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Is the clean development mechanism compatible with an ambitious climate agreement?

Abstract

The developed countries can meet part of their Kyoto commitments by investing in emissions-reducing projects in developing countries (the clean development mechanism, CDM). Since the developing countries have so far not been willing to accept binding emissions commitments, the CDM has been the only mechanism available for ensuring abatement measures in these countries. The authors explore the potential for the CDM in an ambitious climate agreement and discuss, by the help of numerical simulations, whether the CDM is compatible with an ambitious climate agreement.

Keywords: clean development mechanism, climate agreement, emissions trading, emissions reductions.
JEL Classification: Q54, Q56.

Introduction

Under the Kyoto Protocol, the developed countries took on binding quantitative commitments to limit their greenhouse gas emissions for the period of 2008-2012[1]. However, the total global emissions reduction achieved by the Kyoto Protocol is almost negligible (Böhringer, 2002). The reason for this is threefold. First, the developing countries promised emissions reductions, relative to their 1990 level, are modest (5.2 % reductions). Second, the US withdrew its support for the Kyoto Protocol. Third, the developing countries have no binding targets for their emissions.

Each country with a binding emissions commitment under the Kyoto Protocol has been allocated an emissions quota called its assigned amount. The quota is divided into assigned amount units (AAU), which can be traded with other developed countries. This type of arrangement is called a cap and trade system. We, henceforth, refer to an AAUs as an *emissions permit*, or for short a *permit*, and the assigned amount as the *initial allocation of permits*.

In addition to taking part in the cap and trade system, the developed countries can meet their commitments through domestic abatement, funding of projects in other developed countries (Joint Implementation projects) and finally, through the clean development mechanism (CDM).

Despite numerous efforts by the United Nations (UN) to come up with a replacement for the Kyoto Protocol, there is still no sign of a new treaty that would cover a larger share of global emissions and ensure deeper global emission cuts. Under the Copenhagen Accord (2009), the international climate regime could continue with a system in which only developed countries set quantified emission reduction targets and participate in a cap and trade system, whereas developing countries implement abatement measures partly financed by developed countries through CDM.

There is an important distinction between CDM as a project based mechanism and cap and trade system, as the host countries for the CDM projects does not have a binding commitment and hence not an initial allocation of permits. It follows that emissions reductions following from CDM projects must be measured against a baseline for emissions in each project.

The CDM allows developed (investor) countries to earn certified emissions reduction units (CERs) through funding of emission-reduction or emission-removal projects in developing (host) countries. Examples include afforestation (i.e., planting *new* forest), switching to less polluting fuels or energy sources, and implementation of energy efficiency measures.

Since emissions reductions achieved through the CDM may be used in their entirety to offset emissions in developed countries, the mechanism is not designed to bring about an overall decrease in global emissions[2]. However, the CDM is important in reducing the costs of complying with the Kyoto Protocol, since it ensures that the abatement efforts are spread across a larger number of

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[1] See Annex B to the Kyoto Protocol for a complete list of countries that have quantitative emissions commitments. The text of the Protocol is available at http://unfccc.int/kyoto_protocol/items/2830.php.

[2] According to the Kyoto Protocol, the purpose of the CDM is to assist the developed countries in meeting their commitments, and to assist developing countries in achieving sustainable development (see Article 12 of the Protocol). It can be argued that CDM projects result in technology transfers, so that new environmentally sound technology is deployed in developing countries. However, as long as there are no costs (tax or carbon price) associated with emissions in developing countries, significant transfers of new technology are unlikely if they result in higher production costs. Moreover, the CDM may encourage the introduction of new technology even if the most cost-effective measure would be to reduce production. This is because emissions permits can be earned by introducing new technology, whereas it is difficult to define reductions in production as CDM activities. This issue is discussed by Fischer (2005) and Hagem (2009).

countries including developing countries, and there are many low-cost options for reducing emissions in developing countries. Moreover, the expectation that the CDM would result in lower costs may have made the developed countries willing to take on stricter commitments than they would otherwise have done.

This paper discusses how the CDM functions and whether it is compatible with a future climate agreement designed to bring about deep cuts in emissions. We start by describing some of the fundamental weaknesses of the current design of the CDM in the next section. In section 2, we illustrate numerically that an ambitious global target for emissions reductions cannot be achieved by reductions in the developed countries alone. Substantial cuts in emissions in developing countries will be needed as well. Due to the weaknesses of the mechanism, we argue that the CDM mechanism is far from the most cost-effective way of achieving large emissions cuts in developing countries, at least in its present design. We compare the economic costs and the distribution of cost, of various scenarios for involving developing countries in a climate agreement. Our main conclusion is that a project-based emissions crediting mechanism, as the CDM, places a very large economic burden on the developed countries if global emissions reductions are to be cut substantially. This may be an important obstacle for achieving substantial cuts in global emission. Concluding remarks are given in the last section.

1. How does the CDM function?

The CDM Executive Board, which is accountable to the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol, is responsible for approving all CDM projects and issuing CERs. Like one AAU, one CER gives the right to emit one ton of CO_2 equivalent (CO_2e)[1]. In a well functioning permit marked that with no restrictions on the use of CERs, the price on the two types of assets will be identical. We, henceforth, refer to both types as emissions permits. The number of emissions permits issued from a CDM projects corresponds to the estimated emissions reduction from the CDM project, which is the difference between the estimated level of emissions without the CDM project (the business-as-usual or BaU level) and realized emissions after the project has been carried out.

[1] The Kyoto Protocol regulates emissions of several greenhouse gases, of which CO_2 is the most important. Quantities of the other gases, including methane and nitrous oxide, are measured in terms of their global warming potential, in CO_2 equivalents.

