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The Cost Structure of the Clean Development Mechanism

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Abstract

This paper examines the cost of producing emission reduction credits under the Clean Development Mechanism. Using project-specific data, cost functions are estimated using alternative functional forms. The results show that, in general, the distribution of projects in the pipeline does not correspond exclusively to the cost of generating anticipated credits. Rather, investment choices appear to be influenced by location and project type considerations in a way that is consistent with variable transaction costs and investor preferences among hosts and classes of projects. This implies that comparative advantage based on the marginal cost of abatement is only one of several factors driving Clean Development Mechanism investments. This is significant since much of the conceptual and applied numerical literature concerning greenhouse gas mitigation policies relies on presumptions about relative abatement costs. The authors also find that Clean Development Mechanism projects generally exhibit constant or increasing returns to scale. In contrast, they find variations among classes of projects concerning economies of time.

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1 Introduction

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) sets binding targets for the European Community and other industrialized countries (i.e., countries listed in Annex B of the Kyoto Protocol) for curbing anthropogenic greenhouse gas (GHG) emissions. While Annex B countries are committed to limit GHG emissions to pledged amounts primarily through national measures, the treaty offers three market-based mechanisms intended to lower the cost of mitigation: (1) Emissions Trading, (2) Joint Implementation (JI), and (3) the Clean Development Mechanism (CDM).[1] The JI and CDM are two project-based mechanisms that allow Annex B countries to meet their targets by sequestering GHGs or reducing GHGs emissions in other countries. While the JI mechanism enables the Annex B countries to carry out bilateral or multilateral emissions reduction projects among themselves, the CDM encourages investment in sustainable development projects that reduce emissions in developing countries.[2] The Emissions Trading (ET) allows Annex B countries to trade assigned amount units (AAUs) as well as credits generated by the project-based mechanisms among themselves.[3]

In response to the CDM provision, a large number of emissions reduction projects have been initiated in different developing countries, which widely vary both in the type of abatement technology used and the size of operation. This paper examines the abatement cost structure of the CDM projects in the pipeline with the objective of assessing the cost-effectiveness of GHG reductions through the CDM

[1] Annex B countries have accepted targets for limiting or reducing emissions. These targets are expressed as levels of allowed emissions, or "assigned amounts," over the 2008-2012 commitment period. The allowed emissions are divided into "assigned amount units" (AAUs).
[2] The JI and CDM are also intended to attract the private sector to contribute to mitigation efforts. According to the JI and CDM pipeline database, most of the projects are private initiatives (UNEP Risoe CDM/JI Pipeline Analysis and Database, 01 November 2008).
[3] As set out in Article 17 of the Kyoto Protocol, Annex B countries with fewer emissions than permitted are allowed to sell the excess AAUs to the countries with more emissions than permitted.

and providing policy relevant perspectives for improving the existing incentive structure of the mechanism.

The CDM provides an incentive to Annex B countries for meeting their targets at lower costs. For measurable and verifiable emissions reductions that are additional to what would have occurred without the CDM project, an Annex B country earns certified emission reduction (CER) credits, each equivalent to one ton of CO_2 equivalent (tCO_2e hereafter) abatement. The Annex B country is allowed to use the earned CERs to meet part of its emission reduction targets under the Kyoto Protocol or sell the credits to other parties. Stimulating sustainable development through technology transfer and foreign direct investments, the CDM also provides a way for developing countries to contribute to emissions reduction efforts.

Both industrialized and developing countries have responded to the incentives provided through the CDM. As of December 2010, there were 6,700 projects at some stage of the CDM project cycle.[4] If all of these projects were validated by the Executive Board (EB) and implemented to their full potentials, they would generate emissions reductions totaling 3.51 billion tCO_2e and generate an equivalent number of CERs by the end of the first commitment period of the Kyoto Protocol in 2012 (UNEP Risoe CDM/JI Pipeline Analysis and Database, 01 January 2011).

While the rapid increase in the number of CDM projects indicates that this provision aligns the incentives of the Annex B and non-Annex B parties, the role of cost as a motive for investment is less well understood. Improving on this understanding is crucial for policy. This is because most numerical analysis of how the CDM affects the cost of meeting the Kyoto Treaty objectives are based on specified abatement cost curves and the assumption that capital will seek out least-cost projects.[5] This same approach also leads to prediction of the sectors and regions likely to benefit from project investment flows. However, project costs are not synonymous with abatement costs and there are additional

[4] See Larson et al. (2008) for a discussion of CDM implementation rules and the CDM project cycle.
[5] Metz et al. (2007) provide a careful discussion of abatement cost curves in top-down and bottom-up models of mitigation costs and how the models are used to inform policy.

characteristics that influence project investment decisions. Our results suggest these factors are consequential and explain why the current pool of project investments differs from ex ante predictions.[6]

While previous studies provide useful estimates of abatement costs of various pollutants, a majority of those are based on secondary data or approximated coefficients in the abatement functions. In this paper we take advantage of available data on CDM projects to answer several questions that are important for the future of CDM policy design but have not been addressed earlier. The project-level data distinguishes among various types of projects, methodologies for calculating emissions reductions, the countries hosting the projects, and sequence of new project investments for the period 2003-2010. Thus, our dataset allows us to draw distinction among projects across types (technologies), methodologies, locations, and time.

These features of the data allow us to examine the relative role of mitigation and project costs in explaining the pool of observed investments. It also allows us to test two hypotheses important for policy: (1) whether CDM projects exhibit economies of scale in emission abatement, and (2) whether the marginal cost (as well as the average cost) of abatement of CDM projects has decreased over time, presumably due to accumulated experience.

The remainder of the paper is organized in the following way. After selectively reviewing the relevant literature, the following section describes the conceptual model and empirical framework for estimating mitigation cost of CDM projects. Section three describes the CDM project-specific data. Section four delineates the estimation procedures and results. Finally, the last section concludes and discusses the policy implications.

2 Estimating Emissions Abatement Cost of the CDM

One of the early studies on pollution abatement cost was undertaken by Rossi, Young, and Epp (1979). They estimated a cost function in which abatement cost is a function of the volume and quality of both effluent and influent streams and factor prices (i.e., prices of land, labor, capital, and materials). Fraas and

[6] See Rahman et al. (2011) for a review of ex ante predictions for the CDM.

Munley (1984) also estimated water pollution abatement costs based on the framework proposed by Rossi, Young, and Epp.

Goldar, Misra, and Mukherji (2001) identified problems associated with the cost function proposed by Rossi, Young, and Epp, and argue that output of abatement activity should be defined as the reduction in the pollution load. They define output of water pollution abatement as a function of the volume of waste water treated, the difference in the pollution levels of influent and effluent water, and inputs used to purify the water. Golder, Misra, and Mukherji specified a water pollution abatement cost function in which the cost of abatement is an explicit function of the quantum of abatement (i.e., the difference between water quality before and after the treatment) and factor prices. There are some similar studies that did not include factor prices in the abatement cost function (e.g., Mehta, Mundle, and Sankar, 1993).

Another set of studies considered pollution abatement as an inseparable multi-output process, and suggested that the cost of abatement might not be separable from the cost of production (see Pizer and Kopp, 2005; Maradan and Vassiliev, 2005; Boyd, Molburg, and Prince, 1996). Gollup and Roberts (1985) used observed data on utility pollution abatement and production costs to estimate a cost function that included emission control rates as a predictor of production costs. Nordhaus (1994) compared a number of published models in terms of percentage difference of carbon emissions from a baseline path and propose an aggregate formula relating cost to output and reduction of greenhouse gases. In a similar manner, Newell and Stavins (2003) explored the pollution abatement cost heterogeneity (i.e., the relative cost of uniform performance measured in terms of emissions per unit of product output) by using a second-order approximation of the costs around the baseline emissions. Their approach was based on variation in baseline emission rates, thus estimation of the cost function required data on baseline and project emissions. In contrast, Newell, Pizer, and Shih (2003) developed a quadratic abatement cost function in which the cost of pollution abatement per unit of output depends on abatement rather than emissions. Using project-level census data on compliance costs and emissions abatement in four industries, they estimated the parameters of the cost function and compute gains from emission trading.

In their study of power generation and the US SO_2 program, Considine and Larson (2006) considered the use of the atmosphere for the disposal of emissions as a factor of production, priced by tradable emission permits, and derived related input demand schedules in a cost-function framework. The authors applied a similar approach in their paper on the European Union's program for greenhouse gases (Considine and Larson 2009).

Several studies estimated the abatement cost function by separating cost of abatement from the cost of production. Using data from the U.S. Census Bureau, Hartman, Wheeler, and Singh (1994) estimated air pollution abatement costs by industry sectors. Assuming that the abatement cost function was separable from the firm's production cost function, they estimated abatement costs as a quadratic function of emissions abatement. Hamaide and Boland (2000) defined abatement costs as a second-order polynomial function of abatement alone. While estimating the cost of abating agricultural nitrogen pollution in wetlands, Bystrom (1998) estimated linear, quadratic, and log-log specifications of a cost function.

For the projects that generate CERs only, total project costs are synonymous with abatement costs. However, in some cases, project investments increase power generations as well as mitigate greenhouse gas emissions. In this paper, our initial focus will be on a separable cost function; consequently we calculate a net cost of abatement by subtracting out net revenues from the expected sales of electricity, a "by-product" of abatement. Later, we repeat the analysis using total project costs, but include expected power increases as a control.

2.1 The Conceptual Model

As a starting point for the derivation of our applied model, consider the expected project value function, where the value of the investment, V_0, is determined by the discounted value of two streams of profit from a project initiated in year 0 and expected to last *n* years[7]:

$$V_0 = \sum_0^n \pi_t^A e^{-rt} + \sum_0^n \pi_t^E e^{-rt}; \;\; t = 1, 2, \dots, n. \tag{1}$$

[7] See Timilsina and Lefevre (1999) for a related discussion.

where the superscripts A and E distinguish between the expected profits from producing abatement credits and profits from generating electricity. The equation can be expanded to distinguish revenues from costs:

$$\sum_0^n \pi_t^A e^{-rt} + \sum_0^n \pi_t^E e^{-rt} = \sum_0^n p_t^A A_t e^{-rt} + \sum_0^n p_t^E E_t e^{-rt} - \mathrm{C}_0^{\mathrm{J}} \tag{2}$$

For the moment, we treat the costs of producing both abatement credits and electricity as joint, and denote the total discounted costs as: $C_0^J = I_0 + \sum_0^n c_t e^{-rt}$, where c is the annual variable cost of the project. When the rate of expected profit clears the investment hurdle, positive investments are observed and the associated value function can be characterized as:

$$V(I_0^*) = \bar{p}_0^A \sum_0^n A_t e^{-rt} + \bar{p}_0^E \sum_0^n E_t e^{-rt} - C^J(\mathrm{A}_0, \mathrm{E}_0) \tag{3}$$

where the $\bar{p}_0^A$ and the $\bar{p}_0^E$ represent the weighted average prices for abatement and power at the time the investment decision is made. The aggregate output levels consistent with solution values can be recovered via the envelope theorem, as: $\frac{\partial I^*}{\partial \bar{p}_0^A} = \sum_0^n A_t e^{-rt} \equiv \mathrm{A}_0$, and $\frac{\partial I^*}{\partial \bar{p}_0^E} = \sum_0^n E_t e^{-rt} \equiv E_0$, where A_0 and E_0 are the volumes of CERs and of electricity the project is expected to produced over its lifetime, weighted by the discount factor used in the evaluation of the investment function.

The associated joint cost function can be written as:

$$C_\tau^J(\mathrm{w_t}, \mathrm{A}_\tau, \mathrm{E}_\tau; S_\tau) \tag{4}$$

where τ is the initial period of a given project, where w_τ is the vector of expected input prices, and S_τ is the set of state variables, in addition to input prices, that conditioning the optimization problem.

