyses yield similar results for the three types of TT (Schmid, 2012).

How the 700 projects with PDDs that do not mention TT should be treated is an important issue. Most previous studies have simply assumed that TT was not involved. However, the survey responses indicate that almost 70% of the projects that did not mention TT in their PDDs did in fact involve it (see...
Table 2). The assumption that these projects did not involve any TT therefore significantly understates the extent of TT through the CDM. It should be noted that the analyses of PDD statements in this article were based on projects that explicitly stated that they either expected or did not expect to involve TT, and projects that made no mention of it in their PDD were excluded.

The PDD statements relating to TT reflect the expectations of the project participants when the project is being planned. The statements may be biased to meet host-country requirements related to CDM project technology (Dechezleprêtre et al., 2008), so the information in the PDDs may not actually reflect what occurs.6 Responses to the follow-up survey after projects were registered provide a check on the accuracy of the TT statements in the PDDs. At the time of the survey, participants have much better information on any TT that may have occurred in the project.7 A comparison of the PDD statements and survey responses related to aggregate TT is given in Table 2. In summary, 87% of the projects whose PDDs anticipated TT involved TT, and 62% of those projects whose PDDs stated that they would not involve TT did in fact involve TT.

Statistical analyses of TT for the 408 projects covered by the follow-up survey yielded similar results when the PDD statements and the survey responses were used (see online Appendix B in the supplemental files at http://dx.doi.org/10.1080/14693062.2013.812719). This suggests that the PDD statements are sufficiently accurate for an aggregate analysis of TT.

The use of PDD statements implicitly assumes that projects are an appropriate measure of TT. It is an imperfect measure because it is likely that the extent of the transfer differs from project to project (Schmid, 2012). However, the CDM projects do indicate where TT, relative to host country and project type, is taking place.

### 5. Prevalence of TT based on PDD statements

Information relating to 3949 projects, registered as of 31 March 2012, was drawn from the database maintained by the UNFCCC Secretariat. In addition to the TT code, the project type assigned to
each project by the UNEP Risoe Centre was added. The 700 projects that did not mention TT were dropped and the prevalence of TT was summarized by project type, host country and time.

Technology transfer is very heterogeneous across project types (see Table 3). Overall, 39% of projects (accounting for 59% of the estimated emissions reductions) expected to involve TT. Seven of the 24 project types had fewer than 15 projects, whereas six project types had over 100 projects each. Hydro, wind, methane avoidance, and biomass energy accounted for 74% of all projects. The

### Table 3 Technology transfer by project type

| Project type               | Number of projects | Average project size (tCO₂e/yr) | Number of projects (%) | Annual emissions reductions (%) | Percentage of projects with no TT statement (%) |
|----------------------------|--------------------|--------------------------------|------------------------|--------------------------------|-----------------------------------------------|
| Afforestation/reforestation| 38                 | 39,308                         | 41                     | 29                             | 24                                            |
| Biomass energy             | 422                | 63,949                         | 32                     | 41                             | 30                                            |
| Cement                    | 19                 | 169,134                        | 17                     | 16                             | 37                                            |
| CO₂ usage                 | 2                  | 11,844                         | 100                    | 100                            | 50                                            |
| Coal bed/mine methane      | 57                 | 469,118                        | 56                     | 70                             | 12                                            |
| EE households             | 30                 | 41,722                         | 54                     | 71                             | 57                                            |
| EE industry               | 68                 | 26,047                         | 74                     | 71                             | 50                                            |
| EE own generation         | 235                | 153,666                        | 42                     | 64                             | 23                                            |
| EE service                | 5                  | 11,756                         | 75                     | 94                             | 20                                            |
| EE supply side            | 36                 | 413,726                        | 76                     | 92                             | 42                                            |
| Energy distribution       | 6                  | 610,558                        | 60                     | 39                             | 17                                            |
| Fossil-fuel switch        | 71                 | 499,488                        | 85                     | 93                             | 27                                            |
| Fugitive                  | 26                 | 611,470                        | 63                     | 81                             | 38                                            |
| Geothermal                | 12                 | 265,165                        | 88                     | 97                             | 33                                            |
| HFCs                      | 23                 | 3,569,649                      | 91                     | 97                             | 0                                             |
| Hydro                     | 1128               | 107,656                        | 13                     | 9                              | 16                                            |
| Landfill gas              | 228                | 163,319                        | 86                     | 89                             | 21                                            |
| Methane avoidance         | 436                | 38,223                         | 81                     | 83                             | 18                                            |
| N₂O                       | 70                 | 713,660                        | 100                    | 100                            | 6                                             |
| PFCs and SF₆              | 12                 | 309,602                        | 86                     | 94                             | 42                                            |
| Solar                     | 65                 | 28,269                         | 51                     | 38                             | 12                                            |
| Tidal                     | 1                  | 315,440                        | 100                    | 100                            | 0                                             |
| Transport                 | 12                 | 145,067                        | 80                     | 93                             | 17                                            |
| Wind                      | 947                | 103,132                        | 29                     | 32                             | 7                                             |
| Total                     | 3949               | 147,739                        | 39                     | 59                             | 18                                            |
average size varies widely by project type. The percentage of projects that expected to involve TT ranges from 13% to 100% for different project types. The percentages are lowest for project types that use widely available, mature technologies, such as hydro (13%) and cement (17%). Technology transfer is common for N₂O destruction (100%) and hydrofluorocarbons (HFCs, 91%) projects as well as the two CO₂ usage (100%) and lone tidal (100%) projects.

