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Determining Project-Based Emissions Baselines with Incomplete Information

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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. Evaluating reductions requires assigning a 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. 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 baseline determination 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, average industry emissions, and expected emissions.

Key Words: climate policy, Clean Development Mechanism, baseline emissions, asymmetric information

JEL Classification Numbers: D8, Q4

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Introduction

The flexibility mechanisms envisioned in the Kyoto Protocol include not only emissions trading among participating countries, but also project-based emissions reductions in countries not subject to an emissions cap. In particular, the Clean Development Mechanism (CDM) allows investment projects that reduce emissions in developing countries to count toward compliance goals in developed countries. Although such projects hold potential for significant gains in terms of development and lower-cost abatement opportunities, they also pose challenges for policy design. These challenges arise from certain inherent characteristics:

- CDM participation is voluntary.
- Many emissions-reducing projects provide other benefits beyond the value of emissions credits, so some of those investments might occur anyway.
- Evaluating project-based reductions requires assigning a baseline for the emissions that would occur in the absence of the project, which cannot be measured.
- Considerable uncertainty surrounds the determination of that counterfactual.
- 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.
- 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 baseline determination 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 stylized model to evaluate, in a situation of uncertainty and asymmetric information, the efficacy of the main baseline rules currently under consideration:[1]

1) historical emissions;
2) average emissions for the industry; and
3) expected emissions.

The next section presents background for CDM projects and the economic and uncertainty issues that are likely to accompany them. The following section develops a 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.

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), countries developing or funding projects through the mechanism would have to ensure that benefits also accrue to host countries (Art. 12(3)).

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

[1] UNFCCC (2001).

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.[2] Knowing what would have happened in the absence of the cap helps in estimating the 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.

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 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, means forgoing the benefits of a cost-effective greenhouse gas–reduction project and valuable local benefits.

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

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[2] 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).

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 is economic, not just environmental. 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 investing firm would act according to those expectations.

In many instances, however, the project participants may have better information than the certifying authority.[3] 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 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.

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[3] Project participants may be foreign direct investors, host country governments, or firms. We consider 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).

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. (Note that once a firm is participating, incentives are then in place to make changes in variable production factors to reduce emissions beyond those from the technological change.) The baseline allocation thus determines whether otherwise unprofitable projects are implemented.

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.[4]

Economic theory offers ideas for designing contracts to induce project proponents to reduce such distortion, or even to fully reveal what type they are.[5] 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

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[4] 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.

[5] 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).

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.[6] 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.[7] Three problems make these kinds of traditional models either 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.[8]

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

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[6] 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.

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

[8] 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.

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 actual emissions can be observed, emissions in the absence of the project cannot, and actual abatement may therefore be impossible to know.[9]

Allocation and the Investor

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. We now focus on the incentives of the investing party, which for simplicity we will 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. We analyze in particular the role of fixed costs in the decision to participate in a CDM project.

Model with Investment Prerequisite

The differences between the baseline rules can be illustrated with a simple example using an investment in a clean, nonemitting technology. The new production process brings two potential payoffs to the firm: 1) cost savings in proportion to initial emissions, reflecting reduced

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

use of energy inputs; and 2) an increase in general productivity, yielding additional profits. These profits vary from one investment project to another because of market conditions, managers' and workers' skills, or technical expertise. These terms will be represented with the following variables:

k	Investment cost (annualized)
π	Economic benefits
μ	Initial emissions
s	Savings per unit of emissions reduced
t	Market price of emission permits

We assume that the firm knows the value of all those variables with certainty, but the 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 not to be correlated with the firm-specific profit. The certifying authority can verify initial emissions. However, without knowing the profit variable, it cannot determine actual baseline emissions.

Since the investment reduces emissions to zero in this example, the baseline allocation equals the quantity of certified emissions reductions granted. These CERs can be sold at the market price of permits.

Policy Scenarios

We compare five scenarios:

No Policy

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

Optimal

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: $\pi + s\mu - k + t\mu > 0 > \pi + s\mu - k$.

Historical Emissions

With a baseline rule of allocating historical emissions μ, firm will invest if $\pi + s\mu - k + t\mu > 0$. The 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 allocation.

Average Emissions

An industry average baseline offers $\bar{\mu}$ credits to each project joining the program. 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 $\pi + s\mu - k + t\bar{\mu} > 0$. Thus, some of the firms with emissions that are sufficiently costly to the environment do not have enough incentive to invest: $t\mu > k - \pi - s\mu > t\bar{\mu}$. 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: $t\mu < k - \pi - s\mu < t\bar{\mu}$.