The problem can be simplified when costs are not joint, that is, when $C^J = C^A(A) + C^E(E)$. In this case, equation 3 can be restated as:

$$\mathrm{V}(I_c^*) = \mathrm{V}(\mathrm{I}_0^*) - \sum_0^n p_t^E E_t e^{-rt} = \bar{p}_0^A \sum_0^n A_t e^{-rt} - C^{\mathrm{A}}(\mathrm{A}_0) - \mathrm{C^E}(\mathrm{E}_0) \tag{5}$$

where, as before, the optimal level of abatement can be recovered via the envelope theorem. However, in this case we needn't keep track of the optimal level of power generated by the project, since our objective is to estimate the abatement portion of the non-joint cost function, given by:

$$C_\tau^A(\mathrm{w_t}, \mathrm{A}_\tau; S_\tau) \tag{6}$$

where $C_0^A = I_0 - \sum_0^n p_t^E E_t e^{-rt} + \sum_0^n c_t^A e^{-rt}$ and where c_t^A are the variable costs associated with abatement.

In the next section, we focus our attention on the non-joint costs function given by equation (6). However, we also consider as an alternative the joint cost function given by equation (4). As it turns out, there are few practical consequences from choosing version of the applied model over the other.

2.2 The Empirical Emissions Abatement Cost Function

Assuming fixed input prices, the basic expressions for the log-log and log-quadratic functional forms of the abatement cost for project *i* can be given by:

$$\ln(C_i) = \alpha + \beta \ln(A_i) + \theta q_i \text{ and} \tag{7}$$

$$\ln(C_i) = \alpha + \beta \ln(A_i) + \gamma[\ln(A_i)]^2 + \theta q_i, \tag{8}$$

where C is the net present value of total abatement costs, A is total emissions abatement, and q is a vector of control variables (e.g., project duration, project types, and location).[8] Equation 7 is nested in 8 and the two are indistinguishable when γ is indistinguishable from zero. Given the parameter estimates, the marginal cost of abatement can be computed for different types of CDM projects corresponding to equations (7) and (8) by $\frac{\partial C}{\partial A} = \beta . \frac{C}{A}$ and $\frac{\partial C}{\partial A} = (\beta + 2\gamma) . \frac{C}{A}$, respectively.

The vector of input prices, w, associated with the cost functions is not always observed; however, for a given time period and a given location, the prices of the inputs are likely the same. Thus, dummy variables for different project types, location, and time periods can be used as a proxy for the missing input price vector. Said more formally, let x_m be the vector of inputs associated with a specific mitigation methodology, for example generating solar power. The associated vector of prices can vary by time (t) and

[8] In the current setting, we suppress the time subscript assuming that the equilibrium level of abatement would be the same in each year. This restriction is consistent with the CDM pipeline dataset in which expected emissions abatement and investments are annualized based on the PDDs. We expect to relax this assumption in future work when data on actual abatement and investments are available.

place (l), suggesting the notation $p_{x,l,t}$. Because we lack specific information about this vector, we use a triplet of dummies (x, l, t) to proxy the missing input prices. [9]

Separate from differences in costs and expectations explained by start-dates of the projects, the duration of the projects may also matter. Booth (1991) points out that projects can exhibit 'economies of time', such that projects with longer duration are associated with lower cost per unit costs. On the other hand, CDM projects with longer duration are likely riskier than the projects of same size and type with shorter duration. In order to take account of such time relationships, project duration (in years) is also used as a continuous explanatory variable.

In the methodology outlined above, we use electricity prices to account for expected revenue from electricity sales when calculating abatement costs. Still, because the electricity pricing regimes are sometimes complex and subject to direct and indirect subsidies, using average reported prices to disentangle abatement and power revenue streams can introduce its own set of problems and errors. To account for this, we include estimates based on an alternative approach; we calculate the present value of the total project cost without adjustment and, to account for this omission, include the volume of the generated power as a state variable in the cost function. This also allows for the fact that there may be joint-production effects that the baseline methodologies ignore. In this case, Cin equations (7) and (8) represents the present value of the project costs and the vector of control variables q includes electricity output.

3 Data Description

Available information about CDM projects sent to the CDM Executive Board (EB) for consideration through December 2010 is obtained from the CDM/JI Pipeline Analysis and Database of the United Nations Environment Programme (UNEP) Risoe Center. The dataset includes information about individual CDM project, including the project name, type, registration or validation status, approved

[9] This solves the missing price-information problem, but the associated parameter on the dummies likely pick up other attributes of time and place. This is a mixed blessing, since the net effect is to round up otherwise unobserved effects; however it does confound the interpretation of the estimated fixed effects.

methodologies for calculating emissions reductions, involved host countries and credit buyers, expected CERs, and power generation capacity. While information about inputs used in the projects are not available, the technology employed for each project is laid out in the baseline documentation of CDM projects and therefore implicitly in the project classifications, which are based on applied baseline technologies.

Scrutiny of the dataset shows that the CDM portfolio has grown rapidly since its inception in 2003. By December 2010, 6,977 CDM projects have been sent to UNFCCC for validation. 1,079 of these projects have been registered, 351 are in the process of review, 5,270 are in the process of validation, while 226 projects were either withdrawn or rejected by the CDM Executive Board (EB) or terminated by independent Designated Operational Entities (DOE) upon audit. (UNEP Risoe CDM/JI Pipeline Analysis and Database, 01 January 2011). Moreover, there are 49 observations with missing abatement data and 2 observations with zero abatement. The remaining 6,700 CDM projects in the pipeline are expected to reduce approximately 872.47 Million tCO_2e in each year and 3.51 billion tCO_2e by 2012.

Following the UNEP Risoe Center protocol, the CDM projects in the pipeline can be categorized into eight major types: (1) renewable resource based, (2) methane avoidance, coal bed/mine and cement, (3) supply-side energy efficiency, (4) demand-side energy efficiency, (5) hydrofluoro-carbon (HFC), perfluoro-carbon (PFC), and nitrous oxide (N_2O) reduction, (6) fossil fuel switch, (7) forestation, and (8) transport. Except for fossil fuel switch and transport projects, each major category can be divided into several specific types. The CDM board has approved 115 different methodologies to calculate emissions reductions by these projects. The methodologies account for the technologies employed by the projects. For some projects, combinations of two or three relevant methodologies are used. However, approved methodologies can be categorized in six major groups: (1) large scale (AM), (2) large scale consolidated (ACM), (3) small scale (AMS), (4) large scale afforestation and reforestation (AR-AM), (5) large scale afforestation and reforestation consolidated (AR-ACM), and (6) small scale afforestation and reforestation (AR-AMS). Table 1 reports the number and percentage of the CDM projects in the pipeline and annual and total CERs to be generated by the end of the first commitment period by each major project type and methodology.

As can be seen from table 1, about 62 percent of the projects in the CDM pipeline are renewable resource based power generating projects accounting for 43.65 percent and 37.67 percent of the annual and total abatement during the first commitment period, respectively. Methane avoidance, coal bed/mine and cement is the second largest category in terms of number (17.04 percent) and annual abatement (18.32 percent), but HFCs, PFCs, and N_2O reduction is the second largest category in terms of 2012 abatement (22.61 percent). Transport is the smallest and forestation is the second smallest category in terms of both number of projects and abatement. Large scale methodologies (AM) are applied to 6.87 percent of the projects, which account for 27.11 percent of the total annual abatement by the projects in the pipeline. Large scale consolidated (ACM) and small scale (AMS) methodologies are applied to 45.97 and 46.18 percent of the projects that account for 62.16 and 10.09 percent of annual abatement, respectively.

Following UNEP Risoe Center, the expected issuance of CERs for each individual project in each year over the life of the project is calculated by adjusting the annual average emissions abatement with an increment or decrement as reported in the database.[10] The crediting period is either 20 or 30 years for the afforestation and reforestation projects and either 7 or 10 years for all other types of projects. We consider the number of credit years as the duration of the project. In addition to CERs, some projects generate additional electricity output (in addition to the capacity of the baseline). The pipeline database reports the additional electricity generation capacity and expected hours of operation for individual projects. Using this data, the expected electricity output measured in megawatt hours (MWh) are calculated for each year of the project, as well as discounted-weighted lifetime totals.

Individual CDM projects widely vary across types in terms of expected annual average CERs and electricity output. The smallest project in the CDM pipeline is expected to generate only 400 CERs per

[10] The CDM pipeline database reports the annual increment or decrement in a variable namely 'slope.' The expected CER issuance over the life of a project is approximated with a straight line that goes through the annual average value in the mid-year. For a positive (negative) value of 'slope,' expected CERs increases (decreases) each year by the 'slope' amount. There is no change in expected CERs over time when 'slope' is zero.

year, while the largest project is expected to generate more than 10.4 million CERs per year. The median and mean of annual expected CERs from the projects are 49,000, and 130,220, respectively. Figure 1 shows the frequency distribution of the CDM projects within each capacity interval of 10,000 CERs per year. In terms of expected total CERs the size of individual projects ranges from 3,500 to 836.2 million, with a median at 0.4 million and mean at 1.1 million CERs.

Table 2 shows the mean and range of annual expected CERs and electricity generation by various types of CDM projects in the pipeline. In terms of annual expected CERs, H/PFCs & N_2O reduction projects are the largest and demand-size energy efficiency projects are the smallest among the major categories. Fossil fuel switch is the second largest category while forest is the second smallest category. Renewable resource-based project category ranks sixth in terms of annual expected CERs.

Emissions reduction is the sole purpose of the H/PFCs & N_2O reduction, forest, and transport projects. After excluding these categories, electricity generation is a joint purpose of 72 percent of the CDM projects in the remaining categories. While the average additional electricity generation capacity of these projects is about 206 thousand MWh per year, the capacity ranges from 10.0 to 29.8 million MWh (table 2). In terms of average annual additional electricity generation capacity, fossil fuel switching and supply-side energy efficiency are the largest and second largest categories, respectively, followed by the renewable resource-based category. More than 91 percent of the renewable resource-based and more than 80 percent of the supply-side energy efficiency CDM projects are capable of generating electricity. The largest electricity generating project falls into the category of supply-side energy efficiency projects. Geothermal and hydro-electricity projects are the largest and second largest among the renewable resource based electricity generation projects. In particular, electricity generation projects that have the capacity of generating more than one million CERs per year are in hydro, biogas, landfill gas, coal bed/mine methane capture, cement, fugitive, and energy efficiency supply-side and own generation sub-categories.

The UNEP Risoe Center reports initial capital investments in 4,418 of the projects in the pipeline. Annual operation and maintenance cost data for 122 projects are obtained from the PDDs with the help of Climate Solutions (2008). See Annex I for details on how operation and maintenance costs are obtained. Using the available data, initial investment and operation and maintenance costs per unit of $KtCO_2e$ abatement are calculated. Average per unit capital costs and operation and maintenance cost of abatement across the CDM projects categorized by project types are calculated and then used as proxies for the projects for which such data were not available.

The present value of emissions abatement costs for each project are calculated as described in equation (6). The operation and maintenance costs are discounted using real interest rates for the year of fixed capital investment (i.e., the prior year of credit start period). Real interest rates in the host countries are used for unilateral projects, while the rates in the partner countries are used for bi- and multi-lateral projects. Real interest rates for the host and partner countries are obtained from the World Bank (WDI 2010). For the electricity generating CDM projects, the net present value of emissions abatement costs are calculated by subtracting the sum of the discounted flow of electricity sales revenue from the present value of total costs. Wholesale electricity tariffs in different host countries obtained from the PDDs are used to calculate the flow of revenues from electricity sales. Real interest rates are used to discount those revenues.

As implied by duality, the abatement cost function includes the sum of the discounted-weighted flows of CERs and electricity outputs. Real interest rates as mentioned above are used to discount those streams of outputs. Table 3 presents the categorical means and standard deviations of the (discounted) total amount of emissions abatement and electricity outputs over the life of the projects and net present value of total abatement costs of the projects, for which all information are available. Wholesale electricity tariffs in some of the host countries were not available, leaving 6,326 observations for use in the empirical analyses.

