The Road to the Successful Clean Development Mechanism: Lessons from the Past

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Abstract

The Clean Development Mechanism (CDM) has evolved at a surprising speed since 2003 and is considered to have made positive contributions to the development of greenhouse-gas-reducing projects in developing countries. Taking into account its historical significance as the first effort of its kind and its current success, a thorough evaluation of its system and its effectiveness is of critical importance. Against this backdrop, this study closely investigates each stage of the CDM project cycle from development and registration of projects to issuance of certified emission reductions and identifies influential factors for the successful CDM implementation. For the analysis, we performed an extensive quantitative analysis augmented by a descriptive study, based on information of approximately 5000 CDM project.

Our findings suggest that the development of CDM projects is stimulated by favorable economic, social and technical environments in host countries as well as supportive CDM administration. This explains why projects are currently concentrated in certain countries such as China and India. Once projects are developed and submitted for validation, the success of the CDM projects at the next stages of project cycle related to registration and Certified Emission Reduction (CER) issuance is influenced by their types and a choice of Designated Operational Entities and project consultants. In particular, significant difference in registration success exists across project types, which calls for special attention of both the CDM authority and project participants to projects with high risks like energy efficiency, fossil fuel switch and biomass projects. Lastly, we found that performance of projects is affected by very project-specific conditions. For many of the most poorly performing projects, failure is attributable to technical and operational problems at the initial stage of project implementation, which highlights the importance of well-prepared PDDs. Based on the findings, the thesis concludes with policy recommendations to enhance the capacities and improve the performance of the major players under the CDM.

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ABBREVIATIONS

A/R	Afforestation / Reforestation
BAU	Business as Usual
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
COP	Conference of Parties
DNA	Designated National Authority
DOE	Designated Operational Entity
EB	Executive Board
ERU	Emission Reduction Unit
GHGs	Greenhouse Gases
HFCs	Hydroflourocarbons
LoA	Letter of Acceptance
PDD	Project Design Document
UNEP	United Nations Environment Programme
UNFCCC	United Nation Framework Convention on Climate Change

1 INTRODUCTION

1.1 BACKGROUND

By the beginning of the 21st century, a scientific consensus emerged that global warming is a serious threat to the Earth. Expected impacts include significant economic and social problems precipitated by environmental problems such as the Earth's surface warming and sea level rise. Though the magnitude of the impacts are uncertain and vary widely depending on which simulation model is used, recent research results seem to confirm that we will confront disaster in the near future unless immediate action is taken to reduce greenhouse gases (GHG) emissions, the major cause of global warming (IPCC 2001).

Countries began working together on these pressing issues in the 1990s. Through the United Nations, the United Nations Framework Convention on Climate Change (UNFCCC) was formed to investigate climate change problems in a formal way and set goals to mitigate it (UN, 1992). The Kyoto Protocol to the Convention (1997) which entered into force in 2005 requires a strong binding commitment from the developed (Annex 1) countries. It mandated them to reduce their GHG emissions to an individually assigned level[1], but also provides three "flexible mechanisms" to help reduce the costs of achieving these emission reduction targets: emission trading (ET), joint implementation (JI), and the clean development mechanism (CDM)[2]. These mechanisms enable the signatory countries

[1] There are 6 kinds of GHGs to be controlled under the Kyoto Protocol: CO_2, CH_4, N_2O, HFCs, PFCs and SF_6. Each country was assigned different target for the five-year period of the first commitment of Kyoto Protocol between 2008 and 2012 as a form of proportional to the emission level in 1990 (UN, 1998).

[2] The ET is a cap-and-trade system in which Annex B countries can sell or buy credits (AAU: assigned amount of unit) from other Annex B countries. The JI is similar to the CDM in that it is also project based.

to purchase emission credits from countries that bear lower GHG reduction costs, without reducing GHG emissions domestically.

Among the three mechanisms, the CDM is especially special in that it is the first and only set-up that allows developing countries to participate in reducing GHGs under the UNFCCC framework, as defined in Article 12 of the Kyoto Protocol. Considering the current trend of rapidly increasing GHG emissions in developing countries, only those international policy options that include developing countries in climate change efforts have any chance of drastically reducing GHGs in the atmosphere. Thus, the introduction and implementation of the CDM is vitally important as the first international attempt to include developing countries in this global effort.

1.2 MOTIVATION

Despite the historical and practical importance of the CDM, not many researchers have attempted a comprehensive quantitative analysis of CDM project activities. Past studies have addressed CDM projects within a single country or project type. As popular topics, China and renewable energy projects have been mostly studied (Gorina 2007; Doukas, Karakosta et al. 2009). These studies provide valuable in-depth analyses of some specific topics related to the CDM. However, they do not represent a general analysis of its operations world-wide.

The difference comes from the participants of the system. In the JI, both host countries and buyers should be annex 1 countries. Buyer countries will get credits (ERU: emission reduction units) generated from projects which reduce GHG emissions compared to the baseline. The CDM is explained in detail in the next section.

Furthermore, sample size as in the number of projects tends to be small. Castro and Michaelowa (2008) made a quite comprehensive quantitative evaluation of CDM project activities by combining results from several analyses, but were able to include only 313 projects. Such a small sample reduces the credibility of the conclusions. For more generalized results, a thorough analysis with a larger sample size is desirable.

If the lack of a comprehensive analysis and a small sample size are academic issues for more credible and reliable research, there is a current practical issue worth to investigate. Since the first CDM project in 2003, proponents of 4069 projects have applied for registration. However, only 33% of these have been successfully registered as “official” CDM projects. Of these, 31% have issued their first certified emission reduction (CER) (UNEP, 2009). This serious congestion in the pipeline raises doubts about the potential of the CDM to generate actual CERs and how many projects at the validation stage will be realized. At this juncture, it is important to explore and identify the barriers that have caused those project activities to stall, so that current and future projects may be implemented more successfully.

Besides, the first commitment period of the Kyoto Protocol ends soon in 2012. A new international framework is still under negotiation and needs to be established to ensure the continuing efforts to reduce global greenhouse gases. To date, however, no solid and tangible agreement has emerged on which to build a post-2012 framework. The recent Copenhagen Accord of 2009 failed to lead specific international mechanism to replace the CDM. It seems likely that the CDM -possibly with minor reform - will be part of any new agreement (UNFCCC, 2010). For this reason, it is worthwhile to study project experiences with CDM in order to learn lessons for the future.

1.3 OBJECTIVE AND RESEARCH QUESTIONS

The primary objective of this study is to investigate influential factors in the successful implementation of the CDM and provide recommendations to project participants as well as CDM authorities. Here, the CDM authorities include the EB (Executive Board), DOEs (Designated Operating Entities) and DNAs (Designated National Authorities). Of particular interest here are each stage of the CDM project cycle including the proposal, registration and certification. The primary research questions raised in the research are:

1) Development of CDM projects - what factors stimulate the development of CDM projects in a country?

2) Registration success - what factors increase the chance of a project being successfully registered as an official CDM project at the validation stage?

3) Issuance success rates - what caused the discrepancies between the estimated and the actual amount of certified emission reductions (CER)?

This study will address these questions through an extensive quantitative analysis augmented by a descriptive study. The results will provide useful guidelines and strategies for CDM stakeholders.

1.4 DATA

The major data sources for the analysis are the CDM pipeline by UNEP Riso (UNEP, 2009); the CDM database by ISGE (ISGE, 2009); and UNFCCC website (UNFCCC, 2010). The UNEP Riso and ISGE data bases provide similar CDM project information in a tabular format. These are rich sets of detailed project information including project participants, host country information, project type, applied methodologies, validator and verifier, expected annual amount of CER, dates for each stage of the CDM process, and amount of verified CER generation. A crosscheck of the two databases showed them to be reliable with only minor discrepancies. Original project documents found on the website include: project design documents (PDD), validation reports, monitoring reports, and verification reports. In this study, the monitoring and verification reports were closely reviewed especially for the analysis of issuance success rates as discussed in Chapter 5.

The analysis is based on 5089 of CDM project activities which have entered the public comment for validation phase of the CDM pipeline as of 1 July 2009. However, the study does not include "program of activities" (PoA)[3] projects, a recently approved type of CDM project, since those projects have characteristics and rules different from those of regular CDM projects.

[3] A CDM Programme of Activities (PoA) is "a voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programmes), which leads to anthropogenic GHG emission reductions or net anthropogenic greenhouse gas removals by sinks that are additional to any that would occur in the absence of the PoA" (EB 47, Annex 29, paragraph 3).

1.5 OVERVIEW OF CHAPTERS

The paper is constructed as follows. Chapter 2 gives a general introduction to the CDM. The chapter briefly outlines the current system of the CDM including its modalities, institutions, and project cycle, and a description of its current state by project type, country, and status. The overview demonstrates the complexity of the CDM system in terms of its procedures, diverse stakeholders, and technologies.

Chapter 3 presents the first part of the analysis: the inflow of CDM projects. It begins with a descriptive analysis of project entry into the pipeline each year by type and host country. Next, a statistical analysis identifies what has induced the proponents of those projects to enter the pipeline at a country level.

Chapter 4 is an investigation and identification of the determinants of registration success, using a logit model. The results are demonstrated as a function of the effect of individual independent variable on registration success. The chapter concludes with discussions and recommendations based on these results.

Chapter 5 is an exploration of why discrepancies between the expected and actually issued certified emission reduction (CER) occur. A statistical model constructed to explain the discrepancies shows that the independent variables do not fully explain them. A review of actual original project documents for 100 projects produces more useful results.

Conclusions and recommendations with key findings are summarized in chapter 7, which also assesses the significance of this study and suggests topics for future investigation.

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2 OVERVIEW OF THE CDM

This chapter introduces the modalities, institutions, and project cycle of the current CDM system. Its current status, in terms of project type and country is also described. The objective of this chapter is to provide a background on the CDM structure and demonstrate its complexity in terms of procedures, diverse stakeholders, and technologies.

2.1 BACKGROND

2.1.1 Objectives of the CDM

The CDM allows emission-reducing projects in non-Annex I countries to generate emission-reduction credits called CERs. Once the CERs are verified, they can be bought, sold, and traded by the Parties. Two objectives of the CDM are clearly stated in Article 12 of the Protocol. The first is to help Annex I countries achieve their GHG emission reduction compliance at lower costs through the CDM than they can by reducing GHGs domestically. In general, developing countries have cheaper options for reducing GHGs than do developed countries. Since the developing countries have relatively lower energy efficiency and do not have advanced environmentally friendly technology, they can reduce an amount of GHGs similar to a developed country at a lower marginal cost (Ellerman, Jacoby et al. 1998). In addition to reducing global GHG emissions, a second goal is to help host countries achieve sustainable development by improving their economic, social, environmental, and technical conditions. Development and implementation of CDM projects is associated with financial inflow in the affected developing countries as well as technology transfer.

2.1.2 Eligibility for CDM projects

To be eligible for CDM status, project activities must satisfy two basic conditions. First, project participants must be Parties to the Kyoto Protocol and have Designated National Authorities (DNA). Second, projects must lead to "real, additional, measurable, and verifiable" emission reductions below a baseline scenario.

In order to host CDM projects, both Annex 1 parties and non-Annex 1 parties must be members of the protocol[4]. Each party is required to set up a DNA capable of evaluating whether a proposed project contributes to sustainability in a non-Annex 1 country or of authorizing voluntary participation in an Annex 1 country.

Generating emission reductions through the CDM is directly related to the revenue of project participants and also affects the global environment in the long term by reducing GHGs that would otherwise have been produced. The estimate and certification of emission reductions in a transparent and consistent way is critical to the success of the CDM. To maintain transparency and consistency through a CDM project cycle, CDM modalities require project developers to use approved methodologies for estimating baseline and emission reductions and for monitoring the reductions.

2.1.3 CDM governance

Executive Board

The Executive Board (EB) supervises the CDM under the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP).

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[4] Currently, there are 188 member countries in total, 32 Annex 1 countries and 157 non-Annex I countries (UNFCCC, 2009).

The Board consists of ten members from Parties to the Kyoto Protocol, one from each of the five UN regional groups, two others from the Parties included in Annex 1, two others from the Parties not included in Annex 1, and one from the small-island developing states. The term of office of members is two years and can be extended once (CMP, 2005).

The EB's rule-making and rule-enforcing roles were specified in greater detail at the EB 47 meeting in 2009. According to the meeting report (EB47, 2009), the EB is empowered to

1) make decisions on administrative matters such as meeting agendas and documentation, finance and administration, and management of other panels and groups under the CDM, in order to run the EB successfully;

2) make decisions on regulatory matters related to the supervision of the CDM and publish its decisions in meeting reports; and

3) evaluate the observance of CDM procedures and modalities by project participants.

The first two responsibilities are designed to support the general framework of the CDM operation. The third pertains to the survival of individual projects. More specifically, the EB approves of new methodologies, reviews officially validated projects by DOEs and registers them after the review, issues CER credits, and accredits DOEs. A more extensive lift of EB roles can be found in Decision 3/CMP.1.

The EB is also authorized to establish relevant panels, working groups, and teams to facilitate its functions and enhance its performance (CMP, 2005). As of now, there are five groups: a CDM accreditation panel; a methodology panel; a working group for small-scale projects; a working group on afforestation and reforestation; and a team for the registration of projects and issuance of CERs (UNFCCC, 2009).

Designated Operating Entity (DOE)

Each DOE is accredited and designated by the COP/MOP, based on an Executive Board recommendation. The DOE can be a domestic legal entity or an international organization. The two main functions of DOEs are to 1) validate proposed projects and put them forward for registration to the EB, and 2) verify and certify emission reductions. The DOE is responsible for ensuring that project activities are eligible for the CDM and in conformity with its modalities.

Given the nature of its work, DOE decisions should be transparent and consistent. To become a DOE, an organization must meet certain accreditation standards. The EB determines whether an applicant entity meets these standards by assessing its application and conducting on-site visits. Currently, there are 29 DOEs, each with a specialized sector in which it may validate, verify, and certify project activities.[5]

Regular surveillance is required within three years to confirm that a DOE has maintained its capacity to validate and verify project activities and has kept its decisions procedures transparent. If a DOE fails to satisfy those conditions, it can be suspended or its accreditation withdrawn.

Designated National Authority (DNA)

[5] The list of DOEs and their scope of sectors can be found at http://cdm.unfccc.int/DOE/list/index.html.

Parties participating in the CDM each designate a national authority (Decision 3/CMP.1). For a proposed project a DNA sends a letter to the EB for a proposed project confirming that:

1) the Party has ratified the Kyoto Protocol;
2) participation is voluntary; and
3) For a host Party, the proposed project contributes to its sustainable development.

While it is easy to confirm the first two of these conditions, the evaluation of a project's contribution to sustainability in the host country can be subjective and inconsistent. No guidelines or rules have been established to evaluate sustainability.

Moreover, CDM modalities do not give clear guidance on how to establish the DNAs. Currently, there are 146 DNAs, 29 Annex 1 countries and 117 non-Annex 1 countries (UNFCCC, 2009). Countries have established DNAs in different ways and forms: set up within existing government departments, as inter-ministerial committees, and as newly founded organizations (Curnow and Hodes, 2009).

2.2 CDM PROJECT ACTIVITY CYCLE

In order to be officially registered as valid CDM projects and to generate CERs, participants need to follow rigorous and complex validation and verification procedures. The procedures ensure that the projects generate "real and measurable" emission reductions additional to what would have been produced without the project. The project activity cycle with related project participants at each stage is illustrated in Figure 1.

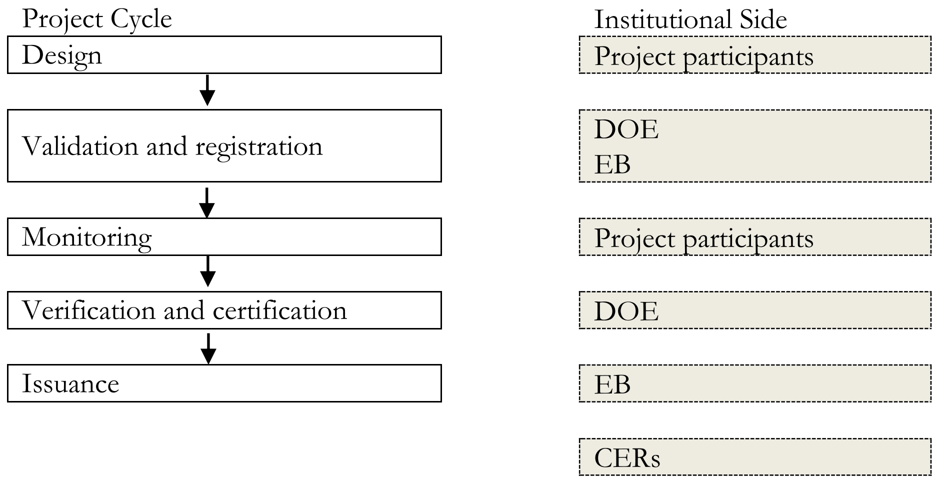

Figure 1. CDM project activity cycle and involved institutions

Design

In the design phase, project participants complete a project design document (PDD)[6]. The Executive Board has developed four types of PDDs: for large-scale projects; for small-scale projects; for large-scale afforestration/reforestation (A/R) projects; and for small-scale A/R projects.

The standardized format of PDDs requires detailed information of projects in a general context as well as in the CDM context. The information explains why the project is eligible for the CDM; how many credits it would generate based on the use of appropriate methodologies; and specifies which entities and governments will participate, in addition to a summary of stakeholders' comments and environmental impacts. Meanwhile, when no relevant approved methodology can be found, project participants have the following options:

[6] The first version of PDDs was published on August 29, 2002; a simplified version for small-scale projects came out on January 31, 2003.

1) request clarifications of approved methodologies;
2) request deviation from approved methodologies;
3) request a revision of existing methodologies; or
4) submit a new methodology.

These are four ways for a project developer to get an appropriate methodology approved and thus complete the PDD. However, the procedure for getting a new methodology approved is time-consuming and expensive; and, there is a high risk of failure. Due to the economic burdens and risks, project developers can be discouraged from participating in the CDM absent a previously approved methodology.

Validation

Upon the completion of a PDD, a participant submits it to a Designated Operational Entity (DOE) for validation. The DOE investigates whether the project meets the validation requirements of the CDM. Meanwhile, simultaneously with its own review process, the DOE posts the project PDD on the web and invites stakeholders to comment on the project for 30 days. These comments are also considered in validating the project.

To complete the validation process, project participants must obtain a letter of approval from the DNAs of their countries, both Annex 1 countries, if there are any, and non-Annex 1 countries. Once the DOE has all the documents needed and finishes the review, it determines if the project is eligible for the CDM. Following these procedures, the DOE either sends a validation report to the EB or notifies the project participant of the reasons for non-acceptance. If a project is not accepted, its participants may revise the PDD and resubmit it.

Registration

When the EB receives all the necessary documents for registration–a validation report from a DOE, a PDD, an approval letter from a DNA, and a receipt for the registration fee--the status of the proposed project is advanced to “request for registration.” A member of the Registration and Issuance Team (RIT) under the EB determines within 20 days (or 15 for small-scale projects) whether the validation has been properly done by the DOE. Based on a successful determination, the secretariat then submits a summary note of the request for registration within 10 days (or 5 for small-scale projects).

During the process of registration, review can be requested by either a Party involved or at least three members of the EB. If review is requested, the EB decides whether to ask for a correction, reject, or accept following review. Unless a review is requested by project participants or the members of the EB and the validation process is evaluated as appropriate, the project will be registered as a valid CDM project.

Registration means that the project is capable of issuing CERs. As the number of proposed projects grew, the average days at the “request for registration” stage also increased significantly. The increased delays raised transaction costs and risks for project developers (IETA 2008). Only recently, in 2009, has the waiting period diminished, approaching the timing experienced in the initial years of the CDM (UNEP Riso, 2009).

Monitoring

During a project activity, emission reduction-related data must be monitored by a project participant or a third party, according to a monitoring plan suggested in the PDD. The parameters to be monitored differ by the type of project and monitoring plan used. The monitoring results must be documented in a report to verify emission reductions. The monitoring report also should include the detailed procedures for calculating emission reductions, using the monitored data.

Verification and certification

The frequency and timing of CER issuance are decided by the project participants. Once they decide to issue CERs, they submit a monitoring report for verification to a DOE of their choosing. The DOE implements verification according to the modalities and procedures of the CDM; provides a verification report to the EB; and states the amount of emission reductions in a certification report. The submitted verification and certification report will be appraised by a member of the Registration and Issuance Team. If a review is not requested for the proposed issuance of CERs, the EB will approve it. If a review is requested, the EB should make a decision regarding approval of the proposed issuance within 30 days.

Issuance of CERs

Once issued by the EB, the CERs are placed in a holding account for an authorized project participant from a non-Annex 1 party. During the issuance process, the CDM registry administrator will deduct some of the CERs to cover the share of proceeds for administration and adaptation and then forward the remaining amount to the holding account. At COP11, the administration fee was set at 0.1$ per CER up to 15,000 CERs per year and 0.2$ for CERs above 15,000. This fee is paid when CERs are issued. Upon issuance, the CERs are transferred into the International Transaction Log that is managed by the EB.

2.3 CURRENT STATE OF THE CDM

The CDM may be assessed through analyzing how many projects are currently at various stages of the project activity cycle; what type of projects appear to be most successful and popular; and which countries are taking advantage of the CDM opportunity.

2.3.1 By status

Since the CDM entered into force in 2005, the number of projects has increased rapidly. As of 1 July, 2009, 1699 projects are registered as CDM projects; three times this number are either at the stage of validation or in the process of registration. In addition to the high number of projects in the pipeline, the CDM has been successful in generating a large amount of emission reductions in non-Annex 1 countries.

In 2007, energy-related CO_2 emissions from fossil fuel were 5983 million metric tonnes of CO_2 in the States (EIA, 2008). This means that the 613,505 kCERs in estimated annual GHG emission reduction from CDM projects[7] amounts to 10.2% of the US CO_2 emissions. If we limit the estimate to projects either already registered or in the registration process, the reduction is still equivalent to 5.5% of US CO_2 emissions.

[7] The estimation includes projects at validation stage too.

Meanwhile, since the beginning of the CDM, 30 projects have been withdrawn by project developers; 592 projects have been rejected by the EB or DOEs at the validation stage. Biomass, hydro power, and methane avoidance projects account for 20, 19, and 18% of the total withdrawn and rejected, respectively.

From the perspective of host countries, China (20%) and India (36%) are the countries with the most rejected and withdrawn projects. One of the popular reasons for the rejection seems to be a failure to prove that the CO_2 avoided is additional to what would have been avoided without the project. More discussion on registration success and rejection will be done in Chapter 4.

Table 1. Status of CDM projects (source: UNEP, 2009)

Status of CDM projects	Number	Estimated annual kCERs
At validation[1]	2575	282,021
In the process of registration[2]	193	25,511
Registered[3]	1699	305,973
Total number of projects (excl. rejected & withdrawn)	5089	613,505
Withdrawn	30	
Rejected	592	

<Note> 1: at the stage of 30 days public comment period, 2: at the stage of requesting registration, 3: at the stage of formally registered as CDM projects>

2.3.2 By project type

Any project activity that satisfies the requirements can be registered as a CDM project. The scope of the activities varies from renewable energy to industrial GHG emission reductions. Also, diverse kinds of technologies and industrial sectors are involved. According to UNEP

Riso (2009)'s category, there are 26 types of project activities under the CDM[8] and each of which is defined in Annex A.