Technology transfer via CDM projects also varies widely across host countries. Most host countries consider the technology used by a proposed project in their approval process (Spalding-Fecher et al., 2012). Typical requirements include the demonstration of a technological benefit, the use of appropriate, environmentally friendly technologies, use of the best available, proven technology, and avoidance of substandard or obsolete technologies. In addition, factors such as the existing availability of a technology, tariffs or other barriers to technology imports, perceived and effective protection of intellectual property rights, technical capacity of the country, and restrictions on foreign investment can affect whether TT via CDM projects is achieved.

The frequency of expected TT by host country is presented in Table 4 for the ten host countries with the most projects and all the other host countries combined. The frequency is higher than the overall average for all host countries except China and India. Over 90% of projects in Indonesia, Malaysia, Mexico, Thailand, Vietnam, and the ‘All other countries’ category were expected to involve TT.

### Table 4 Technology transfer for projects in selected host countries

| Country    | Number of projects | Estimated emissions reductions (CO₂e/year) | Average project size (CO₂e/year) | TT claims as percentage of Number of projects (%) | Annual emission reductions (%) | Percentage of projects where TT could not be determined (%) |
|------------|--------------------|------------------------------------------|---------------------------------|-----------------------------------------------|-------------------------------|-------------------------------------------------------------|
| Brazil     | 205                | 24,175,021                               | 117,927                         | 47                                            | 76                            | 25                                                          |
| China      | 1858               | 367,754,013                              | 197,930                         | 20                                            | 49                            | 6                                                           |
| India      | 805                | 67,474,383                               | 83,819                          | 23                                            | 53                            | 34                                                          |
| Indonesia  | 80                 | 8,308,580                                | 103,857                         | 95                                            | 79                            | 31                                                          |
| Malaysia   | 110                | 6,293,316                                | 57,212                          | 90                                            | 94                            | 36                                                          |
| Mexico     | 140                | 12,520,350                               | 89,431                          | 98                                            | 99                            | 9                                                           |
| Philippines| 57                 | 2,238,466                                | 39,271                          | 59                                            | 87                            | 14                                                          |
| Rep. of Korea| 63               | 18,187,041                               | 288,683                         | 85                                            | 99                            | 35                                                          |
| Thailand   | 67                 | 3,541,395                                | 52,857                          | 100                                           | 100                           | 16                                                          |
| Vietnam    | 90                 | 5,410,299                                | 60,114                          | 96                                            | 83                            | 17                                                          |
| All other countries | 474 | 67,520,169 | 142,448 | 91 | 97 | 28 |
| Total      | 3949               | 583,423,033                              | 147,739                         | 39                                            | 59                            | 18                                                          |

Source: Based on data provided in the PDDs for the 3949 projects registered or undergoing registration as of June 2012. Percentages of TT claims are based on 3249 projects in which the claims could be determined.
Technology transfer is typically more common for larger projects, except in Indonesia and Vietnam, as indicated by a higher percentage for annual emissions reductions than for projects.