4 Estimation Results and Discussions

The log-transformed net present values of the total cost of mitigation by each individual CDM project are plotted against corresponding total abatement and presented in figure 2.[11] We estimate the mitigation cost first employing the log-log model in equation (7), and then examine the more flexible log-quadratic

[11] Plots of costs against abatement levels for specific project types show a similar pattern.

functional form in equation (8) with alternative specifications. To make comparisons easier, we report calculated elasticities or, in the case of the discrete regressors, associated discrete percentage changes in the resultant set of tables and report the underlying estimated parameters in the Annex.

We begin with an ordinary least squares estimation of the log-log model. In particular, the logarithm of abatement cost is regressed on the logarithm of the volume of abatement, logarithm of project duration, and dummy variables for major project types, emission reduction credit start years, and broad geographical regions (model I). Eight project-type dummies are used for major project types as described earlier. Eight credit start year dummies are used for each year during 2005-12. Note that for a small number of projects, credit starts prior to 2005 or after 2012. Since the Kyoto protocol was ratified in 2005, projects for which credit starts prior to year 2005 are grouped together. In the same fashion, projects for which credit starts after the first commitment period (i.e., after 2012) are categorized in a separate group. Five regional dummies are used for the projects located in Africa, Asia and the Pacific, Europe and Central Asia, Latin America, and the Middle East. For analytical convenience, we run the regression without the intercept terms. The coefficient estimates of the continuous variables in the log-log model provide corresponding elasticities while the coefficients of the dummy variables represent the discrete percentage change in mitigation costs as the value of the dummy switches from 0 to 1, which we refer to subsequently as semi-elasticities. The corresponding results for this specification are presented in the second column of table 4.

In order to allow the cost function to have a more flexible functional form, we estimate emissions abatement costs with three alternative log-quadratic specifications. First, the log of abatement cost is regressed on the log of abatement, squared log of abatement, log of project duration, and dummy variables for major project types, emission reduction credit start years, and broad geographical regions (model II). Thus, apart from the squared term, model (II) has the same set of explanatory variables as of model (I). Second, the log of abatement cost is regressed on the same set of explanatory variables as in model (II) plus a set of dummy variables for major groups of approved methodologies (model III). Approved methodologies are categorized into six major groups: large scale (AM), large scale consolidated

(ACM), small scale (AMS), large scale afforestation and reforestation (AR-AM), large scale consolidated afforestation and reforestation (AR-ACM), and small scale afforestation and reforestation (AR-AMS). Finally, the log of abatement cost is regressed on the same set of explanatory variables as in model (III) except that dummy variables for each different methodology and host country are used instead of categorized methodology dummies and region dummies, respectively (model IV). In particular, 86 host country dummies and 206 methodology dummies are used as multiple methodologies are applied for many projects. Estimated elasticities and semi-elasticities for models (II), (III), and (IV) are presented in the third, fourth, and fifth columns of table 4, respectively. [12] The estimates for methodology and host country dummies in model (IV) are suppressed due to space limitation.

As can be seen from Table 4, the coefficient estimate of log of abatement (i.e., elasticity) is positive and highly significant in the log-log model (model I), suggesting that the cost of abatement increases with the volume of abatement. However, a one-tailed test indicates that the elasticity is less than one at 5% significance level, thus implying 'economies of scale' whereby output grows proportionately faster than costs.[13] Estimated coefficient of log of project duration is significantly positive, but a similar test suggests the elasticity is not statistically different from one (table 4). This result suggests that, all thing equal, mitigation cost increases with project duration thus implying 'diseconomies of time.' Estimated coefficients of all project type dummies are positive and significant except for H/PFCs & N_2O reduction projects (table 4). The coefficient estimates for all credit start-year dummies are negative but significant only for years 2007-09, 2012, and later (table 4). Estimated coefficients of the regional dummy variables are negative but significant only for Asia and the Pacific and Europe and Central Asia (table 4), thus implying lower fixed costs in those regions compared to that of Africa, Latin America, and the Middle East.

The inclusion of the squared log of abatement as an additional explanatory variable in the model (model II) does not change the results significantly. While the magnitude of the estimates from models (I)

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[12] Estimated coefficient estimates and their standard errors under models (I)-(IV) are reported in annex table 1.
[13] This test and subsequent ones are one-tailed tests based on a nonlinear combination of estimated parameters and implemented using Stata's (2012) NLCOM post-estimation procedure.

and (II) are slightly different, the estimates for each variable has the same sign and level of significance in both models (see table 4 and annex table 1). The estimated coefficient for the squared log of abatement does not appear to be significant in model (II). A test results indicates that the estimated abatement elasticity is less than one at a 10% significance level (Stata 2012).

The results from model (III) show that inclusion of major methodology dummies alters the magnitude of the coefficient estimates and corresponding elasticities without affecting the signs. As in models (I) and (II), the estimated coefficient for the log of abatement appears to be positive and significantly less than one, while the estimate for the log of project duration is positive and significant.[14] All project-type dummies are positive and significant as in models (I) and (II), while the relative magnitudes of the estimate vary. Regional dummies also have similar estimates with the same levels of significance as in models (I) and (II). In contrast to models (I) and (II), credit start-year dummies for years 2005-6, 2008-9, and 2012 appear to be significant while the signs of the coefficients remain the same. The estimated coefficient of the dummy variable for the large scale methodology group (AM) is positive and significant while the coefficients of the methodology dummies for all other categories are negative and significant (table 4). This result suggests that, relative to the large-scale consolidated methodologies, fixed costs of mitigation are higher for large-scale methodologies and lower for small-scale methodologies and all types of methodologies used for afforestation and reforestation projects.

The results from the full model (model IV) show that the use of dummy variables for each specific methodology and host country instead of categorized methodologies and regions in model (III), respectively, do not substantially change the estimated abatement elasticity. The estimated coefficients of project-type dummies remain positive and highly significant as those in model (III). The result of a one-tailed test indicates that the estimated elasticity for abatement and is less than one at 1% significance level (Stata 2012). However, the estimated elasticity for project duration appears to be much lower and significantly less than one. Also, none of the coefficients of the dummy variables for credit start years appears to be significant in model (IV) (table 4 and annex table 1).

[14] The results of separate test indicates that the the elasticity for project duration not significantly different from one.

The estimated coefficient of the dummy variable for each project type can be interpreted as the conditional expected mean of log of net present cost of mitigation through that type. In the log scale, the difference between the estimates for two different project types is equal to the difference in the expected geometric means of the log of mitigation costs for those project types. In the original scale, the difference is the ratio of the expected geometric means of mitigation costs for those project types. The exponential of the difference between the two estimates provides the percentage change in mitigation cost for switching from one type to the other type of CDM projects.

The estimated coefficients for project-type dummies in model (IV) show that the fixed cost of mitigation is the highest for afforestation and reforestation projects, descending orderly followed by renewable resource based, demand-side energy efficiency, supply-side energy efficiency, methane avoidance, transportation, fossil fuel switch, and H/PFCs & N_2O reduction projects. Considering forestry projects to be the benchmark, mitigation cost decreases for switching from forestry to any other type of projects, when all other variables are held at some fixed values. According to the results of model (IV), the geometric mean of mitigation cost decreases by nearly 76.26 percent for switching from forestry to renewable resource based projects, holding other variables constant.[15] Switching from the forestry to H/PFCs & N_2O reduction projects lowers the expected geometric mean of mitigation costs decreases by 98.30 percent, holding other variables constant.

The estimated coefficients for methodology dummies do not indicate any systematic pattern for large-scale (AM), large-scale consolidated (AMC), and small-scale technologies (AMS), but do indicate significant variations among specific methodologies in each category. The estimates for AM technologies vary from –2.69 to 2.01, estimates for ACM technologies vary from –1.89 to 1.97, the estimates from AMS technologies vary from –1.33 to 1.91, and the estimates for AR technologies vary from –2.12 to –0.27.

[15] The percentage change in the geometric mean of the mitigation cost for switching from forestry projects to renewable resource based projects is calculated as 100×[*exp*(the coefficient for renewable – the coefficient for forest)−1].

The coefficient estimates for the host country dummies ranges from –0.86 to 1.82, without any specificity for regions. While these coefficients reflect country-specific fixed cost of mitigation, the countries that host the most projects are not the ones that have the lowest-valued country dummies when we include them. Figure 3 depicts the total number of CDM projects in individual host countries against the values of the coefficients for country dummies from model (IV). Thus the distribution of the CDM project across host countries does not follow the principle of comparative advantage. This may be because of the special priorities of the (major) host countries due to the renewable resource base or domestic economic policy or both.

Mitigation Cost for Different Project Types

We further examine the cost structures of mitigation through different project types, employing the log-quadratic model with each individual methodology, credit start-year, and host country dummies (model IV). The elasticity and semi-elasticity estimates are presented in table 5, and the coefficient estimates with standard errors are reported in annex table 2. To conserve space, only the discrete-change effects for the dominant (most frequently used) methodology in each project category (indicated by highlighted estimates) and the largest five host countries are presented in the tables.

From table 5 mitigation cost appears to be inelastic to the volume of abatement for all project types. However, the results of separate one-tailed tests indicate that the estimated abatement elasticities are: i) less than one at 1% significance level for renewable resource based, demand-side energy efficiency, and fossil fuel projects; ii) less than one at 5% significance level for H/PFCs & N_2O reduction projects; and iii) less than 1 at 10% significance level for afforestation and reforestation projects (Stata 2012). The estimated elasticities for methane avoidance, supply-side energy efficiency and transportation projects are not significantly different from one.

For each project type, the coefficient estimate of log of abatement is positive and significant, suggesting that the cost of abatement increases with the volume of abatement. However, the coefficient estimates for the squared log of abatement is: i) negative and significant for H/PFCs & N_2O reduction and forestry projects; ii) positive and significant for demand-side energy-efficiency and methane avoidance projects; and iii) not significant for any other project type (see annex table 2). Consequently, the elasticities can and do deviate from mean values over observed project scale.

To illustrate this point, average costs of abatement for different types of CDM projects at different levels of abatement were calculated using the coefficient estimates as reported in annex table 2,. Figure 4 and 5 depict the average cost curves for different types of 10-year long projects in China, which start generating CERs in 2008 and use the dominant methodology for those project categories. As shown in figure 4, the average costs of afforestation and reforestation, renewable resource-based, transport, methane avoidance, fossil fuel switch, and H/PFCs & N_2O reduction projects continuously decrease at a decreasing rate with the volume of abatement, indicating economies of scale. However, afforestation and reforestation, renewable resource-based, and transport projects exhibit higher levels of economies of scale compared to that of methane avoidance, fossil fuel switch and H/PFCs & N_2O reduction projects. As depicted in figure 5, the average costs of demand- and supply-side energy efficiency projects decrease at a decreasing rate as long as the volume of abatement is less than roughly 300 and 1,500 KtCO2e per year. Beyond these levels, the average costs for these classes of projects increases at a decreasing rate with the volume of abatement.

Consistent with this result, the average sizes of the renewable resource based projects in the pipeline have increased over time and the average sizes of demand- and supply-side energy efficiency projects have remained within the range of respective economies of scale (see figure 6). In contrast to the result, the average sizes of H/PFCs & N_2O reduction, transportation, and fossil fuel switch projects have decreased over time, while no systematic change is observed in the sizes of methane avoidance and forestry projects (see figure 6). Based on the estimated average costs, mitigation through afforestation and reforestation projects appears to be most expensive, followed by demand-side energy efficiency, supply-side energy efficiency, renewable resource based, transport, methane avoidance, and fossil fuel switch projects, respectively. Mitigation through H/PFCs & N_2O reduction projects is the least costly. Statistically, the duration of the project does not affect mitigation costs, with the exception of renewable resource based and fossil fuel switch projects, where costs rise (fall) as the duration of the renewable (fossil fuel) projects lengthens.