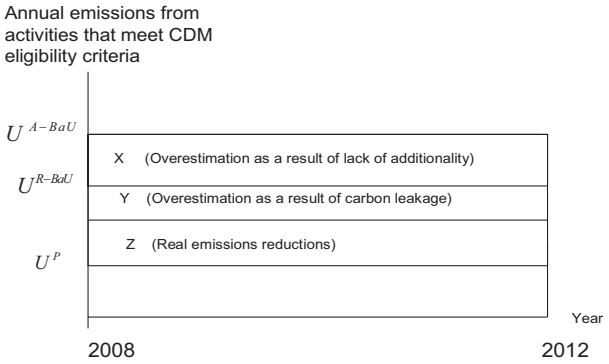

Fig. 1. Illustration of the different sources for overestimation of annual emissions reductions from CDM-projects

For illustrative purposes, assume that a developing country's estimated aggregate BaU emissions have been set at $U^{A\text{-}BaU}$ during a relevant period, for example the Kyoto period of 2008-2012. The observed level of emissions after completion of a number of CDM projects, that meet the CDM eligibility criteria, is given by U^P in Figure 1. If all the projects are approved, they will generate emissions permits corresponding to the difference between $U^{A\text{-}BaU}$ and U^P, in other words the sum of the areas of rectangles X, *Y* and *Z* in Figure 1. These permits can be used in their entirety by developed countries to offset corresponding increases in their emissions.

However, there is a high probability that the real emissions reductions generated by the projects will be lower than the estimated figures that are used as a basis for issuing emissions permits[2]. This is because of problems related to the *additionality criterion* and to *carbon leakage*. A project is *additional* if it would not have been financially viable to carry out the project in case it did not generate emissions permits and thus extra funding. According to the rules a CDM project should only be approved if it meets the additionality criterion. However, since there are substantial profits to be made by such approval, the parties involved in CDM project activities have incentives to present profitable projects as unprofitable, so that projects that would have been carried out in any case might be approved as CDM projects and generate emissions permits[3]. Furthermore, the CDM gives incentives for increasing production of emissions generating goods to gain profits on emissions reductions through the CDM at a

[2] We have focused on the case where the emissions reductions generated by a CDM project are systematically overestimated, since this leads to the greatest profits for the agents with a financial interest in the project. Nevertheless, because of the high level of uncertainty, there may also be cases where the real abatement from a CDM project is *larger* than the estimated figure used as a basis for issuing emissions permits.

[3] If a project does not meet the additionality criterion, the true volume of BaU emissions is equal to the observed volume after completion of the project. In this case, the project does not lead to a real reduction in emissions.

later stage[1]. The parties also have a financial interest in overestimating the BaU emissions from projects that meet the additionality criterion, since this will generate more emissions permits. Moreover, even if a specific investment project is unprofitable unless it can be used to generate emissions permits, there may be alternatives that are profitable and that would also reduce emissions[2]. In such cases, the true BaU emissions level is not equal to emissions before the start of the CDM project, as the investors may claim, but the emissions level that would have been achieved through the alternative profitable investment.

Furthermore, the CDM gives host countries an incentive to have laxer environmental standards in order for domestic firms to benefit maximally. Laxer environmental standards on emissions complimentary to CO_2, as for instance SO_2, lead to higher baseline CO_2-emissions. Hence, more projects may become CDM viable, and each project may generate more emissions permits[3].

The effects of CDM projects in developing countries are overestimated by these types of miscalculation, since the estimated BaU emissions from activities that meet CDM eligibility criteria ($U^{A\text{-}BaU}$) are higher than the true BaU emissions, $U^{R\text{-}BaU}$. The difference corresponds to area X in Figure 1.

Carbon leakage is another problem related to CDM investments. By definition we have carbon leakage from a CDM-project when the generated emissions reductions are partly offset by higher emissions in other parts of the economy. One example of a CDM project with potential leakage is the partial replacement of coal by bio fuel as energy source in a production process. It is reasonable to assume that the replacement of polluting forms of energy with green energy is not the only result of investing in green energy: such investments increase the energy supply, which will also reduce market energy prices and is likely to result in a higher overall level of energy use. If this happens, the reduction in the use of polluting energy resulting from a CDM project will be partly offset by an increase in the use of polluting energy elsewhere in the country. As long as there are no constraints on aggregate national emissions in the host countries, it is difficult to avoid this effect, which is known as carbon leakage. Such leakages are not taken into account when calculating the number of emissions permits earned by a project[4]. In Figure 1, the overall carbon leakage effect is shown by area Y. Figure 1 thus illustrates a case where the additionality and carbon leakage problems result in the overestimation of the effects of CDM projects in a developing country by $Y+X$ tons CO_2, corresponding to the same number of emissions permits. Since emissions permits can be used to offset emissions in developed countries, the global rise in emissions as a result of the CDM projects in this example is $Y+X$ tons CO_2.

It is difficult to estimate the severity of these types of overestimations. Calculations of both Y and X must be based on counterfactual figures, i.e., the estimated emissions levels if the CDM projects had not been carried out. These figures are by nature unobservable. This means that it will never be possible to calculate a precise figure for the global rise in emissions that can be attributed to the CDM. Michaelowa and Umamaheswaran (2006) have assessed the documentation of additionality for 54 CDM projects, and concluded that additionality was only well documented for a minority of these. Schneider (2009) evaluates 93 registered CDM projects and finds that the current tools for demonstrating additionality are in the need of substantial improvement.