Trends in the frequency of TT for CDM projects are shown in Figure 1 for the three countries that host the most projects – China, India, and Brazil – as well as for all other host countries and for all projects combined. The rate of TT has declined over the life of the CDM. The decline has been steeper in China than indicated by the overall average, relatively less steep in India, while Brazil’s rate of TT has resembled that of the overall average. China initially had a rate of TT higher than the average for all countries, but the rate is now substantially lower. India has consistently had a rate of TT lower than the average for all countries. The rate of TT for other host countries has been much higher than the overall average and has declined only slightly.

Several factors contribute to these trends. First, the statistical analysis (see Section 7) indicates that as more CDM projects of a given type have been implemented in a country, the frequency of TT has declined. This suggests that a transfer of technology via CDM projects creates capacity in the

Figure 1 Trend in TT by number of projects
country, which allows later projects to rely more on local knowledge and equipment. The large numbers of projects in China, India, and Brazil have led to declining frequencies of TT to those countries, while the small numbers of projects in other host countries means that they have continued to import technology for CDM projects.

Second, transfer of the technologies used by CDM projects may also occur through other channels. Haščič and Johnstone (2011) have found that the CDM accounts for only part of the transfer of wind technologies to developing countries. The decline in the frequencies for China, India, and Brazil could thus be due to TT taking place via other channels (see Section 8).

Third, the rate of technological change for the technologies used by CDM projects has varied over time. The cost of wind projects, for example, has declined over the life of the CDM (Lantz, Wiser, & Hand, 2012). If the difference between domestically available technology and more advanced imported technology is small, a CDM project may choose the local supplier.

Finally, changes to the mix of project types and host countries have affected the average frequency of TT. New host countries typically have had a higher frequency of TT, so the growing number of host countries has moderated the decline in the overall frequency of TT.

6. Sources of technology imported for CDM projects

Most of the innovation in climate change mitigation technologies has occurred in developed countries. Of the patents filed for 13 mitigation technologies, 60% originated in the US, Japan, and Germany (Dechezlepretre, Glachant, Haščič, Johnstone, & Ménière, 2011; Johnstone, Haščič, & Watson, 2010; Popp, 2011). As shown in Figure 2, the top five technology suppliers for CDM projects are Germany, the US, Denmark, Japan, and China. About 85% of the CDM projects that involve TT obtain their technology from developed countries.

Most CDM project types have used technology from several countries (see Table 5). Although Germany has supplied technology for the largest number of projects, it is the main supplier only for energy efficiency (EE) measures, such as lighting, air conditioning, or appliances, in households (EE households), N₂O destruction, and wind, and is tied with Japan for cement and HFCs. The US is the largest technology supplier for eight project types. China is the main supplier of technology for hydro projects, and Vietnam is the largest technology supplier for energy efficiency measures for power supply (EE supply) projects.

The project types with a sufficient amount of data suggest that project developers have a choice of suppliers. Of the 11 project types with at least 25 projects that claim TT, only EE measures for off-grid power generation (EE own generation) have had a largest foreign supplier country with a share exceeding 50%. The combined share of the four largest supplier countries across these 11 project types ranges from 29% to 97%. The number of foreign supplier countries is ten or more except for EE own generation (7), coal bed/mine methane (9) and solar (9).

7. Statistical analysis

The statistical analysis sought to identify the characteristics of CDM projects and host countries that influence the frequency of TT. A larger, richer country, with a more open economy and more TT via
other channels, is expected to have greater technological capacity and thus less frequent TT via CDM projects. Other studies (Dechezleprêtre et al., 2008; Doranova, Costa, & Duysters, 2010; Schmid, 2012) have used population and gross domestic product (GDP) per capita (size and income), variations in imports and tariff rates (openness), FDI (openness and TT via other channels), Official Development Assistance (TT), and various other measures of technological capacity for their analyses. 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 TT by project type, the following variables were added to the analysis (see Section 2 of online Appendix A in the supplemental files at http://dx.doi.org/10.1080/14693062.2013.812719 for further discussion):

- **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 discounted stock of patent applications that relate to the technology used by the CDM project for the host country. This is a measure of the technological capacity of the host country for the relevant project type by year.
- **Transferred technology**: the number of applications by foreign patent holders that relate to the technology used by the CDM project. This is a measure of technology transferred to the host country via all channels by project type by year.

