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Costs of certified emission reductions under the Clean Development Mechanism of the Kyoto Protocol☆

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ABSTRACT

This paper examines the cost structure of certified emission reductions (CERs) through various types of projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Using the CDM project data, the costs of CERs and their variation across technology and over time and space are estimated by applying alternative functional forms and specifications. Results show that the average cost of CERs decreases with the project scale and duration, scale and duration effects significantly vary across project types, and there is an upward trend in costs. The results also show that the distribution of the projects in the CDM portfolio or a given location does not strictly follow the relative cost structure, nor does the distribution of the CDM projects in different host countries follow the principle of comparative advantage. More than 84% of the CDM portfolio consists of various energy projects with substantially higher costs of CERs than afforestation and reforestation, industrial and landfill gas reduction, and methane avoidance projects, which are only 12% of all projects. While per unit cost of abatement plays an important role in the bottom-up and top-down models to evaluate emission reduction potential and analyze policy alternatives, the findings contradict the presumption of such models that project investors seek out low-cost opportunities. At the aggregate level, the cost of CER by the projects in Asia and Europe is similar but higher than those hosted in Africa, Americas, and Oceania. Yet more than 83% of the projects in the CDM portfolio are located in Asia; more than 69% of the projects are in China and India alone. China appears to have a comparative advantage (i.e., lowest opportunity cost) in energy efficiency projects, while India has a comparative advantage in hydro power projects and Brazil has a comparative advantage in wind power projects. In contrast, energy efficiency category accounts for only 8% of the CDM projects in China, hydro power accounts for 12% of the projects in India, and wind power accounts for 18% of the projects in Brazil. The results provide a basis for evaluating the incentives that the mechanism offers as a cost effective policy instrument that balances greenhouse gas mitigation across sectors and regions, while fulfilling the objective of the convention.

1. Introduction

The Clean Development Mechanism (CDM) is a provision of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) that allows European Community and other countries listed in Annex I of the Protocol to help meet their binding targets of curbing anthropogenic greenhouse gas (GHG) emissions by reducing emissions in developing countries.[2] The CDM provides an incentive to invest in sustainable development projects that reduce emissions in developing countries, presumably at costs lower than that of domestic measures in Annex I countries.[3] For measurable and verifiable emission reductions that are additional to what would have occurred without the CDM project or program of activities (PoA), the project earns certified emission reductions (CERs), each equivalent to 1 ton of CO_2 equivalent (tCO_2e hereafter) abatement. The project owners can either use the CERs to meet their obligation or sell the CERs to an Annex I Party that can use those to meet part of its emission reduction target under the Kyoto Protocol.[4]

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[2] Annex I countries are committed to meet their targets for limiting or reducing GHG emissions primarily through domestic measures. 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).

[3] The Joint Implementation (JI) is another project-based mechanism that enables the Annex I countries to carry out bilateral or multilateral emission reduction projects among themselves.
[4] The Emissions Trading (ET) is the third flexibility provision that allows Annex I countries to trade assigned amount units (AAUs) as well as credits generated by the project-based mechanisms among themselves. As set out in Article 17 of the Kyoto Protocol, Annex I countries with fewer emissions than permitted are also allowed to sell the excess AAUs to the countries with more emissions than permitted.

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Both industrialized and developing countries have responded to the incentives provided through the CDM. Starting in 2004, the number of CDM project activities as well as the investments in such projects has increased exponentially. As of 31 January 2014, 8744 projects are at some stage of the CDM project cycle.[5] If those projects operate at their full potential, those will reduce 1.1 billion tCO_2e emissions every year thereby generating an equivalent number of CERs.[6] While the rapid expansion of the CDM indicates that on the whole the mechanism aligns the incentives of the Annex I and non-Annex I country participants, the distributions of the projects by type (technology) and locations are skewed. Most of the CDM project activities are renewable resource based and are principally located in China and India. Sectors with large mitigation potentials in some other countries, such as agriculture, construction and transport, account for a smaller share of the CDM project activities, and least developed countries with large sequestration potentials have fewer forestry projects (Rahman et al., 2012). Thus, the broad expectation that CDM project activities would be relatively evenly distributed across all developing countries is challenged, raising the question whether the incentive mechanism for undertaking a CDM project activity is consistent with the cost structure.

Most numerical analyses of how the CDM affects the cost of meeting the objectives of the Kyoto Protocol are based on specified abatement cost curves and the assumption that capital will seek out least-cost projects.[7] The same approach also leads to the prediction of the sectors and regions likely to benefit from project investment flows. However, the cost of CERs for a particular project type of a given size can differ across countries due to taxation and trade barriers and even within countries due to factors such as emission factors, costs of connecting to the electricity grids, and the cost of site access. This paper examines the cost of CERs by various types and sizes of CDM projects located in different developing countries, with the objective of assessing the cost-effectiveness of GHG reductions through the CDM to provide policy relevant perspectives.

