MEMORANDUM

No 19/2006

Clean development mechanism (CDM) vs. international permit trading – the impact on technological change.

Cathrine Hagem

ISSN: 0809-8786

Department of Economics
University of Oslo

This series is published by the
University of Oslo
Department of Economics

P. O.Box 1095 Blindern
N-0317 OSLO Norway
Telephone: + 47 22855127
Fax: + 47 22855035
Internet: http://www.oekonomi.uio.no/
e-mail: econdep@econ.uio.no

In co-operation with
The Frisch Centre for Economic Research

Gaustadalleén 21
N-0371 OSLO Norway
Telephone: +47 22 95 88 20
Fax: +47 22 95 88 25
Internet: http://www.frisch.uio.no/
e-mail: frisch@frisch.uio.no

List of the last 10 Memoranda:

A complete list of this memo-series is available in a PDF® format at:
http://www.oekonomi.uio.no/memo/

Clean development mechanism (CDM) vs. international permit trading – the impact on technological change.

by

Cathrine Hagem *,**

Department of Economics, University of Oslo, P.O. Box 1095 Blindern, N-0317 Oslo, Norway

Abstract.

The clean development mechanism (CDM) under the Kyoto Protocol may induce a technological change in developing countries. As an alternative to the CDM-regime, developing countries may accept a (generous) cap on their own emissions, let domestic producers invest in new efficient technologies, and sell the excess emission permits on the international permit market (cap&trade-regime). The purpose of this paper is to show how the gains from investment, and hence the incentive for investment in new technology may deviate between the two alternative regimes. We show that the difference in gains from investment depends on whether the producers face competitive or non-competitive output markets, whether the investment affects fixed or variable production costs and whether the producers can reduce emissions through other means than investment in new technology.

JEL Classification: L13, Q28

Keywords: Climate Policy, Technology Adoption, Emission Trading, Clean Development Mechanism, Technological Change

---

* Work on this article was conducted during my participation in the project "Environmental economics: policy instruments, technology development, and international cooperation" sponsored by the Centre for Advanced Study (CAS) at the Norwegian Academy of Science and Letters in Oslo in 2005/2006. The financial, administrative and professional support of CAS is much appreciated.

** Comments from Geir Asheim and from participants at CAS-workshops are highly appreciated.

1 Introduction

The purpose of this paper is to explore the incentives for investment in energy efficient production technologies under two different climate strategies in developing countries. According to the Kyoto protocol, developing countries have no quantified emission targets for the first Kyoto period (2008 -2012). However, industrialized countries with quantified emission target are allowed to partly meet their reduction commitments through investments in emission reducing projects in developing countries (the clean development mechanism (CDM)). The emission reductions generated from CDM-projects can be used to offset the investor's own emission reduction obligations. We compare the incentives for investment under the CDM with the incentives for investment under an alternative climate policy, namely that the developing country participate in international permit trading on equal terms as the industrialized countries that has ratified the Kyoto Protocol (see UNFCCC (1998), article 17).

According to the Kyoto Protocol, the purpose of the CDM mechanism is not only to reduce the compliance cost for the industrialized countries, but also to assist developing countries in achieving sustainable development (See UNFCCC (1998), article 12). The CDM mechanism is a mean to introduce more environmentally friendly technologies in developing countries. Through spin-off effects from technological improvement in some production units, the CDM mechanism may promote a generally higher level of environmentally friendly technologies in developing countries.

However, there are several drawbacks when it comes to the CDM's ability to promote cost effective abatement efforts in developing countries. An executive board is designated to approve CDM-projects and issue certified emission reduction units (CERs).A condition for the approval of a CDM-project is that the reduction achieved by the project shall be *additional* to any that would occur in the absence of the project activity ((see UNFCCC (1998), article 12).The *additionally* requirement insures that the CERs are based on real emission reductions such that the CDM does not lead to higher global emissions. However, the problem with this criterion is that it must be based on a counterfactual baseline for emission. Once a CDM project is implemented the emissions that would occur without the investment is no longer observable. Both the investor and the host have incentives to overstate the baseline emission in order to make the project more profitable.

Furthermore, the potential investors' effort used in preparing CDM proposals, and the resources used to verify and certify emission reductions may lead to quite high transaction costs for acquiring CERs. (See inter alia Michaelowa (2003) for an overview of estimated transaction cost for various kinds of CDM-projects).

High transaction cost of CDM, and the problems connected with baseline-estimates and verifiability of the emission reduction achieved by the CDM-project, is an argument for including the developing countries in an environmental agreement through a cap&trade-regime instead[1]. A cap&trade-regime implies that a developing country accepts a binding cap for its emissions. The country receives emission allowances (permits) corresponding to its caps for emissions and is allowed to participate in permit trading. If the cap for emissions is generous, a developing country gains from participating in this regime by implementing low-cost abatement options and sell permits on the permit market.