Previous studies have conducted their analyses by estimating the coefficients for a single equation (Dechezleprêtre et al., 2008; Doranova et al., 2010; Haites et al., 2006; Schmid, 2012; UNFCCC,
| Project type                  | Number of projects | Projects with no TT | Number of projects that claim TT | Number of known technology suppliers | Share of four largest suppliers\(^a\) (%) | Share of largest supplier\(^a\) (%) | Largest supplier |
|------------------------------|--------------------|---------------------|---------------------------------|--------------------------------------|------------------------------------------|-------------------------------------|-----------------|
| Afforestation/reforestation  | 38                 | 17                  | 12                              | 7                                    | 70                                       | 25                                  | Norway          |
| Biomass energy               | 422                | 200                 | 94                              | 25                                   | 29                                       | 23                                  | Denmark         |
| Cement                       | 19                 | 10                  | 2                               | 2                                    | 50                                       | 50                                  | Japan/Germany   |
| CO\(_2\) usage              | 2                  | 1                   | 1                               | 1                                    | 100                                      | 100                                 | Denmark         |
| Coal bed/mine methane        | 57                 | 22                  | 28                              | 9                                    | 79                                       | 33                                  | US              |
| EE households                | 30                 | 6                   | 7                               | 2                                    | 94                                       | 94                                  | Germany         |
| EE industry                  | 68                 | 9                   | 25                              | 13                                   | 58                                       | 33                                  | Japan           |
| EE own                       | 235                | 106                 | 76                              | 7                                    | 97                                       | 59                                  | Japan           |
| Energy distribution          | 5                  | 1                   | 3                               | 2                                    | 67                                       | 23                                  | Vietnam         |
| Fossil-fuel switch           | 71                 | 8                   | 44                              | 12                                   | 88                                       | 40                                  | US              |
| Geothermal                   | 12                 | 1                   | 7                               | 10                                   | 77                                       | 35                                  | US              |
| HFCs                         | 23                 | 2                   | 21                              | 6                                    | 81                                       | 24                                  | US              |
| Hydro                        | 1128               | 822                 | 127                             | 23                                   | 73                                       | 49                                  | China           |
| Landfill gas                 | 228                | 25                  | 156                             | 24                                   | 49                                       | 16                                  | US              |
| Methane avoidance            | 436                | 67                  | 290                             | 26                                   | 56                                       | 20                                  | US              |
| N\(_2\)O                     | 70                 | 66                  | 11                              | 87                                   | 41                                       | 41                                  | Germany         |
| PFCs and SF\(_6\)            | 12                 | 1                   | 6                               | 3                                    | 33                                       | 33                                  | Austria         |
| Solar                        | 65                 | 28                  | 29                              | 9                                    | 79                                       | 34                                  | US              |
| Tidal                        | 1                  | 1                   | 1                               | 1                                    | 100                                      | 100                                 | Austria         |
| Transport                    | 12                 | 2                   | 8                               | 5                                    | 88                                       | 88                                  | France          |
| Wind                         | 947                | 627                 | 250                             | 14                                   | 93                                       | 93                                  | Germany         |
| Total                        | 3949               | 1967                | 1282                            | 44                                   | 51                                       | 19                                  | Germany         |

\(^a\) As share of total projects.
2007, 2008; Zheng & Zhang, 2011) or two equations (Haites et al., 2012; UNFCCC, 2010). Both approaches were used and the statistical performances of both approaches were good.

Larger values for population, GDP per capita, imports, FDI, official development assistance (ODA), renewables, and knowledge stock were expected to be associated with lower frequencies of TT for CDM projects, and thus 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 TT, so these variables were expected to have positive coefficients. Abatement potential and technology base were expected to have negative coefficients because a higher value reflects a larger existing technical capacity and so TT by CDM projects should be less prevalent. A positive coefficient was expected for abatement cost because a higher value means that projects are less attractive, and therefore that existing technical capacity is likely to be smaller, which would make TT more common for CDM projects. The expected sign of transferred technology was not clear. If TT via other channels is common, the technical capacity should be larger and transfer for CDM projects should be less prevalent and hence should have a negative coefficient. However, if CDM projects make a large contribution to the transfer of these technologies via all channels, the coefficient should be positive.

Results of the statistical analysis are presented in online Appendix A at http://dx.doi.org/10.1080/14693062.2013.812719. Larger projects were more likely to involve TT. The prevalence of TT declined as the number of projects of the same type in a host country increased. The effect of an additional project was small, but highly significant. This suggests that, as the number of projects of a given type has grown, some technological capacity beyond the requirements of the individual projects has been created.

