The Clean Development Mechanism and its Controversies*

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Abstract

The Clean Development Mechanism (CDM) has been proposed as a means of reducing the costs of abating greenhouse gasses, and for assisting developing countries. Although the CDM offers apparent environmental benefits, in addition to benefiting both investors and developing country hosts, it has generated considerable controversy. We review and evaluate the arguments surrounding the CDM and we provide new empirical evidence concerning its potential benefits.

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INTRODUCTION

It is important that developing countries participate in efforts to limit greenhouse gas (GHG) emissions. Developing countries contribute a substantial and growing share of total emissions. In addition, their participation in plans to control the global stock may be essential in overcoming the resistance within developed countries to implementing the Kyoto Protocol. There is no ethical basis and little political will for coercing developing countries into agreeing to a limit. There is little prospect that they will voluntarily limit emissions without compensation. Such a limit may not be in their self-interest, even if they were able to overcome the problems of free-riding. The Clean Development Mechanism (CDM) has been proposed as a method for obtaining the cooperation of developing countries in controlling GHG emissions. This proposal has been controversial and its efficacy is uncertain. We have two objectives in this paper: to attempt to shed light on the controversy, and to provide empirical evidence of the potential benefits of the CDM.

The growth rate of GHGs emissions in developing countries is increasing, and their aggregate emissions are projected to exceed those of developed countries within a few decades (although developing countries' per capita emissions will still be lower). Even if developed countries manage to control their emissions, global stabilization of GHG concentrations requires reductions in developing countries.

The CDM reallocates reductions from developed to developing countries and therefore does not directly lead to the additional aggregate reductions that are needed for stabilization. However, by participating in the CDM, developing countries may help to defuse political opposition within the developed countries to the Kyoto Agreement. Thus, the CDM might be part of the solution to the problem of excessive emissions,

although it is certainly not the entire solution.

Developing countries were not willing to commit to making reductions under the Kyoto Protocol. Developed countries were not willing to impose sanctions, such as trade or credit restrictions, to induce participation. Since developed countries are responsible for two thirds of current emissions and for three-quarters of historical GHGs emissions, they are largely responsible for the current anthropogenic stock.[11] On ethical grounds it is therefore hard to argue that developing countries should bear the cost of limiting GHGs stocks.

Developing countries may be the greatest victims of global warming, because of geography and because of their limited ability to adapt to a changing climate.[3] Nevertheless, on the grounds of rational self-interest, it is debatable whether they should be willing to incur costs to control the stock of GHGs. The relation between GHGs stocks and global warming, and the resulting damages from global warming, are uncertain and lie in the future. In the meantime, developing countries have urgent needs involving food supplies, health and education, and local environmental problems. Their reluctance to divert resources from these needs in order to target a global environmental problem is understandable.

The Clean Development Mechanism (CDM) was proposed as a means of efficiently reducing GHGs. The rationale for the CDM is the assumption that it is cheaper to reduce emissions in developing countries. Under the CDM, industrialized countries (or firms in those countries) which pay for abatement in developing countries would receive credits. These credits would be used to offset the developed country's agreed reductions. If it functioned properly, the CDM would be similar to a market for tradeable permits, since abatement would tend to occur where it is cheapest. The opportunity to abate cheaply in a developing country rather than expensively at home would be valuable to the developed country – the value is the difference in the abatement costs. Provided that the developing countries are able to capture some

of this surplus, they would be better off than under the status quo. In this sense, the CDM is similar to a market for tradeable permits in which the initial allocation treats the developing countries generously.

Although the assumption that abatement is cheaper in developing countries is plausible, and the CDM has characteristics that offer potential benefits to all parties, the idea has attracted considerable controversy. In the next section we describe the CDM and identify the protagonists in the debate. The following section considers several of the arguments against the CDM. Next we present econometric evidence regarding the assumption that abatement is cheaper in developing countries.

FUNDAMENTALS OF THE CLEAN DEVELOPMENT MECHANISM

We begin with a clarification of terminology, and then discuss the relation between the CDM and a market for permits. We then identify the chief actors in the debate.

Joint Implementation and the CDM

The 1992 UN Framework Convention on Climate Change considered the use of Joint Implementation (JI), a general term which describes cooperative agreements for reducing emissions. In such an agreement, a developed country receives credits for "jointly implementing" an abatement project in a host country. The Europeans proposed JI as a system for allowing emissions trading within Annex I countries. The US wanted to allow Annex I countries to receive credits for financing reductions in developing countries. The US position was controversial because the Framework Convention on Climate Change had called for North-to-South technology transfers in addition to – not as a substitute for – reductions in North's emissions. In much of the literature, JI has been used to refer to the mechanism for promoting cooperation between developed countries and developing country hosts. For example, the UNEP

glossary defines JI as "a controversial concept whereby a developed country would receive some type of credit for emissions reductions it helps to finance in a developing country."[9]

As a means of finessing the disagreement between the US and European positions, and in recognition of the asymmetry between developed and developing countries, the Kyoto Protocol distinguished cooperative agreements between developed countries and agreements in which the host is a developing country. The former type of agreement was denoted "Joint Implementation", and the latter "Clean Development Mechanism". We follow this usage, and we focus on the CDM. Most of the earlier literature does not recognize the distinction, and refers only to JI. Some of the issues surrounding the two types of proposals are the same. However, the asymmetry between developed and developing countries leads to important differences.