Due to the higher transaction costs of CDM, developing countries may become better off under a cap&trade-regime. However, developing countries have been reluctant to accept binding commitments. One reason for this is that uncertainty about the business as usual (BaU) emissions may incur less benefit than expected. If the BaU emissions turn out to be higher than expected when accepting the emission cap, the cost of the cap&trade-regime may become higher than a CDM-regime, in which emissions reductions are calculated based on project specific baseline[2]. Another reason for developing countries to prefer a CDM-regime is that they may expect that this regime lead to higher transfer of technology than would occur under a cap&trade-regime. One reason for this is that an investor under CDM may have more knowledge about efficient investment options and better financing possibility than a manager in the developing country. On the other hand, the host for the investment project may have more information about the impact of an

[1] This argument is inter alia given in Bohm (2002).

[2] Kallbekken and Westskog (2005) explore the cost and benefit of taking binding commitments for developing countries. They find that the efficiency gain from joining the emission trading regime compared to the CDM-regime might not be very large compared to the risk they incur.

investment on production costs and emissions than the investors. Such asymmetries may lead to inefficiencies (this is inter alia discussed in Hagem (1996) and Wirl et al. (1998)) In Millock ((2002) it is shown how technological transfer as a part of the CDM-contract, can create incentives for mitigating the inefficiency loss from asymmetric information.

In this paper, we ignore the impact of possible asymmetries in information. Furthermore, we assume that emissions and emission reductions can be correctly calculated, and we assume that firms have equal access to new technology under both regimes. Hence, in this paper the developing countries' technological development does not depend on under which regime an investment is implemented , but whether the country decides to invest or not.

We focus our analysis on firm facing imperfect competition in the output market, although we also derive the results regarding firms facing a perfectly competitive output market. Due to the high transaction cost of initiating and implementing a CDM-investment project, it is probably quite large emitters for which emissions can be reduced significantly by an investment, which is attractive for CDM investors. These kinds of firms have typically large fixed cost and face an output market with a limited number of competitors (e.g. large power plants or large industry plants producing e.g. cement). When analyzing the incentives for investment under the CDM-regime is thus relevant to consider the case where the potential hosts for CDM-investments may exercise market power in the output market.

An investment is said to have a positive (negative) strategic effect if the other producers' response to the action increases (decreases) the profit of the producer taking the action. (See e.g. Tirole (1988), chapter 8.) With Cournot competition in the output market, each firm's optimal output and profit are decreasing functions of its competitor's output. Hence, if investment in new more environmentally friendly technology increases the investing producer's output, the investment has a positive strategic effect. If on the other hand, the investment causes the producer to decrease its production, the investment has a negative strategic effect. We show that a CDM-contract may give the firm a strategic disadvantage in the output market. A CDM-contract gives the host for the project an income from emission reduction. However, as long as emissions are increasing in output, a CDM-contract may also lead to larger marginal cost of output production. The firm's profit maximizing output falls, which again cause its competitors to increase their output. This implies that a firm's income from emission reductions under the CDM-regime may reduce the firm's profit from the output market.[3]

The relationship between technological change and environmental policy instruments has been widely analyzed in the literature. (See e.g. Jaffe et al. (2002) for an overview). Incentives for investment in new technology when firms are facing an imperfectly competitive output market are inter alia studied in Montero (2002) and Requate (1998). However, these studies compare emission permits and standards, and no studies we are aware of compare the differences in investment incentives between a cap&trade-regime and a CDM-regime in the case of imperfectly competitive output markets.

In the next section we define the developing countries two options for its climate policy. In section 3 we derive the difference in investment incentives under the two options when the firms in the developing countries face imperfectly competitive output markets. In section 4 we derive the results for firm in developing countries facing a perfectly competitive output market. Concluding remarks are given in the last section.

2 CDM-regime vs. cap&trade-regime

We consider a developing country which is given the opportunity to choose between two climate policy options. It can either join the Kyoto protocol on equal terms as industrialized countries, denoted the cap&trade-regime, or the country can let the domestic firms be hosts for CDM-projects, denoted the CDM-regime.

The CDM-regime implies that a foreign investor finances (some of) the cost of implementing the new technology. The host's emission reductions relative to BaU emissions generate "certified emission reduction units" (CERs) which can be used by the investor to offset own emission reduction obligations. The value of each CER thus equals the international permit price.

---

[3] Bulow et al. (1985) show how an increase in profit from one market may reduce the firm's profit in another (imperfectly competitive) market.

If the developing country participates in emission trading, all domestic firms must hold permits equal to their emissions and are allowed to trade permits on the international permit market.

In order to simplify the comparison of the investment incentives under the two different regimes, we assume that emission reduction requirement of the cap&trade-regime is no stricter than the emission reduction requirement under the CDM-regime, which per definition is zero (the country is not obliged to carry out any emission reductions). Hence, if a country accepts a cap, the number of permits assigned to the country corresponds to the business-as-usual emissions. Furthermore, we assume that the country redistributes the assigned permits to the emitting firms in accordance with their business-as-usual emissions. The latter assumption is made for simplification purposes only, and do not affect our result. Achieving an endowment of tradable permits is a pure windfall gain and does not influence the firms' investment decisions (assuming that pure changes in wealth do not affect the firms' investment decision)[4]. Our assumptions about the cap on emissions and the distribution of free permits implies that if no firms take any actions to reduce emissions, their income are identical under both regimes.

