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Project-Based Mechanisms for Emissions Reductions

Balancing Trade-offs with Baselines

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RESOURCES FOR THE FUTURE

Project-Based Mechanisms for Emissions Reductions: Balancing Trade-offs with Baselines

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Abstract

Project-based mechanisms for emissions reductions credits, like the Clean Development Mechanism, pose important challenges for policy design because of several inherent characteristics. Participation is voluntary, so it will not occur without sufficient credits. Evaluating reductions requires assigning an emissions baseline for a counterfactual that cannot be measured. Some investments have both economic and environmental benefits and might occur anyway. Uncertainty surrounds both emissions and investment returns, and parties to the project are likely to have more information than the certifying authority. The certifying agent is limited in its ability to design a contract that would reveal investment intentions. As a result, rules for benchmarking emissions may be systematically biased to overallocate, and they also risk creating inefficient investment incentives. This paper evaluates, in a situation with asymmetric information, the efficacy of the main baseline rules currently under consideration: historical emissions, an average industry emissions standard, and expected emissions.

Key Words: climate policy, Clean Development Mechanism, baselines, asymmetric information, offsets, emissions reduction, tradable emissions permits

JEL Classification Numbers: D8, Q4

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Carolyn Fischer*

Introduction

The Kyoto Protocol set legally binding emissions targets for industrialized countries (Annex I Parties), amounting to a reduction from 1990 levels of at least 5% by 2008-2012. To help meet these ends, it envisioned flexibility mechanisms that include not only emissions trading among participating countries, but also project-based emissions reductions in countries or sectors not subject to an emissions cap. The Clean Development Mechanism (CDM) allows investment projects that reduce or sequester carbon emissions in developing (non-Annex 1) countries to generate Certified Emissions Reductions (CERs) that count toward compliance goals in developed countries.[1] Similarly, "Joint implementation" provides for Annex I Parties to implement projects that reduce emissions in other industrialized countries, in return for emission reduction units.[2] By exploiting these flexibility mechanisms, adherents expect to reduce substantially the costs of complying with the targets. The CDM also forms the key instrument to have the developing countries become part of the Kyoto Protocol.

Offset programs are not new to emissions trading. In the U.S., they have been incorporated into effluent compliance and watershed trading programs, particularly for new or expanding sources. The RECLAIM program for the Los Angeles air basin has allowed the scrapping of old vehicles to generate mobile source emission reduction credits to offset stationary source emissions of criteria air pollutants.[3] However, the Kyoto Protocol elevates

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[1] Article 12.

[2] Article 6.

[3] RECLAIM stands for "Regional Clean Air Incentives Market" and is administered by the South Coast Air Quality Management District.

project-based mechanisms to a whole new scale in terms of potential emissions reductions and in its international scope. Although such projects may offer significant gains in terms of lower-cost abatement opportunities—as well as development benefits in the case of CDM—they also pose important challenges for policy design if an additional goal is to maintain the stringency of the emissions cap. These issues are also important for the value of investments in mitigation projects and certified emissions reductions, which are already being undertaken by energy companies, governments, and other organizations.

The challenges arise from certain characteristics inherent to CDM and project-based mechanisms more generally.[4] First of all, CDM participation is voluntary, and the emissions credits determine both the incentive to participate and the effective cap on emissions. Second, many emissions-reducing projects provide other benefits beyond the value of emissions credits, so some of those investments might occur anyway. Third, evaluating project-based reductions requires assigning a baseline for the emissions that would occur in the absence of the project; that counterfactual cannot be measured, and considerable uncertainty surrounds it. Fourth, access to information will likely be asymmetric: the third-party monitor that will certify emissions reductions will know less about the project fundamentals than the investing and recipient parties. Fifth, the certifying agent is limited in its ability to design a contract that would elicit truthful information from CDM participants regarding their investment intentions. The certification authority can only set the amount of abatement credits, while market forces determine the value of emissions reductions.

The combination of those factors means that rules for determining baseline emissions—the benchmark against which actual emissions will be measured and reductions will be certified—may be systematically biased. The costs of poor baseline determination range from underallocation, which means forgoing some worthy projects, to overallocation, which expands the global emissions cap and may encourage some unjustified investments. This paper uses a

[4] From this point forward, however, we will emphasize the CDM case.

stylized model to evaluate, in a situation of uncertainty and asymmetric information, the efficacy of the main baseline rules currently under consideration:

1) historical emissions;

2) an average emissions standard for the industry; and

3) expected emissions.

The first and third methodologies rely on project-specific information, while the second uses an industry-wide standard to generate a benchmark. The analysis indicates that using individual emissions histories as a baseline generally provides good investment incentives, but it may substantially overallocate to those that would find such investments profitable in the absence of a CDM policy. Policies that rely on industry-wide averages overallocate to some firms and underallocate to others, resulting in poorer investment incentives, less cost-effective abatement, and possibly allocation of too many certified emissions reductions unless the standard is sufficiently strict. The latter two problems are exacerbated when firms can participate in the program without making any required investments.

A baseline of expected emissions is formed by gathering project-specific information to make a reasonable estimate of future emissions. This method strikes a certain balance between the historical and the averaging methods. Increased accuracy reduces the inefficiencies in investment incentives compared with averaging and reduces overallocation compared with historical emissions. However, this method would require that the certifying authority have access to necessary information at costs that do not outweigh the benefits of greater accuracy.

The next section presents background for CDM projects and the economic and uncertainty issues that are likely to accompany them. The subsequent section develops a stylized model to assess the impact of baseline allocations on incentives to engage in emissions-reducing investments, given information asymmetries. The final section discusses the welfare implications of different policies for baseline determination.[5]

Background

The Clean Development Mechanism, as conceived in the Kyoto Protocol, has dual objectives. One is to help the parties in Annex I (the developed countries) achieve their commitment targets at a lower cost than relying fully on efforts conducted at home. Another objective is to provide sustainable development opportunities for the non-Annex I parties. To receive certified emissions reductions (CERs), projects are expected to offer real emissions reductions as well as benefits accruing to host countries, such as the transfer of environmentally sound technology and know-how (Art. 12).

Both the quantity of abatement to be certified and the benefits to the developing country partner would be evaluated on a project-by-project basis. For the latter evaluation, the type of benefits considered and recognized may be important. For example, a requirement for technology to be transferred could imply a very different set of potential projects than merely allowing for a monetary transfer in exchange for reductions. For the types of projects that serve dual purposes of productivity enhancement and environmental improvement, as stipulated by the protocol, the evaluation of emissions reductions may then be quite complicated because of the problem of disentangling influences.

In principle, ensuring compliance in Annex I countries is a relatively straightforward task: because they are subject to an overall emissions cap, one need monitor only emissions.[6] Knowing what would have happened in the absence of the cap helps in estimating the

[5] "Baseline" is the official terminology of the CDM for the benchmark emissions allocation of a project. We use this term as such throughout the paper. In comparison to the traditional use of a "baseline scenario"—which in this case would be no CDM— these baseline rules in effect offer a standard methodology for approximating the emissions in that no-policy scenario.

[6] For the most part, emissions monitoring can be achieved by tracking the entry of fossil fuels into the economy; most Annex I countries have sufficient infrastructure for compiling accurate data (Russia may be a notable exception).

opportunity costs to the economy, but it is not necessary for compliance (except, perhaps, in the thorny area of carbon sinks). The CDM, however, does not operate under a cap; because it is a project-by-project mechanism, to certify actual reductions to credit against Annex I caps, one must know not only actual emissions but also the emissions that would have occurred in the absence of the project. The procedures regarding additionality and baselines for a CDM are detailed in Annex decision 17/CP.7:[7]

> 48. In choosing a baseline methodology for a project activity, project participants shall select from among the following approaches the one deemed most appropriate for the project activity, taking into account any guidance by the Executive Board, and justify the appropriateness of their choice:
>
> (a) Existing actual or historical emissions, as applicable; or
>
> (b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or
>
> (c) The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 percent of their category.

The options are represented here in a stylized form as historical, expected, and average emissions, respectively. Historical emissions are self-evident, and probably the simplest to calculate. Assessing the “economically attractive course” represents an attempt to generate expectations about what baseline emissions would have been, taking into account pre-existing investment incentives. Finally, average emissions use similar, non-CDM projects as a baseline; restricting the pool of comparable projects to top performers then serves to reduce the average allocation. The intent is to encourage projects with lower GHG intensity than top performers and to ensure that projects that would occur on their own do not get allocations.