The CDM and a Tradeable Permits Market

The CDM, like a tradeable permits market, promotes efficiency by directing abatement to the time and place where it is cheaper. Both the CDM and tradeable permits offer developing countries the possibility of capturing some of the surplus created by the savings in abatement costs.

There is, however, an important distinction between the CDM and a market in permits. A permit to emit a given quantity of pollution over a given time period is clearly defined, whereas the CDM could take many forms. This adaptability is one of its most important characteristics. Buying and selling a permit is a straightfoward transaction, but entering into an agreement under the CDM requires negotiating a contract. The developed country and the host need to agree on the terms, including the details of the technology and the financing, and the responsibilities of the host. The most significant transactions costs arise from the need for a third party to decide what it is that the developed country is buying, i.e. the abatement credits it obtains.

The transactions costs appear to be higher under the CDM than in a market for tradeable permits. Nevertheless, the CDM has some practical advantages over a market for tradeable permits.

In order for developing countries to participate in a market for tradeable permits, they must either have permits to sell or an incentive to buy them. Both of these conditions require that the country has agreed to an allocation of permits (a ceiling on emissions). However, the developing countries do not feel obliged to incur costs to reduce GHGs stocks, and are unwilling to agree to an allocation that might lead to such costs. Since the Kyoto Agreement did not constrain the developing countries in any manner, there apparently existed the potential for a mutually advantageous deal between the developed and developing countries. In this deal the developing countries would receive a generous allocation and be entitled to sell permits. Both developed and developing countries would benefit from reduced global emissions, and the developing countries would benefit from permit sales.

Even in the absence of uncertainty it would have been very difficult to strike this kind of deal. The developed countries are reluctant to make the large transfers to developing countries that would have been implicit in this arrangement. Given the uncertainty about future emissions and abatement costs, and thus the uncertainty about what constitutes a generous allocation, there was no chance for such a deal.

The CDM is a compromise that achieves some of the benefits of a market for tradeable permits, without requiring an assignment of property rights to a commodity whose value is highly uncertain. The CDM commits agents to nothing, and therefore involves no *politically visible* risk. (It does, of course, involve the environmental risk associated with doing nothing.) The CDM is merely an agreement to allow certain types of contracts in the future, not a division of property rights. It leaves open the possibility that some of the gains from trade can be realized.

Some of the transactions costs that arise under a CDM would also occur under

tradeable permits. A CDM agreement requires monitoring at the level directly related to the investment project, whereas tradeable permits require monitoring a country's aggregate emissions. This aggregate monitoring, verification of the results, and enforcement of ceilings may be especially difficult in developing countries. It may be difficult to measure aggregate emissions, or to determine whether a target has been exceeded because of reasons beyond the control of the governing authorities. These reasons might include acts of nature such as forest fires, or an undeveloped regulatory structure. Similarly, enforcement may be difficult because of the problem of making credible commitments to impose sanctions against an entire nation – especially a poor one.

Monitoring and enforcement of the CDM presents its own set of problems, but these may be more tractable because of their greater specificity. The target of a CDM is likely to be easier to define and to measure (compared to an economy-wide target). In many cases it may be possible to determine whether the failure to reach the target is due to actions under the control of the signatories. The punishment of non-compliance (e.g. withholding future credits) is more credible, because it is possible to focus the punishment on a narrow group of responsible individuals.

Superficially, GHGs pollution permits appear to be a homogenous commodity, but trade in permits between developed and developing countries is unlike trade in grain, or even trade in SO_2 permits within the United States. It would be difficult to use the judicial system and public pressure to enforce a commitment to reduce emissions within developing countries. Although an actual reduction in GHGs emissions anywhere in the world provides approximately the same environmental benefits, the environmental value of a *promise* to reduce emissions may differ widely. Under the CDM it is easier, relative to a market in permits, to take into account these factors.

Finally, many groups – particularly environmentalists – are skeptical of the benefits of markets in general, and markets for pollution permits in particular. The

CDM requires negotiation between the investor and the host and verification by a third party. In these respects it resembles a political process more than a market transaction. It therefore may face less opposition from environmentalists and other NGOs than would a market in tradeable permits.

The protagonists

The members of different groups have overlapping interests. Environmentalists' ability to lobby for the environment depends to a great extent on their (relative) wealth. Most environmentalists also care about poverty in developing countries. Average citizens – producers and consumers – in developed countries are becoming increasingly aware of global environmental risks, but are reluctant to decrease their consumption of material goods. Many people in developing countries also care about global environmental problems, although these do not lead their list of priorities. Despite their overlapping interests, it is useful to identify distinct protagonists as an aid in sorting through the arguments about the CDM.

Environmentalists want to reduce the stock of GHGs. Their concerns for equity or economic efficiency are secondary to protecting the environment.