We consider the incentives for investment in energy efficiency improving projects. Such projects could typically lead to lower marginal and/or fixed production costs in addition to the value of the emission reduction. In the following section, we consider investment in a (capital intensive) industry where there are few producers, such that each producer has market power in the output market. A competitive output market is analyzed in section 4.

3 Imperfectly competitive output market.

To show the key idea of the impact of imperfectly competitive output markets, we consider two symmetric firms that operate in a developing country and compete à la Cournot in the output market. We assume that the produced good is sold to a foreign country such that we can ignore any welfare effects due to changes in consumer surplus.

[4] The property of free tradable permits is inter alia discussed in Hagem (2002).

The firms are denoted 1 and 2, but we will sometimes refer to them by the use of *i* and *j*. The firms' productions are energy intensive and each firm's investment in new technology reduces the use of energy for any given level of output.

In the following we consider both the case where the investment increases the productivity of a variable (energy intensive) production factor (3.1), and the case where investment reduces the energy insensitivity of a fixed production factor (3.2).

3.1 Investment increases the productivity of a variable input factor.

In this section, we consider the case where emissions are caused by the use of a variable input factor. We ignore other production costs than the cost of the carbon based energy used in the production. Throughout the paper we use capital letters to denote physical variables under the cap&trade-regime, and small letters to denote physical variables under the CDM-regime. Hence, let E denote the use of energy measured in CO_2- units, X the output, and K the technology parameter under the cap&trade-regime, and let e, x and k denote the same variables under the CDM-regime.

The production function is given by;

$$E_i = (1 - K_i) \cdot X_i \qquad i = 1,2 \quad \text{(Cap\&trade-regime)}$$
$$\textit{and} \tag{1}$$
$$e_i = (1 - k_i) \cdot x_i \qquad i = 1,2 \quad \text{(CDM-regime)}$$

We assume that there is (only) one investment option, $K_i = 0$ $(k_i = 0)$ if the firm does not invest, and $K_i = \overline{K}$ $(k_i = \overline{K})$ if the firm implements the investment[5]. $0 < \overline{K} < 1$.

3.1.1 Firms' profit functions

Cap&trade-regime:

[5] The implication of more than one investment option is discussed in the concluding remarks

For each firm the profit (Π) is the sum of net income from permit sale plus the net income from the output market, less of investment cost (if the firm implements the new technology).

$$\begin{aligned}\Pi_i = \; & t\cdot\left[E^0-(1-K_i)\cdot X_i\right] \\ & +\left[p(X_j+X_i)-q\cdot(1-K_i)\right]\cdot X_i-Q(K_i) \qquad i=1,2 \;\; j=1,2 \;\; i\neq j,\end{aligned} \tag{2}$$

where E^0 is the firms BaU emissions (and equal to the allocation of free permits), q is the price of energy measured in CO_2-units, t is the international permit price, $p(X_j+X_i)$ is the output price (as a function of total supply) and $Q(K_i)$ is the investment cost. $Q(K_i)$ equals 0 for $K_i=0$, and equals $\overline{Q}$ for $K_i=\overline{K}$. The price of the output is decreasing in quantities ($p'<0$).

CDM-regime:

In the following, we assume that the CDM-contract is designed to maximize the joint total profit of the investor and host, that is, profit from output production plus profit from generating emission reductions (CERs). This implies that we disregard any deviating interest between the investor and the host when it comes to the implementation of the CDM-project. Furthermore, we assume that all profit goes to the host. The implication of this latter assumption is discussed in the concluding remarks.

If the firm enters into a CDM-contract, the profit (π) is given by

$$\begin{aligned}\pi_i = \; & t\cdot\left[E^0-(1-\overline{K})\cdot x_i\right] \\ & +\left[p(x_i+x_j)-q\cdot(1-\overline{K})\right]\cdot x_i-\overline{Q} \qquad i=1,2 \quad j=1,2 \quad i\neq j\end{aligned} \tag{3}$$

If the firm does not enter into a CDM-contract, emission reductions have no value as CERs can only be generated through a CDM-contract which involves some kind of investments. If the firm does not enter into a CDM-contract, it does not implement the new technology and the profit function is given by[6];

$$\pi_i = \left[p(x_i + x_j) - q \right] \cdot x_i \qquad i = 1,2 \quad j = 1,2 \quad i \neq j \tag{4}$$

To find the differences in the investment incentives under the two different regimes, we consider a two-stage model. At the first stage, the firms choose whether to invest or keep the old technology. (Investment under the CDM-regime means that the firm enters into a CDM-contract). At the second stage, the firms' output decisions are made. We solve the model backwards. In the next section, we derive the Nash equilibrium in the output market (stage 2). In section 3.1.3 we compare the investment decision at stage 1 under the two different regimes, given that the firms can correctly anticipate the Nash-equilibrium outputs at stage 2 (which follows from the various combinations of investment decisions at stage 1).

3.1.2 Second stage – Output market

Cap&trade-regime:

We see from (2) that maximizing Π_i with respect to X_i gives the following first order condition:

$$p' \cdot X_i + p - (q + t) \cdot (1 - K_i) = 0 \quad i = 1,2 \tag{5}$$

From (5) we find each firm's optimal output level as a function of its own technology parameter and the other firm's output ($X_i\,(K_i, X_j)$).