Table 2. CDM projects in each sector (source: UNEP Riso, 2009)

Type	**Number**		**Annual kCER CO_2 eq**	
Afforestation	5	0.1%	134	< 0.1%
Agriculture	1	< 0.1%	26	< 0.1%
Biomass energy	646	14.5%	40,287	6.6%
Cement	30	0.7%	5,824	1.0%
CO2 capture	3	0.1%	29	< 0.1%
Coal bed/mine methane	67	1.5%	30,035	4.9%
EE Households	11	0.2%	839	0.1%
EE Industry	159	3.6%	5,970	1.0%
EE own generation	411	9.2%	57,062	9.3%
EE service	16	0.4%	194	0.0%
EE Supply side	42	0.9%	14,951	2.4%
Energy distribution	8	0.2%	2,449	0.4%
Fossil fuel switch	122	2.7%	40,702	6.7%
Fugitive	26	0.6%	11,497	1.9%
Geothermal	15	0.3%	3,433	0.6%
HFCs	23	0.5%	82,498	13.5%
Hydro	1216	27.2%	128,922	21.1%
Landfill gas	270	6.0%	41,234	6.8%
Methane avoidance	516	11.6%	24,063	3.9%
N2O	67	1.5%	47,818	7.8%
PFCs and SF6	12	0.3%	3,175	0.5%
Reforestation	44	1.0%	2,364	0.4%
Solar	32	0.7%	681	0.1%
Tidal	1	< 0.1%	315	0.1%
Transport	10	0.2%	988	0.2%
Wind	714	16.0%	65,135	10.7%
Total	**5089**	**100%**	**610,625**	**100%**

[8] The UNFCCC has 15 scopes of projects according to their characteristics but UNEP Riso (2009) detailed the scope into 26 different types of projects. The relationship between scopes and types is included in Annex 1.

As of 1 July 2009, 4467 project activities are in the pipeline, excluding rejected and withdrawn ones. Table 2 shows the composition of the activities and estimated annual emission reductions across different project types. Apparently, some project types are much preferred over others. Renewable energy projects tend to be popular. In particular, project activities related to hydro power (27%), wind energy (16%), and biomass energy (14%) account for 57% of all the project activities, while other project types each include quite a small number of projects.

However, a high number of projects does not guarantee the generation of large CERs. The three project types with largest CERs are hydro power (20%), HFC (14%), and wind power (11%) projects; projects related to biomass energy are expected to generate only 7%. This is mainly due to the effect of the global warming potential (GWP) that compares the effect of a specific GHG to that of CO_2[9]. For example, taking its GWP into account, one metric tonne of HFC-23 reduction is equivalent to 9400 metric tonnes of CO_2 reduction (9400 CERs). Therefore, projects reducing GHG emissions with high GWP such as HFC, PFC, and SF_6 tend to create much greater CERs per project than CO_2 reduction projects. HFC and N_2O projects clearly illustrate this point; though they account for only 2% of the total number of projects, these project types generate 22% of the total expected CERs.

2.3.3 By host country

CDM project activities are not evenly distributed across regions and countries. This has been one of the popular criticisms regarding the performance and success of the CDM. As

[9] The GWP for each GHG can be found in Appendix A.

shown in Table 3, four countries, Brazil, China, India, and Mexico, dominate CDM projects, accounting for approximately 76% of all project activities and 81% of the total expected CERs.

More than a half of all CERs is coming from one country, China. This is because China's average CERs per project are larger than other countries due to its high share of industrial gas projects. It is interesting to note that China, taking a pessimistic view, did not jump into the CDM market initially, but later became actively involved after its major market opportunity became apparent.

Table 3. CDM projects in Brazil, China, India, and Mexico (Source: UNEP Riso, 2009)

Country	Number		Annual kCERs	
Brazil	346	7.7%	30,759	5.0%
China	1754	39.3%	349,21	57.2%
India	1127	25.2%	97,025	15.9%
Mexico	154	3.4%	13,214	2.2%
Others	1086	24.3%	120,415	19.7%
Total	4467	100.0%	610,625	100.0%

2.4 SUMMARY

This chapter has described the general structure and the current state of the CDM. It involves diverse groups of stakeholders including project participants, host country governments, and CDM-specific institutional entities such as the EB and DOEs. Proposed CDM project activities must follow complicated procedures to get registered and finally issue CERs. On balance, the CDM must be considered successful, as it has attracted many Annex 1 and non-Annex 1 countries to host emission reduction project activities with more than 5000 projects in the pipeline. Nevertheless, there is much room for improvement that will become evident as we study the complex reasons for what we observe, and learn lessons from past experience.

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3 DEVELOPMENT OF CDM PROJECTS

3.1 INTRODUCTION

The CDM is the first international program to engage participation of developing countries in abating GHG emissions and is expected to remain part of the second commitment period of the Kyoto Protocol with minor (or possibly major) revisions of its modalities. Despite its many problematic issues, it has been rated a "surprising success" considering the large number of projects and participating countries as well as the anticipated large amount of emission reductions (Michaelowa, 2005). Even before the Protocol entered into force, more than 120 projects had already entered the pipeline for validation.

The objective of the CDM is to activate as many emission reduction options as possible, and thus help Annex 1 countries lower the abatement costs for the fulfillment of the Protocol and promote sustainable development in non-Annex 1 countries[10]. Thus, one of the indicators of its success is the increase in the number of participating projects and the amount of CERs generated from them. This chapter outlines the factors that have been most influential in triggering the increase over time in the number of projects and CERs by project types and host countries.

This investigation relies on both descriptive and econometric analysis. The analysis consists of four parts. First, we study the relationship between emission reduction potential and CDM project development for industrial and methane gas projects. Second, we will explore

[10] This statement assumes that all of the registered projects or proposed projects truly bring about "additional" emission reductions.

the relationship between the prevalence of a technology and CDM project development through the analysis of renewable energy projects. Third, we will briefly look at the inflow of projects every month by type and host country. Finally, we perform an econometric analysis to determine the statistical significance of different factors on the development of the CDM projects at the country level. The study will help policy makers modify the current system to make it more effective and to promote more projects in various countries.

3.2 EVOLUTION OF THE CDM

Since the first CDM project came into the pipeline for validation in December 2003, the number has increased rapidly as shown in Figure 2[11]. The figure illustrates the aggregated number of projects at the validation stage and registered each year, with the expected total annual CERs. A close look at the graph reveals that the number exploded with 1326 new projects in 2007; in the subsequent year, 2008, even more projects--1408--came into the pipeline, though fewer projects were submitted in 2009. Meanwhile, the ratio of projects registered and those at the validation stage tend to be relatively consistent at 0.3 on average during the last three years.

[11] Projects which are on the stage of request-registration have been counted as projects at validation stage for simplicity.

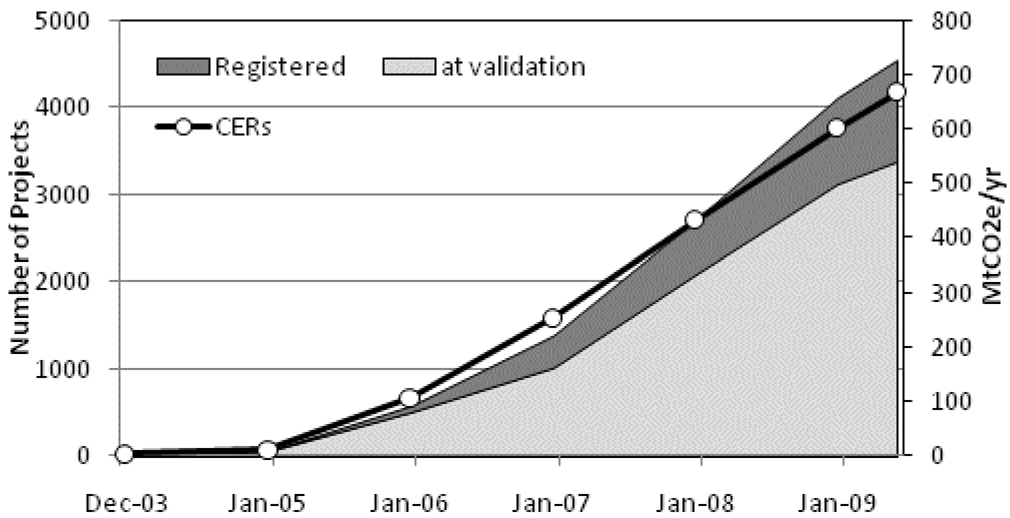

Figure 2. The number of projects and expected CERs in the pipeline over time

Figure 2 also shows the link between the increased number of projects and the CERs available. Over the last 7 years, the expected annual CERs from projects in the pipeline reached 667Mt CO_2e as of 1 Jun 2009. Considering the current CER price[12], 12.9€/tonCO_2, the expected revenue from selling the credits amounts to about 8600 Million €/yr. The annual increase tends to be relatively consistent, with approximately 165Mt CO_2e since 2006. This is because the composition of the CDM by project type has changed over time and the increase in the number of projects did not come at the same time. For example, the similar annual increase in CERs in 2007 and 2008 following the smaller increase in 2006 seems to be related to the larger size of the earlier projects, which included a greater proportion of industrial gas projects. In this chapter, we will review the different patterns of increase across project types and host countries.

[12] The price is based on the spot price on 1 September 2009, quoted from European Climate Exchange website (http://www.ecx.eu).

3.2.1 Effect of emission reduction potential

The BAU emission level can be considered the measure of emission reduction potential; and, as such, defines the scope of project opportunity in the CDM context. Thus, it is frequently assumed that countries with larger emissions would attract project developers in general and become host countries with a large number of projects (Jung, 2006). This section compares BAU emission levels with the expected emission reductions through the CDM, in order to investigate the assumption on the effect of BAU emissions. Only industrial and methane gas projects are considered in our analysis, since their sources are easier to identify and tend to not be regulated under the domestic law in many countries.

3.2.1.1 Industrial gases

CDM projects have been designed to capture and treat industrial gases such as PFCs, $SF_{6,}$ N_2O, and HFCs. These have been the most popular CDM projects, generating large revenues due to their high global warming potential, relatively low treatment costs, short construction periods, and technical simplicity (Lecocq and Ambrosi, 2007; Wara and Victor, 2007).

Industrial gases are generated during the production of particular products: PFC during a process of aluminum smelting and semiconductor; N_2O during the production of nitric and adipic acid; and HFC during the production of rigid foams, refrigeration, air conditioning equipment and aerosol cans (Metx et al., 2007; Solomon et al., 2007; IPCC, 2007). Because the conditions required for the generation of the gases are limited, their sources are easy to identify compared to other greenhouse gases. Another characteristic of those gases is that they have not been regulated within domestic law in many countries and have been emitted into the atmosphere without any treatment due to their non-toxic nature. This implies that CDM projects involved with those gases would not have happened without the CDM.

Figure 3 demonstrates how much emissions of those gases are likely to be reduced in 2010 from the BAU level through the implementation of CDM projects. The gray part of each bar refers to the amount of expected emission reductions. The white part of the bar, on the other hand, shows the amount of projected emissions which will not be treated and instead emitted into atmosphere in 2010. Figure 3-(a) demonstrates that the CDM is quite successful in exploiting possible opportunities for emission reduction of those gases, reducing 38% of the BAU emissions in the non-Annex 1 countries. Among those, China, India, and Argentina attracted enough projects to reduce emissions more than 50%. In the case of N_2O, the small percentage of emission reductions from the BAU level in the graph indicates that there is still a major potential for CDM projects related to N_2O abatement in most countries.

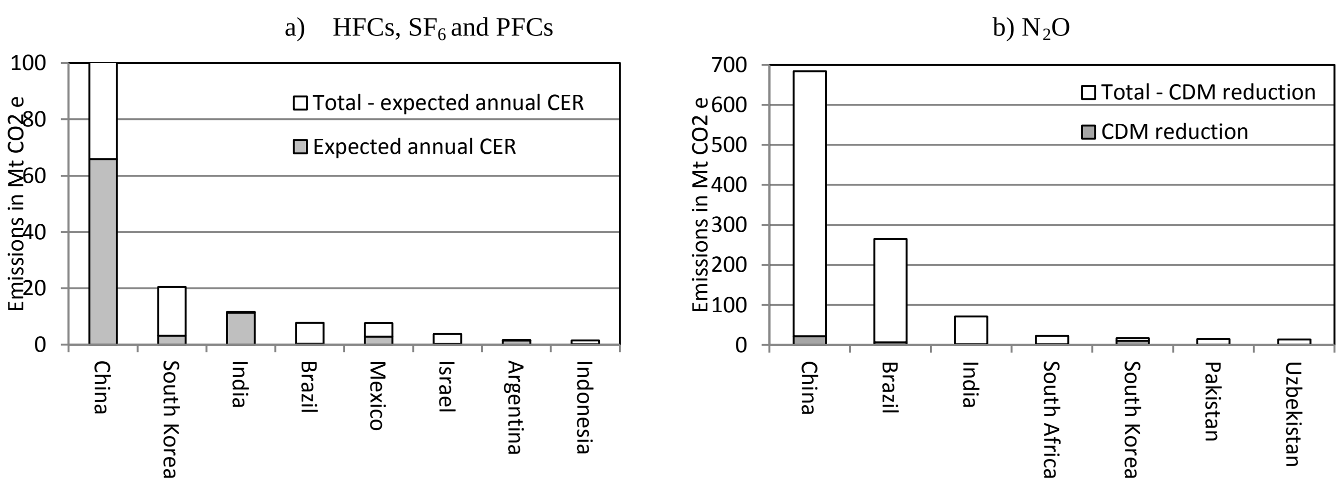

Figure 3. Projected emissions of PFC, SF_6, HFC and N_2O in 2005

Table 3. Correlation coefficients of BAU emission level and expected CERs from the CDM[13]

HFCs, SF6 and PFCs	N_2O
0.910	0.861

Correlation coefficients of the BAU emissions of industrial gases and expected CERs from the CDM in 2010 by country are provided in Table 3. The high correlation coefficients between BAU emission levels and expected CERs in the table tell how closely their numbers are related. In other words, countries with greater emissions of those gases are highly likely to have more CDM projects aimed at them. The high correlation coefficients again support the hypothesis on the positive effect of emission reduction potential on attractiveness of CDM projects.

3.2.1.2 Methane gas projects

There are four major types of projects related to reducing CH_4 gases under the CDM: landfill gas, manure, coal mining, and waste water projects. Most of the anthropogenic CH_4 is emitted through microbial activity in aerobic conditions in landfill, manure, and waste water treatment sites. In addition, CH_4 also exists naturally in various geologically complex reservoirs, such as sands, coal beds, and mines and is vented into the atmosphere during the mining process for safety purposes.

Figure 4 compares the current level of CH_4 emissions from different sources with the expected emission reduction from the CDM, while correlation coefficients in Table 4 show the degree of correlation between the level of emissions and expected CERs. Emissions

[13] The data includes countries with CDM projects of the concerned type that also have historical data of the type included in EIAs (2009). The number of countries included is 8 and 15 for HFCs, SF_6 and PFCs, and N_2O projects, respectively.

from landfill, manure, coal mining and waste water treatment sites, which are the major project types under the CDM related to CH_4 emission reduction. First, the figure as well as the positive correlation coefficients demonstrates that there is a tendency for projects to be established in a country with more emissions; however, the potential is not necessarily closely related to the number of CDM projects. Only landfill gas projects provide a high

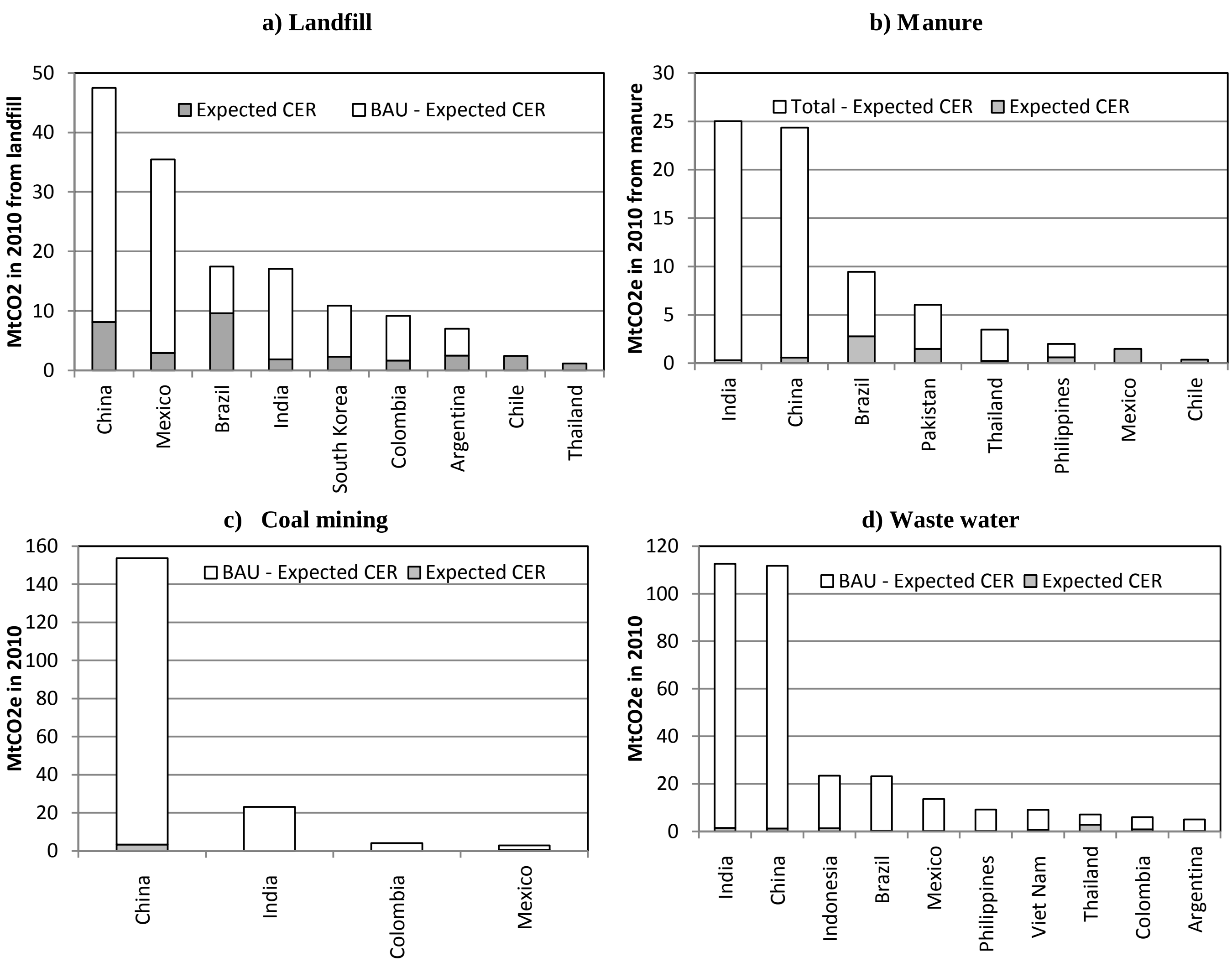

Figure 4. Projected emissions of CH_4 from various sources in 2010 (source: EPA (2006) and UNEP Riso (2009) [14])

[14] The emission reductions were calculated based on PDD information; however, we found that actualized CERs, especially from landfill gas and manure projects, are much less than the estimated amounts, which is

Table 4. Correlation coefficients of BAU CH_4 emissions and expected CERs in 2007[15]

Landfill gas	Manure	Wastewater
0.728	0.059	0.426

correlation coefficient, with the involvement of various countries. Meanwhile, the correlation coefficients of manure and waste water projects are relatively low. This implies that other factors besides the size of emissions in the country influence development of the CDM projects.

The low correlation coefficient of the manure project case is due to the large number of manure projects in Latin America where relatively small amount of CH_4 emissions are generated. While Brazil and Mexico are not the countries with the highest level of emissions from the manure sector, they have hosted 65% of the manure projects. The large number is attributable to an association with an Irish company, AgCert. The company has focused on manure projects in those two countries where it is responsible for 70% of the manure projects. The company's previous experience and familiarity with them led it to undertake a large number of CDM projects in Brazil and Mexico. Meanwhile, not many projects have been developed in China and India which are the two major emitters in the manure sector, leading to the low correlation coefficient.

Second, the expected ratios of emission reductions from the CDM to total BAU emissions vary across project types; the characteristics of a project type have great influence over the

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discussed in depth in Chapter 5. The average level of actualized CERs turns out to be 41% of the estimated amounts.

[15] Correlation coefficients of BAU CH_4 emissions and expected CER generation from the CDM in 2007 by country were calculated. For the case of coal beds, only 2 countries, China and Mexico, are involved with the CDM, which leads to the perfect correlation coefficient so it has not been included. The data includes countries with CDM projects for which there is also historical data of the type included in EIAs (2009). For all the countries included there were 33 landfill gas projects, 16 manure projects, and 17 wastewater projects.

deployment of CDM projects of that type. As shown in Figure 4, landfill gas projects significantly reduce current emissions across countries, while emission reductions from other project types do not. The high ratio of emission reductions from the BAU level for landfill gas projects are due to the relative simple technology involved and easiness to prove additionality. In most of the non-Annex I countries including China, Argentina, Malaysia, Mexico, and Brazil, both municipal solid waste and industrial waste have been regulated locally, with a focus on waste and leachate management but with not much attention paid to the generation of GHG emissions from waste treatment sites. Thus, wastes are usually dumped at landfill sites and left to decay in anaerobic conditions without proper treatment such as a cap-and-gas-capture system. This makes it easy to prove additionality criteria of landfill projects. In addition, emerging technologies for waste management are expected to stimulate more projects in the future.

3.2.2 Effect of prevalent and mature technologies

An analysis of a renewable energy projects was performed to determine the effect of the prevalence and maturity of a given technology on development of CDM projects. For each country, annual power generation is measured to indicate the prevalence and maturity of a technology in the country. This section will compare existing renewable energy power generation with the expected power generation from the CDM.

Renewable energy has not reached its full potential, mainly due to high costs. Against this backdrop, the CDM is evaluated to have increased the economic viability of those projects by enabling them to generate CERs and thus played a significant role in promoting renewable energy project activities in developing countries (Lewis, 2010). The number of CDM-affiliated renewable energy projects has been steadily increasing, accounting for 64% of current CDM project activity.