Notably, the distribution of the CDM projects in the pipeline does not quite follow this relative cost structure (recall table 1). Consistent with the estimated set of relative costs, the project portfolio contains few afforestation and reforestation projects; they account for less than one percent of the total CERs projects in the CDM pipeline are expected to generate. However, less than 5 percent of the projects in the pipeline are H/PFCs & N_2O reduction or fossil fuel switch projects, while about 77 percent of the projects are renewable resource based or demand- or supply-side energy efficiency projects with much higher abatement cost. This difference may be because of the special priorities of the (major) host countries due to the renewable resource base or domestic economic policy or both. Moreover, uncertainties about the functioning of the carbon market may have lead the investors towards the projects generating tradable byproduct (e.g., electricity) although projects that generate CERs only have substantially lower mitigation cost (e.g., HFCs, PFCs, and N2O reduction projects).

Mitigation Cost in Selected Host Countries

More than 72 percent of the CDM projects are located in three CDM host countries: China, India, and Brazil. In order to further examine the effects of location on mitigation cost we estimate the log-quadratic model (IV) for the projects located in these countries separately. The elasticity and semi-elasticity estimates are presented in table 6, and the coefficient estimates with standard errors are reported in annex table 3.[16]

Mitigation cost appears to be inelastic to the volume of abatement for each of the selected countries.[17] The coefficient estimate of the log of project duration is negative and significant for China, positive and significant for India, and positive but not significant for Brazil. Thus, all thing equal, projects in China are characterized with 'economies of time,' while the projects in India are characterized with

[16] Due to space limitation, only the discrete-change effects for the dominant methodology in each project category (indicated by highlighted estimates) are presented in the tables.
[17] The results of one-tailed nonlinear tests indicate that the estimated elasticity for abatement is less than one at 1% significance level for the projects in China, India and Brazil (Stata 2012).

'diseconomies of time.' Duration does not have a significant effect on the mitigation costs of the projects in other major host countries. Relative attractiveness of different types of project and methodologies with each individual host country, and also the effect of timing, appear to be similar to that of the full model (i.e., model IV).

Based on the coefficient estimates as reported in table 6 and annex table 3, relative attractiveness of different types of projects within each individual host country differ slightly. Afforestation and reforestation, demand-side energy efficiency, and renewable resource based projects appear to be the most expensive in all three largest CDM host countries, where H/PFCs & N_2O reduction and fossil fuel switch projects are the least expensive ones. However, more than 67 percent of the CDM projects in these countries are renewable resource based, while only 4 percent are H/PFCs & N_2O reduction and fossil fuel switch projects. Thus, the distribution of different types of projects within each of the major host countries is not skewed toward low-cost projects

Comparing relative average costs of abatement for different types of projects in China, India, and Brazil, it appears that Brazil has a comparative advantage in H/PFCs & N_2O reduction projects, China has comparative advantages in methane avoidance, demand-side energy efficiency, and transportation projects, and India has comparative advantages in renewable resource based, supply-side energy efficiency, fossil fuel switch, and forestry projects. Between the two largest host countries, China has comparative advantages in methane avoidance, demand-side energy efficiency, and transportation projects, while India has comparative advantages in all other types of projects. The distribution of different types of projects across these countries, however, does not quite follow the principle of comparative advantage. Most of the projects in China are renewable resource based electricity generation projects (71 percent), followed by supply-side energy efficiency (15 percent) and methane avoidance projects (10 percent). Renewable resource based projects account for 65 percent of the CDM projects in India, followed by demand-side (12 percent) and supply-side (11 percent) energy efficiency and methane avoidance projects (6 percent). In Brazil, only 2 percent of the projects are H/PFCs & N_2O reduction projects while renewable resource based projects account for 59 percent and methane avoidance projects account for 28 percent. Natural resource base and national policies in these countries may attribute to competitive advantage to certain types of CDM projects.

Joint Cost Estimation

As mentioned in section 2, we also employ an alternative method for estimating mitigation cost through the CDM. Instead of estimating the net cost of abatement (i.e., total project cost minus the revenue from byproduct sales), we regress the total project cost on the volume of abatement, volume of the byproduct (electricity output), project duration, a dummy variable indicating whether the project generates CERs only, and sets of dummy variables for different project types, methodologies, credit start years, and locations. Apart from the inclusion of electricity output as a state variable and the dummy variable indicating single output process, we use the same specifications as in models (I)-(IV). Estimated elasticities for continuous variables and semi-elasticities for dummy variables are presented in table 7.[18]

In general, estimation results appear to be similar to those for net abatement costs as reported in table 4. As can be seen from table 7, the results for log-log and log-quadratic functional form with the same set of explanatory variables are similar while the use of different sets of dummy variables alters the estimates significantly. The estimated coefficient of the log of abatement is positive and significant. Separate tests indicate that, for each model the estimated abatement elasticity for abatement is less than one at 1% significance level thus implying 'economies of scale' (Stata 2012). The estimated coefficients of the log of the volume of tradable by-product and the log of project duration are not found to be significant. The coefficient of the dummy variable indicating single output projects is negative but not significant. The estimates for project-type dummies are all positive and significant indicating that the fixed cost of mitigation is the highest for the afforestation and reforestation projects and lowest for HFCs, PFCs, and N2O reduction projects.

Costs for different project types are also estimated separately under the log-quadratic specification as stated above. Using the coefficient estimates, average costs of abatement for different types of CDM

[18] The coefficient estimates and their standard errors are reported in annex table 4.

projects at different levels of abatement are calculated.[19] In terms of average cost of mitigation, the relative attractiveness of different types of projects appears to be similar to that resulting from the estimation of net abatement cost as reported in table 5. The structures of average cost curves for different project types are similar to those as depicted in figures 4 and 5.

We also estimate the project costs in Brazil, China, and India separately. Relative attractiveness of different types of project within each of these countries, as well as the comparative advantage of these countries for different types of projects appear to be similar to that of the full model (i.e., model IV in table 7) with little exceptions.

5 Conclusions and Policy Implications

In this paper, we look at the cost of producing emission reduction credits under the Clean Development Mechanism using project data. We control for the duration of the projects, the type of technology used in the project and the year in which the project began. In our preferred (full) model, we employ a complete set of fixed effects associated for each host country and for each technology type, but we also estimate versions of the model that use broader classifications of projects and regional dummies rather than host-country dummies. We repeat the analysis for China, India and Brazil, countries that host a large number of CDM projects, and for specific types of projects. Many of the projects generate CERs and simultaneously create additional power-generating capacity, so we consider a separable cost function based on an explicit disentanglement of costs and revenue. We also consider an alternative joint cost functions that is consistent with inseparable costs.

In general, we find no evidence of increasing returns to scale. At mean levels, all calculated elasticities were less than one, although constant returns to scale could not be ruled out in some cases. We found significant variation in scale effects by type of projects; for example, H/PFCs & N_2O reduction

[19] For the electricity generating CDM projects, total project costs vary with the volume of emissions abatement and electricity which are joint outputs. For the purpose of calculating total costs of those projects at different levels of emissions abatement, total electricity output is regressed on total abatement without an intercept term. The coefficient estimate is used to calculate electricity outputs at different levels of emissions abatement and used in project cost calculation accordingly.

projects and renewable energy projects exhibited lower abatement elasticities than aggregate averages. Moreover, results from the flexible-form models suggest variation in scale effects over reasonable ranges of scale for some types of projects.

Surprisingly, we found little evidence that the costs of generating CERs were lowest in the places where investments most often took place. Similarly, the types of projects that attracted the largest number of investors were not the projects associated with the lowest unit production costs. Even for the three individual countries that we examined, investments were not concentrated in projects with the lowest unit costs. The finding is significant, given the important role estimates of unit costs and abatement in the bottom-up and top-down models used to evaluate mitigation potential and analyze policy alternatives, where the presumption is that project investors will seek out low-cost opportunities.

Still, there are several potential explanations that are consistent with a market where unit costs are crucial in characterizing investor decisions. Potentially, it may be the case that the lowest-cost opportunities identified in the analysis have been fully exploited and cannot be duplicated; as a consequence, investors have moved on to higher-cost alternatives. And, there are doubtless ways in which our underlying cost models could be improved, thereby opening up the possibility that future research will find conflicting evidence. However, it is also worth pointing out that unit production costs do not necessarily reflect the true cost or value to investors. In this regard, our findings are consistent with the notion that costs associated with risk and aspects of transaction are significant relative to unit costs and that abatement consumers hold preferences about the underlying technologies used to generate offsets, which in turn creates incentives for investors to differentiate the value of projects by type.

At the aggregate level, we find strong evidence about the effects of project duration on costs, even though differences in timing of outputs have been accounted for by discounting. Quantitatively, the estimated elasticities associated with project duration were positive and significant implying 'diseconomies of time.' However, this result is not consistent for specific types of projects. Costs increased with project duration for renewable resource based projects and declined with project duration for fossil fuel switch projects. For all other types of projects, the effects of project duration on mitigation cost are not significant.

Under the CDM rules, credits were granted for some projects that began prior to 2005. We find evidence that costs fell for projects that begun post-2005 as CDM rules and procedures were developed. At the other end of our sample, some projects already underway are expected to produce credits beyond the first accounting period recognized under the Kyoto Protocol, and there is still uncertainty about the value of these future credits. Evidence from the full set of models is mixed for post-2012. In general, generating post-2012 credits was associated with lower costs, or had no distinguishable effect on cost.

From a technical perspective, we found that introducing additional flexibility in the form of a quadratic term for abatement had little effect on the estimation results. In a similar way, although we took care to separate costs associated with abatement from power generation costs, the alternative joint-cost model we found similar results once we controlled for increases in power generation.

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Table 1. Major types of CDM projects in the pipeline – number and emissions abatement

	Number of projects		Annual abatement		Abatement by 2012	
	Number	% total	KtCO2e	% total	KtCO2e	% total
Project type						
Renewable resource-based	4,181	62.40	380,795	43.65	1,321,041	37.67
Methane, coal mine, etc.	1,142	17.04	159,812	18.32	700,088	19.96
Supply-side energy eff.	689	10.28	120,065	13.76	391,855	11.17
Demand-side energy eff.	301	4.49	11,976	1.37	46,327	1.32
Fossil fuel switch	170	2.54	52,637	6.03	223,290	6.37
HFCs, PFCs, & N2O	116	1.73	138,099	15.83	792,811	22.61
Forest	66	0.99	5,547	0.64	21,051	0.60
Transport	35	0.52	3,543	0.41	10,467	0.30
Total	6,700	100.00	872,473	100.00	3,506,930	100.00
Methodology						
Large scale (AM)	460	6.87	236,546	27.11	1,167,651	33.30
Large scale consol. (ACM)	3,080	45.97	542,307	62.16	1,958,857	55.86
Small scale (AMS)	3,094	46.18	88,073	10.09	359,371	10.25
Afforest. and reforestation	66	0.99	5,547	0.64	21,051	0.60
Large scale (AR-AM)	25	0.37	4,469	0.51	16,202	0.46
Large sc. con. (AR-ACM)	14	0.21	892	0.10	3,913	0.11
Small scale (AR- AMS)	27	0.40	186	0.02	936	0.03
Total	6,700	100.00	872,473	100.00	3,506,930	100.00

Source: UNEP Risoe CDM/JI Pipeline Analysis and Database, http://cdmpipeline.org/.

Table 2. Annual abatement and electricity generation by different types of CDM projects

Project type	Annual abatement (KtCO2e)				Annual electricity output (MWh)			
	Obs.	Mean	Min	Max	Obs.	Mean	Min	Max
Renewable resource-based	4,181	91	0.5	4,334	3,819	119,443	10	5,340,000
Methane, coal mine, etc.	1,142	140	1.0	8,362	378	41,037	141	1,139,500
Supply-side energy eff.	689	174	0.9	3,746	555	661,468	13	29,800,000
Demand-side energy eff.	301	40	0.7	852	16	72,483	7,912	189,214
Fossil fuel switch	170	310	1.1	3,190	74	2,114,566	24,600	9,157,131
HFCs, PFCs, & N2O	116	1,191	8.0	10,437	-	-	-	-
Forest	66	84	0.4	2,036	-	-	-	-
Transport	35	101	2.8	583	-	-	-	-
Total	6,700	130	0.4	10,437	4,842	205,786	10	29,800,000

Source: UNEP Risoe CDM/JI Pipeline Analysis and Database, http://cdmpipeline.org/.