Baselines and Welfare

True additionality requires that the allocated baseline not exceed what would have happened had the firm not participated in CDM. Unfortunately, that information is highly

[7] UNFCCC (2001).

uncertain. As a result, the certifying authority runs the risk of guessing too high or too low in awarding CERs (equivalently, guessing too low or too high on baseline emissions). Guessing too high a baseline and giving away too many CERs means expanding the overall emissions cap for Annex I countries, which implies some marginal increase in the potential damages from climate change. Guessing too low a baseline, on the other hand, risks forgoing the benefits of a cost-effective greenhouse gas-reduction project and valuable local benefits due to insufficient compensation.

Consider the baseline problem from the vantage point of the global community, ignoring for now issues of the international distribution of effort, benefits, and costs. In weighing the risks of under- or overallocation, one must consider the net costs or benefits of expanding the cap compared with the cost savings from shifting the location of abatement effort. If the true baseline is allocated, then overall emissions do not change. However, in shifting some abatement from areas where the marginal costs are high to areas where marginal abatement costs are low (even zero), we have made the total costs of achieving that overall cap strictly lower. Therefore, total global welfare is strictly higher. A corollary to this result is that one can allocate somewhat more than the true baseline without lowering welfare. How much more depends on whether the marginal benefits from reducing emissions (reduced potential climate change burden) are higher or lower than the marginal costs of reducing emissions. If they are approximately equal, the extra damages from loosening the cap are roughly offset by the cost savings from doing less abatement. If marginal costs are higher, welfare improves from loosening the too-tight cap. If marginal damages are higher, welfare is lost by expanding the cap, and fewer permits in excess of the baseline can be allocated without lowering overall welfare.

The full cost of inappropriate baseline determination includes both economic and environmental costs. Receipt of the baseline allocation is conditional on participation, and participation is also conditional on technology transfers; all these decisions are voluntary and depend in part on the attractiveness of the allocation. Thus, baseline rules do not merely redistribute the rents and compliance costs of greenhouse gas policy, they may also introduce complex incentives for potential participants. The cost of inappropriate incentives is not just unintended redistribution of wealth in permits but wasted resources.

Uncertain and Unequal Information

The critical problem is that although actual emissions can be verified, actual reductions cannot. One cannot predict what baseline emissions would have been any better than one can predict what emissions will be.

Many factors contribute to uncertainty about the baseline and about the profitability of an investment project. Fuel prices may fluctuate, consumer tastes may change, exchange rate movements can affect exporting industries, regulation or deregulation can affect electricity production and prices, and other macroeconomic variables have an impact on demand for energy-intensive products. Many of these factors are just as uncertain to the firm or project manager as to the authority that certifies the emissions reductions. If that were all, the certifying authority could assign a baseline rule based on mutually shared expectations, and the investor would act according to those expectations.

In many instances, however, the participants in a project (hereafter “the firm”) may have better information than the certifying authority.[8] Firms may differ in the state of their existing production capital, in their management's ability to implement a change in technology, or in local demand conditions. The profitability of a given technology transfer can vary across firms, and the firms are more likely to know what their particular economic gains are. If that information is private and cannot be obtained without significant cost, a discrepancy is created between the certifying authority's expectations about what the firm would do in the absence of the CDM project and the firm's own expectations. This discrepancy poses serious challenges for designing baseline rules.

This baseline issue is complicated by the dual nature of many technologies. Some technologies are single-purpose and reduce emissions without significantly affecting the rest of

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[8] Project participants may include foreign direct investors, host country governments, and/or firms. We focus on cases where these actors have better information about the project than the authority certifying the emissions reductions. Others consider cases where information asymmetries exist between the parties to the project themselves (e.g., the host country may have better knowledge of the true profitability than the foreign investor). See Hagem (1996).

the production process: the retrofit of scrubbers to remove pollutants at the "end of the pipe," for example. However, these options are essentially nonexistent for greenhouse gas emissions. Typically, the reduction of greenhouse gases entails a major change in the use of fossil fuel inputs and their related products. Many investments that would produce significant emissions reductions through major production process changes could also then produce significant economic gains, and vice versa. For example, an improved production technology may also be more energy efficient, reducing both emissions and the costs of fuel inputs. Although productivity increases and emissions decreases are both good things, determining environmental additionality can then be tricky.

Investment in productive capital or new technology is costly, and the project investors weigh the economic value of the project against those costs. Some projects will pass this economic test and go forward regardless of climate change policy. However, in addition to the economic benefits, there may also be environmental benefits to the project. The firm will not value them in the absence of some intervention or opportunity, such as joining a CDM program. If a firm participates in a CDM project, the total return then equals the economic value plus the sales of CERs. The baseline allocation thus determines whether otherwise unprofitable projects are implemented.

On the other hand, not all reductions require significant fixed costs or new technologies—changes in variable production factors can also reduce emissions. Such alternatives might not be profitable on their own, but would be worthwhile in return for emission credits. Although the CDM is intended to be a mechanism for technology transfer, it is unclear to what extent a major investment in equipment or training is a prerequisite for consideration as a CDM project. A developing country (or company) might also on its own be able to adjust its behavior to reduce fossil fuel use, if allowed to participate and receive credits. Thus, both the design of the baseline allocation rules and the participation requirements are important for determining who partakes in CDM projects, how many additional reductions are achieved, and how many are certified.

CDM Contracts and Asymmetric Information

Asymmetry in access to information is a potentially serious problem for calculating CERs. Because participation in CDM projects is voluntary, certain baseline allocation methods run the risk of selection bias—attracting participants who would be predisposed to making such investments and having low emissions anyway. For example, suppose CDM candidates have a good idea what their baseline emissions would be, but the certifying authority does not. A firm that is planning to be a lower emitter would like to pretend to be a higher future emitter, in order to get a larger allocation.[9]

Economic theory offers ideas for designing contracts to induce project proponents to reduce such distortion, or even to fully reveal what type they are.[10] Normally, this involves offering the firm a menu of different combinations of quantities (e.g., production, effort, or abatement) and corresponding prices. The two contract variables (price and quantity) are used to identify firms with different preferences over those aspects. In this context, each contract in the menu would have to specify a certain fixed transfer payment (and thereby a certain price) for each fixed amount of abatement.

The attention given to project-based mechanisms in the literature has focused mostly on the impact of asymmetric information and costly enforcement between the project partners in a bilateral exchange.[11] It is generally assumed that abatement can be measured *ex post*, information about abatement costs is incomplete, and the investor has declining marginal benefits to abatement.[12] Three problems make these kinds of traditional models either

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[9] Wirl et al. (1998) show that in the absence of an exogenously set baseline, countries participating in a jointly implemented project have incentives to cheat in announcing their intentions, both to each other and to the certifying authority.

[10] Much of the theory of optimal contract design is derived from the theory of optimal regulation of monopolies. See Laffont and Tirole (1993) and Loeb and Magat (1979).

[11] For example, Hagem (1996) considers the problem of contract design for an investing country firm that does not know the true cost to the host country partner of conducting abatement. Liski and Virrankoski (2001) focus on transaction costs in bilateral bargaining. Janssen (1999) considers third-party enforcement of bilateral transactions.

[12] Millock and Hourcade (2001) are an exception, introducing uncertainty over abatement levels into the bilateral framework.

impractical or inapplicable to a decentralized Clean Development Mechanism with third-party validation.

First, in a competitive market for CDM projects and other fungible international carbon credits and allowances, the price of emissions reductions is likely to be fixed by international markets; a contracting party would find it difficult to deviate from prevailing permit prices. In fact, these revelation methods are unnecessary if the investing country's abatement cost function is relatively flat in the area of the corresponding abatement amount. It could offer a constant price per unit of abatement (the international market price), and an efficient amount would be achieved in the absence of any information about the agent's costs: this is the beauty of decentralized markets. Bargaining with “menus,” as described above, is useful only if the goal is to obtain part of the inframarginal rents or if marginal benefits are declining.[13]

Second, the certifying authority is not designing a full contract for abatement. It determines the categories of projects that are eligible—coal plant modernization versus renewable energy—and the procedures by which actual emissions reductions are calculated and certified. In defining the baseline against which abatement is measured, the certifying authority cannot induce two types of eligible projects to make the different conditions known by choosing different packages of provisions, since a larger baseline is always preferred, regardless of type. A believable information-gathering and punishment mechanism would be necessary to design procedures that induce the revelation of firm-specific factors that affect baselines.