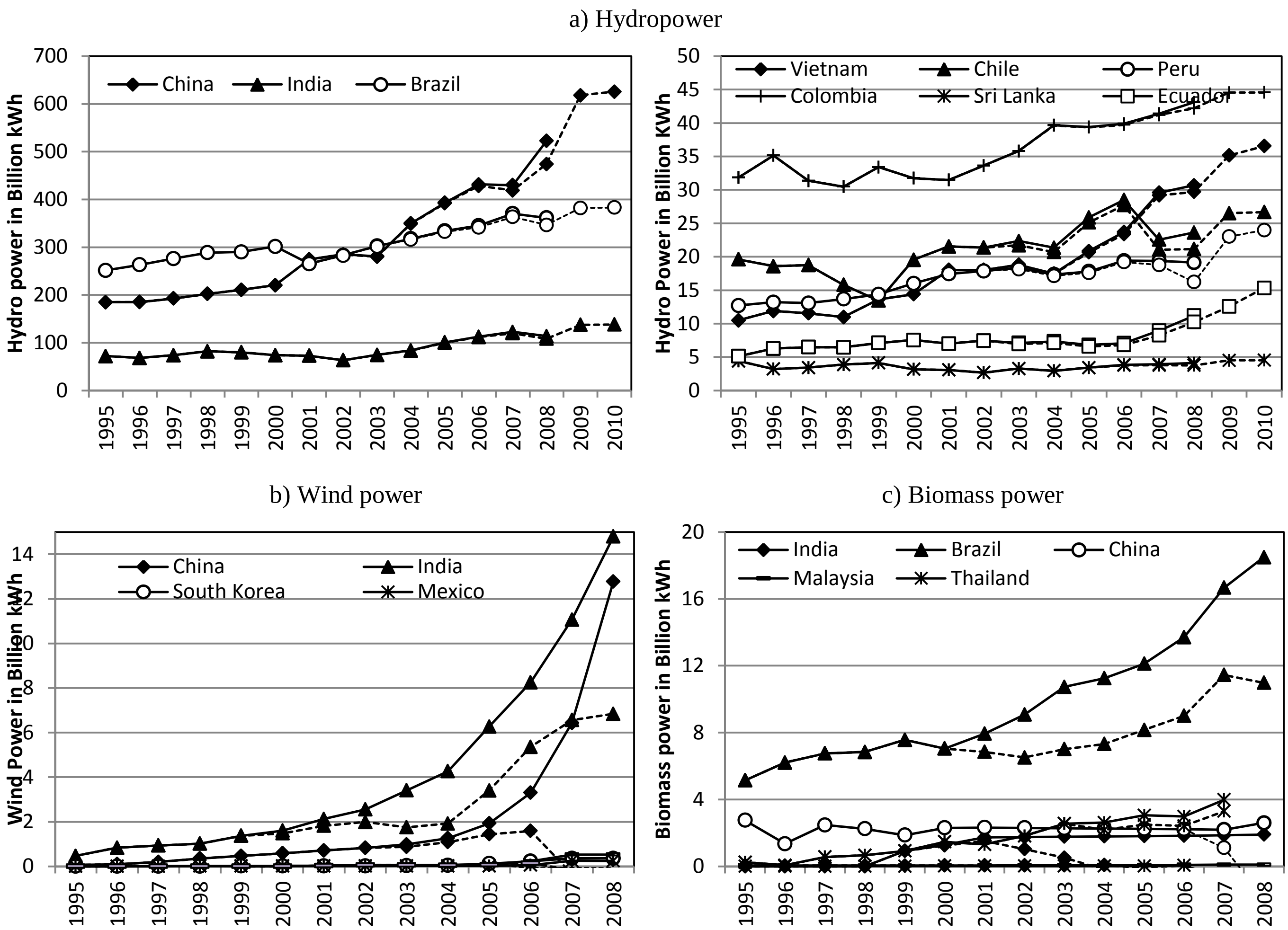

Figure 5. Renewable energy generation and contribution of the CDM

Note: A solid line for actual generation and a dotted line for actual minus expected generation from the CDM project activities (own calculation), source: EIA (2009) and UNEP Riso (2009)[16]

Figure 5 demonstrates the contribution of the CDM to renewable power generation in the major host countries. The vertical distance between the two points on the solid line and the

[16] Due to the over-estimation of power generation from CDM projects as explained in footnote 14, the value of (actual-potential CDM generation) appears to be negative in some cases.

dotted line in the graphs refers to the portion of energy generation from CDM projects[17]. Therefore, the dotted line theoretically refers to the level of energy generation without the CDM. The graph has two things to noteworthy.

First, the graph illustrates that countries with more renewable power generation of a certain type in the past tend to attract more CDM projects of the same type. Hydro power and wind power cases particularly show the very close relationship between power generation from CDM projects and the current practice.

Second, biomass power case demonstrates the role of the CDM in promoting renewable energy: the large amount of power is expected to be generated from CDM projects in India and China despite the currently low level of biomass power generation. Though India has the great potential of sugarcane cogeneration as the second largest sugarcane-producing country in the world, sugarcane use for actual power generation has been inhibited by high upfront costs, technical barriers, and poor domestic policies (Purohit and Michaelowa, 2007). However, the CDM has contributed to overcoming those barriers by helping to promote and deploy biomass power in India. Since the year 2001, when a small number of CDM projects started to generate emission reductions, we observe that the share of power generation from wind and biomass energy projects under the CDM has increased significantly[18]. Considering the large number of projects coming into the pipeline during

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[17] Points on the solid lines in the graphs refer to annual power generation from each source, while points on the dotted lines refer to annual power generation minus the aggregated amount of expected power generation from CDM projects in the pipeline. The distance between the two points on the solid and dotted lines is the aggregated amount of expected power generation from CDM.

[18] Power generation from CDM projects was calculated based on information in PDDs of projects in the pipeline. The database provides information regarding expected capacity and operating hours of the projects.

the last three years, the contribution of the CDM to the deployment of renewable energy might have been expected to be even greater after 2008. The findings by Lewis (2010) support the observation that the CDM has played a crucial role in promoting renewable energy in developing countries through CDM-driven finance, based on the analysis of financial flow and the carbon fund. However, it is hard to segregate the effect of the CDM from other domestic policies favorable to the development and deployment of all renewable energy projects[19].

Thus, we can conclude that the prevalence of a certain renewable energy practice tend to attract more CDM projects of those types; however, economic incentives through the CDM also have promoted projects of a certain type which could not be actualized due to economic viability, as shown in the biomass project case.

For projects which do not have operation hour information, the average of the aggregated projects of the type was used for estimation of power generation: hydro power - 4214.131 hr/year, wind power -2277.834 hr/yr and biomass - 5286.776 hr/year. The amount of power generation from the CDM projects might possibly be overestimated, since 1) the calculation of power generation is based on ex-ante project information that is more likely to be overestimated rather than under-estimated as we will see in Chapter 5 and 2) the estimation includes all the projects in pipeline, though some of them might not be successfully registered.

[19] Another reason for the popularity of CDM renewable power projects is recent political support for these technologies in developing countries where there is a concern for the environment and a rapid increase in energy demand. The governments of many developing countries like China have promoted the development and deployment of renewable energy through domestic policy and laws, by providing incentives such as subsidies and tax cuts, or introducing other policy measures. China formulated an energy plan to promote renewable energy since 2007, titled “Medium and Long-Term Energy Development Plan”. The plan set a specific target for the share of renewable energy in China to be 10% and 15% of the total primary energy for 2010 and 2020, respectively (National Development and Reform Commission, China; 2007). Thus, in addition to the contribution of the CDM, domestic support has lowered the technical and economic barriers to renewable energy and made renewable projects more viable.

3.2.3 Monthly inception of projects by type

This section looks at the implications of the rate of entry into the CDM pipeline of three types of project, industrial gases; renewable energy of several types; and CH_4 gases emanating from mines, landfill gas, manure, and waste water projects.

3.2.3.1 Industrial gas projects

Figure 6 shows the entry of CDM projects related to industrial gases into the pipeline each month. Unlike other project types, most of the HFC projects were developed in the early years of the CDM; no HFC project was initiated in 2009. The lack of new HFC project might imply the exhaustion of opportunities. In addition, a recent decision of the EB is considered to have contributed to the decrease by excluding projects related to HCFC-22, adipic and nitric acid that had been in operation since 2005 (Lutken and Michaelowa, 2008). Meanwhile, there exist a small number of PFC and SF_6 projects in total.

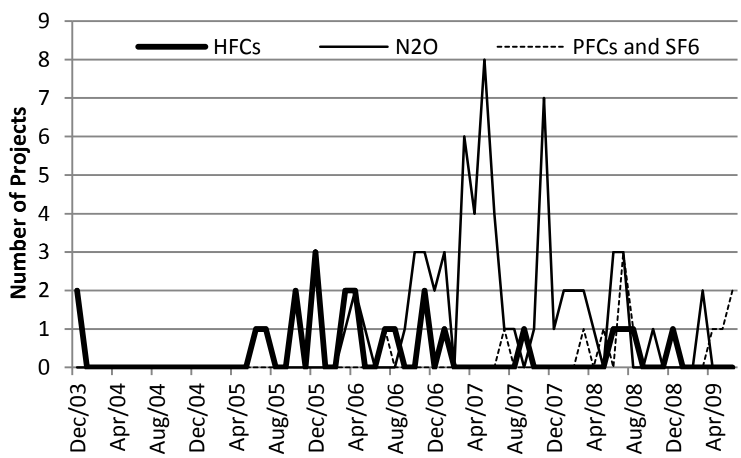

Figure 6. The number of new industrial gas projects into the pipeline each month

The first methodology related to N_2O was approved in February 2005. In 2006, three of the five current methodologies were approved. At this point, we begin to observe more projects coming into pipeline. However, since 2008, the number of new projects has been small. This seems to be partly due to the limited application of existing methodologies, as addressed in Michaelowa et al. (2009). They point out that methodologies can be used only in countries where they are available. Projects for which an approved technology is appropriate were exhausted in 2006 and 2007, which accounts for the reduced number of new projects recently.

3.2.3.2 Renewable energy projects

Figure 7 shows the entry of renewable energy projects into the pipeline each month. As the largest source of renewable energy in the world, hydro power represents almost twice as many projects as other renewable energy types. The most noticeable point about the figure is the high peaks of hydro power projects since 2007. The sudden increase in the number of hydro power projects is mostly attributable to China, accounting for 73% of those entries during the last three years. As explained before, the synergy of the CDM and domestic policy support in addition to the prevalent practice has brought about China's major success in the development of hydro power projects[20].

[20] This also applies to the case of wind power projects in China as explained in the next paragraph.

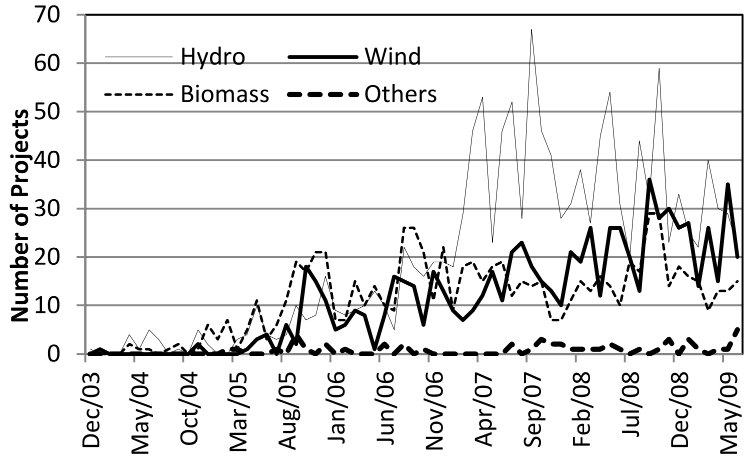

Figure 7. The number of new renewable energy projects into pipeline each month

The inflow of wind power projects has increased at a relatively steady rate over time. China, as the largest and India, as the second largest wind-power producers among developing countries dominate wind power CDM projects, accounting for 48% and 43% of the total wind CDM projects, respectively. Meanwhile, there are around 10 wind power projects in South Korea, Mexico and Brazil all together, and less than 5 projects in the other countries. In the last 2 years, China has increased its wind power generation fourfold. The 2006 total of installed capacity of 2.6 GW had increased by 2008 to 12.21 GW, a nearly fivefold increase in 2 years (REN, 2009).

The inflow of biomass CDM projects has been relatively steady over time, with an average of 190 projects each month. India accounts for 48% of total biomass projects, while Brazil and China represent 17% and 10%, respectively.

In addition to these three major types of renewable energy, a small number of solar and geothermal projects are in the pipeline. There are only 36 solar power projects in the pipeline as of now; but more projects are expected to be developed due to the recent introduction of a programme of activities (Carbon Finance, 2008). Though geothermal technology has been developed and proven in many countries, the initial construction costs are still very expensive, leading to a low number of CDM projects (Doukas, Karakosta et al. 2009).

3.2.3.3 Mines, landfill gas, manure, and waste water projects

Figure 8 shows how many mine, landfill gas, manure, and waste water projects have been submitted for validation. The first thing worthy of attention is the change in the number of manure projects over time. Unlike other project types, the majority of the manure gas projects--approximately 65%--were developed at the early stage of the CDM before 2008. 319 manure projects were submitted for validation in 2006. However, the number of projects entering into pipeline has dropped significantly since 2008. The main reason is the poor performance of the previous projects and the loss of interest by project developers. Furthermore, the poor performance resulted in the bankruptcy of one of the major PDD consulting companies, AgCert, in the field of landfill gas projects in later 2008.

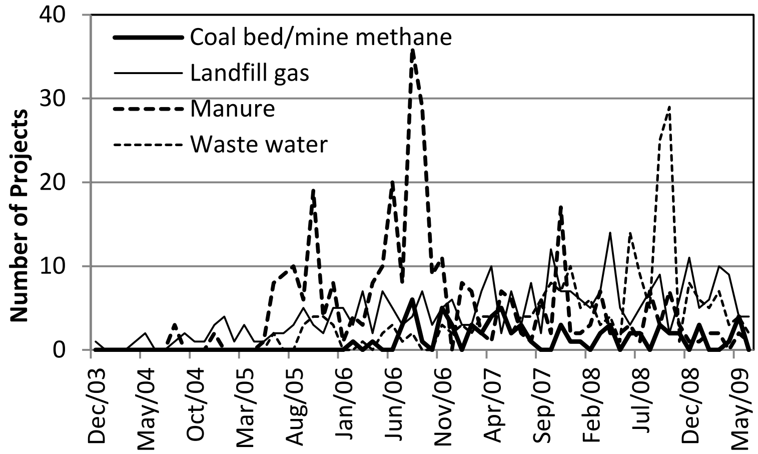

Figure 8. The number of new CH_4 reducing projects into pipeline each month

The number of incoming landfill gas projects has steadily increased over time, despite the current poor issuance success rates of earlier projects. The future of CDM landfill gas projects will be determined by the balance between their poor early performance in reducing emissions and whether the CDM can make them attractive enough to developers.

CH_4 reduction projects at waste water treatment sites suddenly increased in late 2008. Thailand, Malaysia, Indonesia, and China, in that order, are the big contributors to the increase.

Finally, as the largest coal producer and CH_4 emitter as shown in Figure 5, China has hosted 68 of the 69 coal bed/mine projects under CDM. Since the first approved methodology in November 2005, which is rather late compared to other types, approximately 20 projects have been submitted annually for validation on average since 2006. The number is expected to grow once other countries such as India begin initiating projects.

3.2.4 CDM project development by host country

This section will briefly investigate the characteristics of CDM projects and DNAs in the major CDM host countries: Brazil, China, and India.

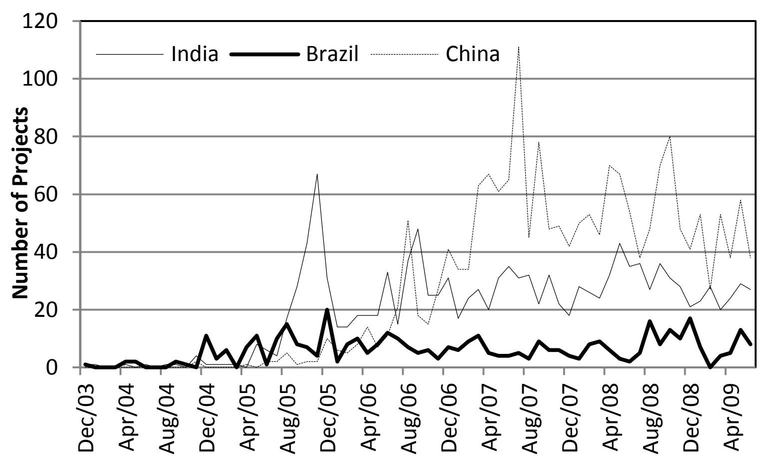

Figure 9. The number of new projects into pipeline in Brazil, China and India each month

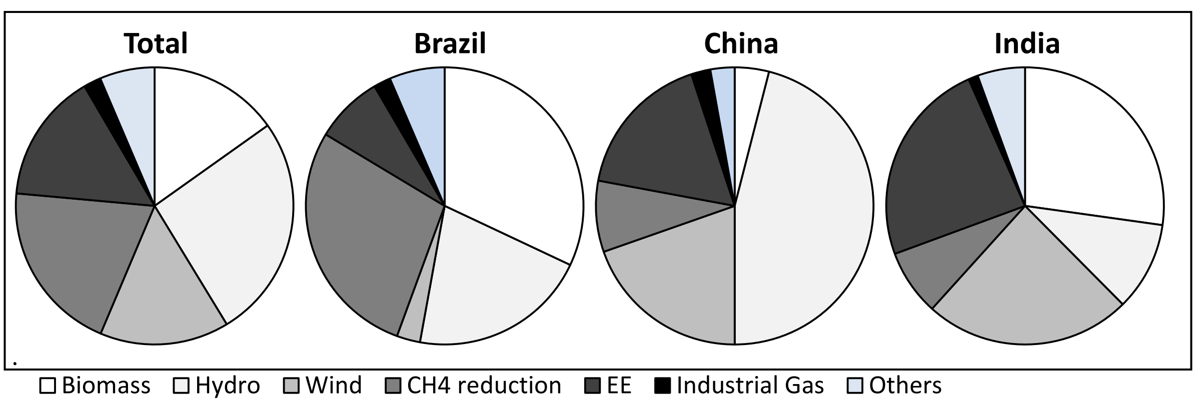

Figure 10. Project type composition by country

3.2.4.1 Brazil

Brazil was the leader of CDM project development at the early stage of the CDM; however, the lead was overtaken by China and India in 2005; Brazil now holds third place in terms of the number of projects in pipeline. Major types of CDM projects in Brazil are renewable energy and CH_4 reducing projects as shown in Figure 10. Among renewable energy projects, biomass and hydro power energy account for more than 50% of the CDM projects in Brazil.

Hydro power is traditionally a major source of energy in Brazil, accounting for 70% of total energy generation in 2007 (EIA, 2008). The large number of hydro power CDM projects is not surprising, considering the accumulated local technology and experience. For biomass energy, even though sugarcane-related biomass had been popular in Brazil before the CDM, several studies suggest that the CDM has contributed significantly to the promotion of electricity generation using biomass (Fuhr and Lederer, 2009; Friberg, 2009).

Manure treatment projects, the next most popular type in Brazil following renewable energy, had been developed as CDM projects by AgCert, an Irish company that managed development, technical operation, and necessary training (Dechezleprere, 2009).

The Brazilian DNA is unique in that its priority is not the promotion of the CDM but rather the environmental integrity of the CDM system in the country. It has five criteria for the evaluation of a CDM project: income distribution; local environmental sustainability; development of work conditions and employment generation; capacity building and technological development; and regional integration and interaction with other sectors. In addition, the processing period for approval is known to be between 4 to 6 months on average, which is somewhat longer than in other major countries such as China and India (Friberg, 2009; Fuhr and Lederer, 2009). The DNA also requires projects to be validated by

DOEs before national approval is requested. These characteristics of the Brazilian DNA seem to have discouraged the promotion of the CDM in the country. This might explain that while Brazil was actively involved with the CDM in its beginning, the number of projects seeking validation has dropped.

3.2.4.2 China

Currently, China dominates the CDM, accounting for 40% of its projects, despite having become engaged more recently than other major countries. China set up its DNA in late 2004. However, with its favorable investment environment, great emission reduction potential, and relatively advanced technology among developing countries, China soon took the lead (Jung, 2005; Friberg, 2009, Schroeder, 2009).

The fundamental position of the Chinese government towards the CDM is to take full advantage of the market system (Schroeder, 2009). Point Carbon Research (2009) points out that the Chinese DNA has a “dynamic and fairly predictable approval system.” Nevertheless, the Chinese DNA has rather strict and political rules regarding approval of projects, such as establishing price floor rates and requiring project owners to focus on three priority areas: energy efficiency improvement; renewable energy; and CH_4 recovery and renewable sectors (NCCCC, 2005; Point Carbon, 2009). In this way, the government can utilize the CDM while additional rules of the DNA enable projects to satisfy the priorities of the country. These rather strict and political rules could have discouraged investors, but considering the large number of projects developed in China, they have not. This might be due to the favorable environments for development of CDM projects in

China. However, even more projects could have been possible with more flexible rules on CDM projects.

The major types of projects in China are renewable energy projects, especially hydro and wind power projects. As explained before, the large number of renewable energy projects was the result of synergy between the CDM goals and domestic support for those projects. Another characteristic of the Chinese projects compared to India and Brazil is their large size. Except for half of the hydropower projects, most of the Chinese projects of other types are large scale.

3.2.4.3 India

India was one of the first CDM movers. The first registered project and the first approved methodology both came from India. Projects in India are mainly small-scale renewable energy projects. Currently, 36% of all small-scale CDM projects are from India. Projects favored there require low upfront investment; many of the early projects were developed by mid-sized private companies that cannot afford big investment (Gorina, 2007). The dominant renewable energy projects are biomass and wind power energy projects, accounting for 47% and 43% of the relevant CDM projects, respectively. India also promotes renewable energy through its national electricity policy; biomass/cogeneration and wind power projects are given additional financial incentives (Curnow and Hodes, 2009). The domestic policy is also thought to have played a favorable role in attracting other CDM renewable energy projects.

The Indian DNA does not have a stringent approval process and tends to favor private sectors, in promoting more CDM projects (Benecke, 2009). Its sustainability criteria for evaluating projects include social, economic, environmental, and technical well-being as well as the contribution to national development priorities set in the national five-year plan. However, the Indian authorities do not have any clear standard or guideline to assess contributions to sustainability (Castro and Benecke, 2008).

3.3 STATISTICAL ANALYSIS

Statistical analysis was performed to identify determinants of CDM project development at the country level. Currently, 75 non-Annex 1 countries have hosted CDM project activities.

3.3.1 Model specification

The most popular regression model for the analysis of count data is poisson regression models, where independent variable is count data. However, its theoretical assumption that the variance of the data is equal to the mean limits its application to many problems. When the observed sample does not satisfy the assumption, another more generalized form should be used for the analysis. In that sense, a negative binomial model is suitable for data with overdispersion, where sample mean exceeds sample variance. The basic form of the model is:

$$\text{Log}\ (Y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \sigma \bullet e$$

where Y is the observed count data, β_i is a regression coefficient, x_i is an independent variable, e is an error and σ is a standard deviation. The main difference with a poisson regression model is that the term, $\sigma \bullet e$, corrects for overdispersion.

3.3.2 Variables

The dependent variable in the model is the aggregated number of projects submitted for validation by each host country. For the choice of independent variables to explain the attractiveness of host countries to potential investors in CDM projects, we considered three perspectives based on the literature: the investment environment, institutional and technical capability, and emission reduction potentials. These are the common factors considered in the econometric analyses of host countries hospitable to the CDM by Point Carbon (2009), Jung (2009), and Larson and Breustedt (2009) among others.

Table 5. Descriptive statics

	Variable	Obs	Mean	Std.Dev	Min	Max
Dependent Variable	Number of projects	75	59.56	240.6697	1	1754
Explanatory Variables	FDI	71	6237.606	14920.04	1	108312
	GHG	74	231.4541	869.1814	0.5	7234.3
	ArCo	73	0.285836	0.140656	0.066	0.799
	DNAdays	75	1046.92	709.3741	1	2476

Therefore, the model is defined as follows

$$\text{Log(No)} = \beta_0 + \beta_1\mathbf{LogFDI} + \beta_2\mathbf{LogGHG} + \beta_3\mathbf{LogDNAdays} + \beta_4\mathbf{ArCo}.$$

Foreign Direct Investment (FDI) is a good indicator for the investment climate of a country in general and has been used as an explanatory variable to capture the effect of an investment environment in a host country in the CDM context (Ellis et al., 2007; Dechezleprere et al. 2008). High FDI inflow indicates that a country has an "enabling condition" for investment. The hypothesis is that investors would go for projects in countries with high FDI. Actually, in India, the legal provisions for CDM investment are the same as for FDI (Benecke, 2009). **LogFDI** refers to a logarithm of the total inflow of FDI in millions of 2008 US dollars. The FID information was collected from the UNCTAD website (2009).

Greenhouse gas emissions are closely related to CDM potential as discussed above. The annual CO_2 emission has been the poplar measure for that purpose. However, since the CDM scheme includes all greenhouse gases and 40% of the expected CERs are associated with non-CO_2 greenhouse gases, the aggregated amount of the all greenhouse gases is a more appropriate and precise measure (Jung, 2007). **LogGHG** is a logarithm of total aggregated greenhouse gas emissions in 2005 in Mt CO2 eq. The emission data is gathered using the Climate Analysis Indicators Tool (WRI, 2008).

