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Contracts for Clean Development – The Role of Technology Transfers

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Abstract

The Clean Development Mechanism (CDM) offers abatement cost savings under the Kyoto Protocol by allowing credits for emission reductions obtained in signatory developing countries. The paper shows that it is necessary to include technology transfers in the CDM to obtain correct incentives for emission reductions when there are monitoring difficulties.

CONTRACTS FOR CLEAN DEVELOPMENT –THE ROLE OF TECHNOLOGY TRANSFERS

1. Introduction

The Kyoto Protocol, signed in December 1997, specifies binding emission reduction targets for anthropogenic greenhouse gas emissions for signatory countries listed in Annex I. The Protocol includes three flexible mechanisms (UNFCCC, 1998): emissions trading (article 17), Joint Implementation, JI (article 6), and, the Clean Development Mechanism, CDM (article 12). Whereas emissions trading and JI apply to signatories listed in Annex I[1], the CDM was developed as a means of involving developing countries in global climate change mitigation policies. Specific conditions were imposed on the CDM in order to guarantee its acceptability. First, it should contribute to sustainable development in the host country of the investment. Second, it should be additional to any existing aid, and not crowd out normal aid payments.

Though the CDM was anticipated to start in January 2000, serious problems obstruct its implementation.[2] The main problems are shared also by the other project based mechanism, JI; the baseline emission scenario is not observable ex ante and it is difficult to verify the emission reduction obtained by the project. Because of the difficulties to observe the actual emission reductions, both the investing party and the host country have incentives to overstate the emission reductions created by the project. The host country in order to obtain a higher transfer payment, and the investing party in order to maximise the credits earned towards its emission reduction commitment under the Kyoto Protocol. Incomplete information limits the efficiency gains from JI

[1] Mainly the OECD countries, except recent entrants Mexico, South Korea, plus Russia and the Central European countries.
[2] Comprehensive expositions are contained in Goldemberg (1998) and Grubb (1999).

(Hagem, 1998), and Wirl, Huber and Walker (1998) and Janssen (1999) propose some mechanisms and institutions to provide correct incentives for JI projects when there is asymmetric information between the investing party and the host party. Yet, the problem of establishing credible contracts for the CDM is somewhat different. First, the host party does not have a binding emissions target. Second, the commercial potential of a CDM project could outweigh the value of its emission reduction credits. And, third, the goal of the CDM is not only to obtain efficient emission reductions but also to contribute to sustainable development in the host country. This paper explicitly incorporates the specific characteristics of the CDM, and will argue that it is necessary to include technology transfers for a full analysis of the CDM. I will show that technology transfers are not only a matter of equity, but can help to solve some of the incentive problems of implementing the CDM with imperfect monitoring of emission reductions. The uncertainty around emission reductions from land use change and forestry activities is particularly great, and difficulties of monitoring and enforcement have reduced the credibility of the CDM among environmental groups. Designing self-enforcing contracts is thus important if the CDM is to be used to its full potential.

The analysis also contributes to solutions of another potential problem of the CDM: "cream-skimming". According to this argument, developing countries that host CDM projects are likely to lose out since the cheap abatement options will be exploited by Annex I countries. If, at a later time, the host countries will be subject to a binding emission reduction target, only more expensive options of abatement remain. Rose, Bulte and Folmer (1999) recently formalized the argument. They showed that under certain assumptions on technological change, the stock of abatement possibilities in the host country indeed could decrease due to the flexibility mechanism. The authors conclude that one policy priority is to design transfer payments to compensate for this effect. Such payments are part of the contracts I analyse here. I will show how a combination of transfer payments and technology transfers can contribute to solving the incentive problem between the investor and the host country when there is private information.

Section 2 presents a model of contracting under the CDM when there is asymmetric information between the investor and the host country related to a technical abatement efficiency parameter. A simplified version of this model yields the standard inefficiency result of contracts under asymmetric information. The aim of the article is to show how this inefficiency may be mitigated in the CDM. The first possibility (Section 3.1) originates from the fact that there may be a commercial rent attached to the project. Depending on the correlation between the technical parameter of the agent and the commercial rent of the project, incentives for truthful emission reductions may be strengthened. A second possibility (Section 3.2) that can mitigate the efficiency loss from asymmetric information originates from the fact that host countries, at present, do not have emission reduction constraints. Future emission constraints would impose different costs on each country, and thus, the reservation utility of each country would be type-dependent. Depending on the correlation between abatement efficiency and reservation utility, type-dependent utility is enough to mitigate the efficiency loss from asymmetric information. In Section 4, I go on to argue that countervailing incentives can be created following Lewis and Sappington (1989a; 1989b) by taking seriously the constraint that the CDM should contribute to sustainable development. This objective would be promoted by technology transfers, which furthermore would mitigate incentives to overstate costs if the correlation between abatement efficiency and the technological capacity that is transferred is negative. Resulting policy implications of the theoretical analysis are discussed in Section 5, while Section 6 concludes.