Expected Emissions

Under an expected emissions rule, the certifying authority assesses with the information available what emissions would be in the counterfactual. 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, $E\{\mu\} = (\Pr\{\pi > k - s\mu\})\mu$.

Table 1 summarizes the decision of the firm to invest and participate in a CDM project, according to different baseline allocation rules.

Table 1: Investment Decisions under Different Baseline Rules

	Invest if
No policy	$\pi + s\mu > k$
Historical baseline	$\pi + s\mu + t\mu > k$
Industry average baseline	$\pi + s\mu + t\overline{\mu} > k$
Expected emissions baseline	$\pi + s\mu + tE\{\mu\} > k$

Equilibrium with Uniform Distribution

To compare the effects of different baseline rules, we need to evaluate the equilibrium investment and emissions, given a continuum of projects with varying profiles of economic benefits and emissions reductions. Consider the following demonstration using independent, uniform distributions of emissions rates and profits, with $\mu \in [0,1]$, $\pi \in [0,1]$, $k = 1$ 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 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 $\pi \geq (1 - s\mu)$ will invest; with the uniform distribution, $s\mu$ is the share of firms meeting this threshold, or the odds that a particular project will pass the investment hurdle.

In a more general formulation, let $A(\mu)$ be the firm's CER allocation under a given baseline rule, which may be a function of the initial emissions rate. A firm will invest if $\pi \geq (1 - s\mu - tA(\mu))$ when CDM participation is conditional on investment. Thus, with the uniform distribution, total investment equals

$$\int_0^1 \left(s\mu + tA(\mu)\right) d\mu \,.$$

The total net allocation for the industry equals

$$\int_0^1 \left(s\mu + tA(\mu)\right) A(\mu) d\mu \ ,$$

and actual emissions reduced equal

$$\int_0^1 \left(s\mu + tA(\mu)\right) \mu d\mu \ .$$

We assume the baseline rules are translated into allocations in the following ways:

	$A(\mu)$:
No policy	0
Historical baseline	μ
Industry average	$\bar{\mu} = 1/2$
Expected emissions	$(1 - s\mu)\mu$

Table 2 presents the results for investment costs, allocations, and emissions under the different scenarios. Net emissions reflect the impact on global emissions compared with the initial state with no investment. The difference results from both the direct reduction in emissions and the increase in emissions by the recipients of the certified reductions (which equal the allocated baseline in this complete abatement example).

Table 2: Effects of Baseline Rules with Uniformly Distributed Emissions and Profits

	Investment	*Allocated baseline*	*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	$\frac{s+t}{2}$	$\frac{s+t}{4}$	$\frac{s}{3} + \frac{t}{4}$	$\frac{s}{12}$
Expected emissions	$\frac{s+t}{2} - \frac{st}{3}$	$\frac{s+t}{3} - \frac{st}{2} - \frac{s^2}{4} + \frac{s^2 t}{5}$	$\frac{s+t}{3} - \frac{st}{4}$	$\frac{s(s+t)}{4} - \frac{s^2 t}{5}$

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.

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

The industry average emissions baseline has several effects. First, the rule produces investment equal to the historical baseline, but the distribution is different.[10] High-emitting firms have less additional incentive to reduce emissions, while lower-emitting firms have more incentive to invest.[11] Second, since the investment decision is less sensitive to initial emissions, actual abatement is lower, despite equivalent levels of investment. Third, 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. Without that precondition, we will see in the next section that emissions are higher and generally higher than with the historical baseline.

The expected emissions rule still overrewards some firms and underrewards 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. Also interesting to note is that this is the only rule for which net reductions are sensitive to the permit price; in all other cases, the extra incentive for abatement is fully offset by extra allocations.

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

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[10] Identical investment results from the definition of the industry average has the average of historical emissions. A stricter definition would reduce investment.

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

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.

We assume that the alternative method for reducing emissions has a variable cost equal to the corresponding energy savings.[12] We also assume that, while investment eliminates emissions, this option only partially reduces emissions by $(1-\alpha)$.

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, the investment decision remains identical to that in the previous section: $\pi + s\mu - k + tA(\mu) > 0$. 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 $\pi + s\mu - k + t\alpha\mu > 0$. 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.