The CDM-relevant institutional conditions should be evaluated based on the performance of a DOE such as the time it takes to issue a LoA; transparency and clarity of its rules; and general awareness and participation of stakeholders. However, those aspects are hard to measure and quantify. Therefore, we use the length of a country's DNA operation as an indirect way to measure the proficiency of the DNAs, hypothesizing that early setup of DNAs means better capacity and specialty[21]. **LogDNAdays** is a log of the number of days that the DNA has been operating.

The technical enabling conditions in a country are also an important factor in hosting more CDM projects. Since the EB clarified that unilateral projects are acceptable for CDM participation, many have been developed by domestic companies. Furthermore, empirical

[21] Due to the unavailability of DNA setup dates, we used the date of the first LoA issuance as the date of DNA establishment.

studies have pointed out that only about 40% of all CDM projects is associated with technology transfer from other countries (Dechezleprere et al., 2008; Seres et al., 2009). This suggests that local availability of technology would stimulate the development of CDM projects. As a proxy for technological capabilities, we use the ArCo technology index developed by Archibugi and Coco (2004). The index considers three aspects related to technological capabilities: the creation of technology, the technological infrastructures, and the development of human skills. Its value is between 0 and 1.

3.3.3 Results

The negative binomial regression models the logarithm of the expected number of projects as a function of explanatory variables. Therefore, the coefficient is the changes in the logarithms of the number of projects in response to a unit change in the explanatory variable, with other variables held constant. The result of the model is shown in Table 7.

First, the significance of the coefficient of alpha assures us that a negative binomial regression model is more appropriate for the analysis than a poisson regression model. As explained before, this is because of existence of overdispersion in the data.

Table 6. The result of the econometric analysis

Explanatory Variable	**Coefficient**		
logGHG	0.589374*	Likelihood Ratio (LR) Chi-Square	148.88
ArCo	-0.02453	Pseudo R^2	0.2370
logFDI	0.152012**	alpha	0.534836*
DNAdays	0.001071*		
_cons	-2.1569*		

Note: Indications of significance levels (Prob > |Z|) are: *= probability of 0.05, **= probability of 0.1

Second, the results show that technological capability is not statistically significant in promoting the CDM in a given country. The coefficients of the other variables are confirmed to be statistically significant and show the expected signs. The investment environment measured by the amount of FDI inflow; emission reduction potential; and the institutional setup measured by the length of days after the first issuance of a LoA all promote CDM projects in the country.

The positive sign of **logGHG** indicates that countries with more emissions are likely to host more projects. A unit change in the logarithm of greenhouse gas emissions will attract 1.8 times CDM projects in the country, with other conditions held the same. Having more FDI also promotes the CDM in the country. Here, the level of FDI is closed related to investment environments in the host country. The high level of FDI inflow refers to "stable political regimes, strong legal environments for contracts and proven enforcement capabilities, macro-economic stability, availability of pools of skilled workers, institutional capacities and other sources of human capital" (Ellis et al., 2007). The size of the coefficient means that a country with 2.7 times FDI has 1.16 times the number of CDM projects.

Third, the empirical evidence indicates that the longer the DNA has been in operation, the more projects the country attracts. A country with a DNA established a month or a year earlier increases the number of projects it hosts by 3% and 50%, respectively, when other variables are held constant.

Meanwhile, the insignificant coefficient of the ArCo indicator seems to contradict our initial expectations. We initially assumed that technical enabling environments are important in promotion of the CDM. Previous research showed that many of the CDM projects have been implemented without technology transfer but based on domestic technology. In addition, the analysis of renewable energy also indicated that countries with previous experience host more projects of the type in general. The contradiction seems to be due to the fact that ArCo might not be a true indicator for environmentally friendly technology. The CDM projects are especially related to specific technology, environmentally benign or reparative technologies.

3.4 CONCLUSIONS AND DISCUSSION

We have described the inflow of CDM projects into the pipeline by project type and country based on the data from 5089 CDM projects that had been submitted for validation as of July 2009. The descriptive study as well as the econometric analysis identified factors influential in promoting the CDM and revealed the following interesting points.

First, we found that *emission reduction potential is closely related to the development of CDM projects* as shown for industrial and methane gas projects in general with high correlation coefficients between the current level of emissions and expected CERs across the countries. However, the degree of the correlation between them varies across project types; manure and wastewater projects show relatively low correlation coefficients between emission reduction potential and expected CERs.

Second, the *ratios of the expected emissions reduction to the total level of current emission vary across types*. The expected emission reductions of HFCs, $SF_{6,}$ and PFC projects reached approximately 40% of the current emission level, because of their high economic returns and relative ease in meeting CDM criteria. Landfill gas projects are also expected to reduce emissions significantly across countries. The different levels of emission reduction ratios are attributable to the characteristics of the project type, as discussed in the previous section.

Third, analysis of renewable energy projects shows that *the prevalent practice of a certain renewable energy project type in the country attracts more projects like them; however, the CDM also actualized projects of not-so-popular type which were not economically viable.* This indicates that the economic viability and maturity of technologies in that country encourage introduction of more CDM projects of the type.

Fourth, *the econometric analysis highlights the importance of emission reduction potential, favorable investment environment, and experience of the DNA in promoting the CDM*. The econometric result also agrees with the result from the descriptive study in the early sections. This suggests that countries with more emissions, favorable investment environment and experience of the DNA tend to attract more CDM projects. The finding can be thought to be connected with the current unequal distribution of CDM projects across countries. According to the finding, countries with enabling environments such as large emission reduction potential, favorable investment environments and skilled DNA would attract more projects in the future. Given the current unequal distribution, the number of projects in the current major host countries will continue to grow and the concentration of CDM projects in certain countries could get worse. Therefore, there should be extra policy support system for the least developed countries that do not have financial, technical and administrative capacity under the CDM, in order to promote CDM projects in those countries in the future.

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4 REGISTRATION SUCCESS

The objective of this study is to identify and investigate determinants of registration success and investigate ways to improve not only the quality of CDM projects but also the efficiency of the system for stakeholders including project developers and the CDM authorities. Following the analysis, four recommendations based on the most significant conclusions are suggested.

4.1 BACKGROUND

Since the CDM entered into force in 2005, the number of CDM projects has increased rapidly. As of July 2009, 1693 projects were registered as CDM projects and three times as many projects are either at the validation stage or in the process of registration (UNEP Riso, 2009).

However, with the increase in the number of incoming projects, the number of rejected and withdrawn projects also has increased, leading to a rejection rate of 12%. High rejection rates can drive away potential project developers unwilling to take a substantial investment risk. In addition, the large number of rejected projects suggests that the CDM attracts many unwanted (i.e. ineligible) projects. These projects exacerbate congestion in the pipeline, lengthening the lead time for all.

4.1.1 Projects rejected or withdrawn

For this chapter, an analysis of the registered and rejected projects as of 1 July 2009[22] was conducted; 1693 projects had been registered, while 620 projects failed to be validated. Currently, projects fail to get validated through one of the following paths: withdrawn by project participants; rejected by the EB; validation terminated; and validation negative as shown in Table 9 (UNEP Riso, 2009). Details of these categories include:

> *Withdrawn:* Project participants decide to withdraw before or after registration.
>
> *Rejected by the EB:* Following validation by a DOE, the EB finds that the validation is not proper and rejects the project[23].
>
> *Validation terminated:* Validation contracts between project participants and DOEs are terminated[24].

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[22] Out of the total 5081 projects in the pipeline, including rejected and withdrawn ones, projects at the validation stage are excluded from the analysis. Because those projects have not been validated by DOEs, final decisions have not yet made regarding registration. Only those that have already been either already registered or rejected/withdrawn, were considered for the analysis. There were 2768 projects at this stage as of July 1 2009.

[23] The EB has a right to accept or reject a project validated by a DOE. At a later meeting regarding the scope of the EB, a decision can made to give the EB the option to register a project "with correction" (Annex II to decision 18/CP.9, para 18 (b)). This option gives the EB more power in evaluating projects. Actually, the number of projects for which corrections are requested has increased with setting up the Registration and Issuance Team (RIT) (DEFRA, 2008).

[24] The reasons for the termination are not disclosed to the public; however, the DOE must submit the reasons to the EB. According to a DOE expert, Robert Dornau (2008), the major reason for validation termination by the project developer/client is that the DOE indicated that the final validation opinion would be negative. Upon receipt of the initial evaluation, the client terminates the contract at an early stage and the DOE is not paid.

Validation negative: A DOE determines that a proposed project is CDM ineligible. If the project participants are still interested in participating in the CDM, they may revise the PDDs, modifying them to make the projects suitable for the CDM criteria.

Table 7. The number of rejected or withdrawn projects (UNEP 2009)

Status of projects	**Number of projects and reasons for the failure**	
Rejected/withdrawn	622	30 (Withdrawn) 112 (Rejected by the EB) 361 (Validation terminated) 119 (Validation negative)

In this study, projects which have been withdrawn and validation-terminated and received negative validation are also treated the same as projects rejected by the EB, since those projects also are not potentially qualified for the next phase, "requesting for registration."

4.1.2 Motivation

The failure of a project to receive CDM registration and validation is of concern to both developers and CDM authorities.

The development of CDM projects is more complicated and risky than for regular projects. To receive CDM validation, a project requires more transaction time and costs to project developers as well as investors due to the following characteristics of the CDM. First of all, the features of the proposed project must meet the requirements of the CDM. Second, the project plan must pass through the complex cycle of CDM project development. To minimize losses of money and time, a developer must make a thorough and systematic analysis of potential project risks before beginning work on a PDD.

Therefore, the analysis of registration success in this chapter will help project developers recognize the potential risks of projects of different types and in different host countries at the initial stage of project development. They will be able to make better decisions, based on the available data at the time of project design. Calculation of the probability of being registered will provide an approximate estimate of registration success; accordingly, they can then decide whether to undertake the project (with or without revising plans) or not.

Meanwhile, the high number of rejected and withdrawn projects means that the CDM is attracting too many ineligible projects. Those projects exacerbate congestion in the pipeline, making the waiting time for validation and verification longer. It would help CDM authorities increase the efficiency of the system to know what factors increased the rejection rate, and try to eliminate or ease them. The analysis in this chapter will help them identify those factors and suggest useful recommendations for improvement.

4.2 MODEL SPECIFICATION

4.2.1 Logit model

A logit model was constructed to investigate a relationship between registration success and project characteristic factors. Ordinary linear regression is not suitable for this type of analysis since we have a dichotomous dependent variable[25]: the dependent variable takes a value of 1 if a project was successfully registered or a value of 0 if a project failed to get

[25] There are two reasons for introducing a logit model for the case of dichotomous dependent variable: First, the predicted value from the linear regression model can be beyond 1 or below 0, whereas the binomial dependent variables are usually 1 and 0. Second, the linear regression model would not satisfy its homoskedasitic assumption with which the variance of errors need to be constant Kohler, U. and F. Kreuter (2005). Data Analysis Using Stata. Texas, Stata Press.

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registered through rejection by either a DOE or the EB. The logit model analyzes whether projects are more or less likely to be registered under different conditions[26]. The general form of the model is

$$\ln\left(\frac{p(Y=1)}{1-\left(p(Y=1)\right)}\right) = \alpha + \sum \beta_i X_i + \varepsilon$$

where, p(Y=1) is the probability of being registered and X is a set of explanatory variables described in the next sections.

4.2.2 Description of explanatory variables

Explanatory variables were chosen based on the literature review, considering their contribution to rejections as well as data availability. The variables fall into three categories: 1) project type related; 2) host country related; and 3) DOE related. The following sections include detailed descriptions of each explanatory variable as well as the rationales for choosing them.

4.2.2.1 Project-type related variables

Project type dummy variable. The characteristics of project types are known to be one of the influential factors on registration success (Mayr and Michealowa, 2008). Among rejected or withdrawn projects, only projects rejected by the EB at the final validation stage, 18% of the total rejected projects, disclose the reasons for the rejection, which are

[26] Two models are generally used for dichotomous dependent variables: logit and probit model. The major difference between them is that they include a different assumption of the variance of errors: those differences are reflected in the coefficients of independent variables. Therefore, predicted probabilities using both models provide very similar results. See Long, J. S. and J. Freese (2003). Regression Models for Categorical Dependent Variables Using Stata. Texas, Stata Press.

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summarized in the IGES CDM Review and Rejected Project Database (2009). The investigation of the reasons in the report supports the hypothesis of the effect of project type on registration success likelihood. According to this database, about 60% of the rejected projects misused baseline and monitoring methodologies; 35% failed to demonstrate additonality of emission reductions.

The two main reasons for the rejection, use of the approved methodologies and demonstration of additionality, are all closely related to the type of projects. First, the ease of applying a methodology differs across project types. Second, some GHGs are more difficult to measure and monitor than others (US EPA, 2006). Third, demonstration of additionality for certain gases is much easier than for others (Wara and Victor, 2007). Therefore, the choice of project type is highly likely to influence a chance of registration.

To evaluate the effects of project types on rejection rates, eight project-type dummies are included in the model[27]: **type_1** (hydropower projects), **type_2** (energy efficiency projects), **type_3** (wind and other renewable projects), **type_4** (CH_4 reducing projects), **type_5** (fuel switch projects), **type_6** (biomass projects), **type_7** (industrial gas projects), and **type_8** (CH_4 avoidance projects).

Table 9 shows the descriptive statistics of the registered and rejected projects by project type. The ratios of registered projects to the total vary across project types. In particular, EE projects and fuel switch projects have relatively high rejection rates, while all the industrial

[27] UNEP Riso (2009) lists 26 project types. Of these, 12—almost half—include fewer than 10 projects. For the simplicity and efficiency of the regression analysis, we aggregated some of the project types with similar characteristics and categorized them into eight types.

gas projects except one were successfully registered—a 99% of a registration success rate. The different registration rates by type strongly support the hypothesis that project type influences successful registration.

Table 8. The number of registered and rejected projects by type

Type	**Registered**	**Rejected**	**Total**
Type_1 Hydro	438 (79.06)	116 (20.94)	554 (100.00)
Type_2 EE	196 (61.64)	122 (38.26)	318 (100.00)
Type_3 Wind & other renewable	262 (82.39)	56 (17.61)	318 (100.000
Type_4 Other CH_4	169 (75.45)	55 (24.55)	224 (100.00)
Type_5 Fuel Switch	44 (55.00)	36 (45.00)	80 (100.00)
Type_6 Biomass	255 (67.11)	125 (32.89)	380 (100.00)
Type_7 Industrial Gas	78 (98.73)	1 (1.27)	79 (100.00)
Type_8 CH_4 avoidance	251 (69.72)	109 (30.28)	360 (100.00)
Total	1693 (73.16)	620 (26.81)	2313 (100.00)

Note: The numbers given in parenthesis represent percentage.

The number of approved methodologies. The increase in the number of the approved methodologies implies an expansion of the range of their applicability in general. The large number of the available methodologies also provides more options for the choice of "proper" methodologies to project participants. Thus, we can hypothesize that the increased number of available methodologies would lead to a reduction in the number of the cases where baseline and monitoring methodologies are misused, lowering the rejection rates.

To test this hypothesis, the number of the available methodologies at the time of validation is considered in the model as an explanatory variable[28]. When we count the number of the methodologies, we also include those that have been replaced or are no longer in use[29].

Figure 11 illustrates the changes in the accumulated number of approved methodologies over time. In the years of the CDM, the number of available methodologies was small but increased at a fast rate, reaching 124 methodologies as of July 1, 2009. The logit analysis will reveal how adding one more methodology affected a project's chance of being registered.

[28] There are three types of methodologies according to the size and scope of projects: large-scale; consolidated; and small-scale methodologies. Each type of methodology has a different scope and applicability depending on the nature of technology and country. The consolidated ones such as ACM2 have broader applicability, while others have very narrow scope with specific condition requirements such as AM26. This means that the addition of ACM2 has had a much greater influence on the system than that of AM26. However, for the sake of simplicity, the effect of each methodology is assumed to be the same in the analysis.

[29] Some of the approved methodologies in the earlier stage of the CDM were later combined and replaced by consolidated methodologies. For example, four of the previously approved methodologies were later replaced by one consolidated methodology, ACM1, and the four became unavailable. This means that the available number of methodologies actually rather reduced by three in total, which is not in accordance with our hypothesis on the effects of the number of the methodologies. In order to avoid this problem, once a methodology was approved, it was counted in the total number of available methodologies even after it became unavailable.

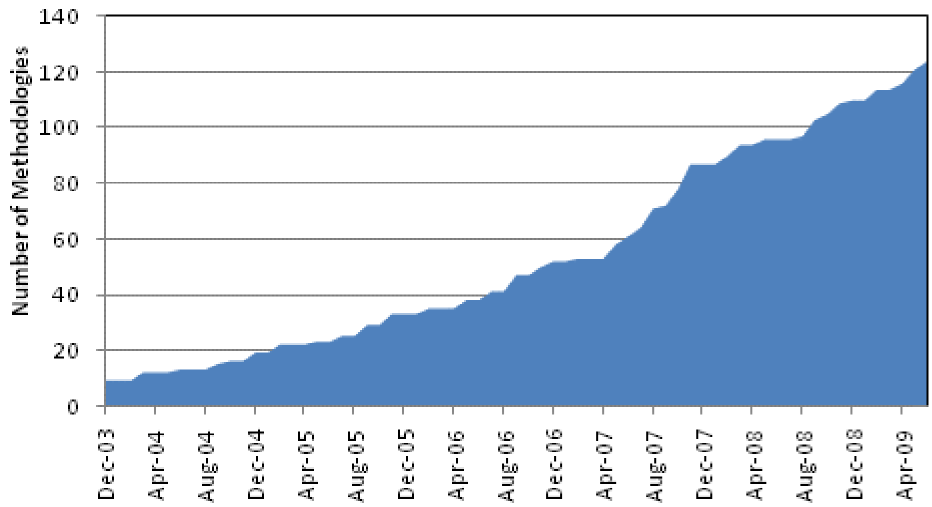

Figure 11. Accumulated number of methodologies over time (UNEP Riso, 2009)

4.2.2.2 Host country-related variables

Country dummy variables. Many researchers have found that the characteristics of host countries influence the success of CDM projects. Some countries have been more successful than others in developing and implementing CDM projects. There are several possible explanations of how host countries influence the chance of registration. Characteristics of host countries are expected to strongly affect the rejection rates of proposed CDM projects from the following three perspectives.

Acquiring a Letter of Acceptance

During the process of validation, a Letter of Acceptance (LOA) should accompany the application. However, because there are no standardized guidelines among countries for evaluating the sustainability of a proposed project, each country must develop its own criteria (Curnow and Hodes, 2009). Projects that would qualify for a Letter of Acceptance in one country might not qualify in other countries. Failure to obtain a LOA from a government means that proposed projects cannot be validated and registered even though they are eligible for the CDM.

The data shows that 480 out of the total 620 withdrawn or rejected projects, 77% of the projects, did not have LOAs. According to CDM procedure, a LOA needs to be ready only by the final review by the EB. Some projects proponents might not even try to get a LOA once they have received a negative review from a DOE. Therefore, it is not clear how many projects actually failed to get registered due to the failure to get a LOA. But there must be relationship between registration and getting LOAs.

Availability of applicable methodologies and easiness of demonstrating additionality.

The applicability of approved methodologies and the level of difficulty in demonstrating additionality also vary among countries due to different domestic legislation and geological and environmental conditions.

Various local regulations

Each country has different rules and regulations for project operations and construction. Some countries might require project participants to have an appropriate operation and construction permit (UNEP-DNV, 2008).

Currently, 65 non-Annex 1 countries have either registered or rejected CDM projects. Considering the number of projects from each country, 5 country dummies are generated: **country_1** (Brazil); **country_2** (China); **country_3** (India); **country_4** (Mexico); and

country_5 (Others). Countries other than Brazil, China, India and Mexico were categorized under **country_5**, which accounts for 24% of the total projects.

The number of registered and rejected projects by country in Table 10 shows that China has an outstanding registration success rate, higher by 9% than others. Performance in India and Mexico is much lower than the average of other countries by 7%. The country dummies will capture general effects of being in the country on registration.

Table 9. The number of registered and rejected projects by country

Country	**Registered**	**Rejected**	**Total**
Brazil	159 (73.61)	57 (26.39)	216 (100.00)
China	578 (82.10)	126 (17.90)	704 (100.00)
India	436 (66.06)	224 (33.94)	660 (100.000
Mexico	115 (66.09)	59 (33.91)	174 (100.00)
Others	405 (72.45)	154 (27.55)	559 (100.00)
Total	1693 (73.16)	620 (26.81)	2313 (100.00)

Note: The numbers given in parenthesis represent percentage.

<u>CDM Experience in the host country.</u> In order to segregate the effect of CDM-related learning in a host country, the accumulated number of projects hosted in the country at the time of validation, **CounEx**, is included as an explanatory variable. The hypothesis is that countries with more experience with CDM projects would have a better CDM-relevant institutional setup and administrative capacity as well as generally favorable economic and

social environments. For these reasons, countries with a large number of CDM projects should have lower rejection rates.

CounPEx, the total number of projects of the same type in the country at the time of validation, is also introduced into the model. As discussed in the previous section, technical characteristics are the one of the key factors improving a project's success in gaining registration and even in performance at the later stage of the CDM. Therefore, countries with more experience in the specific project types may be expected to have more advanced or better technology or better environments for the type of project under consideration, with a lower rejection rate (Dechezleprere et al., 2008).

Table 11 provides the statistical summary of the two variables for registered and rejected projects, respectively. The average level of experience for rejected projects is higher than registered projects. The analysis will enable us to explore whether learning effects gained through greater national experience increases registration rates.

Table 10. The summary of experience of host countries measured in the number of projects

CounEx	Mean	S.D.	Min	Max
Registered Projects	240.8	270.7	0	1326
Rejected Projects	326.8	320.6	0	1524
Total	263.8	287.4	0	1524
CounPEx	Mean	S.D.	Min	Max
Registered Projects	60.1	93.1	0	644
Rejected Projects	85.4	120.0	0	730
Total	66.9	101.6	0	730

Use of specialized PDD consultants. A well-written PDD is very important because the PDD is the only source of information used for validation (Mayr and Michealowa, 2008; Wang, In press). Therefore, the accurate and proper construction of PDDs is critical to increasing a project's chances of achieving verification. As CDM has become popular over time, PDDs have been written not only project participants themselves but also by specialized PDD consultants.

For the study, we hypothesize that PDDs written by more experienced consultants would have higher registration rates. To explore the effect of using experienced PDD consultants, a variable of **PDDCon** has been generated and included in the model. This variable represents the accumulated number of projects a PDD consultant worked on in the prior to the proposed project. Table 12 shows the average level of experience, expressed in the number of projects a consultant has worked. The results indicate that more experience does not always guarantee a higher registration rate, contrary to the original hypothesis.

Table 11. Summary of the use of specialized PDD consultants measured in the number of projects

	Mean	S.D.	Min	Max	Total
Registered Projects	17.1	35.8	0	254	1693
Rejected Projects	23.2	37.9	0	267	620
Total	18.7	36.5	0	267	2313

4.2.2.3 DOE-related variables

DOE dummy variable. DOEs are the accredited entities that recommend project validation to the EB. They validate the projects in accordance with procedures and modalities of the

CDM. Theoretically, the choice of a DOE should not affect registration rates; the average registration rates should be similar among all the DOEs.

However, lack of detailed guidelines for validation and the complexity of the CDM may make performance and competence inconsistent. In this analysis, DOE dummy variables are included to investigate whether choice of DOE actually has an effect on registration rates. Currently, three major DOEs dominate the system, accounting for almost 80% of the validation cases of all registered and rejected projects. Considering the relative contribution, 4 dummy variables related to DOEs were created: **doe_1** (DOE A); **doe_2 (**DOE B); **doe_3** (DOE C) and **doe_d4** (all DOEs other than the first three)[30].