2. The model

The investing party is treated as the principal, with the objective of obtaining emission reductions through the CDM in order to comply with its emission reduction objective under the Kyoto Protocol. For this purpose the principal chooses to invest in emission reduction projects abroad of a quantity of E.[3] The host country's utility from the emission reduction obtained abroad is denoted V(E) and assumed to be an increasing and concave function in E. Potential host countries for the emission reduction investment differ by a technology parameter β, which is distributed on a support $\left[\underline{\beta}, \overline{\beta}\right]$. The demanded emission reduction abroad is a function of the efficiency parameter of the host country, E(β). Emission reduction costs are assumed to be increasing in β, and so $\underline{\beta}$ represents the most efficient agent, and $\overline{\beta}$ the least efficient agent. Furthermore, I simplify the model by assuming constant unit costs of emission reductions, c:

$$C(E(\beta),\beta)=\beta c E(\beta) \qquad (1)$$

In return for the emission reduction credits the investor country makes a transfer payment T(β) to the host country.

The CDM project furthermore carries a commercial rent, denoted π(β). JI projects can also carry a commercial rent, but especially for the CDM, it is crucial not to omit this feature in an analysis of agents' incentives, since the host country itself can propose projects for the CDM with the objective of attracting foreign investment for development. Different assumptions on the relationship between the technology parameter and the commercial rent will be investigated in the analysis. The part of the commercial rent accorded to the host country is denoted $\alpha \in [0,1]$, with (1-α) accruing to the

[3] It is thus implicitly assumed that the marginal cost of emission reductions in potential CDM host countries is lower than the principal's domestic marginal abatement cost.

investing party. The host country's objective is to maximise the income from the emission reduction project, net of costs:

$$U(\beta) = \alpha\pi(\beta) + T(\beta) - \beta c E(\beta)\,. \tag{2}$$

Imperfect information on behalf of the investor creates a possibility for the host country to exaggerate its emission reduction costs in order to receive a larger compensatory transfer. I make the standard assumption that the host country does not know individual values of β, but only its overall density function, f(β), and distribution function F(β) on the support $[\underline{\beta}, \overline{\beta}]$.

Based on the revelation principle, the problem is written in the form of a mechanism under which the host country receives compensation according to the announcement of its technology parameter, $\hat{\beta}$. Assuming that there are no other externalities involved in the transfer of emission reduction credits, the objective of the investing country is:

$$\underset{T(\beta),E(\beta)}{Max} \quad \int_{\underline{\beta}}^{\overline{\beta}} \left[V(E(\beta)) + (1-\alpha)\,\pi(\beta) - T(\beta)\right] f(\beta) d\beta \tag{3a}$$

s.t. (IR) $\alpha\pi(\beta) + T(\beta) - \beta c E(\beta) \geq 0$ (3b)

(IC) $\alpha\pi(\beta) + T(\beta) - \beta c E(\beta) \geq \alpha\pi(\beta) + T(\hat{\beta}) - \beta c E(\hat{\beta}) \quad \forall \beta, \forall \hat{\beta}$ (3c)

Note that it is assumed that the commercial rent is related to the true value of β. The constraints are standard. The individual rationality constraint (3b) imposes the condition that the net profits of the host country have to exceed the alternative opportunities representing its reservation utility, here assumed identical and equal to zero. The incentive compatibility constraint (3c) ensures that the host country will reveal actual costs of emission reductions truthfully, e.g. the announcement $\hat{\beta}$ equals actual costs β.

Before analysing the optimal CDM contract, note that when the commercial rent is zero the problem reduces to a standard model of JI contracts under asymmetric information with a consequent efficiency loss. Since it is well known that such contracts are less efficient under incomplete information, I only present the main implications here and leave the detailed proof to an Appendix:

Proposition 1:

Under asymmetric information, when only considering the marginal emission reduction cost with accompanying transfer, host country utility will be decreasing in the technology parameter ($U'(\beta) = -cE(\beta)<0$); there will be no distortion in the emission reduction for the most efficient agent, $\beta = \underline{\beta}$, but sub-optimal levels of emission reductions will be contracted with all other agents.