Calculations based on general equilibrium models also show that there may be substantial carbon leakage effects. For example, a study by Glomsrød and Taoyuan (2005) showed that approval of coal cleaning as a CDM project activity in China could result in a rise in CO_2 emissions instead of a decrease. This is because the greater energy efficiency of cleaned coal would reduce the demand for raw coal and thus its price, leading to a rise in consumption in other parts of the economy. The rise in energy efficiency and reduction in the costs of transporting coal would also boost economic growth and lead to a rise in energy use and emissions. Using a general equilibrium model for the Chinese economy, carbon leakage was found to exceed 100 percent, that is, the increase in emissions outside the border of the projects more than offset the emissions reductions within the border of the project. Böhringer et al. (2003) showed that if Germany meets its Kyoto commitment partly by means of investments in the power

[1] An example of this kind of perverse incentives created by CDM is given in Wara (2007). He shows that manufacturers in developing countries have stepped up their production of the industrial product HCFC in order to profit by cutting back on the greenhouse gas HFC, which is produced as a by product.

[2] The possibility of earning money on future CDM projects may also discourage actors in developing countries from investing in alternative, profitable energy efficiency projects today. The effect of this on global emissions is discussed in Hagem (1996).

[3] This effect is, e.g., discussed in Rosendahl and Strand (2009).

[44] In principle, the number of permits is calculated on the basis of the difference between the estimated BaU emissions and the actual emissions after the project is completed, corrected for any carbon leakages that are measurable and attributable to the CDM project. However, leakage effects resulting from general equilibrium effects in the economy are not taken into account. The rules for CDM project activities may be found here: http://cdm.unfccc.int/Reference/COPMOP/08a01.pdf. See also http://cdm.unfccc.int/Reference/Guidclarif/glos_CDM_v04.pdf.

sector in India, this will lead to a rise in emissions in other parts of the economy equivalent to 56 percent of the emissions reduction in the power sector.

With respect to leakage, however, it should be added that CDM also may reduce global carbon leakage by lowering the international price of carbon and thus weakening the incentives to relocate manufacturing from developed to developing countries[1,2].

Another weakness of the CDM is that it only applies to certain types of emissions in developing countries. For example, emissions from activities, such as conservation of forests, are explicitly excluded. Moreover, policy reforms designed for example to reduce emissions from transport through higher end-user prices for petrol and diesel (taxes), and low-cost energy efficiency measures such as removal of subsidies, are not approved as CDM project activities. To reduce the degree of uncertainty associated with the emission-reduction effects of CDM projects, the mechanism only applies to emissions reductions achieved through concrete investment projects. This means that the CDM does not ensure that all cost-effective emission-reduction measures are carried out and the transaction costs associated with each project can be significant. In 2007 the Executive Board agreed that project activities under a program of activities can be registered as a single CDM project activity provided that approved baseline and monitoring methodologies are used[3]. This option for programmatic CDM reduces the transaction costs per unit emissions reductions and thus increases the potential for implementing a broader range of low costs abatement options. However, the problem related to lack of additionality and carbon leakage still remains.

Given the Kyoto target, the literature discussed above suggests that under the current rules, the net effect of the CDM is an increase in global emissions due to carbon leakages and overstatement of the baseline emissions. However, the outcome of climate negotiations is influenced by the options for costs reducing means. It can be argued that had it not been for the CDM, the Kyoto Protocol might not have come into force, or might have been laxer, as the CDM serves as a safety valve for the costs of emissions reductions among developed countries. Furthermore, although there are several weaknesses with the current design of the CDM, the mechanism has provided the first standardized emissions offset instrument (CERs) with a global market price. This gives valuable information to developing countries about the potential gain from permit trade and might lead them to join a cap and trade system at a later stage, thus eliminating the need for determining baselines and leakages for individual projects.

1.1. Possible improvements of the CDM. To counteract the weaknesses of the CDM various ways of tightening up the rules have been discussed (see, e.g., Schneider, 2009; Rosendahl and Strand, 2009; and Vöhringer et al., 2006). One possibility is to award each project fewer emissions permits than the number corresponding to the estimated emissions reductions. This would make the CDM more expensive for developed countries and less profitable for developing countries, but would prevent a CDM-caused global rise in emissions and would address much of the criticism that has been levelled against the system. On the other hand, such a strict regime will reduce global cost-effectiveness of the regime, because a number of socially attractive CDM-projects then would become unattractive to the investors.

Another option is to introduce stricter requirements for documenting additionality, and/or to use objective criteria for establishing an exogenous baseline independent of the project. Unfortunately, the stricter the requirements for documentation and control, the more transaction costs will rise (meaning administration, documentation and control costs). There is also a risk that the cheapest and thus most cost-effective projects will not be approved because it will not be possible to substantiate that they meet the additionality criterion by a good margin, even if they actually are additional. It is paradoxical that the most cost-effective CDM projects that meet the additionality criterion are by definition only additional by a very small margin, and are therefore unlikely to pass the additionality test under a stricter regime.

Yet another option is to move away from a project-based mechanism towards inclusion of certain sectors of the developing countries into a global cap and trade system. This type of sectoral crediting, which indeed constitutes the basic feature of the running cap and trade system within EU, would circumvent the need to prove the hypothetical additionality of individual projects. Furthermore, it could significantly reduce the carbon leakage if the "sector" comprised most of the energy intensive production, and more of the potentials for emissions reductions could be exploited. A specific baseline would have to be set for whole sectors. The coun-

[1] Global carbon leakage describes a situation where emissions reductions funded by countries that have binding emissions commitments (developed countries) are partly offset by increased emissions in countries without quantified commitments (developing countries). This may be explained both by leakage effects transmitted through global energy markets (because the prices of fossil energy drop as a result of lower demand in developed countries), and by the relocation of energy-intensive manufacturing from developed to developing countries.