Investors from the developed countries want to achieve exogenous abatement targets as cheaply as possible. In a competitive economy, lower costs of abatement benefit consumers by lowering commodity prices, and benefit (most) owners of factors of production (workers, capital owners) by increasing factor prices. To the extent that these benefits are widely shared – i.e. to the extent that markets are competitive and factor ownership is widely dispersed – the self-interest of investors is aligned with that of consumers and producers in the developed countries. In addition to the immediate pecuniary benefits, investors may also be interested in promoting exports, expanding investment opportunities in developing countries, improving goodwill, and increasing standing in international negotiations.[10]

Host governments want to capture surplus from a CDM transaction. In some cases this surplus may be a monetary transfer, e.g. if the host is paid to maintain forests as a carbon sink rather than harvesting them. In other cases the benefits of the transaction may be in the form of job opportunities, technology transfer, biodiversity and habitat protection, or improvement of local air and water quality. The host government is also concerned that the transaction is consistent with development goals, and that it does not foreclose future development opportunities.

This description of the protagonists' objectives makes the CDM appear universally beneficial. By providing direct benefits to investors and host governments, the CDM makes it cheaper to achieve the environmentalists' objective, thus decreasing resistance to that objective. However, there is considerable dispute about the merits of the CDM.

THE DEBATE OVER THE CDM

In order for the CDM to be successful, it must enable developed countries to reduce their costs of abating GHGs emissions and it must benefit (or at least not harm) developing countries. Both of these conditions have been met with skepticism, although most of the opposition to the CDM has centered on the second criterion. Here we attempt to disentangle and assess the plausibility of the main arguments against the CDM.

♦ *Transactions costs are larger than the difference in abatement costs.* Harvey and Bush [4] summarize UNEP studies on seven developing and three developed countries, and additional studies using estimates of emission reduction cost for Poland, the United Kingdom, Denmark and Zimbabwe. Based on these reports they conclude that monitoring and verification costs could exceed the abatement cost savings. This empirical evidence is valuable, but the magnitudes of the difference in abatement costs and of transactions costs are speculative. Even if the transactions costs are

initially high, they may decrease with experience. The empirical evidence should not be construed as an argument against the CDM, but as a warning not to exaggerate its potential benefits.

♦ *The CDM would interfere with national sovereignty.* [3] This objection is based on developing countries' distrust of developed nations. Without denying the historical basis for this attitude, we emphasize that the CDM is a voluntary arrangement. The objection to the CDM on the basis of distrust is no more rational than is the objection to any form of foreign investment – which developing countries generally pursue. Nevertheless, distrust is a key feature of several arguments against the CDM.

♦ *Developing countries lack the technical expertise to negotiate complex CDMs and would be exploited.* Even if the CDM would generate a net surplus, developing countries would achieve little or nothing, thus violating the second condition for its success. This kind of objection also surfaces in the arena of general trade negotiations at the World Trade Organization. It is another manifestation of the distrust developing countries feel toward developed countries, and taken to its logical conclusion is an argument for minimizing relations.

The lack of technical sophistication *coupled with naivete* is likely to be a serious disadvantage in a negotiating situation. However, lack of technical sophistication in a *skeptical* bargainer may be as damaging to the rival. For example, suppose that the technically sophisticated investor knows the true value of a particular project (i.e. he knows the savings in abatement costs). The unsophisticated but skeptical developing country negotiator cannot accurately assess the value, but assumes that his country (the host) will be cheated. In order to close the deal, the investor may have to offer the host a large share of the surplus; in some cases where there is a positive surplus, the deal is not completed because the investor cannot offer the host enough to overcome his suspicion. In this example, the host may benefit from his lack of information because it can lead to an increased share of surplus. Nevertheless,

imperfect information reduces aggregate expected surplus.

This example suggests that imperfect information resulting from the lack of technical expertise should be viewed as a form of transactions cost. It reduces aggregate surplus and may harm either or both parties in the negotiation. The investor may have as much (or more) incentive as does the host to improve information. Like other types of transactions costs associated with the CDM, it is likely to decrease with experience. Rather than providing an argument against the CDM, the fear of being duped is an argument in favor of providing a public good: public information.

♦ *The CDM may distort host countries' development priorities.* This objection could be viewed as a repetition of the fear regarding the erosion of national sovereignty. However, a fundamentally different kind of argument can be made: the CDM may increase the scope for the abuse of national sovereignty. The analogy between debt and the CDM is useful here.

The ability to borrow on international markets has left developing nations with tremendous debt, in some cases without offsetting benefits. This outcome may be partly due to bad luck, but in part is a consequence of incompetence and corruption on both sides of the debt contract. There is a temptation for borrowers to saddle future generations with debt in order to enjoy the freedom to misspend current loans. The debt contract provides a method for the current government of the developing country, in complicity with lenders, to appropriate future national earnings. Individuals currently in power are not able to sell national assets because they do not own them; they can, however, incur debt, which is a method of selling the future returns to these assets. Unfortunately, this "sale" does not merely represent a redistribution, but may entail enormous real costs. National income may be diverted from useful development projects.

A CDM is likely to involve an intertemporal exchange, as does debt. Instead of an intertemporal exchange of dollars, the CDM may involve the exchange of technology

or development assistance today in return for the promise of using a forest as a carbon sink in the future. If the current benefits are squandered or stolen by the governing elite, the host country may lose from the transaction – even if the global environment benefits. It is conceivable that bribes might be paid to smooth a CDM, or that a bogus project might be invented to launder development assistance.