Third, and most problematic, these revelation mechanisms assume that actual abatement can be established, albeit with a cost to monitoring. Unfortunately, the target of the necessary monitoring and enforcement mechanism is a hypothetical behavior, not an actual one. Although

[13] The existence of these competitive opportunities is why developing countries’ CER suppliers are better off creating credits for competitive sale than with isolated bilateral deals where foreign investor can capture much surplus. See Narain and Van ‘t Veld (2001). Babu and Bibhas (1996) look at the effect of bargaining power on the distribution of gains from bilateral negotiations over abatement and price.

actual emissions can be observed, emissions in the absence of the project cannot, and actual abatement may therefore be impossible to know.[14]

Allocation and the Investor: A Stylized Model

Since project-by-project information gathering is very costly, some general rules for determining project-level emissions baselines have been proposed: historical emissions, average emissions, and expected emissions. Each rule has its own biases in the departure from actual baselines and in incentives to participate. To evaluate their effects, we develop in this section a model that characterizes the incentives of the investing party, which for simplicity we call "the firm." Projects may of course be undertaken by a variety of entities, including governments, joint partnerships, multinational corporations, and local businesses; the key assumption is merely that the parties undertaking the investment and abatement activities are distinct from the authority certifying the amount of emissions reductions.[15]

A formal analytical model of the firm's investment problem is developed first for a general case, and then applied to the specific baseline allocation rules. We analyze in particular the role of fixed costs in the decision to participate in a CDM project. In the first scenario, a significant investment is required to participate, representing a technology-transfer mandate. In a second scenario, smaller projects without major fixed costs—like process improvements—are also eligible, representing no transfer requirement. We focus on investment-related costs and assume the firm does not bear any transactions costs related to monitoring or certification.[16]

We use the analytical model to build intuition about the basic incentives created by allocation and participation rules. To demonstrate these effects, the model is stylized and simplifications are made with respect to the range and distribution of potential projects.

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[14] This concern is raised by Bohm (1994).

[15] See also footnote 5.

[16] This assumption would hold if monitoring costs are either negligible or borne by international sponsors of the certifying authority. The main effect is to eliminate additional modeling complexities, and the implications will be discussed after the model is presented.

Subsequently, numerical simulations are performed to illustrate how project investment, participation and outcomes vary with respect to the effectiveness of the investment and its alternatives at reducing emissions.

Model with Investment Prerequisite

The investment in a new, cleaner production process brings two potential payoffs to the firm: 1) cost savings reflecting reduced use of energy inputs, which we assume are proportional to the emissions reduced; and 2) an increase in general productivity, which yields additional profits. These profits vary from one investment project to another because of market conditions, managers' and workers' skills, or technical expertise.

To formalize a model of the firm's decision making, let these key terms be represented with the following variables:

k	=	Investment cost (annualized);
π	=	Economic benefits;
μ	=	Initial emissions;
ρ	=	Share of emissions remaining after investment;
s	=	Savings per unit of emissions reduced;
t	=	Market price of emission permits;
$A(\mu)$	=	Baseline allocation.

Restated mathematically, if the firm makes a fixed investment that costs *k* in annualized terms, it receives annual flows of economic benefits and energy savings of $\pi + (1-\rho)s\mu$. We assume that the firm knows the value of all those variables with certainty, but the internal profit variable is unknown to the certifying authority. Initial emissions rates also vary by firm, affecting the total returns of the investment, but they are assumed to be uncorrelated with the firm-specific profit. The certifying authority can verify initial emissions. However, without knowing the profit variable—and thereby whether the firm would invest anyway—it cannot determine actual baseline emissions.

In a general formulation, let $A(\mu)$ be the firm's baseline allocation under a given rule, which may be a function of the initial emissions rate. The CERs, which can be sold at the market price of permits, are the difference between the allocation and remaining emissions. Thus, the additional value of participation is $t(A(\mu)-\rho\mu)$. Although theoretically one could have underallocation serious enough to prevent participation when an investment already made, we restrict our consideration to abatement rates and baseline characterizations such that $\rho\mu < A(\mu)$.[17] Thus, we focus on the question of whether to invest or not.

Let $\hat{s} = (1-\rho)s$ be the effective rate of energy savings from the technology. In general, a firm will invest if the gains—the combined profits, energy savings, and the CER sales—outweigh the costs; i.e., if $\pi + \hat{s}\mu + t(A(\mu) - \rho\mu) > k$. Whether or not an equivalent investment project passes this test depends on each firm's individual characteristics, the prices it faces, and the allocation regime.

Equilibrium with Uniform Distribution

To assess the impact of these factors, we need to evaluate the equilibrium investment and emissions, given a continuum of projects with varying profiles of economic benefits and emissions reductions. In the absence of knowing what the actual distribution of potential projects looks like, consider the following demonstration using independent, uniform distributions of emissions rates and profits, with $\mu \in [0,1]$, $\pi \in [0,1]$,[18] $k = 1$ and 0<*s*<1. This normalizes the variables to the investment cost, so that π is the share of those costs recouped by profits, μ is the share of maximum emissions, and *s* represents the energy savings in terms of profits from reducing the emissions share. The assumption that each variable is bounded by 1 in this example means that it is not worthwhile to make any investment for profits or energy savings alone; both must be present.

The uniform distribution has convenient properties. For example, the share of projects with profits exceeding the investment threshold is easy to interpret. In the absence of a CDM policy, given any μ, firms with $\pi \geq (1-\hat{s}\mu)$ will invest; with the uniform distribution, $\hat{s}\mu$ is the share of those firms with emissions μ meeting this threshold, or the odds that the particular

[17] The simplification applies to the average and expected emissions rules, but it is not in actuality very restrictive, as will be explained in the next part.

[18] In other words, the share of firms with (or the probability of) $\mu \leq x$ is $\int_0^x d\mu = x$.

project will pass the investment hurdle. Thus, average initial emissions are $\int_0^1 (\mu) d\mu = 1/2$, and investment is the integral of the odds of investing over the range of emissions rates: $\int_0^1 (\hat{s}\mu) d\mu = \hat{s}/2$.

When CDM participation is conditional on investment, a firm will invest if $\pi \geq (1 - \hat{s}\mu - t(A(\mu) - \rho\mu))$. Thus, with the uniform distribution,[19] total investment equals

$$\int_0^1 \left(\hat{s}\mu + t(A(\mu) - \rho\mu)\right) d\mu = \frac{\hat{s}}{2} + t\left(\int_0^1 A(\mu) d\mu - \frac{\rho}{2}\right) \tag{1}$$

Thus, investment in all regimes is necessarily higher than in the no-policy regime, and it is increasing in the cumulative (or average) allocation.

The total CERs for the industry equal the difference between the baseline allocations and actual emissions for the investing firms:

$$\int_0^1 \left(\hat{s}\mu + t(A(\mu) - \rho\mu)\right)(A(\mu) - \rho\mu) d\mu, \tag{2}$$

and actual emissions reduced equal the difference between pre- and post-investment emissions for the investing firms:

$$\int_0^1 \left(\hat{s}\mu + t(A(\mu) - \rho\mu)\right)(1 - \rho)\mu d\mu. \tag{3}$$

The net reductions to global emissions are the difference between actual reductions from the CDM project and the CERs, since those are used to offset reductions in Annex I countries:

$$\int_0^1 \left(\hat{s}\mu + t(A(\mu) - \rho\mu)\right)(\mu - A(\mu)) d\mu \tag{4}$$

In other words, net reductions are defined as the overall impact on global emissions compared with the initial state with no investment. The difference results from both the

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[19] The only difference in these expressions with a non-uniform distribution of emissions would be the inclusion of a frequency distribution function,i.e., $f(\mu)d\mu$. However, if profits are not uniformly distributed, the expression for the probability of investment is more complicated.

direct reduction in emissions by investors and the increase in emissions by the recipients of the certified reductions.

Policy Scenarios

We now use this framework to compare five policy scenarios.[20]

No Policy

In the absence of CDM, investment will go ahead if the profits and energy savings justify it—that is, if $\pi + \hat{s}\mu - k > 0$. The value of emissions reductions does not play a role (effectively, $t = 0$).

Optimal and Additional

Ideally, every firm for which the investment is justified from a social standpoint would invest—that is, if $\pi + \hat{s}\mu + t(1-\rho)\mu - k > 0$. However, to preserve additionality, one would not want to allocate permits to those that would invest under no policy. Thus, the firms one would want to target are those whose emissions are costly enough in environmental terms that they would justify investment, even though profits and energy savings alone would not: $\pi + \hat{s}\mu + t(1-\rho)\mu - k > 0 > \pi + \hat{s}\mu - k$.

Historical Emissions

The historical emissions rule allocates to each firm a baseline reflecting its individual emissions history, which in this framework is its level of initial emissions μ. The firm will then invest if $\pi + \hat{s}\mu + t(1-\rho)\mu - k > 0$. The full environmental value of emissions reductions enters into consideration, lowering the investment hurdle according to the firm's initial emissions. Thus, all the firms that can justify the investment in terms of social costs and benefits undertake it. Those that would invest under no policy still do, and their profits are raised by the value of the

[20] All of the rules at hand could, in theory, be implemented in lump-sum form, with fixed allocations, or rate-based form, with allocations depending on production levels. Since we are focusing on the investment rather than production questions, we abstract from this issue; some implications are discussed in the conclusion.

net allocation of CERs. That net allocation is by definition always positive, assuring participation.