[2] A study by Kallbekken (2007) showed that the CDM reduces global carbon leakage, whereas Bollen et al. (1999) drew the opposite conclusion.

[3] See http://cdm.unfccc.int/ProgrammeOfActivities/index.html.

tries' governments could be allowed to sell permits on the international market corresponding to the difference between the sectors' baselines and the realized emissions from these sectors. However, in our wording, such a sectoral crediting system is a cap and trade system, opposed to a project-based crediting mechanism as the CDM. Indeed, sectoral crediting can be seen as a step on the path from a project-based mechanism to a full fledged cap and trade system also including developing countries. If all sectors are included, it correspond to a situation where the developing countries are participating in a cap and trade system with initial allocation of permits equal to their business as usual emissions[1].

In the next section we use a numerical model to illustrate the role of the CDM in an ambitious climate agreement. Our numerical model is described in the Appendix.

We consider both the current design of the CDM and a potentially full expansion of the mechanism into a cap and trade system.

2. Involvement of developing countries in an ambitious climate agreement

In this section, we discuss the role of the CDM in an ambitious global climate agreement by comparing a CDM regime with other options. By the use of a simple numerical model we illustrate the degree of cost effectiveness and the distribution of costs across developing and developed countries of various degrees of inclusion of developing countries in an ambitious climate agreement (the definition of an ambitious climate agreement is discussed below). There are several numerical studies of the outcome of the Kyoto Protocol regarding various degrees of abatement contribution from developing countries (see, e.g., Weyant, 1999). The novel contribution of this paper is that we consider a long-term scenario and a much more ambitions climate agreement than the Kyoto Protocol. To evaluate some main properties of the CDM regarding cost effectiveness and distribution of costs in an ambitious climate agreement we consider four stylized scenarios for the design and participation:

1. Global cap and trade system. The initial allocation of permits to developing countries equals their BaU emissions. This corresponds to a system where CDM is expanded to a sectoral cap and trade system which covers all sectors in the developing countries.
2. Global cap and trade system. The initial allocation of permits to the developing countries ensures them zero net costs of their commitments in the agreement[2].
3. CDM regime. Only the developed countries (Annex B countries) participate in a cap and trade system. The developing countries are involved through continuation of the CDM as a project based mechanism.
4. No involvements of developing countries. Only the developed countries (Annex B countries) participate in a cap and trade system. No CDM or other types of developing country involvement.

It is a matter of debate exactly what is meant by an ambitious climate agreement. The EU has adopted the goal of limiting the average rise in global temperature to no more than 2°C above the pre-industrial level. Stern (2006) (the Stern Review) proposes a less ambitious target, since the costs may otherwise become excessive. The Stern Review recommends that the atmospheric concentration of greenhouse gases should not exceed 550 ppm, which would mean that projected global warming does not exceed 3°C[3]. This target can be achieved by following a recommended emissions path in which emissions peak in the next 10-20 years, and are at least 25 percent below the 2004 level in 2050. In the longer term, emissions must be cut to more than 80 percent below the current level[4]. We have used this path for global emissions reductions as a basis, but have only considered the reduction of CO_2 emissions from fossil fuels. In the numerical examples of the costs of a climate agreement, we have considered the year 2050 only[5].

[1] Taking part in a cap and trade regime does not preclude developing countries from obtaining funding and technological transfers from the types of projects that currently come within the scope of the CDM. Such projects would correspond to those known as Joint Implementation (JI) projects under the Kyoto Protocol. However, in a cap and trade regime, the developing countries are responsible for their overall national emissions. Any carbon leakage effects associated with JI projects would therefore have to be offset by emissions reductions in other parts of a country's economy.

[2] Note that with no market imperfections or uncertainties this corresponds to a system with an international emissions tax where the developing countries' share of the reimbursement of the tax revenue exactly covers their abatement costs, which again equals harmonized domestic taxes including a system of financial transfers. See Hoel (1991) for a discussion of the equivalence between taxes and permits. Due to the large degree of uncertainty connected with various aspects of climate change policies, Nordhaus (2006) strongly argues in favor of a harmonized tax on carbon emissions. As the discussion about quantity (permits) versus price (taxes) instruments is beyond the scope of this paper we consider only quantity agreements in this paper.

[3] See Stern (2006). Executive Summary, pp. 15 and 17.

[4] See Stern (2006). Executive Summary, p. 11.

[5] We consider CO_2 emissions from fossil fuels only. The Stern Review includes all greenhouse gas emissions. We have used a CO_2 emissions scenario with the same percentage reduction as the Stern Review. As a result, we estimate somewhat higher greenhouse gas concentrations than those calculated by the Stern Review. Nevertheless, we assume that the cost will be just above 1 percent of GDP, as is close to the estimate in the Stern Review (1 percent).