From total differentiating the firms' first order conditions, and assuming that $p' + p'' \cdot X_i < 0$ to insure the existence of a unique, pure–strategy Nash-equilibrium, we find that[7]

[6] Although the new technology reduces the need for energy per unit production, we assume throughout the paper that the investment is not profitable unless the firm can sell emission permits/CERs.

[7] $\frac{\partial X_i\,(K_i, X_j)}{\partial X_j} = -\frac{p'' \cdot X_i + p'}{p'' \cdot X_i + 2p'}$

$$-1 < \frac{\partial X_i\,(K_i, X_j)}{\partial X_j} < 0\,. \tag{6}$$

(Equation (6) implies that the reaction functions are downward sloping).

Furthermore, we see from the first order condition (5) that

$$X_i\,(\overline{K}, X_j) > X_i\,(0, X_j) \tag{7}$$

For a given level of output from it competitor, the firm produces more if it has invested. We see from (6) that a firm's increased production induces lower output from its competitor. Hence, the competitor's response to the investment increases the investing firm's profit since $p' < 0$. In game theoretical terminology, the investment is said to have a positive strategic effect.

The Nash-equilibrium in the output market is found from solving the two equations given by (5). Let $X_1\,(K_1, K_2)$ and $X_2\,(K_1, K_2)$ denote the Nash-equilibrium outputs in the output market.

From (6) and (7) it follows that

$$X_i\,(\overline{K}, K_j) > X_i\,(0, K_j) \tag{8}$$

$$X_i\,(K_i, \overline{K}) < X_i\,(K_i, 0) \tag{9}$$

Under the cap&trade-regime, investment increases the Nash-equilibrium output of the investing firm, and decreases the Nash equilibrium output from its competitor.

CDM-regime:

If a firm has entered into a CDM-contract, the first order condition for profit maximum is found from maximizing (3) with respect to x_i. The first order condition of the maximization problem is given by

$$p' \cdot x_i + p - (q + t) \cdot (1 - \overline{K}) = 0 \tag{10}$$

If the firm does not enter into a CDM-contract, the first order condition is found from maximizing (4) with respect x_i. In this case, the first order condition is given by;

$$p' \cdot x_i + p - q = 0 \, . \tag{11}$$

From (10) and (11) we find each firm's optimal output level as a function of its investment decisions (that is, the decision to enter a CDM-contract) and the output from the other firm. Let $x_i\,(\overline{K}, x_j)$ denote the solution to (10) and let $x_i\,(0, x_j)$ denote the solution to (11).

Comparing the two first order conditions (10) and (11), we see that

$$x_i\,(\overline{K}, x_j) > x_i\,(0, x_j) \;\; \textit{if} \;\; (q+t)\cdot(1-\overline{K}) < q$$

and

$$x_i\,(\overline{K}, x_j) < x_i\,(0, x_j) \;\; \textit{if} \;\; (q+t)\cdot(1-\overline{K}) > q$$

To find the Nash-equilibrium in the output market we solve the two equations for the firms' first order conditions ((10) and (11)). Let $x_1\,(k_1, k_2)$ and $x_2\,(k_1, k_2)$ denote the Nash-equilibrium outputs under the CDM-regime

As discussed previously, to ensure an existence of a unique Nash-equilibrium in the output market, we have assumed downward sloping reaction functions (see (6)).

Hence, we find that for $(q+t)\cdot(1-k_i) < q$:

$$\begin{aligned} &x_i\,(\overline{K}, k_j) > x_i\,(0_i, k_j) \\ &\text{and} \\ &x_j(\overline{K}, k_j) < x_j(0_i, k_j) \end{aligned} \tag{12}$$

For $(q+t)\cdot(1-k_i) > q$, we find that:

$$\begin{aligned} &x_i\,(\overline{K}, k_j) < x_i\,(0_i, k_j) \\ &\text{and} \\ &x_j(\overline{K}, k_j) > x_j(0_i, k_j) \end{aligned} \tag{13}$$

We see from (12) and (13) that the investment has a positive strategic effect if marginal costs decreases ($(q+t)\cdot(1-k_i) < q$) and a negative strategic effect if marginal costs increases ($(q+t)\cdot(1-k_i) > q$). We refer to the first case as a situation where the investment gives the investing firm a strategic advantage, and the latter case as a situation where investment gives the investing firm a strategic disadvantage.

By comparing the impact of investment under the cap&trade-regime and the CDM-regime, we derive the following proposition:

Proposition 1.

Investment in a technology which increases the productivity of a variable input factor gives the investing firm a strategic advantage under the cap&trade-regime, whereas the investment may give the firm a strategic disadvantage under the CDM-regime.

In the next section we explore how this difference in the strategic effect of an investment influences the difference in the investment incentives under the two regimes.