The estimated coefficients for the variables that reflect both the host country and project type were all statistically significant and all had the expected sign. Abatement potential and technology base had the expected negative sign, while abatement cost had the expected positive sign. This means that TT for CDM projects was less prevalent in host countries with a larger and more economic abatement potential and a larger technical capacity for that project type. The positive coefficient for transferred technology suggests that CDM projects have increased the overall transfer of the relevant technologies to the host countries.

The performance of the country characteristics was mixed. Almost all (with the exception of population, ODA, and renewables) were significant in the one-equation approach, but only GDP per capita and tariff rate had the expected sign. In the two-equation approach, only population, GDP per capita, ODA, and renewables were significant, while two of them – per capita GDP and ODA – had the wrong sign. Dechezleprêtre et al. (2008), Doranova et al. (2010), and Schmid (2012) have also reported mixed results for GDP per capita, FDI, ODA, trade (imports plus exports), and the share of renewables. The positive sign for FDI may indicate that instead of serving as an alternative channel to CDM projects for TT, foreign investment and TT have been stimulated by CDM projects. This result is consistent with the findings by Dechezleprêtre et al. (2008) and Schmid (2012) that TT is more prevalent for CDM projects with foreign participation.

It should be noted that the time lags often differed 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. one vs. two years – were usually similar. This is not surprising given that almost all of these variables necessarily change slowly over time.
The one-equation model was estimated using both the PDD statements and the survey responses as the dependent variables (see Table 1, online Appendix B at http://dx.doi.org/10.1080/14693062.2013.812719). 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.

In summary, the prevalence of TT by CDM projects exhibits 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. As the number of projects of a given type in a host country has grown, some technological capacity beyond the requirements of the individual projects appears to have been created.

8. Contribution of the CDM to TT to developing countries

Two hypotheses are examined here relating to the possible contributions of the CDM to the transfer of technology suggested by the statistical analysis. First, as the number of CDM projects of a given type in a host country grows, sufficient technological capacity is developed to lower the prevalence of TT for future projects. Second, there may be cases where the number of CDM projects is sufficiently large that TT by CDM projects affects the scale of TT via other channels such as FDI.

The frequency of expected TT for CDM projects, as the number of projects of the same type in a host country rises, is shown in Figure 3, which depicts the trends in the frequency of expected TT for all project types, with at least 20 projects that explicitly expected some or no TT for China, India, Mexico, and Vietnam. Although the rate differed, the rate of TT declined as the number of projects increased for most host country–project type combinations. The decline was very small for methane avoidance in Mexico and hydro in Vietnam, despite hosting more than 50 projects. Hydro and biomass energy projects in India initially used domestic technology and then imported technology for some projects before the usual pattern of a decline in the frequency of TT for new projects set in. Hydro projects in China relied virtually exclusively on domestic technology, which is not surprising given its role as the leading foreign supplier of hydro technology for CDM projects.

Determining the role of previous CDM projects in reducing TT for new projects was supported by the responses to one of the follow-up survey questions. Participants that indicated that their project did not involve TT were asked to identify the source of the technology used. Of the respondents, 58% stated that the technology came from an earlier CDM project. That is, the technology used by their project was available domestically, at least in part, because it had already been used by a previous CDM project.

To influence the transfer of the relevant technologies via all channels and total FDI, the impact of CDM projects must be relatively large. CDM projects accounted for a very large share of total capacity additions of several technologies in developing countries. Of the top six developing-country wind-power markets, CDM project capacity covered virtually the entire market for China, Mexico, Morocco, and Egypt, but not for India and Brazil (Spalding-Fetcher et al., 2012). CDM biomass energy projects covered all of the capacity additions in Chile and Malaysia and about half of the total additions in China and India (Spalding-Fetcher et al., 2012). Technologies for the destruction of industrial gases (e.g. HFCs, N₂O, PFCs, and SF₆), which have high frequencies of TT, have been retrofitted to virtually all existing facilities in developing countries as CDM projects. The CDM’s very large
share of capacity additions for wind, biomass energy, and destruction of industrial gases in several countries thus suggests that CDM projects have contributed to the transfer of related technologies to those host countries.\textsuperscript{14}

These technologies could also have been transferred to these developing countries via other channels. An analysis of patent data for wind technology shows that the CDM has had a small direct contemporaneous effect on the transfer of technology from developed to developing countries (Haščić & Johnstone, 2011). The number of applications by foreign patent holders – a measure of TT via all channels – was compared with the number of CDM projects that expected to involve TT. The comparison was limited to the geothermal, HFCs, PFCs and SF\textsubscript{6}, hydro, N\textsubscript{2}O capture, solar, and wind project types, where patent data can be matched with CDM project types. While the units – patent applications and CDM projects – were different, the data show that the number of patent applications was over 3000 times higher than the number of CDM projects expected to involve TT. This suggests that TT via all channels may be much larger than that for CDM projects.