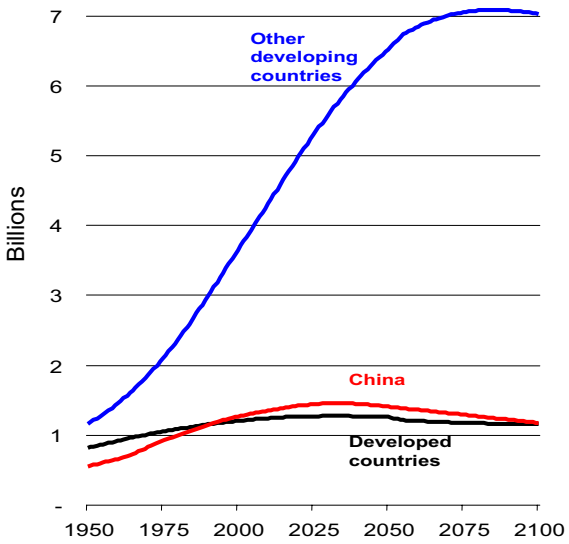

Fig. 2. World population growth 1950-2100. UN projections, medium scenario (billion people)

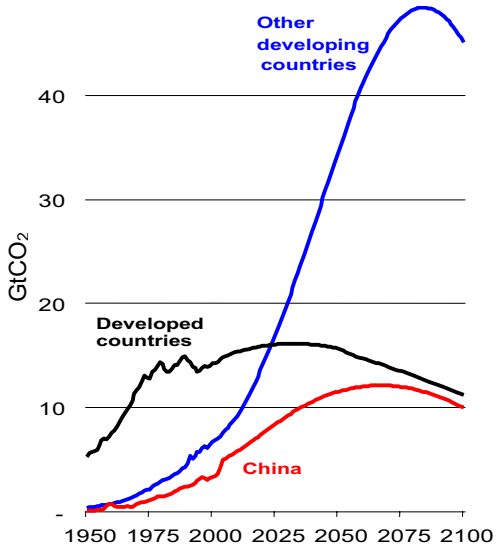

Fig. 3. Global emissions, historical figures and projections from IPCC reference scenario A1 Message

Cutting emissions by 25 percent relative to 2004 by 2050 may appear to be a modest target, but involves a dramatic cut relative to the projected level in 2050 in the reference scenario. As a result of rapid population growth (see Figure 2) and a rise in per capita energy use in developing countries, projected emissions in the reference scenario are more than twice as high in 2050 as in 2004, see Figure 3 and Table 1. Both the emissions figures and the GDP figures in Table 1 are based on the IPCC's SRES scenario A1 MESSAGE, see IPCC (2000)[1].

Table 1. CO_2 emissions, GDP and population in 2004 and 2050 in the reference scenario*

	2004			2050		
	Emissions	GDP**	Population	Emissions	GDP**	Population
	$GtCO_2$	Billion USD	Billions	$GtCO_2$	Billion USD	Billions
Developing countries	12.6	22 950	5.2	46.0	136 445	7.9
Developed countries	14.9	32 146	1.2	15.8	89 024	1.3
World	27.5	55 096	6.4	61.8	225 469	9.2

Notes: * These emissions figures do not include emissions from land use, land use change and forestry (LULUCF). The emissions shown in Figures 1 and 3 do include emissions from LULUCF and are, therefore, somewhat higher. ** The GDP figures are measured in purchasing power parities.

Table 1 shows that in the reference scenario, emissions are estimated to rise by 125 percent by 2050. If we are to cut global emissions by 25 percent relative to the 2004 level by 2050, they should not exceed approximately 20.3 $GtCO_2$. This means that they would have to be cut by 67 percent relative to the 2050 level in the reference scenario.

2.1. Numerical illustrations of the four scenarios. To provide a numerical illustration of the possible scale of global emissions trading and income transfers following the four different scenarios, we have made some calculations based on the target for the atmospheric concentration of greenhouse gases at 550 ppm.

According to the literature, even an ambitious global climate agreement (to achieve the 550 ppm target) may involve relatively modest costs, generally of the order of 0-3.5 percent of GDP in 2050, given a cost effective distribution of emissions reductions (see IPCC, 2007, and Hoel et al., 2009). The Stern Review estimates that the annual costs of stabilizing the concentration of greenhouse gases in the atmosphere at 550 ppm will not exceed one percent of global GDP per year[2]. We have calibrated our numerical model to ensure total annual costs of just above 1 percent of global GDP, given a globally cost effective distribution of emissions reduction. Our model is described in the Appendix.

As mentioned above, the emissions path used in the Stern Review is based on the assumption that emissions in 2050 are reduced to 75 percent of the 2004 level. In our model, this requires a carbon price of

[1] Because the SRES-scenarios where based on population projections from the end of the last century, we have based our scenario on more updated global population projects. Our scenario is therefore based on the per capita emissions and the per capita GDP levels found in IPCC's scenario A1 Message. These figures are then multiplied by the most resent UN population projections, see UN (2004, 2006).

[2] See Stern (2006). Executive Summary, 13.

USD 115.4 per ton CO_2 in 2050. This is in reasonably good agreement with the estimates obtained from other climate models; see the discussion in the Appendix.

It should here be noted that in the model simulations presented in the following, we did for simplicity not take into account carbon leakage and overestimation of emission reductions from CDM-projects as discussed in section 2. This implies that we draw an optimistic view of the CDM's ability to ensure real emissions reductions in developing countries.

2.1.1. Scenario 1. A global cap and trade system. The initial allocation of permits to developing countries equals their BaU emissions. A global cap and trade system ensures a cost effective distribution of emissions reductions. The marginal costs of emissions reductions are equalized across countries. The global costs are consequently minimized, which in our model correspond to 1.1 percent of global GDP. The distribution of costs across countries is depending on the initial distribution of the allocation of permits. If developing countries' initial allocation of emissions permits is set equal to their BaU emissions level (46.0 $GtCO_2$ in 2050), the developed countries' initial allocation of permits must be negative, corresponding to about -25.7 $GtCO_2$. According to our model simulations the optimal strategy for the developed countries will then be to purchase emissions permits corresponding to 30.9 billion $GtCO_2$ from the developing countries. They must surrender 25.7 billion emissions permits for cancellation, and can use 5.2 billion emissions permits to offset annual emissions of 5.2 $GtCO_2$, see Table 2.