Table 13 indicates that contrary to this hypothesis, the choice of DOEs might have an effect on registration rates. Projects validated by DOEs other than the major three have a much lower registration rate--15%. The analysis will reveal whether the influence is statistically significant.

Table 12. The number of registered and rejected projects by each DOE

DOE	**Registered**	**Rejected**	**Total**
DOE A **(doe_d1)**	757 (75.93)	240 (24.07)	997 (100.00)
DOE B **(doe_d2)**	422 (76.73)	128 (23.27)	550 (100.00)
DOE C **(doe_d3)**	220 (76.66)	67 (23.34)	287 (100.000
Others (**doe_d4**)	294 (61.38)	185 (38.62)	479 (100.00)
Total	1693 (73.19)	620 (26.81)	2313 (100.00)

Note: The numbers given in parenthesis represent percentage.

[30] Since the purpose of this study is to show the influence of DOEs on registration but not to condemn any particular DOE, we do not reveal their actual name in the article.

DOE experience. In addition to the DOE dummies, DOE experience in validating projects is also considered in the analysis. Similar to the way we created the experience-related variables, **CounEx** and **CounPEx**, we have constructed the two variables, **DOEEx** and **DOEPEx**, are included in the analysis. **DOEEx** refers to the number of the projects the DOE validated prior to the proposed project. **DOEPEx** represents the number of projects of the type of the proposed project validated by the DOE in the past. Therefore, **DOEEx** is associated with general experience with the CDM projects; and **DOEPEx** is related to specialized experience with the particular CDM project types.

4.2.3 Summary of the variables in the model

Table 14 provides the list of names of all the variables with a short description which will be used in the remaining of this chapter.

Table 13. The name and description of variables in the model

Variable	Description
Status_d	dependent variable with 1 for registered projects and 0 for rejected/withdrawn projects
type_1 **type_2** **type_3** **type_4** **type_5** **type_6** **type_7** **type_8**	dummy variable for hydropower projects dummy variable for energy efficiency projects dummy variable for wind and other renewable projects dummy variable for CH4 reducing projects dummy variable for fuel switch projects dummy variable for biomass projects dummy variable for industrial gas projects dummy variable for CH4 avoidance projects
Meth	number of the approved methodologies at the time of validation of the project
Country_1 **Country_2** **Country_3** **Country_** **Country_5**	dummy variable for Brazil dummy variable for China dummy variable for India dummy variable for Brazil dummy variable for other countries
CounEx	number of the accumulated CDM projects in the host country at the time of validation of the project
CounPEx	number of the accumulated CDM projects with the same project type at the time of validation of the project
PDDCon	number of the accumulated CDM projects by the PDD consultant at the time of validation of the project
Doe_1 **Doe_2** **Doe_3** **Doe_4**	dummy variable for DNV dummy variable for TUV-SUD dummy variable for SGS dummy variable for other DOEs
DOEEx	number of the accumulated CDM projects validated by the DOE at the time of validation of the project
DOEPEx	number of the accumulated CDM projects with the same project type validated by the DOE at the time of validation of the project

4.3 RESULTS

The analysis was conducted using the statistics software Stata Version 10.0. Stepwise logit regression was chosen for the selection of explanatory variables, with a significance level of 0.1[31]. The reference case in the model is a hydropower project (**type_1**) in Brazil (**country_1**) validated by DOE A (**doe_1**)[32].

[31] Annex C provides another way to select appropriate variables - sequential model building approach – besides stepwise selection described in this section. The sequential model building approach is to construct

4.3.1 Analysis results

The result is presented in Table 15. The effect of each variable can be interpreted through the magnitude and the sign of the coefficients as well as odds ratios. The coefficients in the logistic model are interpreted in the same way as in the linear regression model: the coefficients demonstrate how the dependent variable changes according to a unit-change in the explanatory variables. The only difference in the interpretation is that the change in P(Y=1) is not linear for changes in the explanatory variables in the logit model since the dependent variable is the logarithm of the odds.

In addition to the coefficients in the logit model, effects of explanatory variables can be also interpreted using odds ratios. Odds ratios can be calculated by exponentiation of the coefficients in the logit model. Generally, odds ratios are preferred for the analysis of a logit model due to the ease of interpretation (Menard, 2009). An odds ratio greater than 1 implies that a unit-change in an explanatory variable increases a chance of being registered, with all other variables held constant; on the other hand, an odd ratio smaller than 1 indicates that a unit-change in an explanatory variable decreases the chance. However, in general, we pay more attention to the sign of the coefficients than their magnitudes in the analysis of logit models. The next section briefly discusses the effects of each variable on registration.

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models with different sets of explanatory variables and compare their statistical significance and performances. We found that the results between the two approaches are not significantly different.

[32] When a categorical data is coded as a dummy variable, one of the dummy variables is automatically dropped to avoid collinearity. In our model, we have three kinds of categorical variables - project-type, country-, and DOE-related ones; therefore, three dummy variables, namely type_1, country_1, and doe_1, were excluded from the model.

Table 14. Results from the stepwise regression

	Variables	Coefficients	Standard Errors	Z	P>|z|	Odds Ratio
Results	**type_ 2**	-0.66771	0.161298	-4.14	0	0.512880
	type_3	0.50191	0.179443	2.8	0.005	1.651886
	CounPEx	-0.00318	0.000716	-4.44	0	0.996827
	type_5	-0.93261	0.262573	-3.55	0	0.393526
	type_6	-0.39747	0.151892	-2.62	0.009	0.672018
	type_7	3.61611	1.033226	3.5	0	37.19273
	doe_g4	-0.96103	0.162451	-5.92	0	0.382497
	country_2	1.29668	0.160103	8.1	0	3.657144
	Meth	-0.01409	0.003736	-3.77	0	0.986008
	country_4	-0.66463	0.196104	-3.39	0.001	0.514465
	PDDCon	-0.00268	0.001436	-1.87	0.062	0.997319
	DOEPEx	0.00521	0.001522	3.43	0.001	1.005232
	DOEEx	-0.00161	0.000303	-5.31	0	0.998390
	_cons	2.37618	0.177101	13.42	0	
Association/ Predictive efficiency	Gm	349.66				
	Psuedo R^2	0.1300				
	% Correctly classified	75.70%				
Fit statistics	D	2339.476				
	AIC	1.024				
	BIC'	-15469.269				

The effects of project type-related variables. The results showed that several variables from the full model could be eliminated due to their insignificant effects on the chance of registration: Dropping **type_4** (CH_4 reduction) and **type_8** (CH_4 avoidance) among project type-related variables does not significantly change a project's chance of being registered compared to the reference case. In other words, dropping **type_4** and **type_8** demonstrates that being either of these types of project does not significantly change chances of being registered any more than would being a hydropower project, if all other conditions remain constant.

The sign of the coefficients and odds ratios show that wind projects (**type_3**) and industrial gas projects (**type_7**) are much more likely to be registered than the hydropower projects in the reference case, while energy efficiency projects (**type_2**), fossil fuel switch projects (**type_5**), and biomass projects (**type_6**) are less likely to be registered. In fact, the odds of registration are 37 times greater for industrial gas projects than for hydropower projects. The odds of registration for fossil fuel switch projects are only 39% of those of the hydropower case.

PDDCon (PDD consultant experience) appears to be statistically insignificant at the $p<0.5$ level. This implies that a consultant's experience and familiarity with CDM projects does not increase the chance of registration.

The coefficient of **Meth** (number of approved methodologies) indicates that the estimated logarithmic chance of being registered will actually fall by 0.01 when one more methodology become available, holding other variables constant. In other words, adding one more methodology reduces the odds of registration by 2%. The adverse effect of proliferating methodologies conflicts with the initial hypothesis that an increase in the number of methodologies would improve the chance of registration. This contradiction suggests that that while adding more applicable methodologies might broaden the diversity of project types and thus the total number of projects it does not guarantee a higher registration rate unless the quality of the methodologies improves.

<u>The effects of country-related variables.</u> Among host countries, India (**country_3**) and countries other than the big four countries (**country_5**) are eliminated through the stepwise

regression, due to their insignificance. This indicates that projects in countries other than China and Mexico have the same potential for registration as projects in Brazil in the reference case.

In contrast, the results strongly support China (**country_2**) as the host country with the highest registration rate. The odds ratio shows that being in China raises a project's odds of registration by 3.65 compared to the reference case, when all other conditions held the same. At the other extreme, Mexico (**country_4**) seems to be the host country with the biggest risk of project failure to register, with only 50% of odds ratio of other countries except China.

The effect on project registration success of national experience related to CDM seems to be trivial. **CounEx**, the number of CDM projects hosted in the country in the past, appears to have no statistically significant effect on registration. Previous experience with a certain project type in the host country, measured by the variable of **CounPEx,** rather reduces the odds of registration for projects of that type, but by only 1%. This tells us that CDM experience in the affected country in general does not actually increase or decrease registration probabilities. Rather, countries with more experience with a given project type tend to have lower-than-expected registration rate for the type.

<u>The effects of the DOE-related variables</u>

Dummy variables of **doe_2** and **doe_3** appear to be insignificant--validation by either **doe_2** or **doe_3** does not significantly change the probability of registration compared to

doe_1. Only **doe_4** has a different effect on registration rates; the odds of registration are 24% as high for **doe_4** as for other DOEs.

The effect of a DOE's level of experience does appear to have an influence on registration. National experience with the CDM (the number of CDM projects a DOE has validated in the past), **DOEEx**, decreases the possibility of registration, while national experience with a particular project type measured, **DOEPEx**, increases the probability.

4.3.1.1 Predictability power of the model

One way to test a fit of the model is to examine how well it classifies the outcomes compared to the actual observations. If the model predicts a probability of more than 0.5, the outcome is classified as positive. If the percentage of correctly classified cases is high enough, the model can be used to estimate registration probabilities with confidence.

Table 15. Classification table of the stepwise logit model

Classified \ Actual	Registered	Rejected	Total
+	1593	462	2055
-	100	158	258
Total	1693	620	2313

Table 16 presents a classification table from the stepwise logit model. The table shows that 94.1% of projects actually registered are so classified, while only 25.5% of projects actually rejected are so classified. The share of the overall correctly predicted observations is 75.7%. Those numbers tell us that even though the general predictability of the model looks good, it tends to provide over-optimistic estimations about registration, classifying many of the projects actually rejected as registered.

If project developers want to use the model to predict registration at the initial stage of project development, they should be cautious and conservative about interpreting the result. The threshold of the classification probability should probably be stricter. In other words, if we set the threshold of classification at 0.6, only a project with a probability over 0.6 should be considered likely to achieve registration. In the classification, the share of the actually rejected projects increases to 60%, while the share of actually registered projects drops to 73%.

4.3.1.2 The effects of variables on predicted probabilities

The magnitude of a coefficient in the logit model does not represent the relative effects of explanatory variables on the probability of registration, in contrast to the general linear regression analysis. Rather, its magnitude indicates only the difference in the logarithmic odds with a one-unit change of the specific variable with other variables held constant. Therefore, it is hard to interpret the coefficient naturally. In the following sections, graphs are provided to facilitate the understandings of their effects on predicted probabilities for given conditions. The probabilities are calculated based on the stepwise regression results.

The effects of project type-related variables

The effect of project type on registration is shown in Figure 12, with the x axis showing the rise in the number of methodologies. Let us first focus on the effect of different project types on registration. The probability is calculated for the case of projects that are hosted in the countries except China and Mexico and validated by one of the three major DOEs,

(DOEs other than DOE_C.) We assume that the DOE and the project host country have an average level of experience.

Among various project types illustrated in Figure 12, the industrial gas project case appears the most likely to be registered, with a very high probability, close to 1, corresponding to the current success of industrial gas projects. Meanwhile, with 100 available methodologies, the average probability of registration for a renewable energy-related project--wind, hydropower and biomass--is 65%. The probability of being registered for EE and fuel switch projects is only 40% approximately.

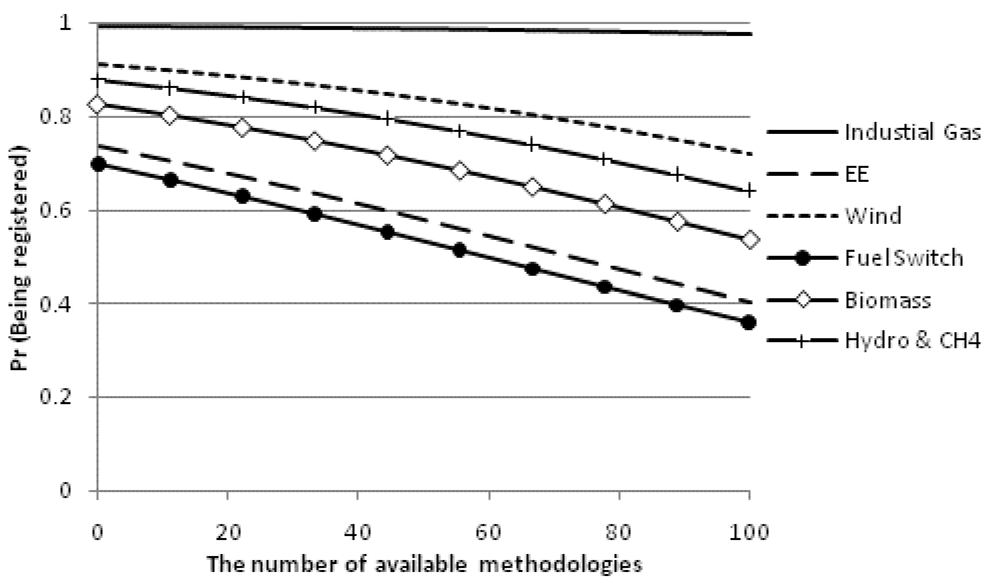

Figure 12. The effects of project types on registration

The differences among the probabilities for different project types become larger as the number of available methodologies increases. From the sign of the coefficient of **Meth**, we can infer that the overall probabilities of being registered diminish as the number of available methodologies increases. Changes in the registration probability become more sensitive as the number of methodologies increases.

The effects of country-related variables

We investigated the effect of different host countries on registration for China (**country_2**) and other countries (**country_5**). Probability was calculated for projects that have been validated by one of the three major DOEs, and for which an average number of methodologies were available. We assume that the DOE and the project host country have an average level of experience.

The differences in the estimated probabilities of a project of any type from China being registered versus other countries is shown in Figure 13. As demonstrated by the previous results of the coefficients, projects hosted in China have higher registration rates for all project types. However, its relative effects differ across project types: The effects of hosting projects in China rather than other countries are more critical for some project types than others. Industrial gas projects are not influenced by the choice of host countries. The second least influenced project type is wind power with a difference in the probability of registration being approximately 0.1. Other project types hosted in China have lower registration rates by 0.2 in general. The project type most sensitive to the choice of host

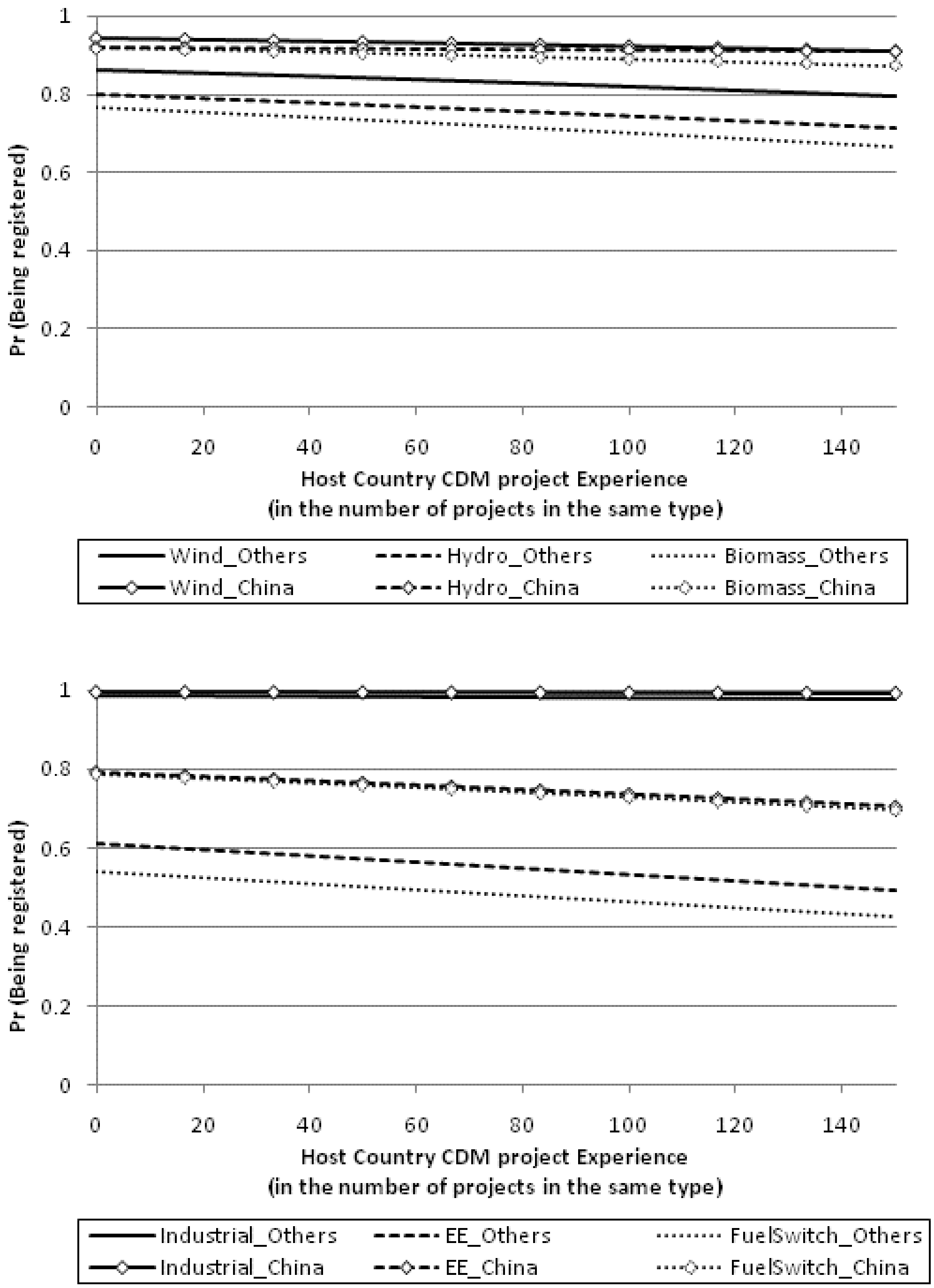

Figure 13. The effects of host country on registration

countries is the fossil fuel switch; the difference comes to 0.27 when the country has experience with 150 CDM projects in the past. We can also observe the effect of country's experience with CDM projects in the graph. The effect seems to be trivial, reducing the probabilities of registration by only 2% if 30 national project experiences are added.

The effects of DOE-related variables

The estimated probabilities are calculated to examine the effects of the choice of DOE on registration for countries other than China and Mexico. For the calculation, other factors such as the number of methodologies and the level of country experience and DOEs are fixed as the average.

Figure 14 shows that the registration probability for projects validated by **doe_4** is lower by 0.1~0.2, depending on project types, than those validated by the other DOEs. In particular, biomass energy projects are more sensitive to the choice of DOE than projects of other types, with greater differences in the estimated probabilities between the **doe_4** and other DOEs: when a DOE has had experience with 150 CDM projects, which is the actual average number of projects per DOE, the estimated probability of registration with **doe_4** is 15% lower than with other DOEs. The differences in the estimated probabilities for projects of other types are less than 10% given an average level of experience.

Meanwhile, the trend of the estimated probabilities shows that the more experienced a DOE is, the higher the registration probability becomes. The changes in the estimated probabilities are not linearly related to the changes in the level of DOEs: above certain

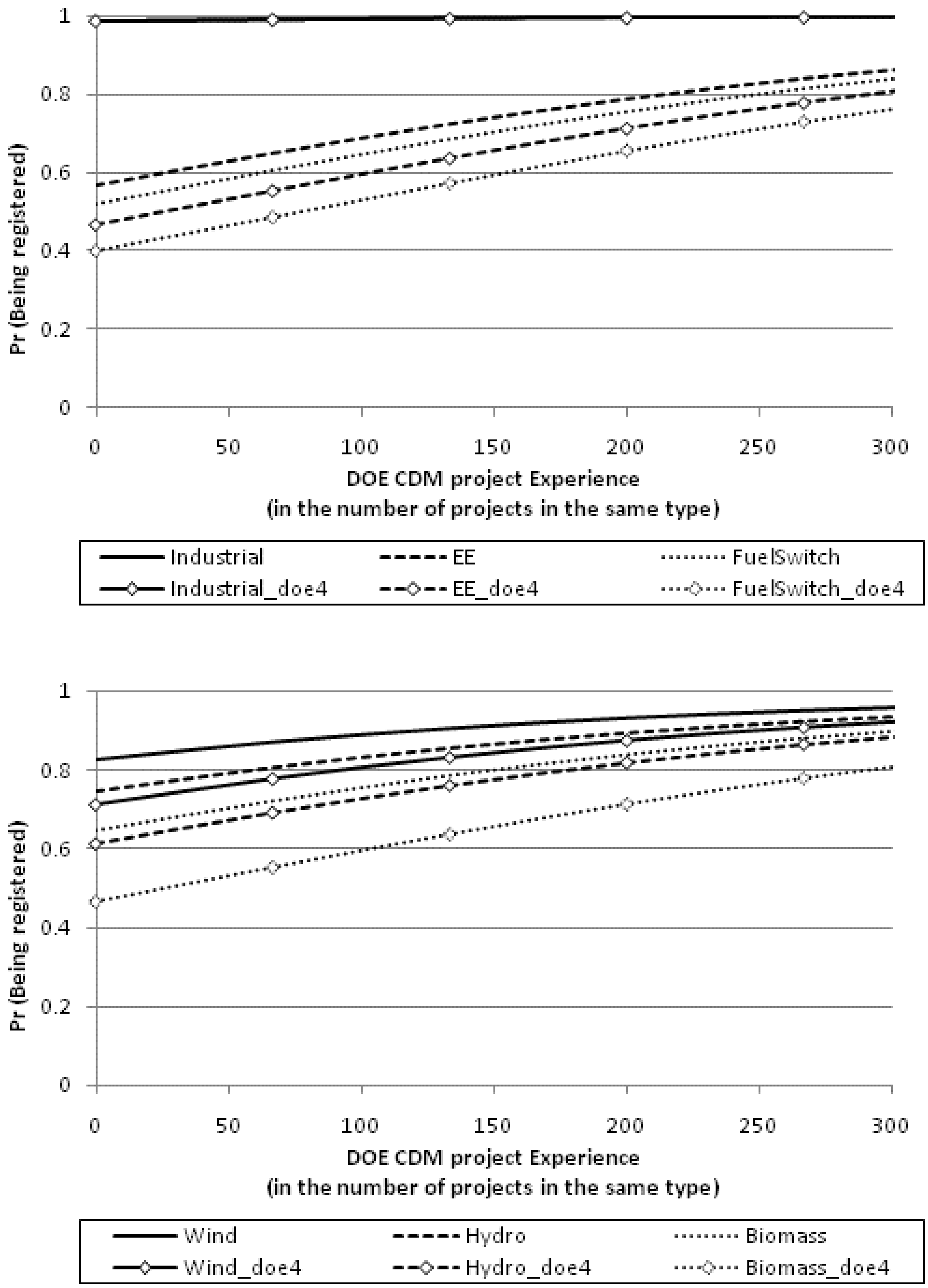

Figure 14. The effects of the DOEs on registration

level of DOE experience, the choice of DOE on estimated registration probabilities diminishes.