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

[12] For initial units of reduction, this assumption should be quite accurate. If marginal costs of abatement are increasing, it does not reflect the full costs of the reductions. However, it is a useful simplifying assumption.

Table 3: Investment Decisions without Investment Prerequisite

	Participate if	*Then, Invest if*	*Else, Invest if*
No policy	n.a.	$\pi + s\mu > k$	$\pi + s\mu > k$
Historical baseline	$\alpha < 1$	$\pi + s\mu + t\alpha\mu > k$	$\pi + s\mu + t\mu > k$
Industry average baseline	$\alpha\mu < \bar{\mu}$	$\pi + s\mu + t\alpha\mu > k$	$\pi + s\mu + t\bar{\mu} > k$
Expected emissions baseline	$\alpha\mu < E\{\mu\}$	$\pi + s\mu + t\alpha\mu > k$	$\pi + s\mu + tE\{\mu\} > k$

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 uniform distribution, total investment equals

$$\int_0^{\underline{\mu}} \left(s\mu + t\alpha\mu \right) d\mu + \int_{\underline{\mu}}^1 \left(s\mu + tA(\mu) \right) d\mu .$$

The total net allocation for the industry equals

$$\int_0^{\underline{\mu}} \left(A(\mu) - (1 - s\mu - t\alpha\mu)\alpha\mu \right) d\mu + \int_{\underline{\mu}}^1 \left(s\mu + tA(\mu) \right) A(\mu) d\mu ,$$

while actual emissions reduced equal

$$\int_0^{\underline{\mu}} \left(\mu - (1 - s\mu - t\alpha\mu)\alpha\mu \right) d\mu + \int_{\underline{\mu}}^1 \left(s\mu + tA(\mu) \right) \mu d\mu .$$

The baseline rules give the following emissions participation cutoffs and allocations:[13]

	$\underline{\mu}$	$A(\mu)$:
No policy		0

[13] For simplicity, we continue to assume that industry average emissions are calculated from no-action behavior (historical averages). If averages are updated to reflect participation and energy-saving investments, the allocations will be less generous.

Historical baseline	1	μ
Industry average	$\bar{\mu}/\alpha$	$\bar{\mu}=1/2$
Expected emissions	$Min[(1-\alpha)/s,1]$	$(1-s\mu)\mu$

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 $\alpha \le 1/2$). For smaller reduction rates, then, those starting with lower emissions will be more likely to participate. With expected emissions, participation occurs when $(1-s\mu)\mu \ge \alpha\mu$; full participation in this case holds if $1-\alpha > s$.

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.

For example, consider the extreme case where $\alpha = 1$. 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, compared to the industry average baseline with the investment prerequisite in Table 2, we see that the investment is lower by *t*/8 and actual emissions reduced are lower by *t*/48. However, allocations are significantly increased, further decreasing net emissions reductions.

$\alpha = 1$	*Investment*	*Allocated baseline*	*Emissions reduced*	*Net reductions*
Industry average baseline	$\frac{s}{2}+\frac{3t}{8}$	$\frac{1}{8}+\frac{11s}{48}+\frac{t}{6}$	$\frac{s}{3}+\frac{11t}{48}$	$\frac{5s}{48}+\frac{3t}{48}-\frac{1}{8}$

The numerical section explores the impact of different levels of α.

Partial Emissions Reduction

To examine the effect of the assumption of a zero-emissions technology, we now consider an investment that does not eliminate emissions but reduces them by fraction $(1-\rho)$. The allocation of CERs then equals the baseline allocation net of remaining emissions liabilities.

The investment decisions will look largely the same as before for the no-policy case and the historical emissions baseline. However, some complications arise in cases where the baseline does not reflect initial emissions. When reductions were complete, postinvestment emissions were necessarily less than allocated baseline emissions. With incomplete emissions reductions, a positive net allocation of CERs is not assured for all baseline rules. Therefore, one must consider the option to invest but not join the CDM program.

We assume that the reductions from the investment are made instead of, rather than in addition to, those available from variable-cost efforts.[14] For investment to ever be worthwhile, it must result in fewer emissions than with alternative means; thus, we assume $\rho < \alpha$. It follows that if a firm would join the program when not investing, it would want to join the program after investing. The investment decision is then $\pi + s(1-\rho)\mu - k + t(\alpha - \rho)\mu > 0$.

If the firm would not participate absent an investment, two questions remain. First, would the emissions remaining after investment be lower than the baseline allocation and justify participation after investment? Second, is investment justified? If postinvestment participation is guaranteed, then the investment decision includes the rents from the net allocation: $\pi + s(1-\rho)\mu - k + t(A(\mu) - \rho\mu) > 0$.