Given a carbon price of USD115.4 per ton, sales of 30.9 billion emissions permits will give a gross sales income of USD3562 billion. According to our calculations, this gives the developing countries a net income corresponding to 1.3 percent of their GDP. The annual costs for the developed countries correspond to 4.7 percent of their GDP.

Table 2. Scenario 1. Global cap and trade system. The initial allocation of permits to developing countries equals their BaU emissions

		Developing countries	Developed countries	World
	$GtCO_2$	46.0	15.8	61.8
Initial allocation of permits	% of BaU	100	-163	33
	$GtCO_2$	46.0	-25.7	20.3
Simulated emissions	$GtCO_2$	15.1	5.2	20.3
Export of emissions permits	$GtCO_2$	30.9	-30.9	0
Emissions reductions	$GtCO_2$	30.9	10.6	42
Marginal abatement costs	USD/tCO_2	115.4	115.4	
Costs of emissions reductions	Billion USD	1 781	611	2 392
Net costs of purchasing permits	Billion USD	-3 562	3 562	0
Net cost	Billion USD	-1 781	4 173	2 392
	% of GDP	-1.3	4.7	1.1

2.1.2. Scenario 2. Global cap and trade system. The initial allocation of permits to the developing countries ensures them zero costs of their commitments in the agreement. According to our model simulations, even if developing countries' initial allocation of permits is reduced from 100 per to 66.4 percent of the BaU emissions level (from 46.0 to 30.9 $GtCO_2$), these countries incur no net costs in a cap and trade system, see Table 3. In this case, the developed countries must receive an overall negative initial allocation of permits of 10.3 $GtCO_2$, and their costs correspond to 2.7 percent of GDP in 2050.

Table 3. Scenario 2. Global cap and trade system. Developing countries are ensured zero costs as their initial allocation of permits equals 66.4 percent of their BaU emissions

		Developing countries	Developed countries	World
Initial allocation of permits	% of BaU	66.4	-65.0	32.9
	$GtCO_2$	30.9	-10.3	20.3
Simulated emissions	$GtCO_2$	15.1	5.2	20.3
Export of emissions permits	$GtCO_2$	15.1	-15.1	0
Emissions reductions	$GtCO_2$	30.9	10.6	41.5
Marginal abatement costs	USD/tCO_2	115.4	115.4	
Costs of emissions reductions	Billion USD	1781	611	2 392
Net costs of purchasing permits	Billion USD	-1781	1781	0
Net cost	Billion USD	0	2392	2 392
	% of GDP	0	2.7	1.1

The initial distribution of the allocation of permits does not affect the distribution of emissions or the total costs in a global cap and trade system. However, it affects the distribution of the final costs across participants. In scenario 2, the initial allocation of permits to developing countries is set such that their costs of participation are zero. This implies that the developed countries' costs of participation correspond to 2.7 percent of their GDP. Hence, compared to scenario 1, their costs are almost halved.

2.1.3. Scenario 3. A CDM regime. When only developed countries participate in the cap and trade system, and the target is to reduce global emissions by 25 percent relative to 2004 by 2050, the overall allocation of permits to the developed countries must be *negative*, corresponding to about -25.7 $GtCO_2$, as in scenario 1. This means that the developed countries must purchase 25.7 billion permits generated from CDM projects per year, which have

to be cancelled, in addition to the permits they have to purchase to offset own emissions.

It is expected that 2.9 billion CERs (permits generated from CDM projects) will be generated by registered CDM projects by the end of the first Kyoto commitment period. This corresponds to an average of 0.36 billion CERs per year[1]. Under an ambitious climate agreement, the CDM market would thus have to be more than 70 times this size if developed countries are to emit anything at all. And this figure does not take into account the additionality and carbon leakage problems described in the previous section.

A crucial question is therefore whether the CDM can bring about sufficiently large emissions reductions in developing countries in the long term. This depends on the *participation rate* of CDM: this term is used to describe the share of the potentially profitable emissions reduction projects that could be implemented as CDM projects. It is here important to keep in mind that there are several important barriers to implementation, such as lack of capacity to identify and assess potential projects, insurmountable transaction costs, uncertainties and delays with respect to approval, and so forth. Unfortunately, estimates of the potential participation rate are highly uncertain. To our knowledge no reliable estimates are available. Jotzo and Michaelowa (2002) scale back their marginal abatement costs curves based on an assumption that the participation rate is within the range of 0-95 percent. Kallbekken (2007) presents some results based on a participation rate of 10 percent. In our numerical model we take a quite optimistic view, and set the participation rate to 70% percent.

Nevertheless, even with an optimistic view on the participation rate, we see from Table 4 that the CDM-based agreement gives global costs of 1.5 percent of global GDP, up from 1.1 percent in the cap and trade systems reported in Tables 2 and 3.

The global costs have increased relative to a global cap and trade system for two reasons[2]. First, the transaction costs associated with the CDM projects are higher than under a cap and trade system. Second, it is not only the low cost abatement measures that are approved as CDM projects.

To expand the volume of CDM projects to the extent considered in this scenario, it would be necessary to include relatively small projects in the portfolio – and the small projects have high transaction costs per unit of emissions reduction. For example, Michaelowa et al. (2003) estimated that the transaction costs for very small projects (200-2000 tCO_2 per year) are about EUR 100 per ton CO_2[3]. Following Kallbekken (2007) and Jotzo and Michaelowa (2002), we assume transactions costs of 20 percent in our numerical model.