CDM project data show that the frequency of TT was higher for projects that involved foreign participants (Dechezleprêtre et al., 2008; Schmid, 2012), which suggests that there is a relationship

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\textbf{Figure 3} Frequency of TT as the number of projects increases for selected project types in China, India, Mexico, and Vietnam. \textit{Note:} These countries are the only ones with at least 50 projects of a single project type. For these countries, all project types with at least 20 projects that explicitly indicate they expect some or no TT are shown. The trend is calculated as the percentage of the current plus all previous projects that expect to involve TT.
between FDI and TT by CDM projects. The estimated investment in registered CDM projects was 6% to 8% of FDI from 2005 through 2009. The foreign share of investment in CDM projects was probably less than 20% (Spalding-Fecher et al., 2012), so foreign investment in CDM projects amounted to less than 2% of FDI for host countries. For a specific country and year, the percentage might be much higher, but, overall, foreign investment in CDM projects was not a significant contributor to FDI.

Many developing countries have a variety of incentives to encourage renewable energy (Castro, Hayashi, Kristiansen, Michaelowa, & Stadelmann, 2011). Few attempts have yet been made to disentangle the contributions of these incentives to capacity additions and associated TT (Peterson, 2008; Pueyo, Mendiluce, Naranjo, & Lumbreras, 2012). Lema and Lema’s (2013) study of CDM wind projects in China and India has concluded that they have used transfer mechanisms that were opened up prior to and independent of CDM projects, rather than the other way around. However, China and India are not typical (Lema & Lema, 2013; Pueyo et al., 2012).

In summary, the evidence on the contribution of CDM projects to the development of broader technological capacity in the host country is mixed. Some technologies, such as hydro in China and India and biomass energy in India, were widely available in specific countries before the CDM was established. The contribution of CDM projects to the country’s technological capacity in these cases has been limited. In other cases – such as wind in China and Mexico, biomass energy in Chile and Malaysia, and industrial gas destruction in all host countries – the CDM projects have accounted for almost all of the capacity additions, and so have probably contributed substantially to the TT that has occurred. On the other hand, patent applications and FDI flows suggest that CDM projects have been but a small part of the total TT that has occurred.

Although TT by CDM projects appears to have contributed to the development of host countries’ technological capacity as the number of projects of a given type has increased, it is likely that other factors – such as domestic policies and TT via other channels – have also contributed. The contributions of the CDM and the other factors have not yet been disentangled, and it may not be possible to do so. If a CDM project with foreign investors involves TT, is the transfer due to the CDM or to FDI? The project may not have been implemented without FDI, or FDI may not have occurred without the CDM. So, is CDM or FDI responsible for the TT?

9. Summary and policy implications

Although technology transfer (TT) is not an explicit objective of the Clean Development Mechanism (CDM), the CDM has contributed to the transfer of mitigation technologies to developing countries. Some CDM projects have used technologies not currently available in the host country, and have thus induced TT. Project participants indicate whether the project is expected to involve TT. It is clear from the project design documents (PDDs) that project participants overwhelmingly interpret ‘technology transfer’ to mean the use by the project of equipment or knowledge not previously available in the host country.

Participant responses to the follow-up survey indicate that the PDD statements that a project expects, or does not expect, to involve TT are reasonably accurate. Of the projects that explicitly state either that they expect or that they do not expect to involve TT, 39% of them have actually involved TT. Over half of the projects with a PDD that did not mention TT actually involved TT.
Those projects are excluded from the analysis, so the above percentage understates the frequency of TT by CDM projects.

The technology transferred to host countries originated predominantly from Germany, the US, Japan, Denmark, and China. Each of these countries is the leading technology supplier for between one (China) and eight (the US) project types. The project types for which sufficient data were available suggests that project developers have a choice among a number of foreign suppliers.