However, if $\rho\mu > A(\mu)$, participation is not worthwhile, but the firm may still choose to invest, doing so according to the incentives under no policy: $\pi + s(1-\rho)\mu - k > 0$. To the extent that such investment occurs without participation, the program avoids overallocating permits. On the other hand, inaccuracies in baseline allocation can also distort marginal investment incentives.

In the cases described here, investment without participation would only occur under the industry average baseline scenario. Historical emissions baselines always ensure a positive net

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[14] 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.

allocation. Since 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), the participation condition always holds in our example. However, we note that if expectations are formed by other means, like industry averages, participation will not necessarily follow investment.

Table 4 summarizes the investment decisions under different baseline rules, conditional on emissions characteristics.

Table 4: Investment Decisions with Partial Reductions

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

Returning to the uniform distribution example, under conditions such that postinvestment emissions are sufficiently reduced (i.e., they always fall below the industry average), all the baseline scenarios basically resemble their counterparts in the complete abatement example. The energy and tax savings are diluted by the incomplete nature of the reductions.

An important different arises in the case of the industry average baseline, where the participation requirement is $\rho\mu < 1/2$. For any $\rho \leq 1/2$, investing firms will always participate. However, for lower reduction rates, some high emitters may want to invest but not join the program. The total investment of initially above-average emitters becomes

$$\int_{1/2}^{1} \left(s(1-\rho)\mu + t\text{Max}[1/2-\rho\mu,0] \right) d\mu \, .$$

Numerical Comparison

To compare the effects of different baseline rules in these different situations, we present a numerical example. Solving for the uniform distribution example, we apply the parameter values s=0.2 and t=0.8 to illustrate the results.

Complete Reductions from Investment

The Table 5 assumes no opportunities for variable cost reductions (α=1), which is equivalent to an investment prerequisite. Table 6 assumes a 10% reduction in emissions can be achieved without investment.

As expected, eliminating the investment requirement increases participation and reduces investment. Since the variable-cost reductions are relatively small, actual emissions reduced decrease with fewer firms opting to invest. The important changes occur with the latter two baseline rules.

Table 5: s=.2 and t=.8; α=1

	Investment	*CERs (% of actual)*	*Emissions Reduced (% from No Policy)*	*Net Reductions*
No Policy	.1	0	.067	.067
Historic Baseline	.5	.333 (125%)	.333 (80%)	0
Industry Average	.5	.250 (136%)	.267 (62%)	.017
Expected Emissions	.447	.250 (110%)	.293 (68%)	.044

Table 6: s=.2 and t=.8; α=.9

	Investment (Participation Rate)	*CERs (% of actual)*	*Emissions Reduced (% from No Policy)*	*Net Reductions*
No Policy	.05	0	.067	.067
Historic Baseline	.460 (1)	.326 (126%)	.326 (75%)	0
Industry Average	.389 (.80)	.310 (163%)	.256 (59%)	-.053
Expected Emissions	.443 (.83)	.252 (108%)	.301 (70%)	.049

With the investment prerequisite, the industry average baseline encourages as much investment as the historic baseline, but it is less effective at generating actual reductions. However, it does not overallocate as many CERs, ensuring a positive net reduction. When the prerequisite is eliminated, similar actual reductions are achieved with less investment costs, but the industry average baseline allocates so many CERs that net reductions are negative.

With the investment prerequisite, 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. Eliminating the prerequisite then allows more cost-effective reductions and more accurate allocation, resulting in an improvement in net reductions.

Table 7 shows that for a small enough α such that participation always occurs, 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.

Table 7: s=.2 and t=.8; α=.5

	Invest	*CERs (% of actual)*	*Emissions Reduced (% from No Policy)*	*Net Reductions*
No Policy	.05	0	.067	.067
Historic Baseline	.3	.35	.35 (81%)	0
Industry Average	.3	.35	.35 (81%)	0
Expected Emissions	.3	.283	.35 (81%)	.067

Incomplete Reductions from Investment

To illustrate the impact of incomplete proportional reductions, Table 8 assumes 50% reductions in emissions (ρ=0.5; just enough such that no investors will retain above-average emissions).