In spite of the extensive regulation of the banking sector there appears to have been considerable abuse of debt contracts between developed and developing countries. In view of the near absence of regulatory experience for CDMs, the danger of abuse here seems even greater. However, the abuse of debt contracts was exacerbated by the moral hazard problem resulting from lenders' belief that they would be bailed out. Investors in CDMs may lack a similar incentive to push bad investments.

The possibility that the CDM would enlarge the scope for abuse by governing elites means that the third party that monitors each agreement needs to be concerned not only that the environmental benefit is achieved, but also that the developing country's objective is met. In order that the second type of monitoring not be construed as paternalism, the third party needs to be truly international.

♦ *CDM investors would choose the most lucrative projects; if, in the future, the developing country is obliged to reduce emissions, it would be left with only high cost options.*[10], [3] Rather than being a mistake, beginning with the most lucrative projects is efficient. The theory of nonrenewable resources provides a useful analogy here: it is efficient to first extract low-cost deposits before mining more expensive deposits. The real fear may not be that investors undertake the most lucrative projects first, but that the host country receives inadequate compensation. This point was addressed above.

♦ *Long term commitments, such as carbon sinks, may foreclose future development opportunities, such as increased agricultural output.*[3], [10] This objection is also a variant of the fear that the host country will be inadequately compensated, in this

case for the loss of an option. The value of this option, for the developing country, must be included in the calculation of that country's abatement cost. Attempts to measure relative abatement costs may neglect option values; in that case, they would be likely to underestimate abatement costs in developing countries.

♦ *By lowering abatement costs, the CDM would discourage developed countries from improving abatement technologies, or would reduce their incentive to alter domestic policies to reduce emissions.* [11], [10] Implicit in this argument is the belief that higher abatement costs contribute to lower emissions. There are two parts to the argument, both implausible.

One part asserts that higher abatement costs promote policy-induced conservation, and thus lower emissions. However, the primary environmental objective is (presumably) lower GHGs emissions, regardless of whether these are obtained by domestic or foreign reductions. By making abatement cheaper, it becomes more likely that abatement targets will be met.

The second part of the argument relies on the existence of a market failure, such as the inability of firms to capture the benefits of cost reductions, e.g. those achieved through learning-by-doing. The knowledge used to reduce abatement cost may be a public good, in which case firms invest too little (from society's perspectives) in developing this knowledge. One way to induce more investment is to provide firms with a (limited) monopoly on future sales of abatement services, e.g. by disallowing the CDM. Here, disallowing the CDM is a quasi-trade restriction – the prohibition against the "import" of abatement services from developing countries.

This trade restriction is an inefficient remedy to the market failure, since it requires the country to forgo the use of cheaper abatement services in developing countries, available under the CDM. In addition, this policy may be ineffective because of time-consistency problems of the type discussed in Karp and Paul.[7] The production of cheaper abatement technologies is an investment decision. Firms make current

research investments because of the expectation of *future* rewards. If a quasi-trade restriction (banning CDMs) is used to induce innovation, the policy needs to affect future abatement costs. Therefore, it is necessary that the trade restriction be maintained in the future. If the real reason for banning the CDM is the desire to induce technological innovation, this reason vanishes as soon as the innovation has been produced. When this innovation occurs, the government has an incentive to begin allowing trade (i.e., to begin using the CDM).[1] Recognizing this, rational forward-looking firms do not take the current trade restriction as a signal of future policy. The current ban on CDMs therefore does not succeed in inducing investment, but it does result in lost opportunities to reduce abatement costs in the current period.

In short, if the desire to induce innovation is the real reason for rejecting the use of the CDM, it is likely to be ineffective because of time-consistency problems. Even if these problems can be overcome, i.e. if the government can make a credible commitment to maintain the prohibition, the restriction is an inefficient means of inducing innovation. The correct policy is to subsidize research, so that private and social returns to this research are equal.

♦ *Investors would transfer obsolete technologies to developing countries, locking them in to a dependent role.* [5]. This claim surfaces in general complaints about foreign investment in developing countries, and is also raised in the context of the CDM. The argument is part conspiracy theory, and in part it is an example of the claim that developing countries get a bad deal in negotiations – an issue which we

[1] This description treats innovation as a one-shot event rather than as a continuous process. Our argument holds in a much more general setting, however. For example, suppose that the level of innovation is a continuous variable. This variable is the "state" in a game between agents and the policy-maker. The latter chooses the extent to which CDMs are restricted. That is, both the government's choice variable and the consequence of agents' actions are continuous, rather than discrete as in the text. The same kinds of time-consistency issues arise in this setting. We adopt the simpler description in the text merely for reasons of exposition.

discussed above.

♦ *In summary*, many of the objections to the CDM are based on the concern that it would be detrimental to developing countries, because of their weak bargaining position relative to developed countries, or because of corruption in governing elites. This concern is not specific to the CDM but also arises in discussions about liberalization of trade and capital markets. One could accept that the exchange between developed and developing countries has been unjust, without concluding that developing countries should seek to reduce exchange However, the recognition of the possibility of unequal exchange can be useful if it helps in constructing a mechanism that does benefit developing countries. Developing countries should participate in the creation of the CDM framework to ensure that it serves their goals.