Technology transfer is very heterogeneous across project types, with relatively low frequencies for project types that use well-established, mature technologies, such as hydro power generation and cement production. Technology transfer is more common for larger projects. The frequency of TT for all CDM projects has declined over time due to reductions in the frequencies for China, India, and Brazil, the countries that have hosted most of the CDM projects. The frequency of TT for all other host countries has been much higher than the overall average and continues to rise as more countries host CDM projects.

The key conclusion from the analysis is that TT by CDM projects has varied significantly by host country and project type and that it has declined as the number of projects of the same type in a country has increased. The statistical analysis yielded the conclusion that the explanatory variables with both a country and a technology dimension (and preferably also time-series data) are better able to explain the frequency of TT than the country characteristics used in earlier studies.

The prevalence of TT by CDM projects has been less frequent for a host country with a larger and more economic abatement potential and a larger technical capacity for that project type. These characteristics suggest that such host countries have been more likely to already have technological capacity related to the specific technology, and hence that the use of imported technology for a CDM project has been less prevalent. The decline in the prevalence of TT as the number of projects of a given type in a host country has increased suggests that some technological capacity beyond the requirements of the individual projects has been created.

Although TT by CDM projects appears to have contributed to the development of host countries’ technological capacity, it is likely that other factors – such as domestic policies and TT via other channels – have also contributed. The contributions of the CDM and these other factors have not yet been, and indeed may never be, disentangled.

A developing-country government that wishes to develop technological capacity related to a specific technology should consider whether there is potential for successful domestic commercial application. It should then develop a strategy for building this capacity, which might include transfer via one or more channels, including CDM projects, and complementary policies, including financial incentives for deployment of the technology.

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Notes

1. Projects in the pipeline include both registered projects and those posted for public comment but not yet registered. Programmes of Activities – a single project covering many small measures, such as efficient stoves – were not included in the analysis.

2. Das (2011) defines three types of TT: Type I – host-country development of a technology; Type II – import with local adaptation or improvement; Type III – technology import. Das analysed the PDDs for 1000 registered projects and found 259 Type IIIs, 6 Type IIs, and no Type Is. However, as shown in Table 1, the PDDs have understated the actual extent of TT.

3. Keywords included: technology, transfer, import, foreign, abroad, overseas, domestic, and indigenous.

4. \[
\frac{51 + 29 + 118}{198} = \frac{49}{49} = 49\% \quad \text{and} \quad \frac{60 + 25 + 193}{278} = \frac{68}{68} = 68\%.
\]
The difference is statistically significant at the 1% level.

5. \[
\frac{118}{51 + 29 + 118} = \frac{60}{60} = 60\% \quad \text{and} \quad \frac{193}{60 + 25 + 193} = \frac{69}{69} = 69\%.
\]
The difference is statistically significant at the 1% level.

6. Spalding-Fecher et al. (2012) has summarized the technology requirements for CDM projects established by various host countries.

7. This is reflected in the decline in the percentage of projects for which TT is unknown, from 23% of PDDs to 4% of survey responses (see Table 1).

8. The 24 project types are listed in Table 3. The UNEP Risoe Centre CDM Pipeline provides monthly updated data for most CDM projects, which are available at http://www.cdmpipeline.org/.

9. The trends were calculated using the number of projects and the year in which each project entered the pipeline. The reductions were larger when the trends were calculated from estimated annual emissions reductions. Actual transfer of technology may not take place until a year or two later.

10. Values for years in which there were fewer than 10 projects for which expected TT was known, e.g. China in 2004, India in 2004, and Brazil in 2010 and 2011, are not shown.

11. The source of the technology was unknown for about 20% of the projects that involved TT, at least partly because the technology has not yet been sourced. If more than one country supplied technology to a project, each country was credited with a fraction of the project.

12. In an analysis of TT via all channels, Dechezleprêtre, Glachant, & Ménière (2010, p. 1) also found a positive coefficient for FDI, which they described as ‘clearly counter-intuitive’, and provided several possible interpretations of this result.

13. The scale for China was truncated at 500 projects. The declining curve for wind power continued for 722 projects.

14. By contrast, CDM projects made up a relatively small share of the hydro capacity additions in most developing countries (Spalding-Fecher et al., 2012).

Supplementary information

Supplementary Content may be viewed online at http://dx.doi.org/10.1080/14693062.2013.812719

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