4.4 DISCUSSION

To discover the reasons why projects fail to get registered, we explored the effects of three types of the explanatory variables--project type-, country-, and DOE-related variables--on registration, using a logit model. Based on the findings, we can draw four significant conclusions and recommendations.

1. *Energy efficiency projects, fuel switch projects, and biomass projects are much more likely to be rejected than others.*

Energy efficiency, fossil fuel switch, and biomass projects are highly likely to have lower registration rates compared to other types of projects, with other conditions held constant. The nature of those project types seems to make it more difficult to claim CDM eligibility, so they are more likely to be rejected. The literature provides two possible reasons for the rejection of those types: the difficulty in proving additionality and the constrained applicability of the available methodologies.

Therefore, developers of these types of projects should pay close attention to these factors. They should be able to clearly demonstrate that proposed projects provide additional GHG reduction (or avoidance). They should also be prudent in choosing a methodology, being especially conservative in the interpretation of the applicability of the general conditions and the use of historical data and coefficients.

At the same time, CDM authorities should make every effort to develop more “high-quality” methodologies. Our analysis shows that an increased number of the approved methodologies did not reduce rejection rates. The quality of methodologies is more important than the quantity.

Recent research has raised a question about the EB's decisions on methodologies and project rejection. Critics claim that these decisions are greatly influenced by the political interests of the EB (Flues, Michaelowa et al. 2009). To avoid the appearance of political concerns, the EB should be more transparent in making decisions on methodologies. Only qualified methodologies that are detailed, well structured, and easy to understand and use should be approved.

2. *Significant difference in registration success exists among host countries.*

According to the model, China is apparently the best host country in which to develop CDM projects in terms of registration success. Since China has been already considered as one of the most promising host countries in many literature (Teng and Zhang, in press; Jung, 2006; Point Carbon Research, 2009), the result is not surprising. In addition to the findings in Chapter 3 that a host country such as China with favorable investment environment and institutional establishment tends to attract more CDM projects, this result confirms that projects are likely to be successfully developed and officially registered in a country with enabling environment.

3. Projects validated by the three major DOEs have a higher likelihood of registration.

A DOE is an accredited entity that conducts validation and verification of projects, ensuring proper qualification and transparency as an inspector. The discrepancies between the significant registration rates across DOEs, however, raise questions regarding the qualification and validation process.

First, the increase in the number of rejected projects by the EB in recently years suggests that their validation work has been inadequate. SGS, one of the major DOEs, has been suspended after a spot check by the EB recently found 6 deviations cases (UNFCCC, 2009). Even when deviations are not very serious, the CDM authority should continue to ensure the level of DOE qualification both before and after accreditation.

Second, for many years there were no standardized guidelines or manual for validation. Only recently, a *CDM Validation and Verification Manual* was developed at EB44; DOEs are now required to use it for their validation reports. The absence of standardized guidelines might have affected their performance, leading to the different registration rates. However, the new manual is still not sufficiently detailed and structured to guide DOEs. It should be redesigned to apply to specific project types or sectors.

It is urgent that the EB to emphasize quality control of DOEs and continue to monitor their validation processes, in order to operate the CDM in a consistent and transparent way.

4. Projects in countries with more CDM project experience are not successfully registered at a higher rate.

Contrary to our initial expectation, no significant learning effect leading to higher registration rates was observed. In fact, countries having more experience with certain project types are less likely to achieve a higher registration rate. This finding suggests two possibilities: 1) exhaustion of good projects and 2) inefficiency in sharing experience. First, ‘good projects’ here refer to those which have CDM suitable characteristics satisfying addtionality criteria and available methodologies. Moreover, if the projects result in great economic benefits through a large amount of CER generation, they cannot be better candidates for the CDM as shown in the case of industrial gas projects. According to economic theory, it is natural for those projects to be taken first under the perfect market system. Therefore, ‘good projects’ will be gradually exhausted in the affected countries and ‘poorer quality projects’ will come into pipeline for validation, which would inevitably lead to higher rejection rates.

Second, the accumulated experience of the CDM at the domestic level has not been effectively shared among affected stakeholders from project developers to the government. Therefore, the CDM authority and the government should be actively involved in promoting an opportunity to share experience and relevant information at both international and domestic levels, through hosting workshops and seminars. The dissemination of expertise related to the CDM will benefit both project developers and governments to develop high quality projects.

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5 ISSUANCE OF CDM CREDITS

5.1 BACKGROUND

Since the first CERs were issued in October 2005, 525 registered project developers had requested and issued CERs as of July 2009. The average success rate of the aggregated issuance is 96%; "success rate" to a ratio of expected emission reductions in the PDD to actual emission reduction credits ex-post. Analysis of the issuance success rates of individual projects however showed that this ratio varied widely.

The number of CERs issued is determined by the difference between the actual emissions measured from a project and the calculated emissions in the baseline that would not have happened without the project. Since both of these quantities involve uncertainty, some discrepancies between the estimated and the actualized CERs might be inevitable. However, credible and precise estimation of CERs is desirable and necessary for planning and financing projects for project developers and for governments developing climate change.

For project developers, CERs are the major source of revenue from the implementation of a project, which means that its financing heavily depends on the generation of CERs. If a project does not perform as well as planned, producing fewer CERs than expected, the project developer is highly likely to face a serious financial problem. Private companies, both buyers and investors, in Annex 1 countries may maximize their profits by choosing to invest more safely in less risky projects. Many CER trades are made in the form of the purchase or sales on future CERs to be generated from a CDM project. Such a transaction always involves uncertainty and risk. At present, investor decisions must rely solely on the CERs estimated in the PDD.

Furthermore, governments in both Annex 1 and non-Annex 1 countries need an accurate indicator to predict the supply of credits in the future market to plan and make policy related to GHG emission reduction. The supply of CERs is closely related to the costs required to fulfill their emission reduction commitments.

This study investigates the discrepancies between the estimated and the actual CERs and identifies what causes them. For the analysis, we first examine the current status of issuance; present major factors affecting issuance success rate cited in the literature in order to establish a point of departure for preparing the analysis; then conduct a qualitative and quantitative analysis. This process should provide some insight into what makes a CDM project successful. The objective is to enable diverse groups of stakeholders to estimate the expected amount of CERs with more accuracy and credibility.

5.2 CURRENT STATUS OF CER ISSUANCE

Approximately 1.4 billion CERs are expected to be generated from registered projects by 2012. If we include the projects now at the validation stage, the accumulated amount of CERs is expected to reach 2.8 billion CERs; this is 46% of annual CO_2 emissions in the US in 2005 (US EPA, 2009). Such a significant amount of expected CERs implies that if all CERs are actualized as expected, their impacts on the carbon market will be substantial.

However, some researchers are skeptical about these big numbers, claiming that the potential of the CDM is exaggerated (Mayr and Michaelowa, 2008; Capoor and Ambrosi, 2007). In fact, only a small amount of CERs, 0.3 billion, has actually materialized so far through the verification process; 30% of the registered projects have initiated issuance, and the rest, 70% of the registered projects, have not as yet (UNEP, 2009).

In addition to the low percentage of projects issuing CERs, another factor complicates the future of CER generation: the performance of CDM projects. Each project PDD provides an estimate of emission reductions according to the methodology pre-approved by the EB. The issuance success rates, thus, demonstrate how the projects have performed compared to the expectation at the initial planning stage of the projects. The short history of CER issuance shows a diverse level of performance—issuance success rate--across projects. At present, this rate ranges from 2% to 715%.

Figure 15 shows the distribution of issuance success rates for 577 projects. The distribution skews to the left slightly, with an average issuance success rate of 82% and a median of 86.6%. This implies that a majority of projects perform poorly—an issuance success rates lower than 100%. Approximately 75% of the projects have generated fewer CERs than expected. Only 25% generated more than anticipated.

Meanwhile, the distribution shows that one project has an extraordinary issuance success rate of 715%. The validation report for the project explains why: when the project participants estimated the amount of CERs, they used the firm capacity, 1/7 of the nominal capacity, to be conservative in their calculation (PDD of 294, 2008). Therefore, the higher

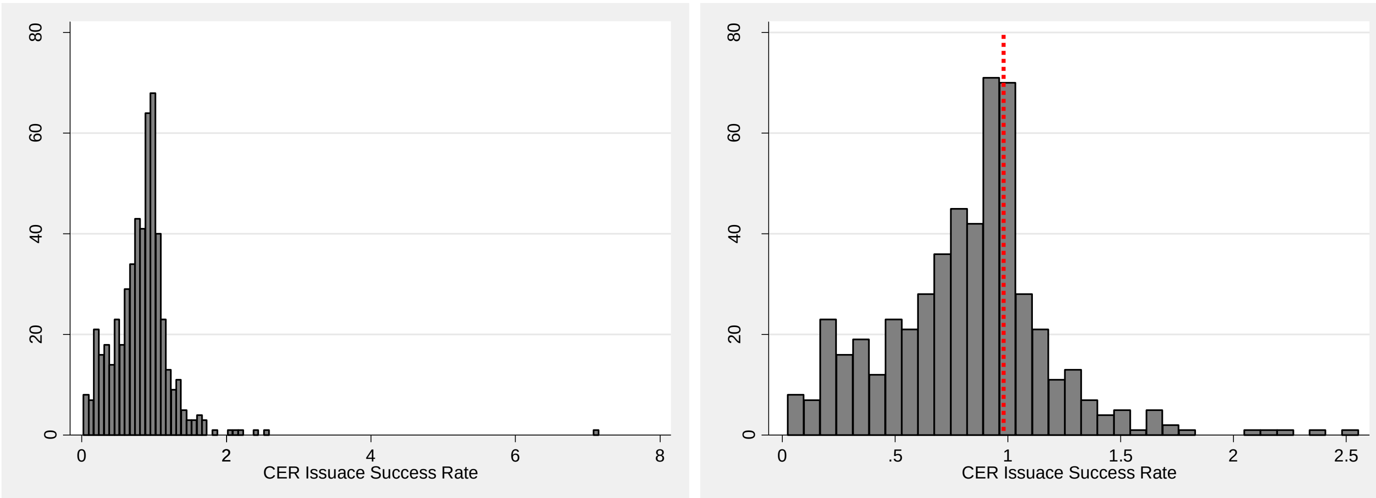

Figure 15. Histogram of CER issuance success rates

issuance success rate is legitimate to some degree for this specific case in which the actual electricity generation used the nominal capacity. The observation related to this project has been excluded from the analysis.

The issuance success rates of the other projects except the outlier fall between 2% and 255%: the worst project, in terms of CER estimation and generation, produced only 2% of the estimated CERs, while the best project produced 2.5 times the PDD estimate. Projects with 10% error in the estimation of CERs generated (an issuance success rate between 90% and 110%) account for 30% of the all projects that have issued CERs.

Meanwhile, since the issuance success rate is a normalized indicator for performance of projects, it does not show the actual amount of differences between estimated and actualized CERs. The logarithmic scale graph in Figure 16 compares the amount of

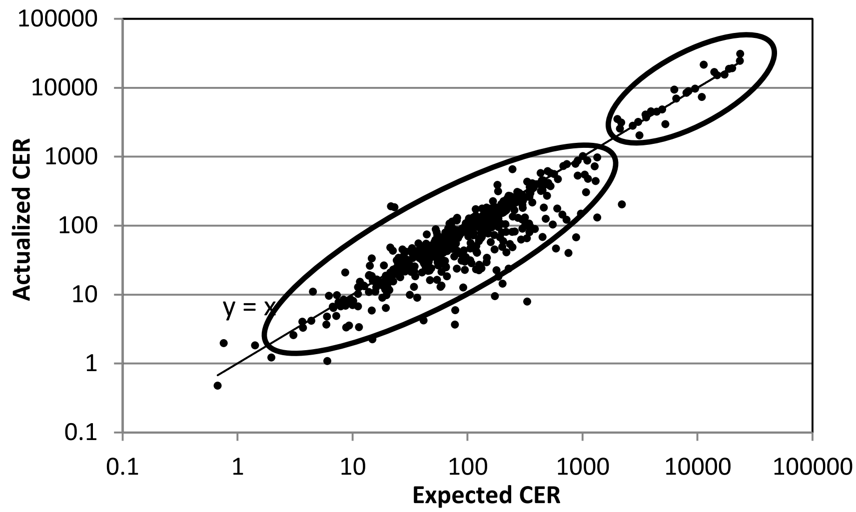

Figure 16. Comparison between expected and actualized CER

actually verified emission reductions with that of estimated reductions in the PDDs. Projects above the line of y=x are those with more CERs than expected, while projects below the line are those with poor performance. The graph clearly shows that 1) many of the projects underperformed, generating fewer credits than expected and 2) many of the large size projects with more than 2000 CER[33] tend to produce more CERs than expected. Due to the much greater CERs of the large size projects, the aggregated average of issuance success rate is raised to 97.6% despite of the large number of underperforming projects.

5.3 FACTORS AFFECTING PROJECT PERFORMANCE

In this section, we describe the various factors pertinent to issuance success rates that we will analyze in the statistical analysis to follow. Reference to the literature places these

[33] There are 26 projects with CERs greater than 2000:20 projects are associated with industrial gas while the other 6 projects are CO_2 and CH_4 reducing projects.

factors in the context of recent thinking about the CDM, and provides a point of departure for the analysis. Here, we explain how those factors are related to issuance success rates and then describe how those factors were incorporated into the statistical model.

5.3.1 Project Type

The issuance success rate of a project is closely related to the type of project it is. The technical characteristics of each type affect the PDD estimation of how many CERs a project will produce as well as its real performance and monitoring (Castro and Micahelowa, 2008). The set-up and operation of some project types involve more complex technology than others. The monitoring process for some project types is more sophisticated and complicated than others, requiring skillful and well-trained employees. For example, the emissions of some greenhouse gases such as CH_4 are hard to measure and monitor (EPA, 2006).

In order to incorporate the effect of the characteristics of project types, project dummy variables were created for the analysis. The dummy variables capture the general effect of the intrinsic characteristics of project types on project performance. To do this, projects were categorized into 9 types and 9 dummy variables were created: $\mathbf{TYPE_1}$(hydro power), $\mathbf{TYPE_2}$ (energy efficiency), $\mathbf{TYPE_3}$ (wind power), $\mathbf{TYPE_4}$ (CH_4 avoidance), $\mathbf{TYPE_5}$ (other CO_2 reducing), $\mathbf{TYPE_6}$ (biomass), $\mathbf{TYPE_7}$ (industrial gas), $\mathbf{TYPE_8}$ (landfill gas), and $\mathbf{TYPE_9}$ (manure projects).

5.3.2 Host Country

A project's host country is a possibly influential factor to be considered in explaining issuance success rates. The host country determines the economic, technological, social, and political environments of the project which have a direct effect on its performance (Curnow and Hodes, 2009). In addition, a country's prior experience with CDM projects could play a positive role in raising the average issuance success rates (Jung, 2006).

However, empirical research by Castro and Michaelowa (2008) shows that host countries with more projects than others are not always superior in terms of performance. For example, the level of issuance success rates for projects in China fell below the average of all the projects. They also could not find any compelling evidence to demonstrate that any country is consistently better than the others. Nevertheless, since Castro and Michaelowa (2008) collected their data at the early stage of CER issuance and used a much smaller sample size, it is worthwhile to revisit the impact of host country variables in the model.

To capture the host country effect, a host country dummy was generated. To consider the relative significance and contribution of host countries in terms of the number of projects, four country dummies were created: $\mathbf{COUN_1}$ (Brazil), $\mathbf{COUN_2}$ (China), $\mathbf{COUN_3}$ (India), and $\mathbf{COUN_4}$ (others).

Variables related to previous CDM experience in a given host country were generated as shown in Chapter 4, in order to identify two effects of CDM-related learning in a host country: **CounEx** is the accumulated number of projects hosted in the country at the time of validation, while **CounPEx** is the accumulated number of projects of the same type in the country at the time of validation.

5.3.3 Project scale and size

CDM projects are classified into either large- or small-scale projects considering the capacity of each type as well as the expected annual amount of CERs. Castro and Michaelowa (2008) found a tendency to overestimate CERs for large-scale projects—those expected to produce greater annual CERs. Small-scale projects perform better on average[34]. Small-scale projects follow a simplified baseline and monitoring methodologies (UNDP, 2003).

We hypothesize that the estimate of CERs for small-scale projects with simpler methodologies and monitoring would be more accurate in practice. To explore this effect, a project-scale dummy was included in the model, 1 for large-scale projects and 0 for small-scale projects. The project-scale dummy variable will capture the effect of administrative and technical difficulties on large-scale projects.

Castro and Michaelowa (2008) attribute the better performance of small projects to conservative estimates in their PDDs for emission reductions and lower technical

[34] Here, small-scale projects do not necessarily generate "small" amounts of annual CERs, in the CDM standard a small-scale project is one having "1) renewable energy project activities with a maximum output capacity equivalent of up to 15 megawatts (or an appropriate equivalent); 2) energy efficiency improvement project activities which reduce energy consumption, on the supply and/or demand side, by up to the equivalent of 15 gigawatt/hours per year; or 3) other project activities that both reduce anthropogenic emissions by sources and directly emit less than 15 kilotonnes of carbon dioxide equivalent annually" (UNFCCC, 2002).

complexity. We added a project-size variable which refers to the expected annual CER in the model to investigate whether there really is any size-related effect on performance.

5.3.4 PDD consultants

PDD consultants estimate and calculate emission reductions at the stage of validation according to methodologies. Their experience, expertise, and familiarity with applied technology as well as with CDM modalities and methodologies affect the credibility and accuracy of CER estimation (Michaelowa, 2005; Mayr and Michaelowa, 2008). Castro and Michaelowa (2008) found that the type of PDD consultants used can also affect performance: "in-house consultants" show better performance regarding CER issuance, but "multi-project" consultants tend to generate fewer CERs than estimated[35]. They conclude that a better understanding of the project enabled in-house consultants to provide better estimates, while multi-project consultants lack this specialized knowledge.

As proxy for experience of PDD consultants, the number of previous projects that a PDD consultant prepared is included as an explanatory variable in the analysis. Due to the unavailability of data, the detailed classification of PDD consultants performed by Castro and Michaelowa (2008) could not be done. Of the variables they used, only the nationality of a PDD consultant is considered and tested in this analysis, as a way to reflect their characteristics. The nationality dummy variable is 1 if they are from Annex 1 countries and 0 if from non-Annex 1 countries. The data shows that consultants from non-Annex 1

[35] "In-house consultants" refer to those who are the owner of the projects and prepare PDDs by themselves. Multi-project consultants refer to those who are involved in various project types rather than specialized in one field.

countries are generally involved with one type of projects, while those from Annex 1 countries tend to be involved in several types. The hypothesis is that projects prepared by non-Annex 1 country consultants would perform better.

5.3.5 The number of verified days

Currently, there is no guideline or rule to decide the timing and frequency of CER issuance. Project participants decide when and how often to issue CERs at their discretion according to their needs. Therefore, projects have followed different time frames for verification and issuance of CERs; thus, the number of crediting days per project differs. The project data shows that issuance success rates improve as the number of issuance increases. A project with multiple instances of issuance tends to perform better in the later rather than in the earlier stages of operation[36]. This suggests that projects may underperform at their initial stage of implementation but that performance may improve with time. We hypothesize that having more verified days affects issuance success rates: the more, the better.

5.4 TWO APPROACHES TO ECONOMETRIC ANALYSIS

To make an inference about various issuance success rates, an econometric analysis was performed. Two approaches were introduced for the analysis: ordinary least square regression and the Heckman selection model.

[36] The issuance success rates of projects at the second time issuance are improved by 70% on average, compared to their first issuance, in the case of 290 projects. Further, success rates at the third time issuance are 17% better than at the second time issuance on average, for 136 projects.

5.4.1 Ordinary Least Squares (OLS) Regression

An OLS regression was performed in order to explore the effect of variables that were identified as determinants of performance in the literature[37]. OLS regression is commonly used in fields from social science to engineering, when inferring relationships between dependent variables and independent variables. As a way of selecting explanatory variables, a stepwise selection was used.

The full OLS model was developed for the analysis of issuance success rates in the form:

$$\text{Issuance success rates} = \alpha + \beta_{1i}\mathbf{TYPE_i} + \beta_{2j}\mathbf{COUN_j} + \beta_3\mathbf{CounEx} + \beta_4\mathbf{CounPEX} + \beta_5\mathbf{PDDCon} + \beta_6\mathbf{PDDCoun} + \beta_7\mathbf{DAY} + \beta_8\mathbf{annualCER} + \beta_9\mathbf{SCALE}$$

where **TYPE**$_\mathbf{i}$ is a set of project type dummy variables for 9 types (i=1,..,9), **COUN**$_\mathbf{j}$ is a set of host country variables for 4 country groups (j=1,..,4); **CounEX** is the number of previous CDM projects in the host country; **CounPEX** is the number of previous CDM projects of similar type in the host country; **PDDCon** is the number of previous CDM projects a PDD consultant developed; **PDDCoun** is a dummy variable of 1 if consultants are from Annex 1 countries or 0 if from non-Annex 1 countries; **DAY** is the length of project operation; **annualCER** is the average of estimated annual CERs in kCER; and **SCALE** is a dummy variable for a large-scale project.

[37] The regression model diagnostics are included in Annex C.

5.4.1.1 Heckman Selection Model

The Heckman model was employed to correct any selection bias in the analysis of issuance success rates. Selection bias exists in the cases where y, the value of a dependent variable, is observed only if certain criteria are met, and is common in applied econometric problems.

Failure to fix the selection bias can lead to poor and biased results which will not reveal the true relationship between dependent and independent variables (Heckman, 1979). One of the well-known examples of selection bias would be a wage problem for working women. Let us assume that we want to explore the effect of education on wages. Because we can observe wages only for those who work, not for those who don't, the dataset including only those who work is not a randomly selected sample. A regression analysis using the observed wage can only result in a biased estimate of the effect of education, since only working women are included in the data.

Likewise, in the context of CER issuance, we can observe CER issuance success rates only for projects that have issued them. The data including only the projects with issued CERs form a non-randomly selected sample. Thus, the regression using those projects may lead to a biased result. Use of the Heckman model can correct this bias by employing a two-step approach. The first stage involves a probit regression, so-called selection equation, to generate the decision probability of issuance using information from all the registered projects. At the second stage, expected errors estimated at the first stage are incorporated in the regression, correcting the bias. The model specification is as follows.

At the first stage, the selection equation is

$$z^*(\text{unobserved}) = \gamma' w + u \quad u \sim N(0, 1)$$

where, z=1 if projects have issued CERs while z=0 if projects have not issued any CERs.

At the second stage, the regression equation is

$$y = \beta x + e \quad e \sim N(0, \sigma^2)$$

where y, issuance success rate, is observed if and only if z=1

For the analysis of issuance success rates, we developed a Heckman model that consists of two equations: a selection equation and an outcome equation. In this analysis, the selection equation concerns the decision related to CER issuance.

Selection Equation

The decision to issue CERs is driven mainly by the economic profitability of the projects. The most likely barrier to economic profitability is the high transaction cost consequent on becoming a CDM project. Many researchers have criticized these high costs (Bruce, 2006; Ellis and Kamel, 2007; and Michaelowa and Jotzo, 2005). The issuance process also involves transaction costs, both a lump sum fee and fee proportional to generated emissions. We can assume that project participants decide to issue CERs when a project becomes economically attractive and profitable, and revenue generated by the issuance is sufficient to cover the transaction costs. In this context, the selection model can be built using the following two explanatory variables: expected amount of CERs by July 2009 and a scale dummy[38].

expected CER: Every procedure of the CDM process affects transaction costs including the process of verifying and issuing CERs. There is a lump sum fee for the issuance of CERs in addition to a fee proportional to the amount of generated CERs. Therefore, we hypothesize that projects are more likely to issue CERs when the expected amount of accumulated CERs is great enough to manage the transaction costs.

scale[39]: The CDM has a generous rule for small-scale projects: they follow a simplified monitoring plan, paying reduced governance costs and fees, and being allowed the same DOE as validator and verifier (UNDP, 2003). This eases project implementation and requires lower transaction costs. Small-scale projects may be expected to issue more often and sooner than large-scale projects.