3.1.3 First stage – Investment decision.

At the first stage each firm decides whether to invest/enter into a CDM contract. When the firms make their investment decisions at stage 1, it is assumed that they can correctly anticipate the Nash-equilibrium in the output market at stage 2. The Nash-equilibrium at stage 2 is a function of both firms' investment decision at stage 1, such that each firm's profit of an investment depends on the investment decision of the other firm. Let $\Pi_i(K_i, K_j)$ denote firm *i*'s profit under the cap&trade-regime and let $\pi_i(k_i, k_j)$ denote firm *i*'s profit under the CDM-regime. Under each regime, there are four different combinations of investment decisions and hence four different outcomes for the profit for each firm.

In table 1 (for the cap&trade-regime) and in table 2 (for the CDM-regime), we summarize that investment game at stage 1, and the payoffs following from the different outcomes at stage 2. (In order to simplify the discussion we refer to the different outcomes by a letter and a number (i.e $\Pi_1(\overline{K}, \overline{K})$ is referred to as A1 (see table 1 and table 2))).

Table 1. Investment decisions and payoffs under the cap&trade-regime.

Firm 1 / Firm 2	Invest ($K_1 = \overline{K}$)	Don't invest ($K_1 = 0$)
Invest ($K_2 = \overline{K}$)	$\Pi_1(\overline{K},\overline{K}) \equiv A1$ $\Pi_2(\overline{K},\overline{K}) \equiv A2$	$\Pi_1(0,\overline{K}) \equiv B1$ $\Pi_2(0,\overline{K}) \equiv B2$
Don't Invest ($K_2 = 0$)	$\Pi_1(\overline{K},0) \equiv D1$ $\Pi_2(\overline{K},0) \equiv D2$	$\Pi_1(0,0) \equiv C1$ $\Pi_2(0,0) \equiv C2$

Table 2. Investment decisions and payoffs under the CDM-regime.

Firm 1 / Firm 2	Invest ($k_1 = \overline{K}$)	Don't invest ($k_1 = 0$)
Invest ($k_2 = \overline{K}$)	$\pi_1(\overline{K},\overline{K}) \equiv a1$ $\pi_2(\overline{K},\overline{K}) \equiv a2$	$\pi_1(0,\overline{K}) \equiv b1$ $\pi_2(0,\overline{K}) \equiv b2$
Don't Invest ($k_2 = 0$)	$\pi_1(\overline{K},0) \equiv d1$ $\pi_2(\overline{K},0) \equiv d2$	$\pi_1(0,0) \equiv c1$ $\pi_2(0,0) \equiv c2$

In the following, we discuss how the two different regimes may lead to different Nash-equilibriums for the investment decisions, although the investment option and the firms' production functions are identical under both regimes.

Since both firms have identical production functions, we must have that

A1=A2, a1=a2, C1=C2, c1=c2, B1=D2, b1=d2, D1=B2 and d1=b2.

Furthermore, we see from the first order conditions (5) and (10), that if both firms invest, the Nash-equilibrium in the output market is identical under both regime, such that *A1=A2=a1=a2*.

We saw in the previous section that investment always increased the investing firm's output ((see (8)) under the cap&trade-regime. Since higher output from firm *i* is a disadvantage for firm *j*, each firm is better off if the other firm does not invest. ($\frac{\delta\Pi_i}{\delta X_j} = p' \cdot X_i < 0$). Hence, under cap&trade-regime we must have that

$$\begin{aligned} D1 &> A1 \quad (B2 > A2) \\ C1 &> B1 \quad (C2 > D2) \end{aligned} \tag{14}$$

Under the CDM-regime, the ranking of the different outcomes depends on whether the investment increases or decreases the investing firm's output. If investment leads to larger output ($(q+t)\cdot(1-k_i) < q$), each firm is better off if the other firm does not invest (as under the cap&trade-regime), and

$$\begin{aligned} d1 &> a1 \quad (b2 > a2) \\ c1 &> b1 \quad (c2 > d2) \end{aligned} \tag{15}$$

In the case where investment leads to lower output ($(q+t)\cdot(1-k_i) > q$), each firm is better of if the other firm invests, and we must have that

$$\begin{aligned} d1 &< a1 \quad (b2 < a2) \\ c1 &< b1 \quad (c2 > d2) \end{aligned} \tag{16}$$

In the following we consider the case where the investment project is such that under both regimes, the firms prefer an outcome where both firm invest compared to an outcome where none of the firm invests.

This implies that $A1=A2>C1=C2$ and $a1=a2>c1=c2$, and it follows from (14) that there is only one possible ranking of the outcomes for firm 1 and 2 under the cap&trade-regime:

$$\begin{aligned} &Firm\ 1: D1 > A1 > C1 > B1 \\ &Firm\ 2: B2 > A2 > C2 > D2 \end{aligned} \tag{17}$$

For this ranking, "invest" is a dominant strategy for both firms, and the unique Nash-equilibrium at stage 1 is that both firms invest under the cap&trade-regime.