Proof: In Appendix.

Since host parties to emission reduction projects would have incentives to maximise the income earned from the project by exaggerating abatement costs in order to get higher financial compensation, demanded emission reduction levels are distorted from first-best in order to get incentive-compatible contracts (as in the models of JI by Hagem, 1998 and by Wirl, Huber and Walker, 1998). In the next Section, I will show how the special features of the CDM may mitigate this distortion.

3. Countervailing incentives as an intrinsic feature of CDM contracts?

3.1. The impact of the commercial rent of the project

The inclusion of a commercial rent linked to the emission reduction project modifies the standard conclusion on the efficiency losses from asymmetric information under JI/CDM. This Section derives the solution to the problem stated in equations (3), following Lewis and Sappington's (1989a) analysis of countervailing incentives.

Necessary and sufficient conditions for an agent to truthfully reveal β are[4]:

$$U'(\beta) = \alpha\pi'(\beta) - cE(\beta) \qquad \forall\beta \tag{4a}$$

$$E'(\beta) \leq 0 \tag{4b}$$

Condition (4b) is a normal monotonicity constraint implying that the lower the abatement cost, the larger emission reduction will be demanded. Unlike the standard case defined in Proposition 1, equation (4a) indicates that agent utility may increase or decrease with β, depending on the relation between the technology parameter and the commercial rent. Whenever $\pi'(\beta) \leq 0$, utility decreases monotonically with β, yielding the standard result in Proposition 1. However, if $\pi'(\beta) > 0$, countervailing incentives will exist. The likelihood of this will be discussed later, but for now, consider the following possibility. Countries with a high β have less efficient equipment for emission reductions. However, an argument on the basis of declining marginal productivity of investment would have that the gain from investing in such a country to update its energy-using equipment would be higher than in a country that already has efficient equipment. While acknowledging that the relationship between the commercial rent and the technology parameter is an empirical matter, we will start by exploring the possible consequences of countervailing

[4] See e.g. Guesnerie and Laffont (1994).

incentives, following Lewis and Sappington (1989a).[5] The calculations are simplified by the assumption that commercial rent is proportional to the technology parameter : $\beta\pi$. The utility of a truth-telling agent then varies according to $U'(\beta) = \alpha\pi - cE(\beta)$. Since E'(β)≤0, the emission reduction effect is likely to outweigh the impact of the commercial rent for low levels of β, whereas for high levels of β, the demanded emission reduction is small and utility will be increasing in β. The solution will therefore differ according to the region of β[6]:

$$\begin{array}{lll} \beta \in \left[\underline{\beta}, \beta_1\right] & & \alpha\pi - cE(\beta) < 0 \\ \beta \in \left[\beta_1, \beta_2\right] & \text{when} & \alpha\pi - cE(\beta) = 0 \\ \beta \in \left[\beta_2, \overline{\beta}\right] & & \alpha\pi - cE(\beta) > 0 \end{array} \tag{5}$$

The utility of an agent can accordingly be defined as follows:

$$U = \begin{cases} \int_{\underline{\beta}}^{\beta_1} \left[cE - \alpha\pi\right] d\beta & \beta \in \left[\underline{\beta}, \beta_1\right] \\ 0 \qquad\qquad for & \beta \in \left[\beta_1, \beta_2\right] \\ \int_{\beta_2}^{\beta} \left[\alpha\pi - cE\right] d\beta & \beta \in \left[\beta_2, \overline{\beta}\right] \end{cases} \tag{6}$$

Since $U(\beta) = \alpha\beta\pi + T(\beta) - \beta cE(\beta)$, solving for the transfer T gives:

[5] At the end of the Section, I will discuss different interpretations of the relationship between the commercial rent and the technology parameter.