Table 3. Net present costs of mitigation and discounted total abatement and electricity outputs over the life of the projects

	No. of Obs.	Net Present Costs (Mill.US$)		Disc. Abatement (MtCO2e)		Disc. Electricity Output (GWh)	
		Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Renewable resource-based	3,918	122.7	201.5	602.7	1,173.1	668.0	1,505.0
Methane, coal mine, etc.	1,131	72.4	209.4	1,020.9	2,533.1	87.0	315.0
Supply-side energy eff.	637	115.3	253.5	1,074.2	2,018.0	896.1	1,728.6
Demand-side energy eff.	301	56.4	125.1	297.2	618.2	34.0	172.8
Fossil fuel switch	122	71.0	107.2	1,737.4	3,271.1	3,445.7	8,632.6
HFCs, PFCs, & N2O	116	108.4	214.9	7,712.8	14,701.9	-	-
Forest	66	568.0	1,794.5	1,466.2	4,389.9	-	-
Transport	35	237.6	329.9	734.0	987.1	-	-
Total	6,326	113.8	278.7	872.4	2,776.6	587.6	1,841.3

Source: UNEP Risoe CDM/JI Pipeline Analysis and Database, http://cdmpipeline.org/.

Table 4. Aggregate model results – elasticities and discrete-change effects.

	Log-log: I	Log-quad.: II	Log-quad.: III	Full Model: IV
Elasticities				
Abatement (ktCO2e)	0.900***	0.897***	0.792***	0.854***
Project duration (years)	0.952**	0.950**	1.087***	0.363*
Discrete-change effects				
Project-type				
Renewable resource	4.032***	4.645***	5.084***	4.957***
HFCs, PFCs, N2O	1.722	2.244**	2.610***	2.318***
Methane avoidance	3.149**	3.759***	4.214***	3.927***
Supply side energy efficiency	3.537***	4.148***	4.486***	4.128***
Demand side energy efficiency	4.064***	4.661***	5.145***	4.488***
Fossil fuel switch	3.177**	3.750***	4.215***	3.598***
Transportation	4.720***	5.336***	5.747***	3.850***
Forest	3.972**	4.570***	6.046***	6.395***
Methodology-type				
Large scale consolidated: ACM (dropped)				
Large scale: AM			0.093*	
Small scale: AMS			−0.421***	
AR large scale cons.: AR-ACM			−1.344***	
AR large scale: AR-AM			−1.063***	
AR small scale: AR-AMS			−1.730***	
Credit start-year				
Prior to 2005 (dropped)				
2005	−0.455	−0.447	−0.419**	−0.132
2006	−0.337	−0.337	−0.282***	−0.039
2007	−0.120***	−0.113**	−0.044	−0.001
2008	−0.293***	−0.279**	−0.210***	−0.133
2009	−0.288***	−0.272***	−0.202***	−0.066
2010	−0.14	−0.128	−0.06	0.102
2011	−0.058	−0.046	−0.011	0.178
2012	−0.381**	−0.371**	−0.344***	−0.139
Post 2012	−0.528*	−0.593**	−0.477	−0.277
Regions				
Africa (dropped)				
Asia and Pacific	−0.247***	−0.241***	−0.248***	
Europe and central Asia	−0.395**	−0.402**	−0.454***	
Latin America	−0.135	−0.139	−0.211***	
Middle East	−0.014	0.011	−0.054	
Host country fixed effects	No	No	No	Yes
Methodology-type fixed effects	No	No	No	Yes
Observations	6,326	6,326	6,326	6,326
Adjusted R-squared	0.991	0.991	0.991	0.993

Note: Host-country and methodology fixed effects used to estimate the full model are suppressed to conserve space. Underlying parameter estimates are given in Annex Table 1. Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. The results of separate one-tailed tests indicate that the estimated abatement elasticities are less than 1.00 at 5% significance level for model I, 10% significance level for model II, and, 1% significance level for models III and IV.

Table 5. Results from project-type analysis– elasticities and discrete-change effects.

	Renewable Resource	H/PFCs N_2O	Methane Avoid.	Supply-Side EE	Demand-Side EE	Fossil Fuel	Trans-port	Afforest Reforest
Elasticities								
Abatement	0.82***	0.56***	0.93***	0.97***	0.95***	0.82***	0.81*	0.90***
Project duration	0.26***	−0.98	−0.03	0.05	−0.11	−0.41*	−0.50	−0.08
Discrete-change effects								
Dominant methodology								
Large scale con.: ACM 1 (dropped)								
Large scale con.: ACM 2	**0.07****	-	-	5.78***	-	-	-	-
Large scale con.: ACM 12	1.84***	-	-	**5.34****	5.91***	-	-	-
Large scale: AM 34	-	**1.99*****	-	-	-	-	-	-
Small scale: AMS-II.D.	1.09***	-	0.01	5.55***	**6.24*****	0.07	-	-
Small scale: AMS-III.B.	0.99	-	-	-	6.25***	**−0.30**	-	-
Small scale: AMS-III.C.	-	-	-	-	-	-	**−0.15****	-
Small scale: AMS-III.D.	−0.52***	-	**0.38*****	-	6.26***	-	-	-
AR small: AR-AMS1	-	-	-	-	-	-	-	**5.92*****
Credit start-year								
Prior to 2005 (dropped)								
2005	−0.14	−0.07	−0.65*	0.14	0.22***	−0.44	-	-
2006	0.08***	−0.55	−0.24	0.04	−0.05*	0.14	0.13	−0.32*
2007	−0.05	−0.33*	−0.12	−0.16*	−0.02*	0.05	−0.09	−0.33
2008	−0.28	−0.01	−0.13	−0.16	−0.07***	−0.09	−0.15	−0.17
2009	−0.15	−0.28	−0.13	−0.13	−0.05***	−0.52	0.20	−0.19
2010	0.06	0.54	−0.12	−0.12**	−0.05***	−0.25	0.17	−0.03
2011	0.18	0.24	−0.07	−0.14	0.04	0.03	−0.12	1.11***
2012	−0.39	2.97*	0.12	−0.17*	0.40	-	-	-
Post 2012	−0.24	-	−0.15	−2.45***	-	-	7.72	-
Selected host country dummies								
Albania (dropped)								
Brazil	5.34***	3.94	5.64***	0.76***	1.09***	6.962***	-	−0.17
China	4.93***	4.029	5.19***	0.05**	0.26***	6.846***	6.61	0.2
India	5.78***	3.668	5.21***	0.02	0.58***	6.611***	7.83	0.15
Mexico	5.69***	3.149	4.51***	0.35***	0.46***	-	6.79	-
Malaysia	5.33***	0	5.05***	−0.35	0.27***	-	-	-
Host country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Methodology fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,919	116	1,129	636	301	120	35	68
Adj. R-squared	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Note: Only the major host-country and dominant (most frequently used) methodology fixed effects are reported while the rest are suppressed to conserve space. Underlying parameter estimates are given in Annex Table 2. Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Highlighted estimates for methodology dummies indicate the dominant methodology for each project type. The results of separate one-tailed tests indicate that the estimated abatement elasticities less than one at 1% significance level for renewable resource based, demand-side energy efficiency, and fossil fuel projects; at 5% significance level for H/PFCs & N_2O reduction projects; and at 10% significance level for afforestation and reforestation projects. The abatement elasticities for other types are not significantly different from 1.00.

Table 6. Results for China, India, and Brazil– elasticities and discrete-change effects.

	China	India	Brazil
Elasticities			
Abatement (ktCO2e)	0.843***	0.87***	0.758***
Project duration (years)	−0.685***	0.533***	0.313
Discrete-change effects			
Project-type			
Renewable resource	7.840***	4.451***	6.475***
HFCs, PFCs, N2O	4.212***	1.580**	2.480**
Methane avoidance	6.847***	3.061***	5.526***
Supply side energy efficiency	7.233***	3.473***	5.664***
Demand side energy efficiency	7.406***	3.961***	8.435***
Fossil fuel switch	6.302***	2.713***	4.357***
Transportation	6.544***	6.106***	-
Forest	9.108***	4.977***	8.236***
Dominant methodology			
Large scale consolidated: ACM 1 (dropped)			
Large scale consolidated: ACM 2	−0.513**	−0.394*	−0.681*
Large scale consolidated: ACM 12	0.114	−0.197	0.569
Large scale: AM 34	1.590***	−0.48	-
Small scale: AMS-II.D.	0.26	−0.112	−1.760***
Small scale: AMS-III.B.	0.66	0.048	1.262***
Small scale: AMS-III.C.	-	−1.710***	-
Small scale: AMS-III.D.	−0.282***	−0.292	−0.02
AR small scale: AR-AMS 1	−0.329	−0.866***	-
Credit start-			
Prior to 2005 (dropped)			
2005	−0.22	−0.018	0.203
2006	−0.304	0.042	0.377
2007	−0.625***	−0.108	0.361
2008	−0.873***	−0.146	0.03
2009	−0.823***	−0.146	0.339*
2010	−0.575**	−0.045	0.445**
2011	−0.448**	−0.027	0.575***
2012	−1.056***	−1.225***	1.566***
Post 2012	−1.684***	−1.987***	2.679***
Methodology fixed effects	Yes	Yes	Yes
Observations	2,583	1,726	389
Adj. R-squared	0.994	0.993	0.991

Note: Only the dominant (most frequently used) methodology fixed effects are reported while the rest are suppressed to conserve space. Underlying parameter estimates are given in Annex Table 3. Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Highlighted estimates for methodology dummies indicate the dominant methodology for each project type. The results of separate one-tailed tests indicate that the estimated abatement elasticities are less than 1.00 at 1% significance level for China, India, and Brazil.

Table 7. Results from the aggregate models for joint costs

	Log-log: V	Log-quad.: VI	Log-quad.: VII	Full Model: VIII
Elasticities				
Abatement (ktCO2e)	0.889***	0.890***	0.823***	0.90***
Electricity output (MWh)	0.015	0.012	−0.011	−0.038
Project duration (years)	0.735*	0.731*	0.810***	0.249
Discrete-change effects				
Non-power projects	0.185	0.151	−0.117	−0.621
Project-type				
Renewable resource	4.727***	5.570***	6.159***	5.784***
HFCs, PFCs, N2O	2.004*	2.725***	3.115***	3.161***
Methane avoidance	3.478***	4.317***	4.879***	4.776***
Supply side energy efficiency	4.212***	5.054***	5.562***	5.073***
Demand side energy efficiency	4.383***	5.209***	5.814***	5.305***
Fossil fuel switch	3.812***	4.604***	5.196***	4.562***
Transportation	4.978***	5.826***	6.336***	4.748***
Forest	4.462***	5.288***	6.571***	6.555***
Methodology-type				
Large scale consolidated: ACM (dropped)				
Large scale: AM			0.174***	
Small scale: AMS			−0.318***	
AR large scale con.: AR-ACM			−0.873***	
AR large scale: AR-AM			−0.691***	
AR small scale: AR-AMS			−1.255***	
Credit start-year				
Prior to 2005 (dropped)				
2005	−0.500	−0.489	−0.471***	−0.150
2006	−0.421*	−0.421**	−0.379***	−0.048**
2007	−0.159***	−0.149***	−0.095**	0.009
2008	−0.258***	−0.238***	−0.185***	−0.071
2009	−0.245***	−0.224***	−0.169***	−0.029
2010	−0.138**	−0.122*	−0.072*	0.093
2011	−0.078	−0.061	−0.016	0.151
2012	−0.235**	−0.221*	−0.191**	−0.012
Post 2012	−0.097	−0.183	−0.065	−0.034
Regions				
Africa (dropped)				
Asia and Pacific	−0.192***	−0.185**	−0.182***	
Europe and central Asia	−0.210**	−0.220**	−0.286***	
Latin America	−0.006	−0.01	−0.052	
Middle East	−0.09	−0.057	−0.115	
Host country fixed effects	No	No	No	Yes
Methodology-type fixed effects	No	No	No	Yes
Observations	6,326	6,326	6,326	6,326
Adj. R-squared	0.996	0.996	0.996	0.997

Note: Host-country and methodology-type fixed effects estimates are suppressed to conserve space. Underlying parameter estimates are given in Annex Table 4. Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. The results of separate one-tailed tests indicate that the estimated abatement elasticities are less than 1.00 at 1% significance level for all of the models.