Under the CDM-regime, the ranking of the different outcomes depends on whether the strategic effect of an investment is positive or negative. If the strategic effect is positive, we find the same ranking of the outcomes as under the cap&trade-regime. Hence, for $(q+t)\cdot(1-k_i) < q$, the ranking must satisfy (15), and there is only one possible ranking of the outcomes:

$$\begin{aligned} &Firm\ 1: d1 > a1 > c1 > b1 \\ &Firm\ 2: b2 > a2 > c2 > d2 \end{aligned} \tag{18}$$

Hence, if the strategic effect of the investment is positive, the Nash equilibrium at stage 1 is that both firms invest under the CDM-regime

Let us now consider the case where investment gives a strategic disadvantage, that is $(q+t)\cdot(1-k_i) > q$, and the ranking of outcomes fulfills (16) . (Note that although $c1<a1$, this is not sufficient to ensure that $a1>b1$ since $b1>c1$.) If the strategic disadvantage of investment is sufficiently large, each firm prefers to "not invest" regardless of what the other firm chooses. Hence, "not invest" may become a dominant strategy, and we have the following ranking of outcomes[8]:

$$\begin{aligned} &Firm\ 1: b1 > a1 > c1 > d1 \\ &Firm\ 2: d2 > a2 > c2 > b2 \end{aligned} \tag{19}$$

This ranking leads to a unique Nash-equilibrium where none of the firm invests.

We can now derive the following proposition:

---

[8]Note that the ranking given by (19) is only one of several possible rankings.

Proposition 2.

Consider the case where the outcome where both firms invest is preferred to the outcome where none of the firms invests under both regimes. This situation leads to a unique Nash-equilibrium where both firms invest under the cap&trade–regime, whereas the CDM-regime may lead to a prisoner's dilemma outcome where none of the firms invests.

Proof of proposition 2.

A numerical example suffices. Let the demand function for the commodity produced by the two firms be $p(x) = 30 - x$*. (*$x = x_i + x_j$ *under the CDM-regime, and* $x = X_i + X_j$ *under the cap&trade-regime). Furthermore let q=1 and t=2.*

For $\overline{K}$ *=4/5 and Q=15, we find that* $D1(\approx 120) > A1(\approx 103) > C1(\approx 100) > B1(\approx 87)$ *and* $d1(\approx 106) > a1(\approx 103) > c1(\approx 93) > b1(\approx 91)$ *which makes it a dominant strategy to invest under both regimes.*

For $\overline{K}$ *=1/5 and Q=3, we find that* $D1(\approx 105) > A1(\approx 101) > C1(\approx 100) > B1(\approx 97)$ *and* $b1(\approx 103) > a1(\approx 101) > c1(\approx 93,4) > d1(\approx 92,6)$ *which makes it a dominant strategy to invest under the cap&trade-regime, whereas it is s dominant strategy to not invest under the CDM-regime.* □

The prisoner's dilemma situation occurs because of the strategic disadvantage of investment under the CDM-regime. Investment has two deviating effects on the marginal cost of output production. On one hand, the investment increases the marginal cost of production because entering into a CDM contract also implies that emissions have become costly. Each unit emission gives one unit less CDM-credits and hence decreases the benefit of the CDM project by the unit cost of permits. On the other hand, the investment increases the energy efficiency and thus decreases the use of energy per produced output, which cet. par decrease the marginal cost of production. If the former effect dominates the latter, the net marginal cost of production increases due to the investment. Lower production from the investing firm leads to higher production from its non-investing competitor. The competitor's increase in production causes the output price to fall and hence hurts the investing firm. If the investment cost plus the fall in income from the product market more than offsets the increase in income following from the generation of CDM credits, the firm is better of not investing if the other firm abstains from investment. The other side of the coin is that a firm becomes better off when its competitor invests if the investment gives the investing firm a strategic disadvantage. Lower output from its competitor increases the output price, and the firm that has not invested gets a larger share of the output market. This may make it a dominant strategy not to invest, although both firms are better off if both invest compares to the Nash equilibrium where none of the firms invests.

The difference in gains from investment between the two regimes followed from the fact that investment in cleaner technology also affected the marginal profit of production differently. In the next section, we consider an abatement option that does not affect the firms' marginal profit of production, and we evaluate how this investment option affects the investment decisions.

3.2 Investment affects the emissions from a fixed production factor.

Consider the case where it is the fixed production factor and not the variable production factor that generates emissions. This is for instance the case if emission follows from heating /cooling of the production plant. Furthermore, assume that there is a possibility for the firm to reduce emissions through various kinds of abatement efforts.

The abatement cost function, D, is given by

$$D(E_i, K_i) = (1 - K_i) \cdot C(E^0 - E_i) \quad i = 1,2 \quad \text{(cap\&trade-regime)}$$

and

$$D(e_i, k_i) = (1 - k_i) \cdot C(E^0 - e_i) \quad i = 1,2 \quad \text{(CDM-regime)},$$

where $E^0 - E_i(e_i)$ is abatement carried out by firm i. Marginal abatement cost is positive for all $E^0 - E_i(e_i) > 0$, and is increasing in abatement ($C' > 0, \quad C'' > 0$).

Since output is independent of emissions, the profit from the output market is independent of any abatement efforts. Let $p\overline{X}$ denote the firm's profit following from the Nash-equilibrium output at stage 2. Since each firm's output is independent of the investment decision, this correspond to a situation where *A1(A2)=D1(B2), B1(D2)=C1(C2), a1(a2)=d1(b2) and b1(d2)=c1(c2)* in table 1 and table 2.