Table 8: s=.2 and t=.8; ρ=.5; α=1

	Investment	*CERs (% of actual)*	*Emissions Reduced (% from No Policy)*	*Net Reductions*
No Policy	.05	0	.017	.017
Historic Baseline	.25	.083 (125%)	.083 (17%)	0
Industry Average	.25	.075 (209%)	.033 (7%)	–.041
Expected Emissions	.207	.060 (105%)	.073 (15%)	.011

Table 9: s=.2 and t=.8; ρ=.5; α=.9

	Investment (Participation Rate)	*CERs (% of actual)*	*Emissions Reduced (% from No Policy)*	*Net Reductions*
No Policy	.05	0	.017	.017
Historic Baseline	.21 (1)	.106 (119%)	.106 (22%)	0
Industry Average	.139 (.63)	.158 (437%)	.053 (11%)	–.105
Expected Emissions	.193 (.66)	.068 (102%)	.083 (17%)	.017

The historical baseline, with its efficient investment incentives, always accomplishes the most actual reductions. When reductions are large, the historical baseline also allocates the most, in absolute terms. However, the industry average baseline without the investment prerequisite always overallocates the most compared with actual reductions, the result being the highest total emissions. When reductions are half of initial emissions, it also allocates the most in absolute terms.

The industry average baseline with the investment prerequisite encourages as much investment as the historical baseline but has a lesser effect on emissions reductions. The expected emissions baseline generates more reductions and fewer allocations than either of the averaging baselines, and although the reductions are lower than with the historical baseline, the allocations are significantly smaller.

It is interesting to note that in no case do total emissions fall compared with no policy; allocations always 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.

Discussion

We have focused on investment decisions to understand how baseline rules might affect decisions to incur significant fixed costs. However, other aspects are important for evaluating the likely effects of different baseline rules on efficiency and welfare. For example, managing participation and certifying reductions may involve significant administrative or transaction costs. Also, the distinction between lump-sum and rate-based allocation schemes merits attention. Production is a behavior that affects total emissions. For rules that determine the baseline as an emissions rate multiplied by actual output, the participating firm can increase its allocation of emissions credits by increasing production. As a result, rate-based baseline rules also subsidize production, which can have important implications for emissions.

This section offers both a summary and a broader comparison of the baseline allocation rules, enriched by a discussion of not only the investment incentives but also the behavioral effects and welfare consequences that are less readily quantified.

Evaluation of Proposed Baseline Rules

Absolute Historical Emissions

A rule using historical emissions as a baseline would function like a lump-sum (versus behavior-dependent) allocation of emissions permits.[15] Since such an allocation is fixed, then conditional on project participation, the incentives for abatement behavior are efficient, meaning reductions will be made as long as the additional costs do not outweigh the price of permits. A fixed allocation also ensures that the behavior of the inframarginal firms is unaffected; that is, firms that would definitely (or definitely not) go ahead with the project will not change their decisions based on small changes in the baseline allocation. However, for projects closer to the borderline, the exact allocation will matter.

Since the allocation is conditional on participating, it may not offer accurate incentives if historical emissions under- or overestimate counterfactual emissions, particularly if investments are lumpy.[16] For a firm whose emissions would grow (or grow faster than a trend), an

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[15] If baselines reflected future behavior and 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. This of course leaves open the question of how CDM baselines are defined for new projects; some options for doing this are discussed below.

[16] 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.

underallocation would mean the permit rents might not cover the fixed costs of a worthwhile investment. For a firm whose emissions would decline anyway, an overallocation would induce participation that might not otherwise be worthwhile, given monitoring or fixed abatement costs. However, to the extent actual baseline emissions would decline because of investments that are profitable regardless of participation, overparticipation does not necessarily imply overinvestment.

For participating firms, the primary loss in terms of global welfare arises not from distorting incentives to individual firms but from expanding the global emissions cap by allocating too much to firms that would have made the investments anyway for purely economic reasons. The magnitude of this loss depends once again on the difference between prospective marginal damages from future climate change and marginal costs of abatement, and on the size of the overallocation to the inframarginal firms. Unnecessary monitoring costs may also be a problem. For marginal firms, the welfare loss from inaccurate baseline assessment is not only expansion (or contraction) of the global cap, but also inefficient investment or forgone opportunities.

Industry Average Emissions

Industry average emissions rates are a familiar permit allocation method in tradable performance standards (TPS) systems. However, a rule using the average sectoral emissions rate as a baseline for CDM projects creates an unusual type of TPS. First, permits can be traded outside the sector. This means that the average emissions rate is an allocation rather than a binding performance standard for CDM participants, and the permit price will be determined by international markets rather than adjusted according to the scope of participation within the sector. Second, the program is voluntary.