A majority of previous studies providing useful estimates of abatement costs of various pollutants are based on secondary data or approximated coefficients in the abatement functions. Rahman et al. (forthcoming) estimated GHG emission abatement costs under the CDM using imputed project cost data. Castro (2014) collected plant-level cost data for 109 CDM projects and calculated abatement costs, adjusting for baseline costs.[8] However, actual abatement by the projects in operation, incurred CER issuance costs, and the difference between the crediting period and project life are not considered in these studies. In this paper we use project-level production and cost data for a large sample of CDM project activities, as reported in the project design documents (PDDs). Apart from expected CERs, byproduct outputs, and fixed and variable costs of the projects, the data distinguishes among various types of projects, methodologies for calculating emission reductions, the countries hosting the projects, and sequence of new project investments for the period 2003–2013. For calculating the cost of CERs for each project, we adjust the expected CERs and byproduct outputs by actual credit issuance rate, consider effective lengths of crediting period and project life, and take account of CER issuance costs. As our objective is to provide accurate estimates of CER costs for different CDM technologies, we do not consider the baseline costs for the projects, because baseline costs are relevant for mitigation cost estimation.

The unique features of the CDM project activity-level data allow us to draw distinctions among projects across types (technologies), methodologies, locations, and time, and test two hypotheses important for policy design: (1) whether CDM projects exhibit economies of scale in certified emission reduction, and (2) whether the average cost of CER by the CDM projects has decreased over time, presumably due to accumulated experience. Based on the estimated costs, we further examine the role of CER costs in explaining the observed CDM investments.[9] In particular, we examine whether the distribution of projects follows a type-specific cost structure, such that there are more projects of the types for which the average cost of CER is relatively lower. We also examine whether the distribution of the projects in different host countries follows the principle of comparative advantage (i.e. whether countries hosting specific types of projects generate CERs at a lower average cost over others).[10]

The remainder of the paper is organized in the following way. The next section describes the conceptual model and empirical framework for estimating the cost of CERs by the CDM projects. Section three describes the CDM project data. Section four delineates the estimation results and discusses the implications. Finally, the last section concludes the paper.

2. Estimating the cost of certified emission reduction

In the case of CDM projects, the costs of CERs are not necessarily the same as total project costs. Many CDM projects generate byproducts of CERs. For example, renewable resource based projects generate electricity, energy efficiency projects saves electricity, while afforestation and reforestation projects produce forest products. Total project costs are larger than CER costs for the multi-output CDM projects, and the cost of CERs may not be separable from the cost of byproducts. The cost of CERs is equivalent to the total project cost for the projects that generate CERs only.

Previous studies estimating pollution abatement costs can be categorized into two groups. The first group 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 of the primary output (see Considine and Larson, 2009, 2006; Pizer and Kopp, 2005; Maradan and Vassiliev, 2005; Newell et al., 2003; Newell and Stavins, 2003; Boyd et al., 1996; Nordhaus, 1994). The second group of studies estimate the pollution abatement cost function by separating cost of abatement from the cost of production (see Castro, 2014; Rahman et al., forthcoming; Hamaide and Boland, 2000; Bystrom, 1998; Hartman et al., 1994).

In this paper, we estimate a separable cost function for CERs.[11] Our dataset provides total fixed and variable costs for the projects; it does not distinguish between CER costs and total costs for the multi-output projects. Developing a conceptual model for separable cost function, we calculate the net cost of CERs by subtracting expected value (i.e., revenues from the sales) of the byproducts from the fixed and variable costs of the project. Due to a paucity of data on various transaction costs associated with project development, approval, and implementation, we are unable to take account of such costs.[12] Such costs, however,

[5] These projects are either registered (with or without issued CERs) or in validation. See the UNEP Risoe CDM/JI Pipeline Analysis and Database (http://cdmpipeline.org/publications/CDMPipeline.xlsx-January2014) and Larson et al. (2008) for a discussion of CDM implementation rules and the CDM project cycle.

[6] This number represents the potential of projects known to be issuing as adjusted by their rate of issuance up to January 2013 ($<= 1$).

[7] 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.

[8] The baseline is generally conceived as the situation without the CDM project, which may be new investment or status quo — continuation of the current situation without a new investment (Castro, 2014). For many energy projects, baseline is the status quo with expenses such as buying energy from the grid or buying coal. Avoiding or reducing such expenses is considered as revenue for the CDM project and is included in the cost calculation (Castro, 2014).

[9] See Rahman et al. (2012) for a review of ex ante predictions for the CDM.

[10] For the definition and explanation of comparative advantage, please see Boudreaux (2008).

[11] Rahman et al. (forthcoming) estimate both the separable emission abatement cost as well as project costs (when abatement cost is not separable) for the CDM using imputed cost data. They found similar results for both models upon controlling for the byproduct in the joint cost estimation.

[12] Michaelowa and Jotzo (2005) outline various transaction costs associated with the CDM projects. In addition, projects may incur site access costs, byproduct marketing costs (e.g., connecting electricity to the grid), etc. We do not consider PoAs nor their costs.