Another basis for rejecting the CDM is that it might harm the environment, via its effects on induced changes in policy and technology. Although it is possible to rationalize this position, the rationalization is implausible. Environmentalists should encourage the formation of the CDM.

A third basis for skepticism about the CDM is that the potential benefits are small. The transactions costs may be greater than the difference in abatement costs, and the abatement cost in developing countries may be underestimated, e.g. by ignoring options values. The best way to test this conjecture is to experiment with the CDM. This experimentation may help to reduce transactions costs and lead to better estimates of the actual abatement costs. The construction of a framework for the CDM, and obtaining the information needed to improve its operation, are public goods. The developed countries should be willing to underwrite the costs of providing these public goods.

ASSESSING THE POTENTIAL GAINS OF THE CDM

It is widely believed that the costs of abating GHGs are lower in developing countries, and that the potential gains of the CDM are large. Above we discussed empirical evidence that questions this assumption. Here we describe a simple econometric model that provides a different way of examining the question.

We treat carbon dioxide emissions as the proxy for GHGs, and we estimate the relation between these emissions and GDP for developing countries. Using these estimates, we calculate the marginal reduction in GDP caused by a reduction in the country's emissions. This marginal change provides a measure of the country's marginal abatement costs. We compare these estimates of developing country marginal costs to an estimate of the equilibrium price of permits when carbon trade is allowed amongst OECD countries, which are required to reduce their emissions to 1990 levels. That estimated equilibrium price was derived in Karp and Liu.[6]

The model and the estimates

We use data from developing countries to estimate a two-equation system adapted from [6]. One equation, the revenue function, explains GDP as a function of carbon emissions and other factors, and the second equation explains the level of emissions. We have data for 37 developing countries, including 15 low income countries, 16 lower-middle income countries, and 6 upper-middle income countries. These 37 countries account for 61% of the total CO_2 emissions and 40% of the total GDP of the 158 developing countries (defined as countries in which 1996 per capita GNP was \$9,635 or less).[12] Thus, the countries in our sample have high intensity of emissions, relative to their income.

We assume that there exists a GDP-pollution trade-off frontier that depends on the country's factors of production (e.g., labor and capital). This frontier is the

graph of the maximum level of GDP for a given level of emissions and for given factors of production. Denoting Y, E and Z as, respectively, GDP, CO_2 emissions and the vector of exogenous factors of production, the implicit form of this trade-off frontier is $G(Y, E) = F(Z)$, for some functions G and F. The variables Y and E are endogenous. Inverting the function G, we write the trade-off as $Y = H(Z, E)$. This equation is the revenue function. We can think of E as a proxy for "environmental services"; these services play a role in production similar to other factors such as labor and capital.

The level of emissions is determined by the country's level of income, its economic structure (e.g. manufacturing as a share of output) and regulatory decisions. This emissions function is $E = M(Y, X)$, where M is some function and X is a vector of exogenous explanatory variables. In the absence of data about many of the variables which should ideally be included in the vector X, we include only the quantity of energy consumption for commercial use. We consider energy consumption as a proxy for the country's economic structure (i.e. as an alternative to share of manufacturing in GDP).[2]

Our data consists of annual observations from 1975 to 1990 for the 37 countries: Y is GDP (measured in constant 1987 US$); E is Industrial CO_2 Emissions (in kt, i.e. thousands of metric tons); K is Physical Capital Stock (in constant 1987 US$); L is Labor Force; H is Human Capital Education (General pupils); N is Commercial Energy Use (kt of oil equivalent)[3]; Pop is the country population. We include a

[2]In order for the linear model to be identified, we need at least one variable in the vector Z to be excluded from the vector X, and vice-versa.

Dean [2] estimates a similar two-equation model for China, using water pollution as the emissions variable. She uses this model to decompose the environmental effects of trade liberalization into an income and a composition effect.

[3]The GDP data, industrial CO2 data, commercial energy use, population and labor force data are taken from World Development Indicator 1998 CD-ROM.[12] The physical capital stock (constant

time trend, t, in the revenue function to account for exogenous changes that we cannot measure, and we include country-specific constants in both the revenue and emissions equation to account for factors such as land and culture. We divide all variables (except time and the country dummies) by country population and take logs to obtain the following log-linear per capita relations:

$$y_{it} = c_i + \alpha_1 k_{it} + \alpha_2 l_{it} + \alpha_3 t + \alpha_2 h_{it} + \alpha_5 e_{it} + \varepsilon_{1t} \tag{1}$$

$$e_{it} = d_i + \beta_1 y_{it} + \beta_2 n_{it} + \varepsilon_{2t} \tag{2}$$

Lower case variables y, k, l, h, e, and n are the logs of the per capita of the corresponding upper case variables. The subscript i identifies the country and the subscript t identifies the time period; ε_{it} is the error associated with equation i in period t. Equation (1) is the revenue function and equation (2) is the emissions function.