Moreover, to take into account that a CDM regime may induce a larger share of high cost emissions reduction projects than in a cap and trade regime, we have adjusted the marginal abatement costs curve in our numerical model by the implementation of the following assumption: if we rank all of the developing countries' abatement options according to their costs (per unit emissions reduction), we assume that projects acceptable for CDM are evenly spread across the distribution. For further calibration details, see the Appendix.

Table 4. Scenario 3. The CDM-case

		Developing countries	Developed countries	World
Initial allocation of permits	% of BaU	-	-163	-
	$GtCO_2$	20.0	0.5	20.5
Simulated emissions	$GtCO_2$	26.0	-26.0	-
Export of emissions permits	$GtCO_2$	26.0	15.3	41.3
Emissions reductions	$GtCO_2$	57	97	67
Marginal abatement costs	USD/tCO_2	167	167	
Costs of emissions reductions	Billion USD	2 168	1 274	3 443
Net costs of purchasing permits	Billion USD	-4 336	4 336	-
Net cost	Billion USD	-2 168	5 611	3 443
	% of GDP	-2.0	6.3	1.5

A perhaps surprising result from our calculations is that, although the costs of provision of emissions reductions units are increased in the developing countries, the developing countries are better off in a CDM-based regime than under the cap and trade system considered in scenario 1. Their net benefits have increased from 1.3 percent to 2.0 percent of GDP. The reason for this is the impact on the permit price following from the binding participation rate. The binding participation rate drives up the marginal abatement costs. This leads to a higher equilibrium price on permits. This hurts the buyers and benefits the sellers. As we see from comparing Table 2 and Table 4, the developed countries' costs of participating are almost increased by 35 percent.

2.1.4. Scenario 4. Developing countries arenot involved. Table 1 shows that if we are to cut global emissions by 25 percent relative to the 2004 level by 2050, they would have to be cut by 67 percent relative to the 2050 level in the reference scenario. This cannot be achieved by reductions in the developed countries only. Even if all the de-

[1] http://cdm.unfccc.int/Statistics/index.html. The CDM has been operational since the beginning of 2006.

[2] In the numerical simulations we have not taken into account the problems related to estimations of real emissions reductions, as we discussed in section 2.

[3] If, however, new rules, as mentioned in section 2 open for approval of a program of activities, transaction costs related to smaller projects could be scaled down.

veloped countries reduced their emissions to nil in 2050, while developing countries follow their BaU-path, global emissions would *rise* by 67 percent. Thus, an ambitious global target for emissions reductions cannot be achieved without substantial cuts in emissions in developing countries as well. Hence, the scenario 4, as defined above, could be ruled out as a solution.

3. Main conclusions from the numerical illustrations

A main conclusion from our numerical illustrations is that in order to achieve an ambitious target for global emissions reductions, developing countries have to contribute, and their contributions must be substantial. Scenarios 1-3 illustrate different ways to involve the developing countries. A general result from economic theory is that a (cost-effective) global cap and trade system always leads to lower total costs than a (non-cost-effective) CDM regime. This is confirmed by our numerical examples.

The various designs of a future agreement lead to different distribution of costs across countries. In our numerical model we found that the developing countries would prefer the CDM regime to the cap and trade system even if they got an allocation of permit corresponding to their business as usual emissions in the cap and trade regime. This is, however, not a general result, but is due to the estimated abatement costs functions, participation rate and transaction costs. One can always discuss the realism of simple numerical models, as the one applied in this paper. However, we know from economic theory that restrictions of permit sale drives up the permit price, which *cet par* benefit the suppliers. Our numerical model illustrates that it is not obvious that the developing countries in total benefit from expanding the current CDM to sectoral cap and trade and finally to a full cap and trade system, even though they receive a generous initial allocation of permits.

Another important lesson from our numerical illustration is that the costs carried by the developed countries can be significantly higher with an agreement based on CDM compared to a global cap and trade regime. Our calculations indicated that compared to the cap and trade regime where developing countries did not gain from participation (zero costs scenario), the developed countries' costs of the CDM regime is more than doubled.

Concluding remarks

If global emissions are to be stabilized at a level that prevents unacceptable global warming (550 ppm), substantial cuts in emissions in developing as well as developed countries have to be carried out. So far the only contributions to emissions reductions in developing countries are through the CDM. In section 1 we discussed several of the weaknesses of this mechanism and argued that for any given target for the developed countries' emissions reductions, the mechanism is likely to induce an increase in global emissions. In order to evaluate the CDM as an element of an ambitious climate agreement we carried out some numerical simulations of various stylized scenarios. A main conclusion from our simulations is that a CDM regime may substantially increase the global costs of reaching large cuts in global emissions compared to a global cap and trade system. Perhaps even more unfortunate feature of the CDM regime is that it leaves the developed countries with a probably intolerable economic burden.

The literature suggests that even an ambitious climate agreement can be achieved by global costs around 1 percent of global GDP. These optimistic costs estimates presuppose a cost effective distribution of emissions reductions. Developing countries have so far not expressed any willingness to bear any of the economic burdens following from a global climate agreement. However, if the developed countries have to cover all the costs, their economic burden of a cost effective agreement would still not exceed 3 percent of their GDP, according to our calculations (scenario 2). This may still be within the acceptable range, but assumes cost effectiveness along all dimensions. However, a CDM regime is not cost effective and may substantially increase the developed countries' economic burden. Our simulations indicate that a CDM regime more than doubles the developing countries' costs compared to a cap and trade system where the developing countries' net benefit of participation is zero (scenario 2 vs. scenario 3). This is partly due to an inefficient distribution of emissions reductions in a CDM regime and partly due to the large economic transfer from developed to developing countries.