[6] It is assumed that $cE(\overline{\beta}) < \alpha\pi < cE(\underline{\beta})$.

$$
T(\beta) = \begin{cases} \int_{\underline{\beta}}^{\beta_1} [cE - \alpha\pi] d\beta + \beta[cE - \alpha\pi] & \beta \in [\underline{\beta}, \beta_1] \\ \beta[cE - \alpha\pi] \quad\quad for & \beta \in [\beta_1, \beta_2] \\ \int_{\beta_2}^{\beta} [\alpha\pi - cE] d\beta + \beta[cE - \alpha\pi] & \beta \in [\beta_2, \overline{\beta}] \end{cases} \tag{7}
$$

Define total surplus from the CDM project as W:

$$W=V+\beta[\pi\text{-}cE]. \tag{8}$$

Substituting for T(β) in the original problem defined in equation (3a), using derivation by parts and the definition of W, the welfare maximisation problem can be rewritten as:

$$
\underset{E(\beta)}{Max} \quad \int_{\underline{\beta}}^{\beta_1} \left\{ W - \frac{F(\beta)}{f(\beta)} [cE - \alpha\pi] \right\} f(\beta) d\beta + \int_{\beta_1}^{\beta_2} W \, f(\beta) d\beta + \int_{\beta_2}^{\overline{\beta}} \left\{ W - \frac{(1 - F(\beta))}{f(\beta)} [\alpha\pi - cE] \right\} f(\beta) d\beta \tag{9}
$$

Assuming an interior solution, the first order conditions of the optimisation problem are:

$$
V'(E(\beta)) - c\left(\beta + \frac{F(\beta)}{f(\beta)} \right) = 0 \quad\quad \forall \beta \in [\underline{\beta}, \beta_1] \tag{10a}
$$

$$
V'(E(\beta)) - c\left(\beta - \frac{(1 - F(\beta))}{f(\beta)} \right) = 0 \quad\quad \forall \beta \in [\beta_2, \overline{\beta}] \tag{10b}
$$

Unlike the standard result of Proposition 1, there is now no distortion in the emission reduction demanded either by the most efficient agent or by the least efficient agent. However, the distortion in the emission reductions demanded for units with $\beta \in [\underline{\beta}, \beta_1]$ involves a suboptimal level of emission reductions, whereas units with $\beta \in [\beta_2, \overline{\beta}]$ will be demanded too large a reduction compared to the socially optimal reduction. In the mid interval, where the countervailing incentives exactly balance each other, agents are pooled at the same emission reduction level and receive no rents (see Lewis and Sappington, 1989a, for formal proofs). The presence of countervailing incentives thus limits the information rents that the regulator normally has to pay when there is asymmetric information. The results of this Section can be summarized in the following proposition:

Proposition 2:

When the implementation of the CDM project involves a commercial rent shared between the host country and the investor, the efficiency of the CDM depends on the relation between the commercial rent and the abatement cost. If profits are invariant to or decrease with the marginal abatement cost, the standard inefficiency result under asymmetric information prevails. However, if $\pi'(\beta)>0$, countervailing incentives can occur and the investor can then partially limit the information rents transferred to the host country.

Proposition 2 was illustrated above with a derivation based on the simplifying assumption that the commercial rent is linear in the technology parameter. Maggi and Rodriguez-Clare (1995) show how the effect of countervailing incentives depends on whether the agent's net utility is quasi-concave or quasi-convex in the private parameter, but I have here chosen the simplest representation in order to introduce the possibility that countervailing incentives may exist due to the commercial rent linked to CDM projects. As stated in Proposition 2, the information rents accorded to agents and the distortion of the emission reduction will depend on the sign of $\pi'(\beta)$. Earlier, a simple hypothesis was formulated implying that $\pi'(\beta)>0$. However, the relation is really a matter of empirical verification and of the type of greenhouse gas, and the opposite relation could apply. For example, since there is a close link between energy use and carbon dioxide emissions, projects with a large potential for energy savings through efficiency investments normally yield large carbon dioxide emission reductions. The older the current energy equipment is, the larger are the potential savings. This would imply that countries with old infrastructure also have low carbon dioxide emission reduction costs, and if the commercial potential from such projects also increase the older the current equipment is[7], then $\pi'(\beta)<0$. The risk of a commercial project will also vary according to country, however. Developing countries tend to have higher country risk, and whether this effect is large enough to outweigh other considerations such that $\pi'(\beta) > 0$ is an empirical matter.