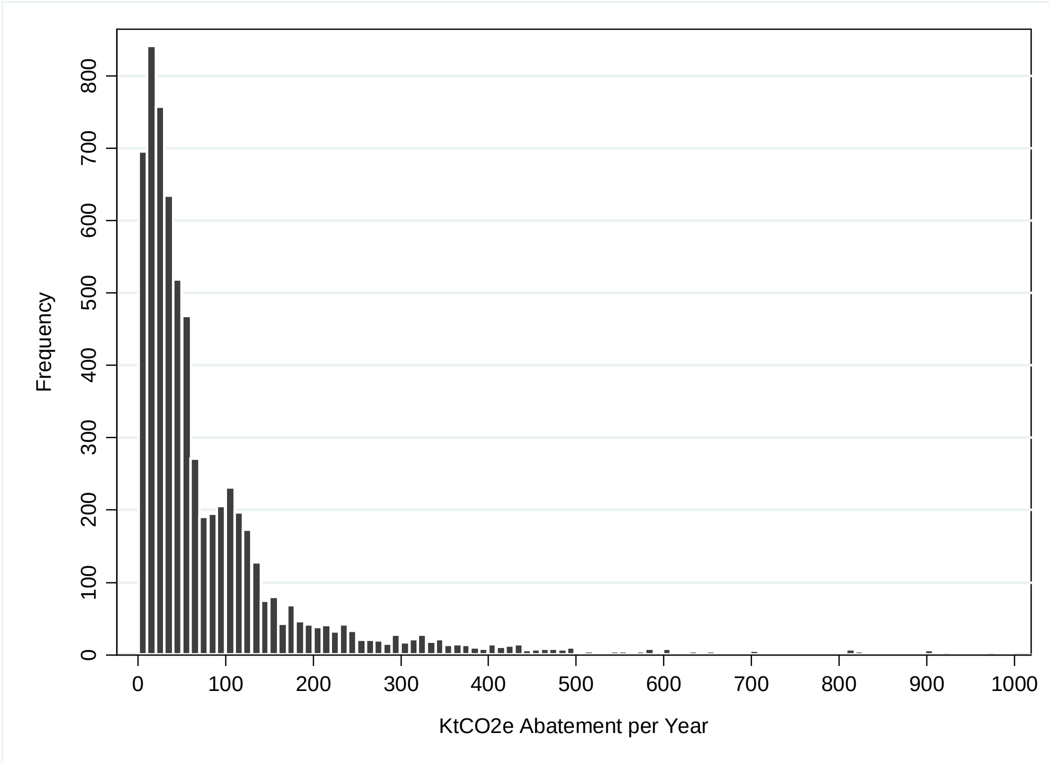

Figure 1. Frequency distribution of the CDM projects by size (KtCO2e abatement per year).

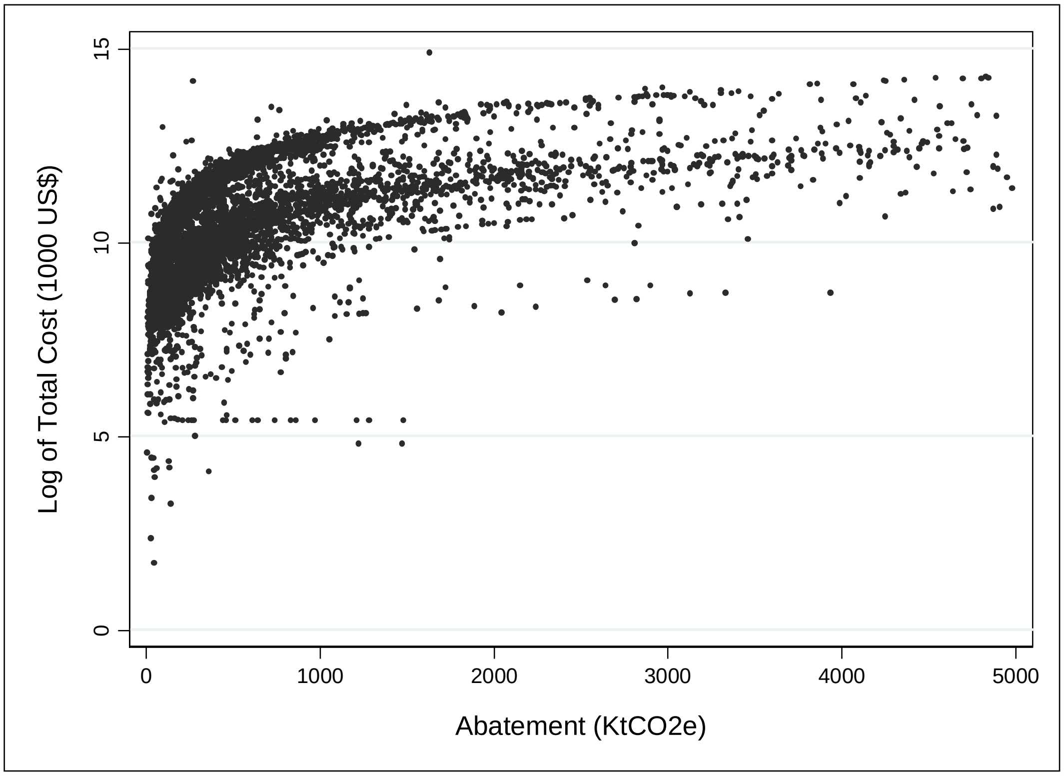

Figure 2. Log-transformed total cost of abatement.

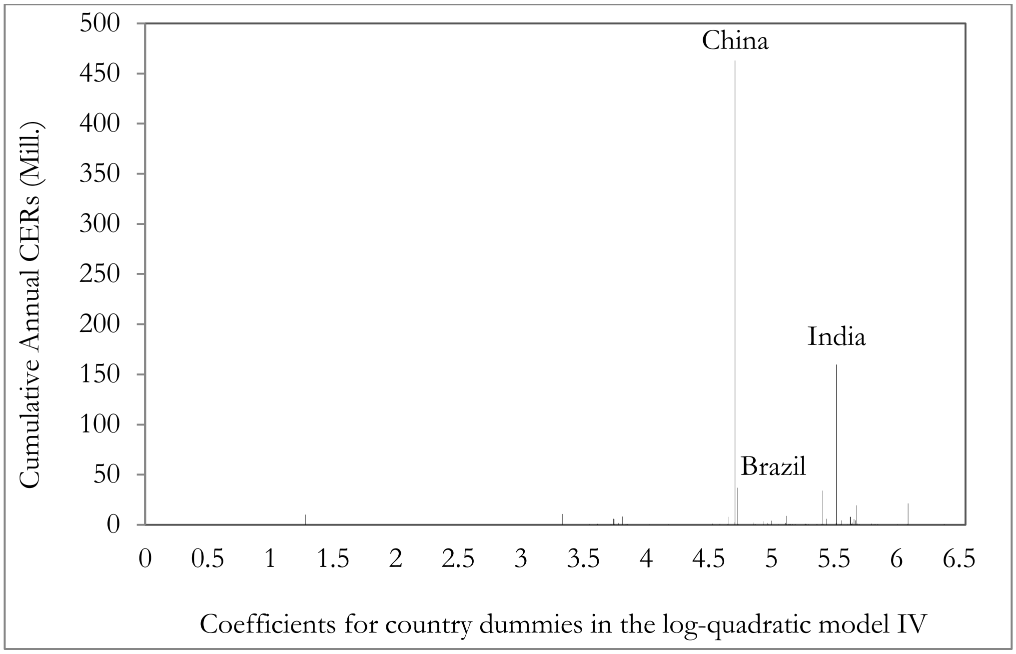

Figure 3. The coefficients of country dummies from model (IV) and total number of CDM projects in individual host countries

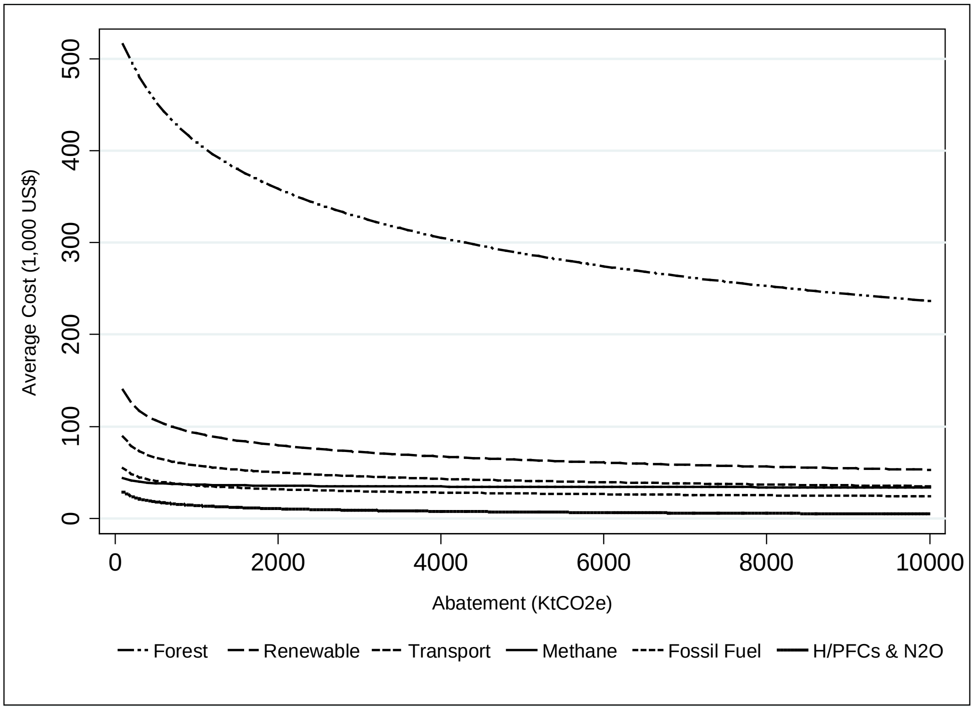

Figure 4. Estimated average mitigation cost curves for forest, renewable resource-based, transport, methane avoidance, fossil fuel switch, and H/PFCs & N2O reduction projects

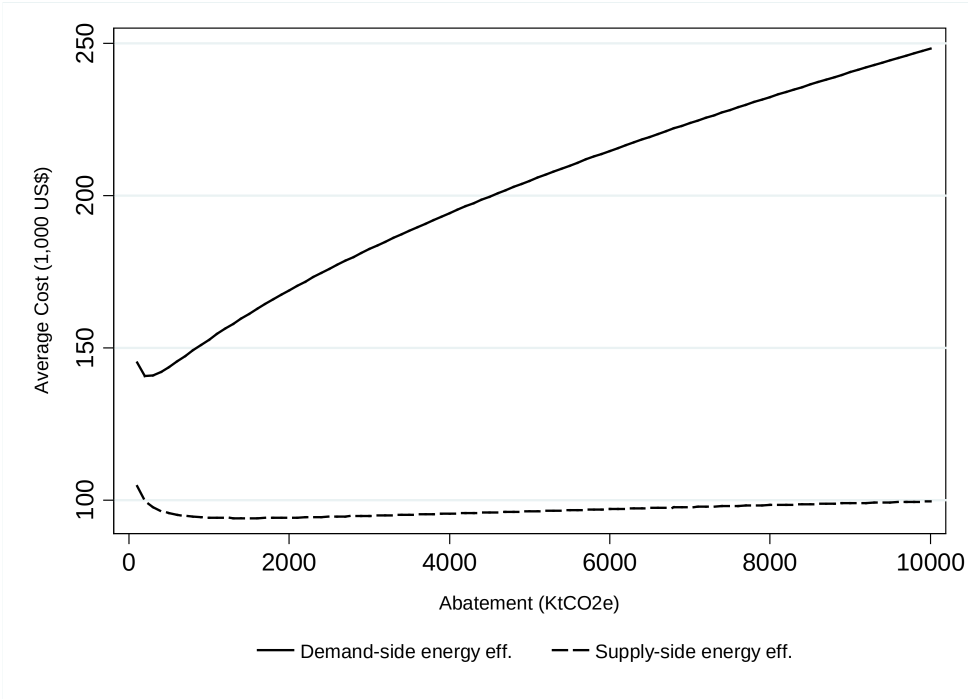

Figure 5. Estimated average mitigation cost curves for demand- and supply-side energy efficiency projects.