Average Emissions

An industry average baseline offers $\bar{\mu}$ credits to each project joining the program. This average allocation is determined based on industry-wide parameters and is independent of the firm's characteristics. We will allow this average to be defined in different potential ways, such as by average initial emissions, or by the average emissions of relatively clean firms; the point is that the allocation is identical for all participants. Compared to no policy, this baseline lowers the hurdle across the board, without respect to the individual emissions saved. If investment is a precondition for participating in the CDM program, a firm will invest and join if $\pi + \hat{s}\mu - k + t(\bar{\mu} - \rho\mu) > 0$. Thus, some of the firms with emissions that are sufficiently costly to the environment do not have enough incentive to invest: $t\mu > k - \pi - \hat{s}\mu + t\rho\mu > t\bar{\mu}$. Meanwhile, some firms with relatively low emissions are given the extra push to invest, something they would not have done under the historical emissions baseline: $t\mu < k - \pi - \hat{s}\mu + t\rho\mu < t\bar{\mu}$.

The policy restriction we impose to ensure participation is that the average emissions standard is set higher than the post-investment emissions of the highest emitter ($\bar{\mu}$ and ρ such that $\bar{\mu} > \rho\mu$ for all μ). Otherwise stated, we assume the technology is always cleaner than the standard.[21]

Expected Emissions

Under an expected emissions rule, the certifying authority uses the information available to it about the firm's characteristics to assess what emissions would be in the counterfactual, $\tilde{\mu}$. Although these emissions are not actually uncertain, they are unknown to the certifying authority. The authority is here assumed to observe initial emissions and determine expected emissions, knowing the odds that an investment would be made in the absence of policy. In other words, expected emissions are defined here as a weighted average of initial emissions and postinvestment emissions, where the weights derive from the probability distribution of profits: $E\{\tilde{\mu}\} = (\Pr\{\pi > k - \hat{s}\mu\})\rho\mu + (\Pr\{\pi < k - \hat{s}\mu\})\mu$. Consequently, the net allocation of CERs is always positive in our example. However, we note that if expectations are formed by other means, participation may not be assured. With our uniform distribution, these expectations simplify to a function of the firm's observable initial emissions:[22] $E\{\tilde{\mu}\} = \mu(1 - s(1-\rho)^2\mu)$.

Policy Comparison

Table 1 summarizes the stylized allocation rules and the decision of the firm to invest and participate in a CDM project.

Table 1: Investment Decisions Under Different Baseline Rules

	Allocation Rule	*Investment Decision*
	$A(\mu)$:	Invest if:
No policy	0	$\pi + \hat{s}\mu > k$
Historical baseline	μ	$\pi + \hat{s}\mu + t(1-\rho)\mu > k$
Industry average baseline[23]	$\overline{\mu}$	$\pi + \hat{s}\mu + t(\overline{\mu} - \rho\mu) > k$
Expected emissions baseline	$\mu(1-s(1-\rho)^2\mu)$	$\pi + \hat{s}\mu + t((1-\rho)\mu - s(1-\rho)^2\mu^2) > k$

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[21] Else some firms would invest but not participate, as under the no policy scenario. Then the investment decision is whether $\pi + s(1-\rho)\mu + t\text{Max}[\overline{\mu} - \rho\mu, 0] > k$. For lower reduction rates, some high emitters might want to invest but not join the program. Since smaller reductions will be incorporated with variable cost changes, we consider this additional complication unnecessary at this time.

[22] Recall from the definition of expected emissions, $E\{\tilde{\mu}\} = (\Pr\{\pi > k - \hat{s}\mu\})\rho\mu + (\Pr\{\pi < k - \hat{s}\mu\})\mu = (1-\hat{s}\mu)\mu + \hat{s}\mu\rho\mu = \mu(1 - s(1-\rho)^2\mu)$.

[23] We maintain the assumption that $\overline{\mu} > \rho$, meaning that all investments reduce emissions below this standard and are assured a positive net allocation of CERs.

From these allocation rules, we can already see some of the implications for net reductions as laid out in (4). Since having no policy produces some reductions and no allocations, net reductions are necessarily positive. Since historical emissions set $A(\mu) = \mu$, net reductions are by definition zero—and thereby less than with no policy. Since expected emissions are less than historical emissions ($A(\mu) < \mu$ for all μ), that rule always produces positive net reductions. Finally, since the average industry emissions standard may allocate more or less than initial emissions, it can generate positive or negative net reductions. A question remains whether any of the baseline rules, though they all generate more abatement activity in the developing country, actually generate more net reductions than the no-policy case.

A Clean Technology Example

The differences between the baseline rules can be illustrated analytically with a simple example using an investment in a clean, nonemitting technology.[24] For example, the project could install wind, solar, or renewable energy technologies for generation, displacing coal-fired plants or other fossil fuel sources. When the investment reduces emissions to zero, the baseline allocation is equal to the quantity of certified emissions reductions granted.

Table 2 presents the results, derived from assuming that $\rho = 0$, substituting the allocation definitions, and solving for investment costs, allocations, and emissions under the different scenarios. Note that net reductions reflect the impact on global emissions compared with the initial state, rather than with no policy.

With no policy, *s*/2 is the share of firms with high enough combined profits and emissions to invest regardless, abating emissions by *s*/3. With the historical emissions baseline, an additional *t*/3 units of abatement occur through more investment. However, both they and all other investing firms choose to participate in CDM and are allocated their historical emissions.

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[24] While this example may still seem restrictive, it introduces the key methods and intuition; the effects of incomplete emissions abatement will be evaluated numerically.

Since all covered reductions are offset by extra emissions by CER purchasers, global emissions rise by the amount of abatement that would have occurred anyway, *s*/3.

Table 2: Effects of Baseline Rules on Investment in a Clean Technology

	Investment	*CERs*	*Emissions reduced*	*Net reductions*
No policy	$\frac{s}{2}$	0	$\frac{s}{3}$	$\frac{s}{3}$
Historical baseline	$\frac{s+t}{2}$	$\frac{s+t}{3}$	$\frac{s+t}{3}$	0
Industry average	$\frac{s}{2}+t\bar{\mu}$	$\left(\frac{s}{2}+t\bar{\mu}\right)\bar{\mu}$	$\frac{s}{3}+\frac{t\bar{\mu}}{2}$	$\frac{s}{3}+\frac{(t(1-2\bar{\mu})-s)\bar{\mu}}{2}$
Expected emissions	$\frac{s+t}{2}-\frac{st}{3}$	$\frac{s+t}{3}-\frac{st}{2}-\frac{s^2}{4}+\frac{s^2t}{5}$	$\frac{s+t}{3}-\frac{st}{4}$	$\frac{s(s+t)}{4}-\frac{s^2t}{5}$

The industry average emissions baseline has several effects. For comparison, consider the standard of average historical emissions, or $\bar{\mu}=1/2$. That rule produces investment equal to the historical baseline, but the distribution is different. High-emitting firms have less additional incentive to reduce emissions, while lower-emitting firms have more incentive to invest.[25] Since the investment decision is less sensitive to initial emissions, actual abatement is lower, despite equivalent levels of investment. Meanwhile, initially high-emitting firms that would invest anyway are not allocated as much, but firms with low initial emissions are overallocated emissions. With investment as a precondition for joining the program, the net effect is a much lower allocation, which then translates into more net reductions than with the historical baseline—but not more than with no policy.[26] Finally, as the standard is reduced, we see that investment, and with it CERs and abatement, are also reduced—however, net reductions may

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[25] Unless they have the option to join the program without investing, which is explored in the next section.

rise. To see if the average allocation can offer truly additional reductions, let $\bar{\mu}^*$ represent the industry average standard that leads to the greatest net emissions reductions. Maximizing the expression for net reductions with respect to the average emissions standard and solving, we get $\bar{\mu}^* = (t-s)/(4t)$. Substituting this value back into that expression for net reductions, we find that this standard does indeed produce net reductions in excess of the no-policy case of $(t-s)^2/(16t)$. Furthermore, we see that the reductions-maximizing standard is higher when the emissions price is relatively high, and lower when firms realize relatively more cost savings on their own.

The expected emissions rule still over-rewards some firms and under-rewards others, reducing investment compared with the historical baseline. However, the degree of inaccuracy is less than with the industry average rules, and the more appropriate investment results in lower actual emissions, though still not so low as the historical baseline. But since overallocation is tempered, total emissions may be lower than with no policy. Also interesting to note is that, unlike with the historical baseline, net reductions are sensitive to the permit price through the formation of expectations. On the other hand, the average emissions rule makes the permit price a factor only if the standard differs from the historical average; in all other cases, the extra incentive for abatement is fully offset by extra allocations.