The title of this paper asks whether the CDM is compatible with an ambitious climate agreement. We believe the answer is no. A CDM regime probably put too high economic burden on the developed countries. Hence, likelihood of developed countries being willing to adopt an ambitious climate agreement will therefore be considerably reduced if the CDM is not replaced by a cap and trade system.

The developing countries have not been willing to take on binding emissions commitments. Many of them are, not surprisingly, sceptical to the idea of quantitative commitments since their future economic development, and thus their "need" to generate emissions, is uncertain[1]. Furthermore, these

[1] See Kallbekken and Westskog (2005) for a numerical analysis comparing the costs of a binding agreement and the CDM.

countries are probably sceptical to quantitative commitments due to a future pressure on lowering their allocation of permits over time. An argument put forward by developing countries is their right to have the same economic growth and, if necessary emissions profile, as developed countries have had in the past. They probably fear that once included in a cap and trade regime, sustaining a generous allocation of emissions permits over time might be difficult. A long-term agreement that includes corrections over time to allow for unforeseen changes, for example related to economic growth, could help to reduce the level of uncertainty and reduce the developing countries' risk of facing (high) costs of participation. This might be important as our analysis suggests that developing countries have to be involved in a less costly way than the current CDM if an ambitious climate agreement should be achieved.

In our analysis we compared the current CDM regime with a regime with full cap and trade participation from developing countries. A stepwise approach to full participation in a cap and trade system is to initially include only a limited number of industrial sectors of the developing countries. In terms of impact on total costs and distribution of costs, the sectoral approach has many of the same features as a CDM. The costs of providing emissions reductions increase, as emissions reductions are not cost effectively distributed across the economies. Total emissions reductions in developing countries will be less than first best and the equilibrium permit price will be higher than in a fully fledged cap and trade regime. Another negative feature of the sectoral cap and trade approach is a potentially large-scale carbon leakage if, for example, only a limited share of the energy intensive industrial sectors are included in the cap and trade system. Carbon leakage is of course also a problem with the current design of the CDM, as we discussed in section 1. In the numerical simulation we did not take carbon leakage into account. Accounting for leakages would makes the sectoral cap and trade and the current design of the CDM less favourable compared to a fully fledged cap and trade regime. Furthermore, in our numerical simulations we made the quite optimistic assumption that 70 percent of emissions in developing countries could be abated through CDM projects. However, if the sectors included in a sectoral cap and trade cannot provide sufficient emissions reductions, the CDM regime cannot ensure the fulfilment of an ambitious climate agreement, as we have defined this concept in this paper.

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Appendix

In this paper, we have used a simple calibrated model that divides the world into two regions: developed and developing countries.

The model includes linear marginal abatement cost curves for each region. They are calibrated on the assumption that the marginal cost is USD115.4 per ton CO_2 in both regions when reducing emissions by 67 percent from the BaU level. In other words, the model does not assume that there may be a greater potential for low-cost emissions reductions in developing than in developed countries. Furthermore, when we consider cap and trade regimes it is assumed that there is perfect competition in the permit market, so that the marginal costs in all countries are the same as the carbon price. Moreover, we assume that all countries meet their commitments. As further explained below, our simulations of a regime where developing countries are involved through CDM only, does not imply global cost effectiveness.

In the model, emissions in region i, E_i, are found by assuming a quadratic abatement cost function:

$C_i(q_i) = 1/(2b_i)(E_{0i} - E_i)^2$,

where E_{0i} is the volume of BaU emissions in region i, and b_i is a region-specific parameter. Hence, $E_{0i} - E_i$ is abatement in region i. The marginal abatement cost function follows:

$C_i'(q_i) = (1/ b_i)(E_{0i} - E_i)$.

Emissions in region i is given by:

$E_i = E_{0i} - b_i p$,

where p is the carbon price. The parameter b_i is calibrated based on the assumption that reducing emissions 67 percent from the BaU level in 2050 will require a carbon price of USD 115.4 per ton CO_2.

It is very uncertain how high the price of carbon must be to reduce global emissions to 20.3 $GtCO_2$ in 2050. IPCC (2007b) gives some idea of the level of uncertainty. For a scenario where the target is a greenhouse gas concentration of 550 ppm CO_2e, the IPCC suggests that the price in 2050 will be in the range USD 30-155 per ton CO_2. Hence, our is within the upper half of the price interval estimated by the IPCC.

Given the linear structure of the model, the carbon price is determined by the following equation:

$$p = \frac{\sum_i E_{0i} - \sum_i Q_i}{\sum_i b_i},$$

where Q_i is the total initial allocation of permits for country i.

When modelling CDM we have taken into account that there are some additional transaction costs and that not all types of abatement efforts could be approved as CDM-projects, i.e., that the *participation rate* is lower than 100 percent.

Assume that region i is the developing region. Let δ be the participation ratio. This implies that only a share δ of all abatement activities in region i could be approved as CDM-projects. We assume that the potential CDM-projects, with respect to their cost levels, are evenly distributed among all potential abatement projects. This implies that reducing emissions to δ67 percent by the use of CDM only, will require a carbon price of USD115.4 per ton CO_2.

Furthermore, we have to take transaction costs into account. Let τ be the CDM transaction cost ratio in the sense that when CDM is the applied mechanism, all abatement costs are scaled up with this ratio. Then the marginal abatement costs related to CDM is given by:

$C_{CDM}'(q_i) = (1/ b_i^*)(E_{0i} - E_i)$,

where $b_i^* = \delta b_i/(1+\tau)$. With our numerical assumptions (20 percent transaction costs), $\tau = 0.2$ while we consider a case with a participation rate at 70 percent ($\delta = 0.70$).