Cap&trade-regime:

The firms' profits under the cap&trade-regime can be written:

$$\Pi_i(K_i) = \quad t \cdot \left[E_i^0 - E_i \right] - (1 - K_i) \cdot C(E^0 - E_i) \\ - Q(K_i) + p\overline{X}$$

Maximizing the firms profit with respect to E_i gives the following first order condition:

$$t = (1 - K_i) \cdot C'(E^0 - E_i) \tag{20}$$

Let $E_i(\overline{K})$ denote the solution to (20) for $K_i = \overline{K}$ and let $E_i(0)$ denote the solution to (20) for $K_i = 0$

We define the gains from investment ($\Delta\Pi_i$) as the increase in profit due to investment, that is

$$\begin{aligned} &\Delta\Pi_i = \Pi_i(\overline{K}) - \Pi_i(0) = \\ &\left[t \cdot (E^0 - E_i(\overline{K})) - (1 - \overline{K}) \cdot C(E^0 - E_i(\overline{K})) - \overline{Q} \right] \\ &- \left[t \cdot (E^0 - E_i(0)) - C(E^0 - E_i(0)) \right] \end{aligned} \tag{21}$$

The firm invests under the cap&trade-regime if (21) is positive, that is, if *A1(A2)=D1(B2)>B1(D2)=C1(C2)*.

CDM-regime:

If the firm enters into a CDM-contract, the profit function is given by

$$\pi_i(\overline{K}) = \quad t\cdot\left[E^0 - e_i\right] - (1-\overline{K})\cdot C(E^0 - e_i)$$
$$-\overline{Q} + p\overline{X}$$

Maximizing the firm's profit function with respect to e_i, gives the following first order condition:

$$t = (1-\overline{K})\cdot C'(E^0 - e_i) \tag{22}$$

Let $e_i(\overline{K})$ denote the solution to (22).

If the firm does not enter into a contract, there is nothing to gain by reducing emissions and profit arises only from the output market.

The gains from investment under the CDM-regime, denoted $\Delta\pi_i$ is given by

$$\Delta\pi_i = \pi_i(\overline{K}) - \pi_i(0) = t\cdot\left[E^0 - e_i(\overline{K})\right] - (1-\overline{K})\cdot C(E^0 - e_i(\overline{K})) - \overline{Q} \tag{23}$$

The firm invests under the CDM-regime if (23) is positive, that is, if *a1(a2)=d1(b2) > b1(d2)=c1(c2)*.

We see from (20) and (22) that $E_i(\overline{K}) = e_i(\overline{K})$. This implies that the firm's profit if it has invested is identical under both regimes, that is *A1(A2)=D1(B2)=a1(a2)=d1(b2)*. By comparing the gains from investment under the two regimes ((21) and (23)), we derive the following proposition:

Proposition 3.

If the only abatement possibility is to reduce emissions from a fixed production factor, the gains from investment under the CDM-regime is always higher than (or equal to) the gains from investment under the cap&trade-regime.

Proof of proposition 3:

If we compare (21) and (23), we see that $\Delta\pi_i = \Delta\Pi_i$ *for* $E_i(0) = E^0$. *For* $E_i(0) < E^0$, *we find that* $\Delta\pi_i > \Delta\Pi_i$ *since* $\left[t \cdot (E^0 - E_i(0)) - C(E^0 - E_i(0))\right] > 0$ *if it is profitable for a firm under the cap&trade-regime to implement any abatement effort if it does not invest.*

□

For the investment option considered in this section, there is no strategic disadvantage of investing. The difference between the two regimes is only that under the CDM-regime the firm only gets access to the permit market if it invests, whereas under the cap&trade-regime, the firm has an option to earn money on emission reduction even without investment. It can sell excess permits if it implements some abatement effort under the cap&trade-regime. If the abatement effort (for K=0) is profitable, *B1(D2)=C1(C2)>b1(d2)=c1(c2)*, and the gains from investment is larger under the CDM-regime than under the cap&trade-regime[9]. Hence, an investment option that is not implemented under the cap&trade-regime may be implemented under the CDM-regime.

If no abatement effort is profitable unless the firm has invested, that is, *B1(D2)=C1(C2)=b1(d2)=c1(c2)*, the gains from investment is identical under the two regimes.

4 Competitive output markets.

In the section 3 we considered a situation where the firms faced an imperfectly competitive output market. In the case where investment affected the marginal profit from production (3.1), it also affected the strategic position in the output market, which again changed the competitor's equilibrium output and hence the equilibrium output price.

[9] As pointed out in section 2, the difference in the gains from investment between the two regimes does not depend on whether the firms receive any permits free of charge under the cap&trade-regime. The net gains from investment under a CDM-regime is always larger than (or equal to) the gains from investment under a cap&trade-regime, since (A1-B1) = (D1-C1) $\leq$ (a1-b1) = (d1-c1). Distributing permits free of charge increase the profit for firms under the cap & trade regime by $t \cdot E^0$, whether they invest or not.

If we consider the case where the firms only produce a small share of the world market, the price of the produced good are independent of their output, and is hence not affected by their investment decision. The investment only affects the investing firm's output, and does not change the equilibrium output price. This implies that each firm considers its benefit from investment as independent of the other firm's action.