Perhaps unsurprisingly, allowing the interested parties to choose their own method of baseline allocation would provide for the greatest amount of investment and of overallocation. Since expected emissions are always lower than historical emissions, the firm would always prefer either historical or average emissions: $\text{Max}[\bar{\mu}, \mu]$. Thus, below-average emitters would want the average rule and above-average emitters would choose historical emissions. As a result, this rule would provide all of the investment of the historical baseline, plus the additional investment of the average emissions baseline for those initially below the standard. Thus, additional reductions would be made, but many more CERs would be allocated. Since net

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[26] Without that precondition, we will see in the next section that emissions are higher and generally higher than with the historical baseline.

reductions are zero for the historical baseline and negative for below-average emitters, net reductions would necessarily be negative. Expressed mathematically, net reductions would be

$$\int_{0}^{\bar{\mu}} \left(\hat{s}\mu + t(\bar{\mu} - \rho\mu)\right)(\mu - \bar{\mu})d\mu + \int_{\bar{\mu}}^{1} \left(\hat{s}\mu + t(1-\rho)\mu)\right)(\mu - \mu)d\mu < 0 \qquad (5)$$

Model without Investment Precondition

Opportunities to reduce emissions may exist that do not involve capital investments, like modifying the production process or switching to higher-quality fuel. Then, some firms that see little economic benefit to investing could be given an incentive to make worthwhile emissions reductions, if participation did not depend on investment.

Suppose now that undertaking a fixed investment is not a requirement for participation in a CDM project. Firms that choose to participate but not invest then face incentives to use other methods to reduce their emissions and generate CERs. The option to undertake such cost-effective reductions then also affects the decision of whether to invest or not.

Consider an alternative method that is available to reduce emissions by $(1-\alpha)$ without incurring a fixed cost; instead, it involves variable costs, which for simplicity we assume are proportional to emissions and just equal to the corresponding energy savings.[27] This method can represent the "low-hanging fruit"—smaller-scale options that incur no significant net costs, but also reap no net benefits without a reward to emission reductions. We also assume that this method is less effective at reducing emissions than the fixed-cost technology ($\rho < \alpha$); in fact, unlike the investment technology, it may not generate sufficient reductions to guarantee a positive net allocation of CERs under each of the baseline rules. Furthermore, we assume that

[27] For initial units of reduction, this assumption should be quite accurate. In the absense of a value to emission reductions, firms should be just indifferent between conservation costs and energy savings. If marginal costs of abatement are increasing, it does not reflect the full costs of the reductions. However, it is a useful simplifying assumption.

the reductions from the investment would be made instead of, rather than in addition to, those available from variable-cost efforts.[28]

The firm then faces two decisions. First, the firm will choose whether to participate. Profits from participation are the net receipts from permit sales, since the other costs are just outweighed by the energy savings. Thus, the firm will join the program and engage in variable-cost reductions if the allocation it gets would exceed its remaining emissions: $A(\mu) > \alpha\mu$.

Next, the firm decides whether to invest. If it would not participate without investing, the investment decision remains identical to that in the previous section. If it would participate anyway, the hurdle is now that profits from investing must be greater than those from participating, not just greater than zero. In this case, the firm would invest if $\pi + \hat{s}\mu - k + t(A(\mu) - \rho\mu) > t(A(\mu) - \alpha\mu)$. Rearranging, we see that the baseline allocation drops out of the investment decision: invest if $\pi + \hat{s}\mu - k + t(\alpha - \rho)\mu > 0$. Importantly, this metric is also the socially efficient investment decision, meaning that for any baseline rule, if the firm would participate anyway, the decision to invest is always cost effective for the additional reductions.

Equilibrium without Investment Prerequisite

When investment is not a prerequisite for the CDM, equilibrium behavior reflects the additional participation decision. Let $\underline{\mu}$ denote the cutoff level of emissions below which firms would participate in the CDM without investing, given a baseline rule. With the investment prerequisite, that cutoff was predetermined as $\underline{\mu} = 0$; without it, the cutoff depends on the allocation mechanism. With the uniform distribution, total investment equals the share of those

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[28] This assumption does not significantly change the flavor of the results. If the variable cost options are not merely alternative but additive opportunities, participation in a CDM project can induce firms to find reductions in addition to those afforded by the investment. This incentive means that some gain is made with the firms that would have invested anyway, reducing some of the overallocation problem.

who would otherwise participate who find the investment project preferable, plus the share of those who would not otherwise participate who find the project worthwhile:

$$\int_0^{\underline{\mu}} \left(\hat{s}\mu + t(\alpha-\rho)\mu\right) d\mu + \int_{\underline{\mu}}^{1} \left(\hat{s}\mu + t(A(\mu)-\rho\mu)\right) d\mu. \tag{6}$$

The total CERs for the industry then equal

$$\begin{aligned}&\int_0^{\underline{\mu}} \left(A(\mu) - \left(\hat{s}\mu + t(\alpha-\rho)\mu\right)\rho\mu - \left(1-\hat{s}\mu - t(\alpha-\rho)\mu\right)\alpha\mu \right) d\mu \\ &+\int_{\underline{\mu}}^{1} \left(\hat{s}\mu + t(A(\mu)-\rho\mu)\right)(A(\mu)-\rho\mu) d\mu,\end{aligned} \tag{7}$$

while actual emissions reduced equal

$$\begin{aligned}&\int_0^{\underline{\mu}} \left(\left(\hat{s}\mu + t(\alpha-\rho)\mu\right)(1-\rho)\mu + \left(1-\hat{s}\mu - t(\alpha-\rho)\mu\right)(1-\alpha)\mu \right) d\mu \\ &+\int_{\underline{\mu}}^{1} \left(\hat{s}\mu + t(A(\mu)-\rho\mu)\right)(1-\rho)\mu d\mu\end{aligned} \tag{8}$$

Comparing Policies

For our different baseline rules, Table 3 summarizes the participation and investment decisions, using the same definitions as in the previous section.

Table 3: Investment Decisions without Investment Prerequisite

	Participate if	*Then, Invest if*	*Else, Invest if*
No policy	n.a.	$\pi + \hat{s}\mu > k$	$\pi + \hat{s}\mu > k$
Historical baseline	$\alpha < 1$	$\pi + \hat{s}\mu + t(\alpha-\rho)\mu > k$	$\pi + \hat{s}\mu + t(1-\rho)\mu > k$
Industry average	$\alpha\mu < \overline{\mu}$	$\pi + \hat{s}\mu + t(\alpha-\rho)\mu > k$	$\pi + \hat{s}\mu + t(\overline{\mu}-\rho\mu) > k$
Expected emissions	$\alpha\mu < E\{\tilde{\mu}\}$	$\pi + \hat{s}\mu + t(\alpha-\rho)\mu > k$	$\pi + \hat{s}\mu + t(E\{\tilde{\mu}\}-\rho\mu) > k$

where $E\{\tilde{\mu}\} = \mu(1-s(1-\rho)^2\mu)$ as before. Combining the participation decision and the baseline definitions gives the following participation cutoff levels of emissions:

Table 4: Cutoff Emissions Rates and Baseline Allocations

	$\underline{\mu}$
Historical baseline	1
Industry average	$\bar{\mu}/\alpha$
Expected emissions	$\text{Min}\left[\frac{1-\alpha}{s(1-\rho)^2},1\right]$

Note that with the historical baseline, firms will always participate, whether investing or not. With the industry average baseline, everyone will participate if the variable-cost adjustments always reduce emissions below the average (in this case, if $\alpha \leq \bar{\mu}$). For smaller reduction rates, then, those starting with lower emissions will be more likely to participate. With expected emissions, participation occurs when $(1-s(1-\rho)^2\mu)\mu \geq \alpha\mu$; full participation in this case holds if $1-\alpha > s(1-\rho)^2$. That is, the variable-cost method must reduce emissions sufficiently relative to the expected reductions from the investment alternative.

The option to join but not invest creates both positive and negative effects. On the positive side, cheaper reductions are made available and the investment decision is improved for imperfect baseline allocations. On the negative side, overallocation can increase substantially for firms with relatively low initial emissions under the industry average baseline rule.

An Extreme Example

For example, consider the extreme case in which the variable-cost method achieves negligible reductions, while the investment is perfectly clean. In other words, $\alpha = 1$ and $\rho = 0$. Furthermore consider the most generous definition of the industry average: $\bar{\mu} = 1/2$. Then the only firms to participate without investing would be those with emissions that are already below the industry average with that baseline rule. In the equilibrium solution, presented in Table 5, we see that the investment is lower by *t*/8 and actual emissions reduced are lower by *t*/48, compared to the industry average baseline with the investment prerequisite in Table 2. However, allocations are significantly increased, further decreasing net emissions reductions.