Since y and e are endogenous, we estimate this system using Three-Stage Least Squares. Table 1 contains the coefficient estimates and t statistics. All parameters except for $\ln y$ in the second equation are highly significant. The second equation implies that energy consumption and emissions are approximately proportional.[4] The sum of all the coefficients in the first equation is 1.2, which implies increasing returns

1987 local price) and human capital stock data are drawn from Nehru and Dhareshwa Data Set.[8] We convert the physical capital stock data from local price to US$ by using the exchange rate data from *World Development Indicator 1998 CD-ROM.*

[4]Our estimates of equation (1) would be very similar if we had used a single equation model with energy consumption rather than emissions on the right hand side. We present the results of the systems estimator because we will use the estimate of the price of tradeable carbon emissions permits, obtained in Karp and Liu.[6] That paper found that income was significant in the emissions equation. We are blending the results of two models (the first for OECD countries and the second for developing countries). We want those models to be as similar as possible, and therefore use a systems estimator in this paper.

to scales in capital, labor, human capital and "environmental services".

Table 1: Estimation Result

VARIABLE	Coefficient	t-ratio
Revenue function		
ln(K per capita)	0.300	7.871
ln (L per capita)	0.497	3.878
t	-0.005	-3.605
ln(H per capita)	0.056	3.371
ln(E per capita)	0.353	8.841
CONSTANT	8.072	13.950
Emissions function		
ln(Y per capita)	-0.029	-1.427
ln(N per capita)	1.069	60.580
CONSTANT	1.793	6.717

This estimation is comparable to that for OECD countries, [6] although the magnitudes of the elasticities are different. The point estimate of the elasticity of GDP with respect to capital is 0.3 for developing countries, compared to 0.52 for OECD countries. The corresponding elasticities of labor are 0.497 (developing countries) and 0.29 (OECD), and the elasticities of emissions are 0.35 (developing countries) and 0.11(OECD). The negative coefficient on the time trend implies that if the inputs for which we have data (K, L, H and E) had been held constant, per capita GDP would have declined by approximately half a percent per year ($e^{-.005} - 1 = -4.988 \times 10^{-3}$).

A number of economists have expressed the opinion that growth in developing (particularly in Asian) countries has not been associated with substantial increases in factor productivity, but instead has been a consequence of increases in factors of production. If this opinion is correct we would expect the coefficient on the time trend to be small and possibly statistically insignificant. We were surprised that it

was negative and significant. When we included a time trend in the second equation (also negative and significant) the magnitude of the trend in the first equation falls slightly in magnitude (by about 10%) but remains negative and significant. This change in model specification leads to very small changes in other coefficients, and virtually no change in the estimates of marginal costs that we report in the next section.

We failed to reject the hypothesis of constant returns to scale in production; the p-value of the test is 0.12. When we impose the restriction of constant returns to scale, the elasticity of output with respect to labor falls from .497 to .304 and the elasticity with respect to skilled labor falls from .056 to .047. The other coefficients are virtually unchanged. More important for our purposes, our estimates of the marginal costs are virtually unchanged.

Marginal product of emissions

The key premise of the CDM is that the marginal cost of abating CO_2 emissions is significantly lower in developing countries than in developed countries. The evidence reviewed by Harvey and Bush, [4] described above, provides mixed support – at best – for this premise. Here we provide a different perspective on the relative abatement costs in developing and in OECD countries.

We suppose that initially OECD countries are able to trade CO_2 emissions permits amongst themselves, and that each country is given an allocation of permits equal to its 1990 level of emissions. Thus, aggregate OECD emissions are constrained by the Kyoto Agreement. In [6] we obtained an estimated equilibrium price of \$157 (in 1990 dollars) for a ton of CO_2, using the OECD production function coefficients described in the previous subsection. Thus, under an efficient (i.e., a competitive equilibrium) allocation of emissions within the OECD, the marginal OECD abatement cost is \$157

per ton.[5]

Now suppose that in addition to being able to trade permits amongst themselves, the OECD countries are able to use the CDM to purchase emissions from developing countries. These CDM transactions are efficient if and only if a developing country has a marginal abatement cost of less than \$157. We use our estimates of equation (1) to calculate the marginal product of emissions in developing country i

$$MP_i = \frac{\partial Y_i}{\partial E_i} = \alpha_5 A_i E_i^{\alpha_5 - 1} \tag{3}$$

where $A_i \equiv e^{c_i}\ K_i^{\alpha_1} L_i^{\alpha_2} e^{\alpha_3 t} H_i^{\alpha_4} Pop_i^{1-\alpha_1-\alpha_2-\alpha_4-\alpha_5}$. This marginal product is the opportunity cost of a unit of emission, so it can be interpreted as the marginal abatement cost in country i.

In calculating MP_i we treat A_i as a constant, equal to its estimated 1990 level. We made the same assumption for the OECD countries in estimating the equilibrium price under intra-OECD trade. Thus, our estimates of the developing and OECD marginal abatement costs are comparable. The magnitude of A_i obviously affects the level of MP_i and we know that it is not literally true that A_i will remain constant. However, we are not really concerned with the absolute levels of marginal abatement costs. We care about the level of these costs relative to the OECD costs, and about the variation of costs amongst the developing countries.