The second point means that the option to join the program or not, combined with this form of allocation, creates a selection bias. A relatively clean firm can join the program, do little in terms of reduction, and still receive a net transfer for having below-average emissions. On the other hand, a very dirty firm may have inexpensive options for reducing its emissions but 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.

Thus, this method tends to provide insufficient incentives for high emitters, since they are allocated only a fraction of their actual counterfactual emissions. Meanwhile, it overrewards not only firms that would reduce their emissions in the future anyway, but also those that are already relatively low emitters. One method to prevent firms from joining without making significant efforts to reduce emissions is to require major investments as a prerequisite for participation. Although this requirement would deter some below-average emitters from joining, it would encourage others to undertake costly investments that are not justified, since the value of the allocation outweighs the environmental gains.

Emissions Rate Baselines

In practice, both the historical and average emissions baselines might not be allocated in lump sum, but rather in rate-based form. For example, instead of using a fixed baseline, permits might be allocated according to a firm's historical emissions rate times 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 the impact on incentives. Allocating the baseline based on a current behavior (like actual output) generates a subsidy for that behavior. As a consequence of the production subsidy, the firm has an incentive not to reduce overall emissions through conservation, but rather to focus on emissions rate reduction.[17]

Such a method has the same complications as the previous ones 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.

[17] See Fischer (2001).

In the absence of other market imperfections, an output subsidy would create efficiency losses. 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. An output subsidy can help bring prices and production more in line with what society would want. The firm joining the CDM program may face 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 (see Bernard et al. 2001). If, however, the participating firm is a manufacturing facility competing primarily with firms in Annex B countries, an output subsidy would generally not be warranted to prevent leakage (although it might offset other imperfections in developing countries' output markets).

Thus, the desirability of output-based allocations in a CDM program requires a more comprehensive understanding of market environments in the candidate countries. Unfortunately, the appropriateness of output allocations is likely to vary depending on individual project circumstances. Having different allocation rules for different participating industries and countries based on fine-grained details of market structure and performance is unlikely to be possible.

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 stronger output subsidy. An industry average emissions rate offers a consistent output subsidy across firms in that industry, but not between sectors. A tradeoff thus arises between accuracy of allocation and appropriateness of the output support.

Expected Emissions

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. As with the industry average rules, 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.

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.

Participation Requirements

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. Still, such rules are likely to suffer from the same problems of asymmetric information as the baseline rules.

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. 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.

Conclusion

Selecting a reasonable method for determining baseline emissions is critical to the success of incorporating project-based emissions reductions strategies into an 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 projects in developed countries.

The challenges for 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. The potential benefits are the availability of less expensive abatement opportunities. The risks are certifying too many emissions reductions and expanding the emissions cap for countries adhering to the Kyoto Protocol.

The most likely baseline rules are based on 1) historical emissions, 2) average industry emissions, with or without an investment requirement, and 3) expected emissions. Historical emissions, assuming they do not underestimate actual emissions trends, generally provide good investment incentives, but they may substantially overallocate and constitute a windfall to firms that would find such investments profitable even in the absence of a CDM policy. Industry averaging policies would overallocate to some firms and underallocate to others, resulting in poorer investment incentives, less cost-effective abatement, and allocation of too many certified emissions reductions. The latter two problems are exacerbated when firms can participate in the program without making any required investments.

Gathering project-specific information to make a reasonable estimate of future baseline emissions strikes a balance between the historical and the averaging methods. Increased accuracy would reduce the inefficiencies in investment incentives compared with averaging and reduce 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.

It has been shown that allocation 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.

All of the rules at hand could, in theory, be implemented in lump-sum or rate-based form. Lump-sum allocation, in a situation where participating firms are competing closely with nonparticipating firms, could raise marginal production costs and divert some output to higher-emitting firms. Rate-based allocation, on the other hand, could provide inefficient subsidies that outweigh the leakage potential and risk exacerbating the effects of inaccuracies in the baseline rule. For longer time horizons, rate-based allocation might more easily accommodate changing market conditions over time.

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. These latter costs, judged in welfare terms, depend on the marginal damages of climate change and how they compare with the price of emissions permits. 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.[18]

Indeed, the real benefits could come from the successful experience and development that lead non-Annex I 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. 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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[18] See Kopp et al. (2002).

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