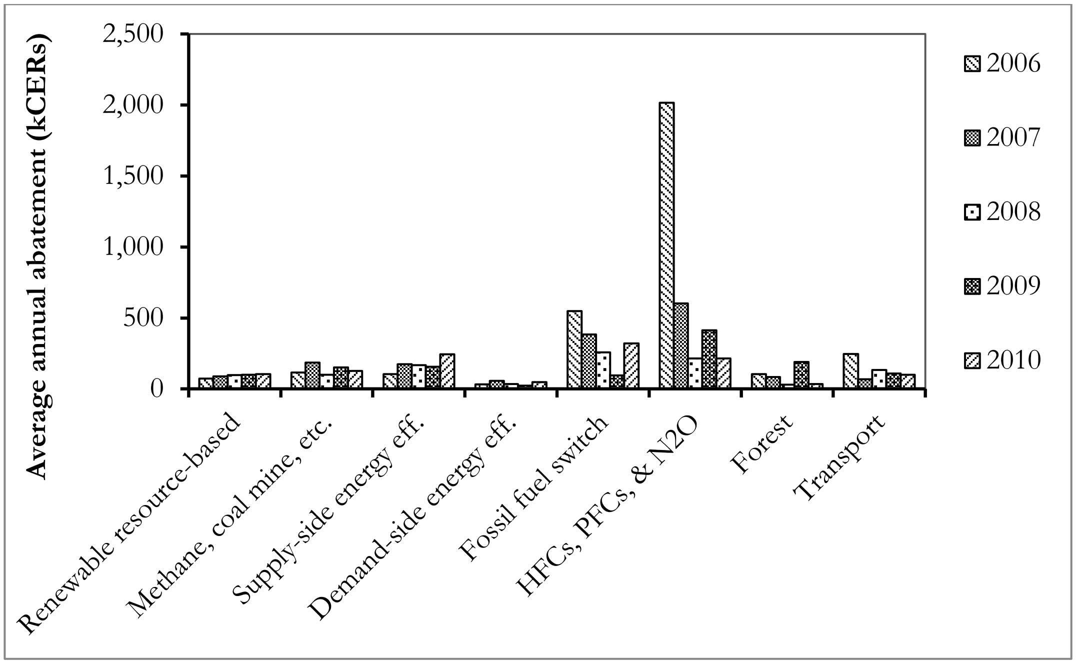

Figure 6. Average annual abatement by different types of projects during 2006-10

Annex I. The methodology for calculating the present value of totals cost of mitigation

The capital cost data is not a reporting criterion for the CDM, but is sometimes used in the demonstration of additionality for the project. Of those PDDs that contain capital cost information, it is often reported as "capital costs" or "fixed costs" for the project, and generally includes procurement of any plant and/or machinery dedicated to the realization of the CDM project, construction and civil works, engineering consultation (non-ongoing) (Climate Solutions, 2008). In some cases, costs incurred for the validation, registration, and verification of the project, contingency and margin money for working capital, interest during construction, and licenses were included in the capital costs. Some PDDs also reported operation and maintenance costs. From the reported operation and maintenance costs, project sub-type averages per unit of abatement are calculated and used as proxies for the projects for which such costs were not reported (Climate Solutions, 2008).

It is important to note two facts with regard to the capital cost data from CDM project activity (Climate Solutions, 2008). First, it should not be assumed that the CDM projects have been implemented yet and so capital cost outlays may not have occurred. The CDM project data represents all projects that have been put forth for validation and registration. This may, and often does, occur prior to commitments on capital purchases have been made. However, it is largely expected that these projects will be implemented. Second, it should not be assumed that the reported capital expenditures on CDM projects are solely attributable to the CDM. For instance, wind farm and hydro projects are implemented to increase the host country's power generation capacity. In the absence of the CDM, it is likely that capital expenditures would have taken place regardless, in order to increase the host country's power generation capacity, albeit with a different technology and less of a capital outlay. However, for certain project types, where there is no revenue stream other than CDM credits, e.g., landfill gas and animal waste flaring projects, it would be fair to assume that the capital cost expenditures are solely attributable to the CDM.

The present value of the total costs of each CDM project is calculated as the sum of initial capital investments (fixed costs) and discounted flow of operations and maintenance costs (variable costs) over the life of project. In particular, the present value of the total costs of the *j*th project is calculated as: $C_0^J = I_0 + \sum_0^T c_t e^{-rt}$, where I_0 is the initial investments, c is the annual operations and maintenance costs, T is the duration of the projects in years, and r is the real effective interest rate. For the projects that generate CERs only, C_0^J represents the present value of total mitigation costs. To calculate the net mitigation costs for the CERs and electricity generating projects, the discounted sum of the flow of revenues from the sales of electricity is subtracted from the project costs: $C_0^J = I_0 + \sum_0^T c_t e^{-rt} - \bar{p}_0^E \sum_0^T E_t e^{-rt}$, where E is annual electricity output and $\bar{p}_0^E$ is the wholesale electricity tariff.

For the purpose of estimation of the cost function, the flows of CERs and electricity outputs are discounted using the same interest rate. The discounted total CERs and electricity outputs are given by $\sum_0^T A_t e^{-rt}$ and $\sum_0^T E_t e^{-rt}$, respectively.

Annex Table 1. Estimation results of the log-log and log-quadratic models

	Log-log: I	Log-quad.: II	Log-quad.: III	Full model.: IV
Log of abatement (ktCO2e)	0.900***	0.674***	0.580***	0.776***
	(0.044)	(0.212)	(0.062)	(0.067)
Squared log of abatement	-	0.019	0.019***	0.007
	-	(0.021)	(0.005)	(0.006)
Log of project duration (years)	0.952**	0.950**	1.087***	0.363*
	(0.482)	(0.473)	(0.080)	(0.133)
Project-type dummies				
Renewable resource	4.032***	4.645***	5.084***	4.957***
	(1.331)	(0.994)	(0.267)	(0.054)
HFCs, PFCs, N2O	1.722	2.244**	2.610***	2.318***
	(1.251)	(0.966)	(0.282)	(0.095)
Methane avoidance	3.149**	3.759***	4.214***	3.927***
	(1.223)	(0.894)	(0.267)	(0.057)
Supply side energy efficiency	3.537***	4.148***	4.486***	4.128***
	(1.270)	(0.945)	(0.279)	(0.079)
Demand side energy efficiency	4.064***	4.661***	5.145***	4.488***
	(1.226)	(0.914)	(0.269)	(0.087)
Fossil fuel switch	3.177**	3.750***	4.215***	3.598***
	(1.247)	(0.952)	(0.270)	(0.199)
Transportation	4.720***	5.336***	5.747***	3.850***
	(1.234)	(0.924)	(0.289)	(0.137)
Forest	3.972**	4.570***	6.046***	6.395***
	(1.682)	(1.327)	(0.351)	(0.126)
Methodology Dummies				
Large scale consolidated: ACM (dropped)				
Large scale: AM			0.093*	
			(0.050)	
Small scale: AMS			−0.421***	
			(0.037)	
AR large scale con.: AR-ACM			−1.344***	
			(0.279)	
AR large scale: AR-AM			−1.063***	
			(0.279)	
AR small scale: AR-AMS			−1.730***	
			(0.277)	
Credit start-year dummies				
Prior to 2005 (dropped)				
2005	−0.455	−0.447	−0.419**	−0.132
	(0.372)	(0.366)	(0.184)	(0.095)
2006	−0.337	−0.337	−0.282***	−0.039
	(0.233)	(0.229)	(0.108)	(0.031)
2007	−0.120***	−0.113**	−0.044	−0.001
	(0.044)	(0.048)	(0.068)	(0.107)
2008	−0.293***	−0.279**	−0.210***	−0.133
	(0.112)	(0.113)	(0.066)	(0.099)

Annex Table 1. Estimation results of the log-log and log-quadratic models (continued)

	Log-log: I	Log-quad.: II	Log-quad.: III	Full model.: IV
2009	−0.288***	−0.272***	−0.202***	−0.066
	(0.066)	(0.069)	(0.064)	(0.131)
2010	−0.14	−0.128	−0.06	0.102
	(0.086)	(0.081)	(0.063)	(0.113)
2011	−0.058	−0.046	−0.011	0.178
	(0.062)	(0.060)	(0.067)	(0.105)
2012	−0.381**	−0.371**	−0.344***	−0.139
	(0.167)	(0.178)	(0.123)	(0.359)
Post 2012	−0.528*	−0.593**	−0.477	−0.277
	(0.317)	(0.257)	(0.307)	(0.661)
Region dummies				
Africa (dropped)				
Asia and Pacific	−0.247***	−0.241***	−0.248***	
	(0.062)	(0.061)	(0.070)	
Europe and central Asia	−0.395**	−0.402**	−0.454***	
	(0.174)	(0.175)	(0.123)	
Latin America	−0.135	−0.139	−0.211***	
	(0.124)	(0.123)	(0.079)	
Middle East	−0.014	0.011	−0.054	
	(0.113)	(0.113)	(0.110)	
Observations	6,326	6,326	6,326	6,326
Adj. R-squared	0.991	0.991	0.991	0.993

Note: Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Estimates of methodology dummies and host country dummies for the full model are suppressed due to space limitation.