Table 5: Incentives with Average Emissions Baseline

$\alpha=1,\ \rho=0,\ \bar{\mu}=1/2$	*Investment*	*Allocated baseline*	*Emissions reduced*	*Net reductions*
No Prerequisite	$\frac{s}{2}+\frac{3t}{8}$	$\frac{1}{8}+\frac{11s}{48}+\frac{t}{6}$	$\frac{s}{3}+\frac{11t}{48}$	$\frac{5s}{48}+\frac{3t}{48}-\frac{1}{8}$
Investment Prerequisite	$\frac{s+t}{2}$	$\frac{s+t}{4}$	$\frac{s}{3}+\frac{t}{4}$	$\frac{s}{12}$

We can see this result more generally by subtracting the CERs from the actual reductions to get net reductions:

$$\int_0^{\underline{\mu}}\left(\mu-A(\mu)\right)d\mu+\int_{\underline{\mu}}^1\left(\hat{s}\mu+t(A(\mu)-\rho\mu)\right)(\mu-A(\mu))d\mu \qquad (9)$$

As with the investment precondition, net reductions are by definition zero with the historical emissions baseline (since $A(\mu)=\mu$) and positive with the expected emissions allocation (since $A(\mu)<\mu$). Substituting $A(\mu)=\bar{\mu}$ into the previous equation, we can rewrite the net reductions under the average emissions rule as

$$\int_0^1\left(\mu-\bar{\mu}\right)d\mu-\int_{\underline{\mu}}^1\left(1-\hat{s}\mu-t(\bar{\mu}-\rho\mu)\right)(\mu-\bar{\mu})d\mu \quad = \quad \frac{1}{2}-\bar{\mu}-\chi(\bar{\mu}) \qquad (10)$$

where $\chi(\bar{\mu})=\int_{\underline{\mu}}^1\left(1-\hat{s}\mu-t(\bar{\mu}-\rho\mu)\right)(\mu-\bar{\mu})d\mu$. Since $\underline{\mu}=\bar{\mu}/\alpha$, $\mu>\bar{\mu}$ for all $\mu>\underline{\mu}$, ensuring $\chi>0$. Thus, net reductions can only be achieved if the standard is sufficiently strict: $\bar{\mu}+\chi(\bar{\mu})<1/2$. (Furthermore, they are maximized when $-\chi(\bar{\mu})=1$.) Since the average of historical emissions is 1/2, this rule necessarily raises net emissions.

As further analytical solutions to the general problem are too complex to be useful, we next employ numerical simulations to explore the impact of different levels of α, ρ, and $\bar{\mu}$, with and without an investment requirement for participation.

Numerical Comparison

To illustrate the results, we apply the parameter values *s*=0.2 and *t*=0.8 to the solutions from the uniform distribution example, reflecting the idea that social benefits of reductions are likely to be large relative to the private benefits. For the average emissions baseline, we consider two standards: $\bar{\mu} = .5$, the average of initial (historical) emissions, and $\bar{\mu} = .2$, reflecting a stricter standard of the 20th percentile of initial emissions.

Complete Reductions from Investment

First, consider the case of an investment in a technology that completely eliminates emissions. The following figures depict on the one side the shares of investment and participation, and on the other side the actual, certified and excess emissions reductions that result under the different baseline rules. “Excess reductions” denote net reductions in excess of those that occur under no policy. Figures 1 and 3 present the case of an investment prerequisite, while Figures 2 and 4 assume there is an alternative method of abatement that is 10% effective and no investment is required to participate.

With the investment prerequisite, we see that the historical industry average baseline (i.e., $\bar{\mu} = .5$) encourages as much investment as the historical emissions baseline, but it is less effective at generating actual reductions. However, it does not overallocate as many CERs, ensuring a positive net reduction. The expected emissions policy generates less investment than either of the other baseline rules, and actual reductions that fall in between those of the historical and average baselines; however, since fewer CERs are given, net reductions are larger.

As expected, eliminating the investment requirement increases participation and reduces investment. Since the variable-cost reductions are relatively small, as fewer firms opt to invest, actual emissions reductions are smaller. However, all but the expected emissions baseline overallocate to a greater extent, lowering net reductions. In fact, the historical industry average baseline allocates so many CERs that net reductions are negative. For the expected emissions baseline, eliminating the prerequisite allows for more cost-effective reductions and more accurate allocation, resulting in an improvement in net reductions.

It is interesting to note that in only one case do total emissions fall compared with no policy: when investment is a prerequisite for participation and a sufficiently strict average emissions standard is used to determine the baseline. In this case, less abatement occurs, but even fewer reductions are certified. In all other regimes, allocations outweigh (or at least offset) actual reductions. As discussed earlier, the net cost of this expansion in terms of welfare depends on the difference between the marginal benefits and costs of abatement.

On the other hand, if participants, as opposed to the certifying authority, can choose the baseline methodology, overallocation will always occur. Above-average emitters will select the historical baseline, while below-average emitters will choose the industry average—and engage in too much investment if that is a prerequisite for participation. Using the same parameter values, 60% of firms invest (compared to 50% with the historical baseline) with the prerequisite; emissions reductions rise to 0.35, but CERs are inflated to 0.49, resulting in excess reductions of -0.21, or three times the increase in global emissions over the no policy regime compared to the historical baseline.

Investment Prerequisite

No Prerequisite and
10% Effective Abatement Alternative

Investment Prerequisite

Figure 1: Investment and Participation Rates

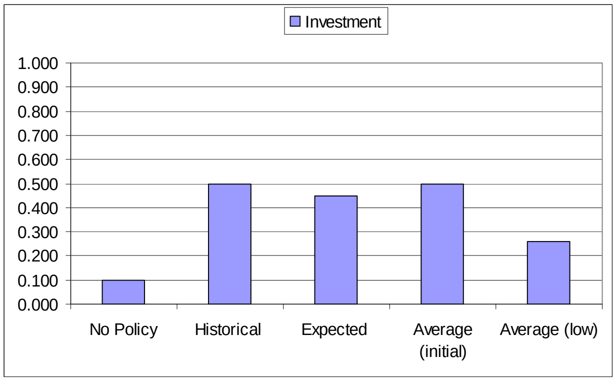
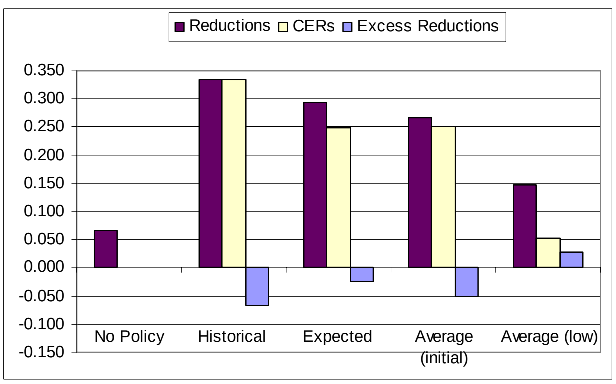


Figure 3: Emissions Reductions



No Prerequisite and
10% Effective Abatement Alternative

Figure 2: Investment and Participation Rates

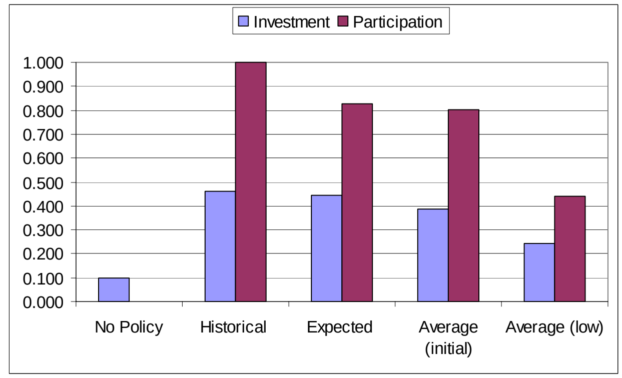
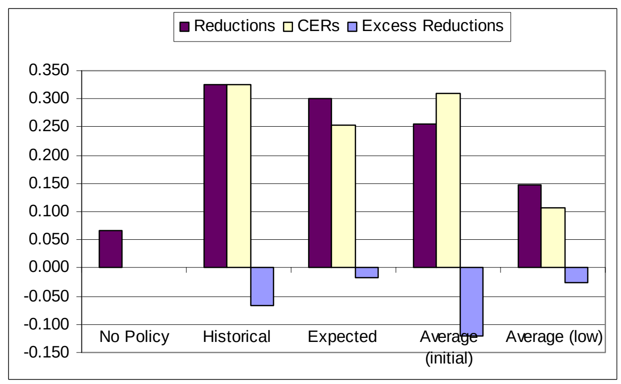


Figure 4: Emissions Reductions



***s* =.2, *t* =.8; α =.9, ρ =0.**

Figures 5 and 6 show that when the alternative method is sufficiently effective (that is, for a small enough α such that participation always occurs, except in the case of a strict average emissions rule), the investment and abatement decisions become identical across baseline rules. The only difference then lies in the allocation, for which the expected emissions rule performs the best. The strict average standard does not overallocate much, but neither does it encourage as much abatement.