We cannot observe the effect of carbon price on issuance decisions because we cannot observe the price for the projects which have not issued CERs. Therefore, only two variables are included.

Accordingly, the specification of the selection equation is as follows.

$$z = \beta_0 + \beta_1 \mathbf{SCALE} + \beta_2 \mathbf{eCER}$$

[38] A selection equation shall include at least one of a covariate which does not belong to an outcome equation. This type of variable is named an exclusive variable.
[39] The scale of CDM projects between large and small is not solely determined by the size of annual CER. Therefore, small scale projects do not necessarily have smaller annual CERs than large scale projects.

Where z is 1 if a project has issued CERs or 0 if it hasn't; **SCALE** is a dummy variable for the large-scale projects; and **eCER** is the expected amount of CERs in Kt CO_2e by July 2009.

Outcome Equation

The outcome equation has the same specification as the OLS in the Heckman model.

$$\text{Issuance success rates} = \alpha + \beta_{1i}\mathbf{TYPE_i} + \beta_{2j}\mathbf{COUN_j} + \beta_3\mathbf{CounEx} + \beta_4\mathbf{CounPEX} + \beta_5\mathbf{PDDCon} + \beta_6\mathbf{PDDCoun} + \beta_7\mathbf{DAY} + \beta_8\mathbf{annualCER} + \beta_9\mathbf{SCALE}$$

5.4.2 Description of explanatory variables

Project Type. Table 17 and Figure 17 clearly show the variation in issuance success rates across project types. The performance of landfill gas and manure projects is very poor: they generate an average of only 40% of the estimated CERs. CH_4 avoidance projects also have a relatively low average issuance success rate of 82%. However, the amount of CERs from energy efficiency and industrial gas projects is close to the PDD estimates on average. More than 50% of the industrial gas projects overperformed, issuing more than the CERs estimated in the PDDs.

Table 16. Descriptive statistics by project type

Project Type	Observations	Issuance success rates			
		Mean	**S.D.**	**Min**	**Max**
Hydro (**$TYPE_1$**)	99	0.923	0.324	0.179	2.554
EE (**$TYPE_2$**)	26	0.973	0.335	0.539	2.084
Wind (**$TYPE_3$**)	98	0.815	0.239	0.103	1.281
CH_4 (**$TYPE_4$**)	52	0.821	0.351	0.322	2.394
Other CO_2 (**$TYPE_5$**)	34	0.838	0.330	0.229	1.651
Biomass (**$TYPE_6$**)	105	0.922	0.334	0.108	2.210
Industrial Gas (**$TYPE_7$**)	30	1.052	0.319	0.431	2.122
Landfill Gas (**$TYPE_8$**)	37	0.414	0.322	0.029	1.178
Manure (**$TYPE_9$**)	43	0.418	0.271	0.024	1.074

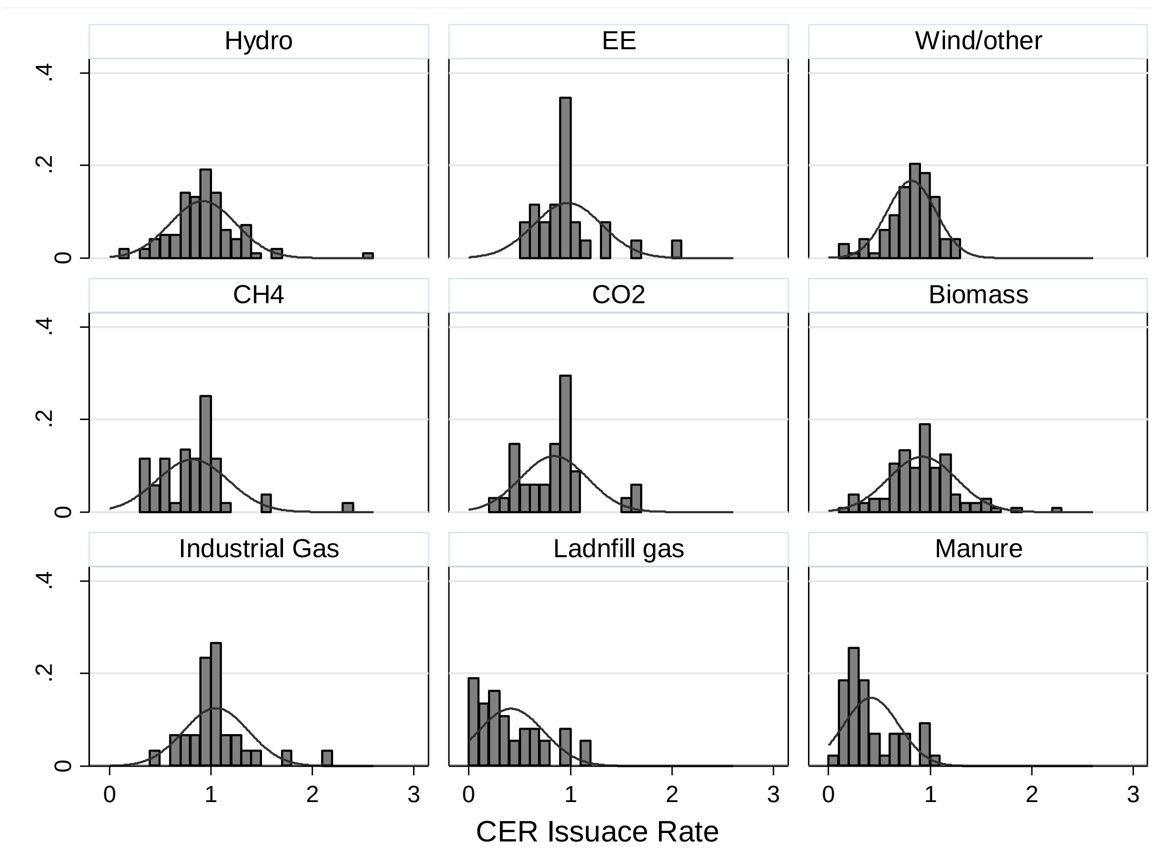

Figure 17. Histogram of CER issuance success rates by project type

Host country. The distribution of CER issuance success rates vary across countries, in terms of their means, spread, and skewness, as shown in Table 18 and Figure 18. Issuance success rates of the projects in China and India are relatively higher on average than those in other countries. In particular, the small number of poor projects and the fact that 10 of the projects performed at 150% of the PDD estimate raises the average performance of projects in India.

Table 17. Issuance success rates by country

Host Country	Observations	Issuance success rates			
		Mean	**S.D.**	**Min**	**Max**
Brazil	91	0.758	0.361	0.029	1.525
China	120	0.838	0.317	0.103	1.706
India	194	0.903	0.330	0.192	2.394
Others	119	0.712	0.406	0.024	2.554

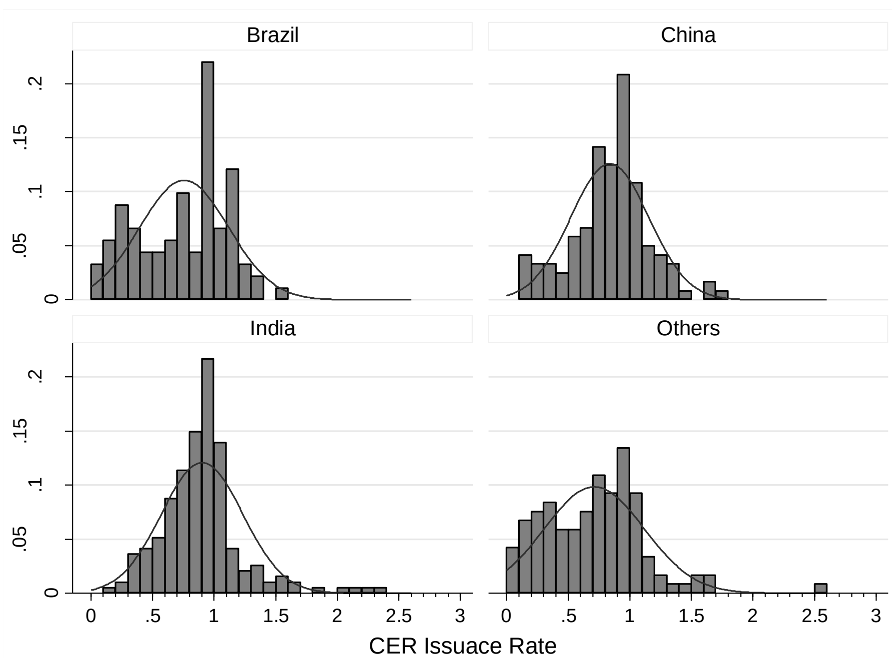

Figure 18. Histogram of CER issuance success rates by host country

Countries other than China and India have relatively low average issuance success rates. However, the differences in performance across host countries do not seem to significantly correlate with their economic and social characteristics. Castro and Michaelowa (2008) attributed these lower average rates of issuance success to the high number of project of types performing very poorly, such as landfill and manure projects, in the low-performing countries. The statistical analysis will reveal whether the host country has any significant effect on issuance success rates, excluding the effect of project types.

Project scale and size. The annual CER of the 524 projects with issued CERs is widely distributed from 0.54 to 10430 M tonnes CO_2e per year. Despite the wide range, more than 90% of the projects are estimated to produce less than 400 million tonnes CO_2e per year. On the other hand, a small number of industrial gas projects account for greater CER generation. The highly skewed distribution leads to 309 million tonnes CO_2e of the average annual CER. Meanwhile, there are 332 large scale projects and 192 small scale projects, respectively.

Table 18. Descriptive statistics of covariates

Covariates	Observations	Mean	S.D.	Min	Max
SCALE (Project scale)	523	0.635	0.482	0	1
annualCER (Project size)	523	309.556	1133.6	0.54	10430.45
PDDCoun (consultant country)	523	0.298	0.457	0	1
PDDCon (consultant experience)	523	7.398	15.252	0	120
DAY (Total verified days)	523	945.46	682.14	31	2908

PDD consultant. Up to now, 211 PDD consultants have been involved in the preparation of PDDs of those projects with issued CERs: 170 consultants are from non-Annex 1 countries and are responsible for 366 projects, while 41 consultants from Annex 1 countries prepared

156 projects. The level of their prior experience with CDM project activities varies considerably from 0 to 120 projects.

Total verified days. The average number of verified days since the first day of a project's crediting period is 44, approximately 2.6 years. The initial review of verification reports revealed that poor performance has resulted from delay and operation failure at the initial stages of projects in many cases. More detailed analysis of PDD documents will be discussed below.

5.4.3 Results

5.4.3.1 Ordinary least square model

Stepwise regression was performed with probability of 0.2, using STATA 10. Table 20 provides our modeling results. The following three models were explored:

Model 1: project type dummy+ other covariates

Model 2: host country related variables + other covariates

Model 3: full model with all the covariates

As explained above, Castro and Michaelowa (2008) claimed that issuance success rates in a host country are affected more by the composition of its CDM projects than by its national economic, social, and technical characteristics. To investigate this claim, Model 1 has only project-type dummy variables in addition to other project specific covariates; Model 2 has only host country-related variables including host country dummies and CDM experience in the host country in addition to others. Model 3 includes all the covariates, both of project type and country variables in the model.

The coefficient of determination, R^2, is a popular measure of the explanatory power of a model; it refers to a ratio of the squared residuals explained by the model to the total

Table 19. Results of ordinary least square regressions

		Model 1	Model 2	Model 3
Coefficients[40]	**$TYPE_1$(Hydro)**	dropped		Dropped
	$TYPE_2$(EE)	-.0722666**		Removed
	$TYPE_3$(Wind)	-.0849282*		Removed
	$TYPE_4$(CH_4)	-.0848399**		Removed
	$TYPE_5$ (Other CO_2)	-.1136158**		Removed
	$TYPE_6$ (Biomass)	removed		Removed
	$TYPE_7$ (Industrial)	.1729501*		.2859222 *
	$TYPE_8$(Landfill)	-.4525337*		-.3837424*
	$TYPE_9$ (Manure)	-.4229661*		-.3687754*
	Brazil		dropped	Dropped
	China		.0806181**	Removed
	India		removed	Removed
	Others		removed	Removed
	CounEx		removed	-.000267**
	CounPEx		.0006894***	.0009585**
	PDDCon	.0017255**	.0017208**	.0015017**
	PDDCoun	-.1271508*	-.2122369*	-.1332224*
	DAY	.00005*	.0000867*	.0000451**
	annualCER	removed	.0000476*	Removed
	SCALE	removed	-.1283258*	-.0491656**
	_cons	.8819793*	.8364581*	.8851819*
Association/ Predictive efficiency	R^2	0.3033	0.1720	0.3024
	Adjusted R^2	0.2911	0.1608	0.2902

Note: Indications of significance levels (Prob > |Z|) are:
*= probability of 0.05, **= probability of 0.1, ***=probability of 0.15

[40] Coefficients in the parenthesis are those that are statistically insignificant at p<0.1.

squared residuals (Kohler and Kreuter, 2005). Given R^2, Model 1 is the best among the three. The low R^2 of Model 2 apparently demonstrates that using only host-country covariates does not explain the variances in issuance success rates. It is interesting that Model 3, even with more covariates of both country and project type, has lower R^2 than Model 1 with only project-type variables. This underscores previous findings that host country-related variables are not statistically relevant to issuance success rates, while project types have dominant effects on the performance.

For project types, the results from both Model 1 and Model 3 suggest that 1) issuance success rates for industrial gas projects are higher in general than other project types and 2) landfill and manure projects are apparently “bad” projects with poor performance. Wind, CH_4 avoidance, and CO_2 reducing projects show inconsistent results: their coefficients are statistically significant in Model 1, but not in Model 3. Depending on the set of covariates, their significances are not robust.

As explained above, the country-related dummy variables appear to be irrelevant to issuance success rates. The dummy variable for China alone is significant in model 2, though not in model 3. This signals that project success in China is the result not of being in that country but of the favorable composition of project types.

However, a country’s prior experience with a given CDM project type appears to improve issuance success rates, as shown in the results of model 2 and model 3. According to Model 3, one more CDM project experience of a given type in the country raises its issuance success rate by 0.0009. This suggests that learning effects from prior CDM project activities of the same type in a host country improve its capacity to estimate emission reductions with accuracy.

Results of Model 1 demonstrate that general project characteristics such as size and scale do not have significant effects on project performance, contrary to our hypothesis. Only the variable of **DAY** appears to be significant. The positive sign of the coefficient of **DAY** means that projects that have been operated for a longer time have higher issuance success rates, which is consistent with our expectation. However, the effects on issuance success rates seem not to be immense given the absolute value of the coefficients.

Meanwhile, the results suggest that the role of PDD consultants is critical in estimating CERs, with statistically significant coefficients of PDD-related variables in all three models. When a PDD consultant has one more experience with a CDM project activity, it raises the issuance success rate of her next project by 0.001.

Contrary to the general expectation that consultants from Annex 1 countries, being familiar with advanced technology, would provide better support for preparation of PDDs, the amount of CERs estimated by consultants from non-Annex 1 countries is more accurate in general. This result partially supports the observation by Castro and Michaelowa (2008) that consultants with better understanding of the project as in-house or technical specific consultants perform better, while the performance of multi-project consultants is below the average. It appears that consultants from non-Annex 1 countries produce projects with better performance because they have greater knowledge specific to an area, technology, regulation and so on.

5.4.3.2 Heckman Selection Model

The result of the Heckman selection model does not support the existence of selection bias in the data set with an insignificant inverse Mills ratio. The likelihood ratio test fails to reject the null hypothesis that the model has a selection bias, confirming that the selection and outcome equations are independent.

Table 20. Results of Heckman selection model

	Outcome Equation		Selection Equation	
Coefficients	**$TYPE_1$(Hydro)**	dropped	**SCALE**	.6270909
	$TYPE_2$(EE)	(.028999)	**eCER**	-.0001885
	$TYPE_3$(Wind)	-.0897799*		
	$TYPE_4$(CH_4)	-.1086174*	**_cons**	.5320229
	$TYPE_5$ (Other CO_2)	-.1020637**		
	$TYPE_6$ (Biomass)	(-.0098882)	**Mills lambda**	(-.1074375)
	$TYPE_7$ (Industrial)	.1406764**		
	$TYPE_8$(Landfill)	-.4339274*		
	$TYPE_9$ (Manure)	-.4339274*		
	PDDCon	.0018136*		
	PDDCoun	-.1159274*		
	DAY	.0000533*		
	annualCER	(-.0000156)		
	SCALE	(-.0233323)		
	_cons	.8968165*		
Association/ Predictive efficiency	Wald Chi2 (24)	219.4		

Note: Indications of significance levels (Prob > |Z|) are:
*= probability of 0.05, **= probability of 0.1, ***=probability of 0.15, ( )= insignificant

The results of the outcome equation of the Heckman selection model shown in Table 21 are not significantly different from those in the previous section: the signs and magnitudes of the coefficients and the statistical significances of the independent variables in the two models are very similar to each other.

5.5 REVIEW OF PROJECT DOCUMENTS

Econometric analysis is one of the truly powerful methods for making inferences and offering explanations of what we observe in many fields, but it is not infallible. The relatively low R^2 of 0.3 indicates that the covariates explain only 30% of the total variations in issuance success rates. In this section, we investigate individual project documents in search of reasons for issuance success or failure in addition to the factors evaluated in the econometric analysis.

Comments on discrepancies in emission reductions among projects can be found either in the monitoring reports conducted by project participants or verification reports made by DOEs. However, not every project explains the reasons behind the discrepancies in those documents. For this study, we investigate the projects with lower than 50% of issuance success rates. This includes 100 projects out of 531 having CER issuance.

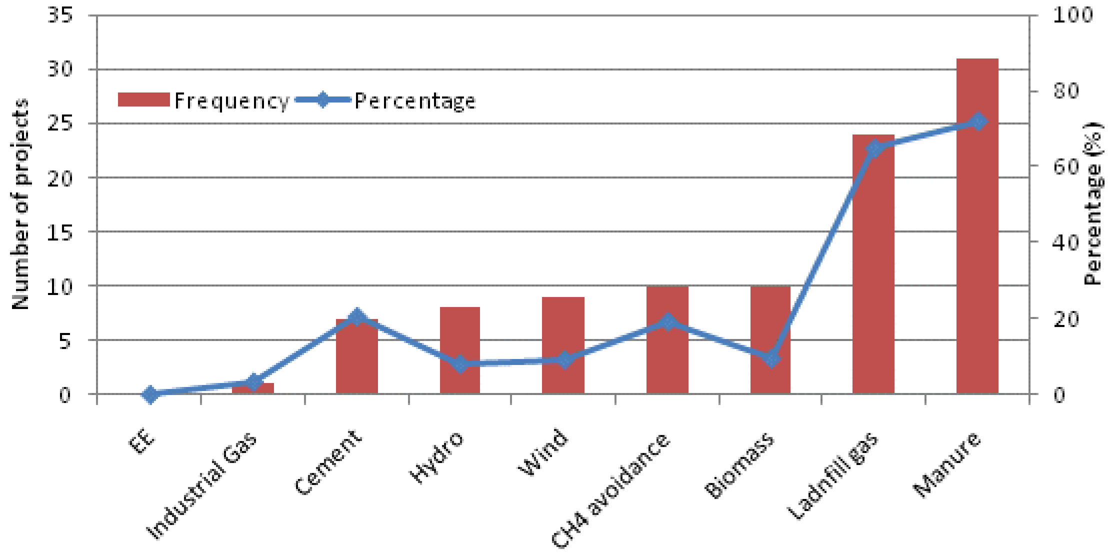

Figure 19. Distribution of 100 projects with the lowest issuance success rates

Figure 19 provides an overview by type of the projects having lower than 50% issuance success rate. The figure shows that certain types of projects such as landfill gas and manure projects appear to perform "badly." In the graph, the bar refers to the number of projects of the type, while the blue markers on the line correspond to the percentage of projects of the type with the low CER issuance. For example, there are 31 manure projects with lower than 50% issuance success rates; those projects account for 70% of all manure projects with CER issuance. The poor performance of landfill gas and manure projects is consistent with our findings from the econometric analysis in the previous section.

For other types, except energy efficiency and industrial gas projects, approximately 10% are categorized as "bad" projects, generating less than 50% of the CERs estimated in their PDDs. However, the performance of energy efficiency and industrial gas projects seems to be much better overall, with only a couple appearing among the worst 100 projects.

Table 21. Reasons for underperformance found in project documents

Reasons	Number of projects
Wrong estimation method of emission reductions	32
Delay in construction	14
Technical problems during operation	8
Uncontrolled exogenous factors	8
Financial problems	4
No comment	36
Total	100

Table 22 provides a list of reasons for the low performance identified by verifiers or project participants themselves in their validation or monitoring reports. According to the manual developed by the EB, they are not actually required to explain the specific reasons for the discrepancies between the expected and the actual CERs if they can prove that emission reductions have been successful following monitoring and implementation in accordance with the PDD.

However, many of the verifiers or project participants did comment on why some projects failed to achieve the expected amount of emission reductions. Within the documents for the 100 underperforming projects, commentators for 64 included reasons, and for 36 they did not. The five reasons, as categorized in Table 6 are detailed below.

Methods for estimating emission reductions[41]

[41] CDM project activities under this category are CDM reference number 71, 91, 329, 505, 798, 822, 893 and 1664.

As shown in Figure 4, almost 70% of the manure projects with issuance are among the 100 bad projects. They generated far fewer CERs than expected due to the difference between theoretical emission reduction estimate method and actual monitored emissions. The expected CH_4 emission reduction was based on the livestock population and the IPCC default value. In fact, the actual amount of the biogas monitored during the project turned out to be much smaller than the calculation. This case shows the importance of selecting a methodology. A wrong choice can lead to drastic financial problems when a poor estimate causes a project to fail to generate expected CER profits. Most of the underperforming manure projects--30 out of 32--were developed by one consulting company, AgCert.

Delay in construction[42]

Many of the projects were affected by unexpected delays in the construction phase, leading to less emission reductions. This category includes delays in construction and in obtaining necessary equipment so that the actual operation of the projects started later than planned. The length of delays varies case by case, ranging from 2 to 20 months. For some projects, equipment was installed in several stages, which was not reflected in the PDD where installation was planned as a single stage. Five landfill gas projects and three wind projects fall into this category. Projects in this group are expected to generate emission reductions closer to the original estimate in the long term, once construction is finalized and operation of the projects are back to normal.

Technical problems during operation[43]

[42] CDM project activities under this category are CDM reference number 8, 72, 198, 218, 254, 330, 426, 450, 491, 778, 887, 923, 1118 and 1261.

Many of the technical problems associated with instability of a system and technical inexperience occurred at an initial stage of project activity. These cases include monitoring problems; problems with the equipment; many serious delays due to technical failure; and changes in the mixture of raw material which affected the efficiency of the system. Observers of three of the landfill gas projects and three of the waste heat projects cited technical problems as reasons for poor performance.

Uncontrolled exogenous factors

Many landfill gas projects had problems in their operations due to uncontrolled variables. The quality and quantity of landfill gas is very sensitive to changes in the weather such as temperature and rain and the behavior of anaerobic micro-orgasms in the soil. These factors cannot be controlled or anticipated with precision.

Furthermore, many of those landfill projects do not have adequate documentation from the period in which they were used as dumps, rather than well managed. It is hard to estimate the composition of waste, which is a source of landfill gas generated by a project.