Suppose that over the 1990-2010 period the growth in factors of production in country i are such that A_i increases by a factor of λ_i In this case, the right side of

[5]We used data on OECD countries to estimate equations (1) and (2). Using the parameter estimates from equation (1) we constructed the inverse demand function for each ORECD country by setting the price they would pay for a permit equal to their marginal product of emissions, equation (3) below. Adding the individual country's demand gives us aggregrage OECD demand, which we set equal to the aggregate level of emissions allowed under the Kyoto Agreement, to obtain an estimate of the equilibrium price.

equation (3) should be multiplied by λ_i If we had a consistent set of projections for the increases in all the factors for all of the countries (including the OECD countries), we could use these to obtain an estimate of λ_i for each i. Since we can only find projected increases for some factors for some countries, any attempt to estimate λ_i would involve considerable guesswork on our part. Since MP_i is proportional to λ_i, our results would be largely determined by this guesswork.

Therefore, we adopt the simpler (in our view, "neutral") assumption that λ_i is the same for all countries.[6] If we interpret all of the results described below as indications of relative, rather than absolute abatement costs, there is no additional loss of generality in assuming that $\lambda = 1$ for the developing countries.[7] If, for example, the reader thinks that the index of factors of production, A_i, for a particular developing country i (or for a group of developing countries) will grow more quickly or slowly than the average OECD growth, the abatement costs for that country (or that group of countries) should be increased or decreased accordingly.

Our comparisons assume that the CDM begins in the year 2010, the time at which OECD countries have (tentatively) agreed to reach their Kyoto targets. We choose the value of E_i in equation (3) by assuming that developing country emissions continue rising, from their 1990 level, to the year 2010, at an annual rate equal to the

[6] This assumption does not mean that all of the factors grow at the same rate in all countries. It means that the index A_i grows at the same rate.

[7] In constructing the estimate of the equilibrium price when trade takes place only amongst OECD countries, it is important to assume that $\lambda_j = \lambda^{OECD}$ (a constant, where j is an index of OECD countries). A change in this constant would lead to a proportional change in the estimated OECD price. However, if the values of λ_j were not the same for all OECD countries, the estimated price would depend on all values of λ_j, not merely on their average value. In this paper we compare abatement costs in developing countries with an equilibrium price which we take as fixed. We are not solving for a new equilibrium price. Consequently, our estimate of the marginal abatement costs in a specific developing countriy i can be raised or lowered, depending on our view of how the value of λ_i compares with the fixed OECD value of λ^{OECD}.

average rate over the 1975-1990 period. We adopt this assumption because of the lack of a consistent set of estimates for the rate of increase of emissions for all developing countries. There are estimates for some countries, and it worth comparing these with the averages we compute. For example, the Department of Energy's Annual Energy Outlook for 2000 (http://www.eia.doe.gov/oiaf/aeo) projects annual increases of 6.5% for China and India, two of the largest emitters amongst the developing countries, while the estimates we use are 5% for China and 7% for India.

Our estimated price \$157 for a tonne of CO_2 implies a price of \$575 for a tonne of carbon.[8] This price is much higher than the range found in the literature, reviewed by Karp and Liu [6] and by Tol [**?**]. Tol reports that most estimates of abatement costs are in the range of \$1.4 to \$35 per tonne of CO_2 (i.e., from \$5 to \$125 per tonne of carbon – see the previous footnote) with most estimates at the low end of the range. Our model may exaggerate the cost of abatement, and thus exaggerate the price of permits. The fact that we use the same econometric model to estimate costs in both regions at least means that the two sets of estimates are comparable. Since we are interested only in *relative* abatement costs, any absolute bias in the estimation of abatement costs is unimportant. We have no way of knowing whether the (possible) bias is larger in one or the other region.

Our estimates of marginal products of emissions for the developing countries might be biased upward because we use industrial carbon emissions to proxy total carbon emissions. Industrial emissions include only emissions arising from burning fossil fuels and manufacturing cement, and contributions from other solid, liquid and gas

[8] CO_2 has a molecular weight of $12 + 2(16) = 44$. Thus the ratio of the weight of CO_2 to carbon is $\frac{44}{12} = 3.666\,7$. That is, $3.666\,7$ tonnes of CO_2 contain one tonne of carbon. We use this factor in converting tonnes of carbon to tonnes of CO_2, and in converting prices. If a country has an abatement cost of \$100 per tonne of CO_2 emmissions, that country would be willing to pay \$366.67 for the right to emit one tonne of carbon. In some of the literature it is not clear whether the authors have in mind the price of carbon or the price of CO_2.

fuels and gas flaring.[12] In some developing countries, CO_2 emissions arising from burning fossil fuels exclude the majority of total emissions. For example, 60% of urban and almost all rural households in sub-Saharan Africa still rely on biomass energy for household energy needs. [1], [4] Therefore, some developing countries might have a high marginal product of industrial CO_2 emissions (and thus have a high opportunity cost of abating these emissions); nevertheless, their cost of abating non-industrial emissions might be much lower. Since our model does not include these non-industrial emissions, our estimates of marginal product of emissions might be too high for developing countries. On the other hand, our exclusion (because of a the lack of data) of the option value of being allowed to emit may bias our estimates downward.