Annex Table 2. Estimation results for different types of CDM projects

	Renewable	HFCs	Methane	SS-EE	DS-EE	FFS	Transpt.	Forest
Log of abatement	0.98***	1.07***	0.83***	0.78*	0.55***	0.78***	0.88	1.25***
	(0.09)	(0.23)	(0.07)	(0.29)	(0.07)	(0.15)	(0.95)	(0.14)
Squared log of abatement	−0.01	−0.03**	0.01*	0.02	0.04***	0.01	−0.01	−0.03**
	(0.01)	(0.01)	(0.00)	(0.02)	(0.01)	(0.01)	(0.09)	(0.01)
Log of project duration	0.26***	−0.98	−0.03	0.05	−0.11	−0.41*	−0.50	−0.08
	(0.03)	(1.47)	(0.16)	(0.04)	(0.07)	(0.15)	(0.22)	(0.21)
Dominant methodology dummies								
Large scale con.: ACM 1 (dropped)								
Large scale con.: ACM 2	0.07**	-	-	5.78***	-	-	-	-
	(0.02)	-	-	(0.95)	-	-	-	-
Large scale con.: ACM 12	1.84***	-	-	5.34***	5.91***	-	-	-
	(0.05)	-	-	(1.00)	(0.06)	-	-	-
Large scale: AM 34	-	1.99***	-	-	-	-	-	-
	-	(0.41)	-	-	-	-	-	-
Small scale: AMS-II.D.	1.09***	-	0.011	5.55***	6.24***	0.07	-	-
	(0.03)	-	(0.07)	(0.93)	(0.05)	(0.16)	-	-
Small scale: AMS-III.B.	0.99	-	-	-	6.25***	−0.30	-	-
	(0.61)	-	-	-	(0.07)	(0.22)	-	-
Small scale: AMS-III.C.	-	-	-	-	-	-	−0.15**	-
	-	-	-	-	-	-	(0.01)	-
Small scale: AMS-III.D.	−0.52***	-	0.38***	-	6.26***	-	-	-
	(0.05)	-	(0.01)	-	(0.06)	-	-	-
AR small: AR-AMS1	-	-	-	-	-	-	-	5.92***
	-	-	-	-	-	-	-	(0.52)
Credit start-year dummies								
Prior to 2005 (dropped)								
2005	−0.14	−0.07	−0.65*	0.14	0.22***	−0.44	-	-
	(0.07)	(0.43)	(0.24)	(0.07)	(0.01)	(0.30)	-	-
2006	0.08***	−0.55	−0.24	0.04	−0.05*	0.14	0.13	−0.32*
	(0.01)	(0.64)	(0.18)	(0.07)	(0.02)	(0.26)	(0.39)	(0.13)
2007	−0.05	−0.33*	−0.12	−0.16*	−0.02*	0.05	−0.09	−0.33
	(0.15)	(0.14)	(0.17)	(0.06)	(0.01)	(0.27)	(0.17)	(0.37)
2008	−0.28	−0.01	−0.13	−0.16	−0.07***	−0.09	−0.15	−0.17
	(0.14)	(0.29)	(0.23)	(0.11)	(0.01)	(0.29)	(0.29)	(0.16)
2009	−0.15	−0.28	−0.13	−0.13	−0.05***	−0.52	0.2	−0.19
	(0.16)	(0.22)	(0.14)	(0.09)	(0.01)	(0.54)	(0.21)	(0.23)
2010	0.06	0.54	−0.12	−0.12**	−0.05***	−0.25	0.17	−0.03
	(0.14)	(0.40)	(0.17)	(0.04)	(0.00)	(0.40)	(0.14)	(0.40)
2011	0.18	0.24	−0.07	−0.14	0.04	0.03	−0.12	1.11***
	(0.12)	(0.59)	(0.12)	(0.10)	(0.02)	(0.29)	(0.28)	(0.14)

Annex Table 2. Estimation results for different types of CDM projects (continued)

2012	−0.39	2.97*	0.12	−0.17*	0.40	-	-	-
	(0.46)	(1.16)	(0.15)	(0.07)	(0.22)	-	-	-
Post 2012	−0.24	-	−0.15	−2.45***	-	-	7.72	-
	(1.02)	-	(0.08)	(0.09)	-	-	(2.00)	-
Selected host country dummies								
Albania (dropped)								
Brazil	5.34***	3.94	5.64***	0.76***	1.09***	6.96***	-	−0.17
	(0.04)	(4.26)	(0.14)	(0.05)	(0.08)	(1.06)	-	(0.21)
China	4.93***	4.03	5.19***	0.05**	0.26***	6.85***	6.61	0.20
	(0.09)	(4.09)	(0.11)	(0.02)	(0.03)	(1.38)	(1.95)	(0.37)
India	5.78***	3.67	5.21***	0.02	0.58***	6.61***	7.83	0.15
	(0.05)	(4.56)	(0.10)	(0.04)	(0.05)	(1.23)	(1.82)	(0.40)
Mexico	5.69***	3.15	4.51***	0.35***	0.46***	-	6.79	-
	(0.05)	(3.96)	(0.14)	(0.06)	(0.03)	-	(2.42)	-
Malaysia	5.33***	-	5.05***	−0.35	0.27***	-	-	-
	(0.12)	-	(0.11)	(0.49)	(0.04)	-	-	-
Observations	3,919	116	1,129	636	301	120	35	68
Adj. R-squared	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99

Note: Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Highlighted estimates for methodology dummies indicate the dominant methodology for each project type. Estimates of other methodology dummies and host country dummies are suppressed due to space limitation.

Annex Table 3. Estimation results for selected CDM host countries: Brazil, China, and India

	China	India	Brazil
Log of abatement (ktCO2e)	1.013***	1.266***	0.489
	(0.207)	(0.168)	(0.353)
Squared log of abatement	−0.013	−0.038**	0.029
	(0.015)	(0.017)	(0.032)
Log of project duration (years)	−0.685***	0.533***	0.313
	(0.160)	(0.195)	(0.273)
Project-type dummies			
Renewable resource	7.840***	4.451***	6.475***
	(0.829)	(0.645)	(0.999)
HFCs, PFCs, N2O	4.212***	1.580**	2.480**
	(0.655)	(0.672)	(1.007)
Methane avoidance	6.847***	3.061***	5.526***
	(0.788)	(0.613)	(0.982)
Supply side energy efficiency	7.233***	3.473***	5.664***
	(0.805)	(0.630)	(1.029)
Demand side energy efficiency	7.406***	3.961***	8.435***
	(0.796)	(0.619)	(1.001)
Fossil fuel switch	6.302***	2.713***	4.357***
	(0.930)	(0.677)	(0.986)
Transportation	6.544***	6.106***	-
	(0.842)	(0.580)	-
Forest	9.108***	4.977***	8.236***
	(0.881)	(0.695)	(1.238)
Methodology Dummies			
Large scale consolidated: ACM 1 (dropped)			
Large scale consolidated: ACM 2	−0.513**	−0.394*	−0.681*
	(0.243)	(0.235)	(0.371)
Large scale consolidated: ACM 12	0.114	−0.197	0.569
	(0.303)	(0.241)	(0.408)
Large scale: AM 34	1.590***	−0.48	-
	(0.270)	(0.464)	-
Small scale: AMS-II.D.	0.26	−0.112	−1.760***
	(0.353)	(0.230)	(0.517)
Small scale: AMS-III.B.	0.66	0.048	1.262***
	(0.535)	(0.338)	(0.414)
Small scale: AMS-III.C.	-	−1.710***	-
	-	(0.100)	-

Annex Table 3. Estimation results for selected CDM host countries: Brazil, China, and India (continued)

Small scale: AMS-III.D.	0.26	−0.112	−1.760***
	(0.074)	(0.203)	(0.215)
AR small scale: AR-AMS 1	−0.329	−0.866***	-
	(0.423)	(0.294)	-
Credit start-year dummies			
Prior to 2005 (dropped)			
2005	−0.220	−0.018	0.203
	(0.320)	(0.148)	(0.178)
2006	−0.304	0.042	0.377
	(0.265)	(0.105)	(0.239)
2007	−0.625***	−0.108	0.361
	(0.233)	(0.091)	(0.230)
2008	−0.873***	−0.146	0.03
	(0.225)	(0.090)	(0.248)
2009	−0.823***	−0.146	0.339*
	(0.223)	(0.095)	(0.187)
2010	−0.575**	−0.045	0.445**
	(0.223)	(0.087)	(0.205)
2011	−0.448**	−0.027	0.575***
	(0.225)	(0.095)	(0.214)
2012	−1.056***	−1.225***	1.566***
	(0.262)	(0.318)	(0.375)
Post 2012	−1.684***	−1.987***	2.679***
	(0.225)	(0.392)	(0.354)
Observations	2,583	1,726	389
Adj. R-squared	0.994	0.993	0.991

Note: Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Highlighted estimates for methodology dummies indicate the dominant methodology for each project type. Estimates of other methodology dummies are suppressed due to space limitation.

Annex Table 4. Results of the log-log and log-quadratic models with electricity output

	Log-log: V	Log-quad.: VI	Log-quad.: VII	Full model.: VIII
Log of abatement (ktCO2e)	0.889***	0.589***	0.534***	0.761***
	(0.023)	(0.173)	(0.039)	(0.088)
Squared log of abatement	-	0.026*	0.025***	0.012*
	-	(0.015)	(0.003)	(0.005)
Log of electricity output (MWh)	0.015	0.012	−0.011	−0.038
	(0.036)	(0.041)	(0.012)	(0.027)
Log of project duration (years)	0.735*	0.731*	0.810***	0.249
	(0.390)	(0.379)	(0.056)	(0.126)
Dummy for non-power projects	0.185	0.151	−0.117	−0.621
Project-type dummies				
Renewable resource	4.727***	5.570***	6.159***	5.784***
	(1.167)	(0.940)	(0.229)	(0.083)
HFCs, PFCs, N2O	2.004*	2.725***	3.115***	3.161***
	(1.122)	(0.956)	(0.237)	(0.058)
Methane avoidance	3.478***	4.317***	4.879***	4.776***
	(1.107)	(0.883)	(0.225)	(0.027)
Supply side energy efficiency	4.212***	5.054***	5.562***	5.073***
	(1.147)	(0.930)	(0.237)	(0.049)
Demand side energy efficiency	4.383***	5.209***	5.814***	5.305***
	(1.155)	(0.939)	(0.234)	(0.068)
Fossil fuel switch	3.812***	4.604***	5.196***	4.562***
	(1.161)	(0.969)	(0.235)	(0.095)
Transportation	4.978***	5.826***	6.336***	4.748***
	(1.138)	(0.928)	(0.247)	(0.203)
Forest	4.462***	5.288***	6.571***	6.555***
	(1.498)	(1.287)	(0.303)	(0.234)
Methodology Dummies				
Large scale consolidated: ACM (dropped)				
Large scale: AM			0.174***	
			(0.036)	
Small scale: AMS			−0.318***	
			(0.027)	
AR large scale con.: AR-ACM			−0.873***	
			(0.224)	
AR large scale: AR-AM			−0.691***	
			(0.224)	
AR small scale: AR-AMS			−1.255***	
			(0.224)	

Annex Table 4. Results of the log-log and log-quadratic models with electricity output (continued)

	Log-log: V	Log-quad.: VI	Log-quad.: VII	Full model.: VIII
Credit start-year dummies				
Prior to 2005 (dropped)				
2005	−0.5	−0.489	−0.471***	−0.15
	(0.363)	(0.358)	(0.166)	(0.072)
2006	−0.421*	−0.421**	−0.379***	−0.048**
	(0.217)	(0.213)	(0.093)	(0.011)
2007	−0.159***	−0.149***	−0.095**	0.009
	(0.054)	(0.057)	(0.044)	(0.085)
2008	−0.258***	−0.238***	−0.185***	−0.071
	(0.089)	(0.089)	(0.041)	(0.084)
2009	−0.245***	−0.224***	−0.169***	−0.029
	(0.062)	(0.065)	(0.041)	(0.107)
2010	−0.138**	−0.122*	−0.072*	0.093
	(0.069)	(0.069)	(0.039)	(0.097)
2011	−0.078	−0.061	−0.016	0.151
	(0.062)	(0.063)	(0.041)	(0.088)
2012	−0.235**	−0.221*	−0.191**	−0.012
	(0.110)	(0.118)	(0.074)	(0.264)
Post 2012	−0.097	−0.183	−0.065	−0.034
	(0.232)	(0.189)	(0.183)	(0.366)
Region dummies				
Africa (dropped)				
Asia and Pacific	−0.192***	−0.185**	−0.182***	
	(0.074)	(0.072)	(0.044)	
Europe and central Asia	−0.210**	−0.220**	−0.286***	
	(0.104)	(0.095)	(0.080)	
Latin America	−0.006	−0.01	−0.052	
	(0.121)	(0.119)	(0.053)	
Middle East	−0.09	−0.057	−0.115	
	(0.091)	(0.093)	(0.084)	
Observations	6,324	6,324	6,324	6,324
Adj. R-squared	0.996	0.996	0.996	0.997

Note: Asterisks ***, **, and * indicate significance at 1%, 5%, and 10% levels. Estimates of methodology dummies and host country dummies for the full model are suppressed due to space limitation.