Other cases include a hydropower plant where management of the dam area prevented it from operating normally, and a waste gas project also involving biogas where the quantity was affected by seasonal change. As in the landfill projects, part of this problem was a lack of historical data on the quantity and composition of waste. Since landfill sites in many

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[43] CDM project activities under this category are CDM reference number 96, 226, 347, 493, 850, 924, 1151 and 1258.

developing countries are not controlled by the government, many of them do not have well maintained records, which makes the estimation of emission reductions difficult.

Financial problems[44]

The economic situation of a region as well as factors inherent in a project itself also affected its performance. Four projects were unable to reduce emissions as estimated for financial reasons. Of these four, a CO_2 capture project in the chemical industry replaced the initial raw material with a new one in order to reduce costs. However, the change in the raw material affected the performance of the system, generating less emission reductions. A steel-producing project had to shut down its plant temporarily when an economic downturn reduced demand for steel. A hydropower project and a waste heat use project had to run with low load factors due to lack of available finance, which resulted in fewer emission reductions for each.

In summary, review of the 100 poorly performing projects revealed five categories of reasons for poor performance: delay in construction; financial problems; technical problems in operation; methods of estimating for emission reductions; and uncontrollable factors. Among these, estimation methods and uncontrolled factors appear to be closely related to specific types of projects: Estimation methods for manure projects and uncontrollable factors with landfill gas. We can conclude that project type, especially for these two, is a critical factor in determining project performance.

[44] CDM project activities under this category are CDM reference number 330, 698, 1320 and 1462.

However, regardless of project type, project-specific operation and implementation elements such as delay, financial problems, or technical difficulties account for the poor performance of the other 60% of the "bad" projects. The variance in the host countries of these cases also suggests that poor performance is not country specific but rather project specific.

5.6 DISCUSSION AND CONCLUSIONS

In this chapter, we demonstrated that issuance success rates vary among projects; summarized major factors affecting their performance from the literature; performed an econometric analysis to identify the statistical effects of those factors on issuance success rates; and finally reviewed the documented reasons why the 100 projects with the poorest performance fell short. Based on the findings, three main conclusions point to ways in which greater issuance success may be achieved.

1. *Project-specific operation and implementation conditions such as delay, financial status, and technical problems resulted in poor performance.*

Econometric analysis is a useful tool in explaining and analyzing various economic and social problems we face; but it cannot explain everything. The model identifies some of the influential factors in issuance success rates, but with a low R^2. Given the available data and limited variables, the model does not provide a full explanation of diverse issuance success rates.

Review of the original project documents of low performance projects revealed that low issuance success rates are mainly caused by project-specific conditions and characteristics except for manure and landfill gas projects. This suggests that econometric models alone might not be useful in predicting expected issuance success rates of projects.

2. Landfill gas and manure projects display a higher performance risk, resulting in very low issuance success rates on average.

Both econometric analysis and thorough review of project documents suggest that landfill gas and manure projects tend to generate much smaller CERs than estimated on average. The performance of landfill gas projects is vulnerable to uncontrollable factors such as changing weather and anaerobic conditions of the sites. Furthermore, the lack of historical data makes it hard to estimate the amount of greenhouse gas emissions from the sites, since there is no basis for comparison.

Well established historical data is the key to the improvement of accurate estimates of emission reductions for landfill gas projects. In the case of manure projects, the approved methodology seems to be inappropriate, causing extreme over-estimation of CERs. Emission reductions of this type should be estimated in a very conservative way, considering past experience. In the long term, more accurate and proper methodologies for this project type should be developed.

3. PDD consultants play a crucial role in providing accurate estimates; consultants from non-Annex 1 countries tend to perform better than those in Annex-1 countries.

The number of PDD consultants is growing as the CDM thrives. The econometric analysis shows that their nationality as well as their experience affects issuance success rates. Projects by consultants from non-Annex 1 countries perform better than those from Annex 1 countries. Furthermore, more experienced consultants provide more accurate estimates of emission reductions in general. Therefore, project participants should keep in mind the important role of PDD consultants in estimating emission reductions and pay more careful attention in choosing the right consultant based on previous experience and knowledge of the technical and economic background of the projects.

3. The initial stage of project implementation is crucial in generating the estimated amount of CERs; thus, desirable performance can be obtained only for well-planned projects.

The positive sign of the coefficient of the crediting period implies that, in general, projects perform better with longer implementation periods. In addition, the review of project documents clearly shows that much of the poor performance has been caused by delay of the construction and operation and lack of experience at the initial stage of projects. These results suggest that projects need to be well-prepared at the design stage, reducing initial technical and administrative errors and mistakes in order to quickly achieve desirable performance.

5.7 REFERENCES

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6 SUMMARY AND CONCLUSIONS

The CDM is the first and only emissions offset system which involves developing countries in GHG emission reductions under the UNFCCC. Despite many skeptical views of the CDM as well as the operational and procedural problems in its infancy, the CDM has evolved at a surprising speed and is considered to have made positive contributions to the development of greenhouse-gas-reducing projects in many developing countries. Taking into account its historical significance as the first effort of its kind and its current success, a thorough evaluation of its system and its effectiveness is worthwhile for both private project participants and policy makers.

6.1 MAJOR FINDINGS

The research specifically focuses on each stage of the CDM project cycle from development and registration of projects to issuance of CERs and identifies influential factors for success at each stage through a descriptive and analytical study. Throughout the study, the following three major findings emerged.

First, chapter 3 suggests that the attractiveness of CDM projects to potential developers is heavily influenced by the environmental, political, and technical environments of host countries including their emission reduction potential, domestic policy support, and general investment environments. Countries with more emissions and stable investment environments attract more projects. Furthermore, the availability and applicability of approved methodologies as well as the prevalence and maturity of appropriate technologies may affect the development of CDM projects, as shown for a large number of hydro power projects.

This suggests that the current unequal distribution of CDM projects across countries would not be solved under the current system, since the number of projects in the current major host countries will continue to grow and the concentration of CDM projects in certain countries could get worse. Therefore, there should be extra policy support system for least developed countries that do not have financial, technical and administrative capacity under the CDM, in order to promote CDM projects in those countries in the future.

Second, in chapter 4 we found that successful registration depends on the specific characteristics of the project types, of the DOE, and of the host country. Energy efficiency, biomass, and fuel switch projects are project types which tend to have higher registration risks; projects in China overall have a high probability of being registered; and finally registration success probability turns out to vary across DOEs.

In particular, registration success probabilities turn out to vary significantly across project types. This is due to the fact that the nature of certain project types seems to make it more difficult to claim CDM eligibility, so they are more likely to be rejected. This result stresses the importance of development of good quality methodologies and appropriate use of them.

Third, chapter 5 concludes that issuance success rates are project-specific, while specific project types such as landfill gas and manure projects have had mostly very low issuance success rates. We found that the econometric model had limited proves to explain the discrepancies between the estimated and actualized amount of emission reductions, given the explanatory variables available. In fact, review of monitoring documents indicates that for many of the most poorly performing projects, failure is attributable to technical and operational problems at the initial stage of project implementation. The finding highlights the importance of well-prepared PDDs.

In summary, our findings suggest that the development of CDM projects is stimulated by favorable environments in host countries as well as supportive CDM administration. Once projects are submitted for validation, the success of the CDM projects in terms of registration and CER issuance is influenced by their types and a choice of DOEs and PDD consultants. However, we also found that their performance depends on very project-specific conditions.

6.2 LIMITATIONS

This study has several limitations related to analysis methods used in the study as follows.

First, some of the explanatory variables chosen for the econometric analysis may not be the best but were selected due to limited data availability. For example, we used the number of available methodologies as proxy for methodology availability, in order to investigate its effect on registration success probability. However, the variable does not capture quality and applicability of the methodologies. Therefore, a simple increase in the number of available methodologies by one would not be truly equivalent to a unit increase in the availability of methodologies.

Second, due to the small number of projects from particular countries and examples of project types in the pipeline, projects of those types and countries had to be grouped together for the econometric analysis. We recognize that their unique characteristics might be lost through aggregation during the econometric analysis.

Lastly, the large sample size of approximately 5000 projects used in the research increases the credibility and the generality of the conclusions; however, it also adds complexity in interpreting the results and difficulty in controlling the interactions among the selected explanatory variables. Different countries might have more or less potential for any given project type. Projects of one type are large in nature, while others might be small. For this reason, the statistical analysis has been interpreted with care, with emphasis on understating the system.

6.3 POLICY RECOMMENDATIONS

How might the quality of projects in general be improved? How might domestic environments be made more hospitable to CDM projects by the DNAs and their governments? The quality of projects is influenced by the work of each stakeholder under the CDM including the EB, the DOEs, the DNAs and their governments, PDD consultants, and project participants. A CDM project can be successful only when all of these players perform as expected. The findings from this study suggest ways to enhance the capacities or maintain the excellent performance of all key players under the CDM.

• **The EB**: The EB is the decision entity related to the CDM modalities and operations. The importance of its role in the success of the CDM cannot be exaggerated. First of all, the *EB* *needs to pay special attention to certain project types with high risks in registration and CER issuance* such as biomass energy, energy efficiency, landfill gas, and manure projects. These project types require developing proper methodologies and setting clearer guidelines for their applicability. Thus, the EB shall consider to provide different weight on CER price depending on project types and so on as suggested by Sutter and Parreno (2007).

Second, the *EB should accredit and manage DOEs in a systematic and standardized way* in order to consistently maintain expected quality. Their improved performance will reduce the current heavy workload of the EB for reviewing results done by the DOEs, by increasing the credibility of their validation and verification results.

Third, we found that CDM projects are concentrated in countries with enabling environments. When the initiation of CDM projects is entirely left to the invisible hand of the market, unequal distribution among countries cannot be avoided. Therefore, the EB *should provide special supportive rules for those least developed countries*, other than the current exemption of the adaption levy, which is not enough to attract investors.

• **The DOEs**: The analysis result suggests that the choice of DOEs affects probabilities of registration success. DOEs should be neutral and consistent in validating and verifying projects. In addition, they should maintain the quality of their work, providing credible evaluation. Their most important task is to maintain the human and institutional capacity to keep up with the rapid increase in the number of projects.

• **The DNAs and their governments**: The descriptive and econometric results highlight the differences among host countries regarding their ability to fully exploit the potential of

CDM projects. First of all, we found that there is still much room left for the CDM project development in many countries, considering the current level of emissions. *Governments can promote the CDM by increasing public awareness and by establishing human and institutional capability* in their countries.

The study showed that domestic experience with the CDM does not improve registration probability and issuance success rates. This may reflect a lack of active information sharing in the country. The government should make efforts to establish an efficient experience-sharing system in the country.

Another critical measure is for the government to build an efficient DNA which has clear evaluation criteria and does not delay the approval process. Since there are no standardized rules and guidelines regarding the operation of DNAs, each government has to use its discretion in operating the entity and evaluating projects. As discussed in the earlier chapters, the DNA can either encourage or discourage investors depending on their rules and efficiency.

This study also showed that accurate estimation of expected CERs depends on a well recorded historical data. Therefore, it is desirable to set up a good data establishment system to support the CDM and other offset systems that may emerge.

- **Project participants**: Our analysis indicates that the engagement of PDD consultants is important to a successful CDM registration and implementation. However, we also found that the number of PDDs a consultant had worked on in the past did not necessarily ensure success. Rather, a local consultant with good understanding of the area and the project but with less CDM experience can provide a better quality PDD. Therefore, project participants should be prudent in choosing a right PDD consultant for their projects. As shown in the previous issuance experience, project participants should try to minimize the initial technical and operational problems, which are major causes for the reduced CER generation. Technical breakdowns can be prevented or at least reduced by conducting a preliminary pilot study or investing in a similar project in the area if possible.

6.4 REFERENCE

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APPENDIX A:

Fenhann's CDM project category by UNEP Riso (2009)

Project Type	Explanation
Afforestation & Reforestation	According to LULUCF rules
Agriculture	Irrigation, alternative fertilizers, rice crop CH4 (Biogas under methane avoidance)
Methane avoidance	Projects producing biogas from manure, waste water, industrial solid wastem Palm oil solid waste, or avoid CH4 by compostiong or aerobic treatment
Biomass energy	New plant using biomass or existing ones changing from fossil to biomass, also biofuels
Cement	Projects where lime in the cement is replaced by other materials, or neutralization with lime is avoided.
CO2 capture	Recovered CO2 from tail gas substituting fossil fuels for production of CO2
Coal bed/mine methane	CH4 is collected from coal mines or coal beds. This includes Ventilation Air methane (VAM)
Energy distribution	Reduction in losses in transmission/distribution of electricity/distric heat, Country interconnection
EE Households	Energy Efficiency improvements in domestic houses and appliances
EE Industry	End-use Energy Efficiency improvements in industry
EE own generation	Waste heat or waste gas used for electricity production in industry
EE Service	Energy Efficiency improvements in buildings and appliances in public & private service
EE Supply side	More efficient power plants producing electricity and district heat, Coal Field Fire Extinguishing
Fossil fuel switch	Switch from one fossil fuel to another fossil fuel (including new natural pas power plants)
Fugitive	Recovery instead of flaring of CH4 from oil wells, gas pipeline leaks, charcoal production, fires in coal piles
Geothermal	Geothermal energy
HFCs	HFC-23 destruction
Hydro	New hydro power plants
Landfill gas	Collection of landfill gas, composting of MSW, or incinerating of the waste instead of landfilling
N2O	Reduction of N2O from production of nitric acid, adipic acid, caprolactam
PFCs	Reduction of emissions of PFCs
Solar	Solar PV, solar water heating, solar cooking
Tidal	Tidal power
Transport	More efficient transport
Wind	Wind power

APPENDIX B:

Global Warming Potential (Source: Climate Change 1995, The Science of Climate Change: Summary for Policymakers and Technical Summary of the Working Group I Report, page 22.)

Species	**Chemical formula**	**Lifetime (years)**	**Global Warming Potential (Time Horizon)**		
			20 years	**100 years**	**500 years**
CO_2	CO_2	variable	1	1	1
Methane *	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170
HFC-23	CHF3	264	9100	11700	9800
HFC-32	CH2F2	5.6	2100	650	200
HFC-41	CH3F	3.7	490	150	45
HFC-43-10mee	C5H2F10	17.1	3000	1300	400
HFC-125	C2HF5	32.6	4600	2800	920
HFC-134	C2H2F4	10.6	2900	1000	310
HFC-134a	CH2FCF3	14.6	3400	1300	420
HFC-152a	C2H4F2	1.5	460	140	42
HFC-143	C2H3F3	3.8	1000	300	94
HFC-143a	C2H3F3	48.3	5000	3800	1400
HFC-227ea	C3HF7	36.5	4300	2900	950
HFC-236fa	C3H2F6	209	5100	6300	4700
HFC-245ca	C3H3F5	6.6	1800	560	170
Sulphur hexafluoride	SF6	3200	16300	23900	34900
Perfluoromethane	CF4	50000	4400	6500	10000
Perfluoroethane	C2F6	10000	6200	9200	14000
Perfluoropropane	C3F8	2600	4800	7000	10100
Perfluorobutane	C4F10	2600	4800	7000	10100
Perfluorocyclobutane	c-C4F8	3200	6000	8700	12700
Perfluoropentane	C5F12	4100	5100	7500	11000
Perfluorohexane	C6F14	3200	5000	7400	10700

§ Derived from the Bern carbon cycle model.

* The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production.

APPENDIX C:

Sequential building approach

Models were built in a sequential manner by adding more variables to the previous model. The first model, M1, includes only project type dummy variables and an intercept and the sixth model, M7, is the full model with all explanatory variables. Since the models are nested, the comparisons of their predictive efficiency and the goodness of the fit are easy by interpreting indicators. Popular indicators of statistical significance of the models are the changes in Chai statistics and Psuedo R^2. Other indicators include AIC and BIC (Menard 2009). The detailed explanation on those indicators can be found in Long and Freese (2003). Generally, smaller D, AIC and BIC and larger Gm and Psuedo R^2 mean a better fit. Indicators in Table A suggest that adding more variables in the model improves the predictive efficiency and fit of the models in our case, moving from M1 to M7, except M5. The comparison of the indicators between M4 and M5 shows that M5 with PDDCon in addition to the variables included in M4 is not superior to M4; therefore, the variable of PDDCon is excluded for the later models. Consequently, M1 performs the worst, while M7, the full model with the most variables, the best.

The results from M7 in Table A are similar to the results from the stepwise logit model in Chapter 4. The only differences are that 1) the coefficients of **type_3** and **country_4** in M7 are statistically insignificant, meaning that the effect of being a wind power project on registration does not significantly different from being a hydropower projects, the reference

Table A. Model comparisons (1)

		M1	M2	M3	M4
Coefficients[45]	type_d1				
	type_d2	-0.854535	-1.026236	-0.7113811	-0.986864
	type_d3	(0.214364)	(0.1433147)	0.4453561	(0.2080226)
	type_d4	(-0.206063)	-0.4595301	(-0.086091)	(-0.353438)
	type_d5	-1.127958	-1.342038	-0.9867209	-1.28392
	type_d6	-0.6156789	-0.9617654	-0.3992075	-0.4796911
	type_d7	3.02808	3.085643	3.319902	2.938704
	Type_d8	-0.4945237	-0.6863256	(0.0506008)	(-0.143076)
	Meth		-0.0262754	-0.0324676	-0.0235944
	county_d1				
	county_d2			1.02999	1.33022
	county_d3			(-0.078432)	(0.1123894)
	county_d4			-0.5143158	(-0.425170)
	county_d5			0.2302512	(0.0437031)
	CounEx				(-0.000393)
	CounPEx				-0.0023676
	PDDCon				
	doe_d1				
	doe_d2				
	doe_d3				
	doe_d4				
	DOEPEx				
	DOEEx				
	_cons	1.328629	2.864193	2.557262	2.444178
Association/ Predictive efficiency	Gm	107.66	222.77	288.59	303.73
	Psuedo R^2	0.0400	0.0828	0.1073	0.1129
	% Correctly classified	73.19%	73.45%	73.67%	74.92%
Fit statistics	D	2581.482	2466.374	2400.552	2385.406
	AIC	1.123	1.074	1.049	1.044
	BIC'	-15273.741	-15381.103	-15415.940	-15415.592

[45] Coefficients in the parenthesis are those that are statistically insignificant at $p<0.05$.

Table A. Model comparisons (2)

		M5	M6	M7
Coefficients[46]	type_d1			
	type_d2	-0.9870414	-1.014064	-0.7894936
	type_d3	(0.2032396)	(0.321706)	(0.3987727)
	type_d4	(-0.361177)	(-0.381168)	(-0.207832)
	type_d5	-1.281821	-1.235853	-1.082371
	type_d6	-0.4871678	-0.514163	-0.4838277
	type_d7	2.939014	2.877995	3.432347
	type_d8	(-0.145668)	(-0.208246)	(-0.190630)
	Meth	-0.0228417	-0.024560	-0.0126327
	county_d1			
	county_d2	1.296814	1.388167	1.481662
	county_d3	(0.0749255)	(0.188582)	(0.2227479)
	county_d4	(-0.395802)	(-0.440062)	(-0.483960)
	county_d5	(0.0130369)	(0.196467)	(0.1806867)
	CounEx	(-0.000436)	(-0.000301)	(-0.000199)
	CounPEx	-0.0021924	-0.002182	-0.0031828
	PDDCon	(-0.00189)		
	doe_d1			
	doe_d2		0.288128	(-0.094051)
	doe_d3		0.506534	(-0.005903)
	doe_d4		-0.371136	-1.047611
	DOEEx			-0.0016244
	DOEPEx			0.0043287
	_cons	2.470534	2.348703	2.326533
Association/ Predictive efficiency	Gm	305.53	333.15	349.16
	Psuedo R^2	0.1136	0.1239	0.1298
	% Correctly classified	74.79%	75.27%	75.79%
Fit statistics	D	2383.614	2355.528	2339.976
	AIC	1.044	1.034	1.029
	BIC'	-15409.639	-15422.232	-15422.292

[46] Coefficients in the parenthesis are those that are statistically insignificant at $p<0.05$.

case and projects in Mexico does not have a significantly different registration probability from those in Brazil and 2) the magnitudes of the other coefficients in the two models are slightly different, while their signs coincides with each other. Comparisons of the indicators such as Psuedo R^2, D and AIC for the two models suggest that the stepwise logit model is slightly superior to M7.

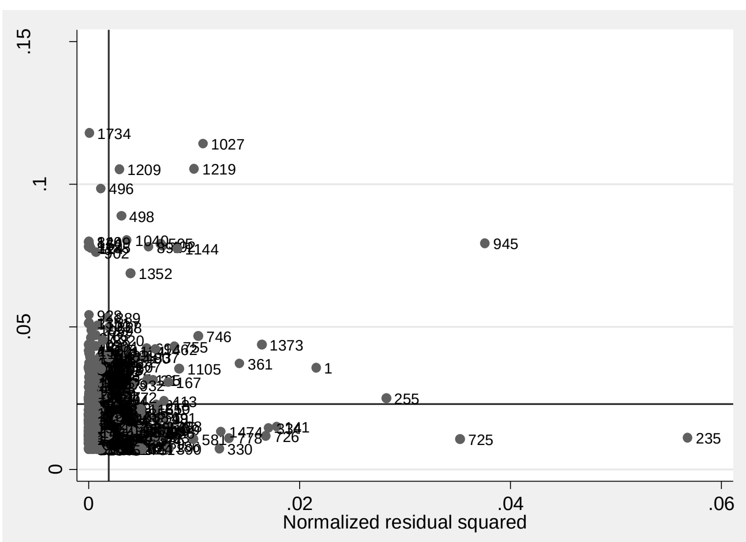
Meanwhile, the model comparisons not only enable us to evaluate the performance and efficiency of different models but also provide qualitative information regarding explanatory variables. For example, **Country_d4** and **Country_d5** are statistically significant in Model 3 but not in Model 4, when the two variables of **CounPEx** and **CounEX** are added in the model. This implies that the association between those countries and registration can be explained by the level of experience in hosting CDM projects in the country; while **Country_d2** has a strong effect on the chance of being registered, with significant coefficients in all the models. For the case of **type_8** (CH4 avoidance projects), the coefficient becomes insignificant by including country dummy variables in M3, while the coefficients are statistically significant in M1 and M2. This suggests that the effect of being CH4 avoidance projects (**type_8**) on registration is explained by the choice of countries.

APPENDIX D:

Regression Diagnostics for Issuance Success Rates Model

1. Influential data

Stata command, lvr2plot, is performed in order to find influential observations, which can significantly affect the results of the model. The influential observations are usually an odd combination of covariates. We found a project activity with CDM ID 945 as a possible influential observation, with high Cook's D. The project is a small-scale methane avoidance project ($Type_4$) in India, with an issuance success rate of 2.4, which is very high for its project type. In addition, few crediting days and a PDD consultant with no prior experience are all factors working against the high success rate. Therefore, we exclude the observation from the econometric analysis.



2. Test for an omitted variable

The omission of relevant variables causes a bias in the estimation of coefficients. The Ramsey test is one way to test model specification; it can be performed with ovtest command in Stata. Model 1 rejects the null hypothesis that the model has no omitted variables, meaning that the model specification is not appropriate. We tried to add other possible explanatory variables such as DOE- relevant variables to solve the omitted variable problem but the Ramsey test still shows the model has an omitted variable.

3. Test for multi-colinearity

We checked the multi-colinearity using vif command in Stata. The cut-off for the VIF (variance inflation factor) is 10. When VIF is great than 10, the investigator should question colinearity among the covariates. The results of VIF of the model indicate there is no serious colinearity.

Variable	VIF	1/VIF
$Type_2$	1.15	0.86945
$Type_3$	1.19	0.83947
$Type_5$	1.09	0.91725
$Type_7$	1.1	0.90758
$Type_8$	1.17	0.85688
$Type_9$	1.21	0.82551
PDDCon	1.06	0.94616
PDDCoun	1.22	0.82012
totalDays	1.12	0.89038
Mean VIF	1.15	