Figure 1 about here

Figure 1 compares the estimated OECD price (= marginal abatement cost) of \$157 with our estimates of the developing countries' marginal abatement costs, obtained using equation (3), our parameter estimates, and the assumptions regarding A_i and E_i described above. The figure shows considerable variation in the estimated costs; it is lower than \$157 for 19 out of the 37 countries in our sample. For several of those 19 countries the difference is small, and is likely to be less than the transactions costs associated with the CDM. Only the countries with the lowest estimates of abatement costs, China and Indonesia, have estimates in the range reported by Tol [**?**]. Unless transactions costs are very large, these countries appear to be amongst the best candidates for CDM.

CONCLUSION

We addressed two questions in this paper. First, we asked whether the Clean Development Mechanism is a good idea in principle. Second, we asked whether there is likely to be a large difference in the abatement costs between OECD and developing countries. In order for the CDM to be useful in practice, such a difference must exist.

The major reason for favoring the CDM is its potential to generate savings in abatement costs. In this respect, the CDM is similar to an international market in emissions permits. Despite these similarities, there are important differences between the two institutions. The transactions costs associated with the CDM are more obvious than are the costs of a market in permits. However, it may be impossible to avoid those transactions costs, regardless of how the reallocation (between OECD and developing countries) of emissions is achieved. Also, the CDM is more feasible politically, because it does not require an explicit division of property rights, and it does not trigger the same visceral distaste that some environmentalists feel toward markets.

Despite its apparent advantages, some people have opposed the CDM on principle, worrying that it may hurt developing countries or reduce abatement efforts in OECD countries. In our view, neither of these objections is compelling, but the first is the more important. In order for CDMs to become sufficiently widely used to play a significant role in reducing emissions, informational asymmetries – both real and perceived – must be overcome. The developing countries must be able to negotiate with confidence. The costs of acquiring information about relative abatement costs must be underwritten by OECD countries.

Anecdote and casual empiricism suggests that abatement costs are much lower in developing countries. Previous research questions this view. We provided another perspective by comparing the marginal opportunity cost of emissions in developing

and OECD countries. We estimated these marginal costs using country panel data. These estimates incorporate several (implausible) assumptions which we regard as neutral, since they do not obviously bias our conclusions in one direction or the other. Our estimates also neglect non-industrial emissions, which are likely to be important in developing countries. This neglect is likely to lead to a downward bias in the estimated difference in abatement costs between OECD and developing countries, and is therefore likely to underestimate the true benefits of the CDM.

Nevertheless, our estimates are useful because they suggest that there is considerable variation in abatement costs across developing countries. The results also support previous research which suggests that we should be guarded in our optimism about the potential cost savings that can be achieved by CDM. Some developing countries appear to be poor choices for CDMs, although in others the savings can be substantial. Our highly aggregated model cannot be used to identify (definitively) which developing countries belong in which group, but only to suggest candidates.

In summary, we suspect that both the advantages and the disadvantages of the CDM have been exaggerated. At this stage, it seems to be worthwhile pursuing the development of the CDM, in order to learn about relative abatement costs and to reduce transactions costs. The CDM may become an important means of reducing the costs of controlling GHGs, although it does not seem likely that it will lead to a wholesale transfer of abatement activities from OECD countries towards developing countries.

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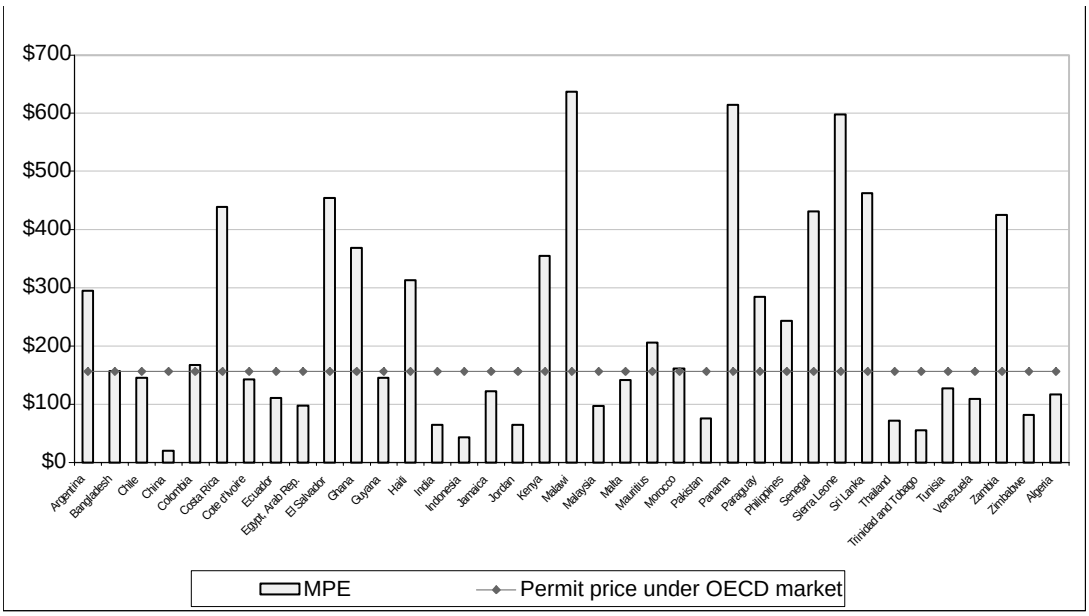

Figure 1: Marginal opportunity costs of abatement for developing countries.