No Investment Prerequisite and 50% Effective Abatement Alternative

Figure 5: Investment and Participation Rates

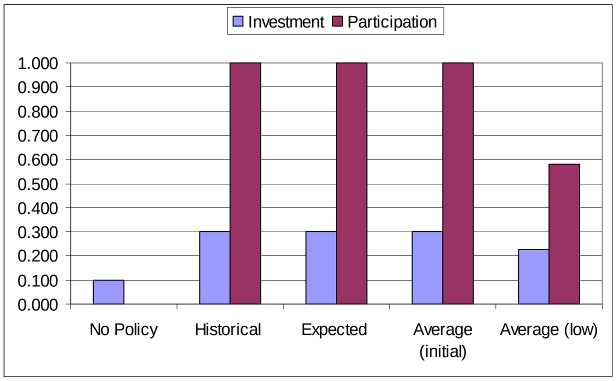
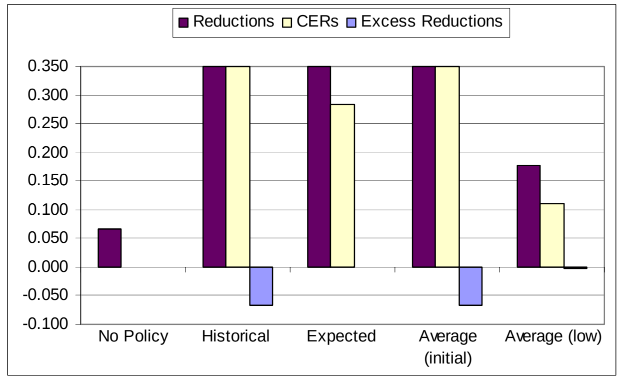


Figure 6: Emissions Reductions



***s* =.2, *t* .8; α =.9, ρ =0.**

Incomplete Reductions from Investment

Next, consider the case in which the investment reduces emissions only partially. To illustrate the impact of incomplete proportional reductions, Figures 7-10 assume 50% reductions in emissions (i.e., just enough such that no investors will retain above-average emissions).

As we know, the historical baseline, with its efficient investment incentives, always accomplishes the most actual reductions, while the industry historical average baseline without the investment prerequisite overallocates the most compared with actual reductions, the result being the highest total emissions. When reductions are large, the historical baseline certifies the most reductions, but when reductions are half of initial emissions, the industry average baseline allocates the most in absolute terms. The expected emissions baseline generates more reductions and fewer allocations than either of the averaging baselines. In the absence of an investment prerequisite, the expected emissions regime ensures full participation—and thereby efficient abatement incentives—and also allocates no more than is justified.

Investment Prerequisite and 50% Effectiveness

No Prerequisite and 10% Effective Abatement Alternative

Investment Prerequisite and 50% Effectiveness

No Prerequisite and 10% Effective Abatement Alternative

Figure 7 Investment Rates with Less Effective Technology and Prerequisite

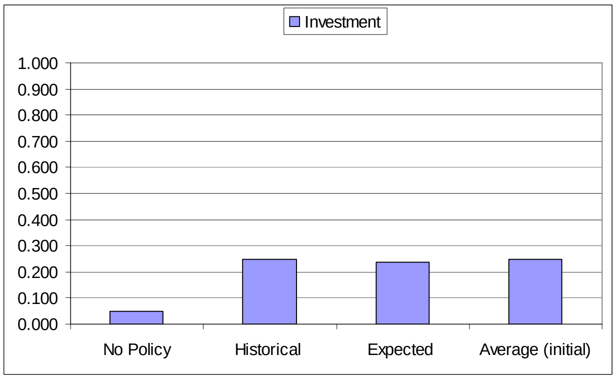


Figure 8 Investment and Participation Rates with Less Effective Technology

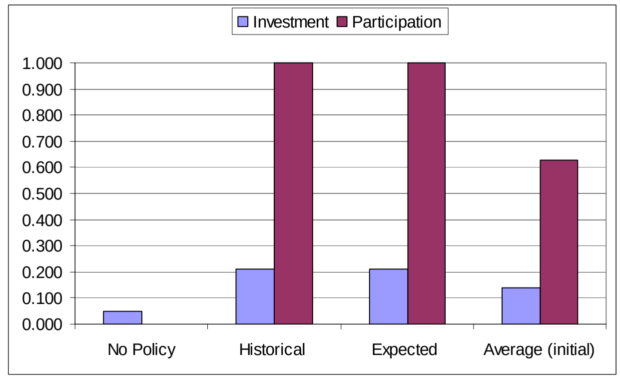


Figure 9 Emissions Reduction with Less Effective Technology and Prerequisite

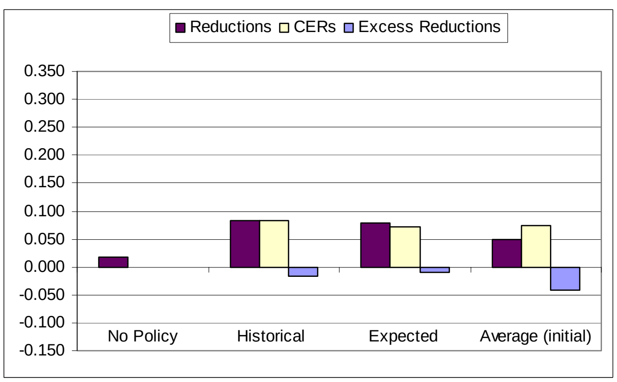
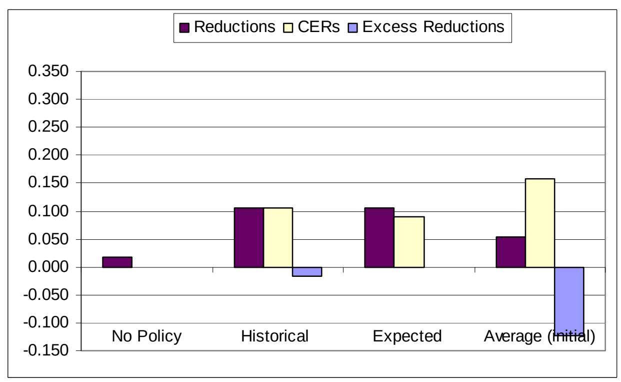


Figure 10 Emissions Reduction with Less Effective Technology and No Prerequisite



s =.2, t =.8; α =.9, ρ =.5.

Finally, although we have not explicitly incorporated transaction costs for CDM participation, including any monitoring or enforcement costs borne by the participants, the analysis offers intuition about their effects as well. Transaction costs essentially make the participation decision a second investment decision.[29] Some firms that would invest might not choose to participate if the value of the net CER allocation does not cover the transaction costs. Effectively, then, the costs of investing in the absence of CDM are smaller—and the reductions that would occur anyway are larger—relative to what occurs with the program. Second, in the absence of an investment prerequisite, the alternative abatement method would now involve a fixed cost, so fewer would choose that. However, for firms that would participate in any case, the investment decision remains as originally presented, since the transaction cost is incurred regardless. Thus, the essential differences among the baseline rules are characterized similarly with transaction costs as with investment costs alone.

Other Issues

Although we have focused on investment incentives, the design of baseline rules can affect other behavior as well. For example, if current emissions practices affect the future baseline, then an incentive would exist to increase emissions before joining a CDM project. This is why a historical emissions approach should be based on emissions that occurred prior to implementation of CDM, and why expected emissions need to be based on factors that cannot be manipulated. Second, even if the baseline amount is predetermined, if the annual allocation is conditional on continuing operations, it may not offer proper long-run incentives.[30]

Another important design choice is the option to implement a baseline method in rate-based, rather than lump sum, form. For example, instead of using a fixed baseline, permits might be allocated according to a firm's historical emissions rate multiplied by actual output (or perhaps use of some input), in order to incorporate trends in demand and production. Although this rule might in some ways make baselines more realistic and responsive to external conditions, it is important to recognize that the allocation then also functions as a production

[29] Mathmatically, this creates extra cutoff points in the distribution for participation, much like in the section without the investment prerequisite.

[30] See Baumol and Oates (1988), Chapter 14 for the problem of long-run inefficiency of grandfathered permits conditional on entry into and nonexit from the regulated industry.