Hence, this corresponds to the situation described in section 3.2, and we must have that *A1(A2)=D1(B2), B1(D2)=C1(C2)* and *a1(a2)=d1(b2), b1(d2)=c1(c2)*. The difference between the two regimes is only that under the CDM-regime, the firms get access to the permit market if they invest, but not if they do not invest, whereas under the cap&trade-regime, the firms have an option to earn money on permit sale, through the implementation of various abatement efforts, even though they do not invest (as discussed in the previous section). Hence, the gains from investment cannot be lower under the CDM-regime than under the cap&trade-regime.(*(A1-B1)= (D1-C1)≤ (a1-b1)=(d1-c1)*).

This discussion leads to the following proposition:

Proposition 4.

If firms face a competitive output market, the net gains from investment under a CDM-regime is higher than (or equal to) the gains from investment under the cap&trade-regime.

Hence, it is more likely that investment occurs under the CDM-regime than under the cap &trade regime when the firms are facing competitive output markets (and the access to abatement technology is identical under both regimes).

5 Concluding remarks

The purpose of this paper was to compare the incentives for investment in new technology under two different climate policies. We showed that if the producers face competitive output markets, or if the investment do not influence marginal production cost, the gains from investing under a CDM-regime is larger than (or equal to) the gains from investing under a cap&trade-regime. When producers face an imperfectly competitive output market, an investment may give the firm a strategic disadvantage in the output market under a CDM-regime. This effect makes it less profitable to invest under a CDM-regime than under a cap&trade-regime.

If firms compete in perfectly competitive markets, or if the investment only affects the emissions from a fixed production factor, there is no strategic effect of the investment. In that case, the only difference between the incentives for investment follows from the difference in firms' opportunity to reduce emission without investing, and a CDM-regime may induce more investment than a cap&trade-regime. However, the CDM-regime leads to higher abatement cost for the producers than a cap&trade-regime as the most efficient abatement option is not always chosen (if the most efficient abatement does not include an investment).

In the paper, we considered a situation where there was only one investment option. However, there may be a range of different technologies that can reduce emissions and/or increase the energy efficiency of the firm. Since investment affects the firms strategic position in the output market differently under the two regimes considered in this paper, it can also be the case that the firms chooses different level of investment under the two regimes .

We have also ignored the fact that, in principle, the calculated emission reductions from a CDM-project should correct for leakages. We showed that investment in new technology in one firm affected the equilibrium output of the other firm, and hence also affected the emissions from the other firm (carbon leakage). Taking this effect into account makes it even less profitable to invest if the investment gives the firm a strategic disadvantage in the output market. Investment then both makes the firm lose market shares and increase the competitors output (and hence emissions), which reduces the calculated emission reduction achieved by the investment.

We have also assumed that the hosts for the CDM projects receive the whole net income from the project. However, it is likely that investor seeks to achieve more than a zero profit from its investment. In that case, the producers in the developing countries get less incentive to invest in new technology under the CDM regime compared to a cap&trade-regime (where they do not have to share the profit with the foreign investor).

References:

Bohm, P. (2002): "Improving Cost-effectiveness and Facilitating Participation of Developing Countries in International Emission Trading", *International Environmental Agreements: Politics, Law and Economics* **3**, 261-275.

Bulow, J., J. Geanakopolos, and P. Klemperer (1985): "Multimarket Oligopoly: Strategic Substitutes and Compliments". *Journal of Political Economy* **93**, 488-511

Hagem, C. (1996): "Joint Implementation under asymmetric information and strategic behavior". *Environmental and Resource Economics*, **8**, 431-447

Hagem, C. (2002): " A note on the Kyoto Protocol, Tradable Quotas, and Firm Survival, *Environmental and Resource Economics* **22**, 467-468.

Jaffe, A.B., R.G. Newell and R.N. Stavins (2002): "Environmental Policy and Technological Change", *Environmental and Resource Economics* **22**, 41-69.

Kallbekken, S. and H. Westskog (2005): "Should developing countries take on binding commitments in a climate agreement? An assessment of gains and uncertainty". *Energy Journal*, **26** (3): pp. 41-60.

Michaelowa, A., M. Stronzik, F. Eckerman and A. Hunt (2003):"Transaction costs of the Kyoto Mechanism", *Climate Policy*, vol 3, issue 3, September 2003, 261-278

Milloc, K. (2002): "Technology transfer in the Clean Development Mechanism: an incentives issue", *Environment and Development Economics* **7**, 449-466

Montero, J-P (2002): Permits, Standards, and Technology Innovation", *Journal of Environmental Economics and Management* **44**, 23 - 44.

Requate, T. (1998): "Incentives to innovate under emission taxes and tradable permits", *European Journal of Political Economy* **14***, 139-165.*

Tirole, J. (1988): *The Theory of Industrial Organization*, The MIT Press, Cambridge

UNFCCC (1998): "The Kyoto Protocol to the Convention on Climate Change", (http://unfccc.int/essential_background/kyoto_protocol/

Wirl, F., C. Huber and I.O. Walker (1998): "Joint implementation: strategic reactions and possible remedies" *Environmental and Resource Economics*, **12**, 203-224