(or input) subsidy. As a consequence, the firm has less incentive to reduce overall emissions through conservation.[31]

However, in certain circumstances, some of which may be quite valid for CDM situations, an output subsidy could enhance the gains from a project. For example, the developing country's plant owner may be a poorly regulated monopoly, underproviding its output (e.g., electricity) and overcharging customers. Making emissions costly (or reductions valuable) can then exacerbate this problem by driving up prices. An output subsidy can help bring prices and production more in line with what society would want, benefiting consumers in the developing country—or at least insulating them from increased prices due to the CDM project.[32] Another circumstance that may justify an output-based allocation is if the firm joining the CDM program faces competition from other nonparticipating domestic producers, whose emissions thereby remain unregulated. If these other firms are close competitors and have higher emissions rates, an output subsidy can help divert production back toward the now-regulated participating firm, further reducing overall emissions.[33] If, however, the participating firm were a manufacturing facility competing primarily with firms in Annex I countries, an output subsidy would generally not be warranted to prevent leakage (although it might offset other imperfections in developing countries' output markets).

Rate-based versions of these allocation methods have the same complications as their lump-sum counterparts in terms of investment and participation decisions. To the extent that it would be more accurate, those complications will be mitigated. However, to the extent that the rule is overly generous, the subsidy impact looms larger. Which effect dominates depends on the project characteristics and market environments in the candidate countries. Indeed, the strength of the particular subsidy will depend on both the price of CERs and the baseline rule. Historical emissions rates are project-specific, so firms with higher previous emissions will receive a

[31] See Fischer (2001).

[32] See Gersbach and Requate (2004) on optimal rebating under imperfect competition. Of course, in the developing country context, better regulation, management, and competition would likely do much more to help consumers.

[33] See Bernard et al. (2001).

stronger output subsidy. An industry average emissions rate offers a consistent output subsidy across firms in that industry, but it may offer less efficient investment incentives and less accurate allocations. A tradeoff thus arises between accuracy of allocation and appropriateness of the output support.

Conclusion

Selecting a reasonable method for determining baseline emissions is critical to the success of incorporating project-based emissions reductions strategies into any emissions trading program. In the international program for reducing greenhouse gases, the Clean Development Mechanism is a main focus for baseline rules, but the issue also applies to strategies for carbon sinks and potential offset projects in developed countries. The obstacles to accurate baseline determination include general uncertainty, asymmetric information between the certifying authority and participants, costly administrative and information-gathering activities, and insufficient policy tools to ensure revelation of true emissions. As a consequence, a policy balance must be struck between the accuracy of the abatement measures, which are needed to preserve the environmental integrity of the projects, and the efficient performance of the system, which is needed to assure cost-effective and productive investment strategies.

In response to these challenges, three main options for baseline rules have been advanced: 1) historical emissions, 2) expected emissions, and 3) a standard for average industry emissions. They represent different trade-offs between the root problems of inaccurate baseline accounting: inefficient participation and inefficient investment. For investments that would be profitable anyway, an allocation of credits induces unnecessary participation in the CDM and non-additional CERs, which expand the global emissions cap. For marginal firms, the value of the permit rents determines whether the investment costs are incurred. The welfare loss from inaccurate baseline assessment for these projects involves not only expansion—or contraction—of the global cap, but also the undertaking of inefficient investments from overallocation or the forgoing of worthwhile opportunities due to underallocation.

A rule using historical emissions as a baseline primarily risks overparticipation; however, the incentives for investment and abatement behavior are generally efficient. The exception would be when true baseline emissions would be changing (or deviating from the historical trend) in the absence of any investment. For a firm whose emissions would grow faster, the rule might underallocate and discourage participation; for a firm whose emissions would decline anyway without investment, an overallocation would induce participation that might not otherwise be worthwhile.

The industry average emissions rule tends to perform poorly from an incentives standpoint. It provides insufficient incentives for relatively high emitters to participate, since they are allocated only a fraction of their actual counterfactual emissions. A very dirty firm may have inexpensive options for reducing its emissions, but it must push its emissions below the average to receive a net transfer, and that transfer must then offset the full cost of all reductions to make participation worthwhile. Meanwhile, it over-rewards not only firms that would reduce their emissions in the future anyway, but also those that are already relatively low emitters, since they could do little in terms of reduction and still receive a net transfer for having below-average emissions. Requiring major investments as a prerequisite for participation would deter some below-average emitters from joining, but it would encourage others to undertake costly investments that are not justified, since the value of the allocation outweighs the environmental gains. Tightening the standard reduces the overallocation problem, but it also exacerbates the underallocation problem; the corresponding improvement in net reductions comes at the cost of less abatement activity.[34]

With an expected emissions rule, the third-party verifier would attempt to gather project-specific as well as industry-specific information and make an educated guess about the likely baseline emissions in the absence of policy. To the extent that expectations are inaccurate, marginal investment incentives will not be efficient. However, to the extent that expectations are more accurate than the other, cruder methods, the allocation of CERs will be more appropriate and result in less expansion of the global emissions cap. On the other hand, this rule is likely to be more expensive to implement because of the costs of information gathering. Also, this approach risks inviting strategic behavior that attempts to create “better” sets of expectations. Thus, this method would require that the certifying authority have access to necessary information at costs that do not outweigh the benefits of greater accuracy.

Clearly problematic would be to allow participants, as opposed to the certifying authority, to choose the baseline methodology. They would select the rule that affords them the largest baseline, ensuring overallocation and encouraging too much investment if that is a prerequisite for participation.

Designing eligibility requirements presents another opportunity for screening projects worthy of receiving any baseline allocation. One could require a major investment rather than minor improvements. For example, building a wind farm that clearly would otherwise be uneconomic could qualify, but not updating the boilers in a power plant. However, by including only “clearly uneconomic” projects, one risks excluding many projects that deserve to qualify and cost less (being less uneconomic). Participation requirements would better serve the goal of promoting cost-effective emissions reductions by focusing on eliminating the “clearly economic” projects.

Sustainable development benefits are intended as another requirement for eligibility in a CDM project. Such ancillary benefits can be important and represent another yardstick for participation in addition to emissions abatement. They can legitimately affect the public priorities for projects and can affect the welfare costs of erring in the baseline allocations.

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[34] It is interesting to compare this baseline rule to more familiar tradable performance standards (TPS) systems, since both allocate permits based on an average industry standard. The main differences are twofold. First, the CDM program is voluntary, which creates a selection bias for relatively clean firms to join the program. Second, permits can be traded outside the sector. With a traditional TPS, if clean firms selected into the program, the standard would be more easily achieved and the price of permits would fall. With CDM, the permit price is determined by international markets, so the average emissions rate is an allocation rather than a binding performance standard. See also Fischer (2003).

Understanding how requires knowing not only the size of the sustainable development benefits, but also how they might be correlated with the private economic and environmental benefits driving investment and policy choices.

It has been shown that allocation and participation rules alone cannot induce firms to truthfully reveal their baseline emissions. Although a third-party certification authority would not be able to set the transaction price, one could incorporate a quality parameter to CERs, which would function like a price differential. By allowing the certification authority to contract over two different project aspects—baseline emissions and abatement quality—one may restore power to design more efficient revelation mechanisms. This option will need to be the subject of future research.

Since participation in these emissions reduction projects is voluntary, any baseline rule is likely to err by allocating too much overall. The cost savings must then justify not only the costs of administrating the program but also the costs of expanding the cap. Those depend on the difference between prospective marginal damages from future climate change and marginal costs of abatement, and on the size of the misallocation. However, one could argue that the cost of having a bit more global emissions may be a lot lower than the cost of encumbering the nascent institutions for developing countries' participation with complex project approval criteria that reward rent seeking, distort markets, and so forth.[35] In this case, the focus should be on simplicity and good investment incentives, such as with a basic historical emissions rule. If additional, unbiased information can be obtained at low cost, it could be used to help eliminate clearly economic projects and improve the accuracy of expected baselines.

Indeed, the real benefits could come from the successful experience and development that lead non-Annex B parties to join in the emissions cap, thus eliminating the need for determining baselines for individual projects. Also deserving mention are the sustainable development benefits the countries get even before graduating into the cap. Although harder to quantify and not included in this calculation, these benefits offer a reason to lean toward a generous approach.

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[35] See Kopp et al. (2002).

In the meantime, however, further study is needed to evaluate which baseline rules are most appropriate in what situations. In particular, for the different types of projects, we need to better understand the correlation between abatement investments and other productivity enhancements, as well as the nature of uncertainties and information availability. Furthermore, we need to recognize the impact of market imperfections and institutional differences in developing countries and how they might affect participation, investment, and allocation.

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