3.2. The impact of an anticipated future emission constraint

A second important feature of the CDM to bring into the analysis relates to the fact that the host country currently does not face an emission reduction target. It may however anticipate such a constraint in the future (see Rose, Bulte and Folmer, 1999) and each country's reservation utility will depend upon its belief in the severity of this future constraint. Intuitively, the higher a country's current marginal abatement cost the more reluctant it will be to allow other countries to 'mine' its abatement opportunities, since the higher will be its expected marginal user cost of exploiting those abatement opportunities today rather than when necessary to obtain its own emission reduction target. This translates into an assumption that the reservation utility of each country can be written as $\bar{u}(\beta)$, with $\bar{u}'(\beta) > 0$.

[7] Standard assumptions on decreasing marginal productivity imply a larger profit potential from energy investments in countries with low levels of energy infrastructure.

The impact of type-dependent utility is similar to the countervailing incentives created by the existence of a commercial rent. It amounts to a reformulation of the problem stated in equations (3) with the reservation utility equal to $\bar{u}(\beta)$, instead of 0 in equation (3b). Type-dependent utility may occur for several reasons, but a direct link to the features of the CDM seems to reside in the anticipation of future emission constraints. Maggi and Rodriguez-Clare (1995) show how the assumption on type-dependent utility will affect the solution to the problem. The necessary conditions for an incentive-compatible scheme (4a) and (4b) now changes into:

$$U'(\beta) = \alpha\pi'(\beta) - cE(\beta) - \bar{u}'(\beta) \tag{11a}$$

$$E'(\beta) \leq 0 \tag{11b}$$

Condition (11b) is identical to (4b). Equation (11a) now indicates that even when $\pi'(\beta) \leq 0$, agent utility may decrease or increase with β depending on the sign of $\bar{u}'(\beta)$. If the reservation utility were linear in β, the results would be qualitatively similar to the standard model, with utility unambiguously decreasing in β. The plausible assumption of a reservation utility that increases with the marginal abatement cost will similarly result in utility monotonically decreasing in β. However, it is possible that if $\bar{u}'(\beta)$<0 and $\bar{u}''(\beta) \leq 0$, countervailing incentives exist, which may mitigate the information rent due to private information. The main objective here was to illustrate that there can exist different possibilities under which countervailing incentives may occur as intrinsic features of CDM contracts and mitigate the inefficiencies normally resulting from asymmetric information. On the basis of the above discussion it does not seem likely, though, that $\bar{u}'(\beta)$<0 and that countervailing incentives can arise for this reason. In the next Section, it will therefore be shown how countervailing incentives can be created for contracts under the CDM even if not intrinsically present.

4. Technology transfers as a means of creating countervailing incentives

The previous Section applied the theory of countervailing incentives (Lewis and Sappington, 1989a) to the design of emission reduction contracts under the CDM. As shown in Lewis and Sappington (1989a, 1989b) and in Maggi and Rodriguez-Clare (1995), countervailing incentives can result as an intrinsic feature of production or utility functions. However, the principal can also create countervailing incentives. In this Section, I will show how the inclusion of technology transfers into the CDM can create incentives that will mitigate efficiency losses from incomplete information.

In order to facilitate emission reductions in the CDM, the investing party can transfer productive capital to the host country. In the context of the CDM, the capital represents emissions abatement technology. It is denoted K and has an ex ante unit cost of (β_ec) for the investing party. For simplicity, I follow the assumption made in Lewis and Sappington (1989a) of a fixed proportion production function such that each unit of K enables the agent to produce one unit of emission reduction.

The host country can use this technology as it wishes, in particular to produce further emission reductions that it may resell on an international emission credit market. The host country objective is now[8]:

$$U(\beta) = T(\beta) - \beta c E(\beta) + \beta c K \qquad (12)$$

The modified objective of the investing country is:

$$\underset{T(\cdot),E(\cdot),K}{Max} \int_{\underline{\beta}}^{\overline{\beta}} [V(E(\beta)) - T(\beta)] f(\beta) d\beta - \beta_e cK \tag{13a}$$

s.t. (IR) $T(\beta) - \beta c E(\beta) + c\beta K \geq 0$ (13b)

(IC) $T(\beta) - \beta c E(\beta) + c\beta K \geq T(\hat{\beta}) - \beta c E(\hat{\beta}) + c\beta K \qquad \forall \beta, \hat{\beta}$ (13c)

The investing party's objective function now includes its expected cost of the technology. The reformulated problem is similar to the basic problem stated in equations (3) and its solution is therefore omitted here (see Lewis and Sappington, 1989a). The effect of including technology transfers is summarised in Proposition 3:

Proposition 3:

The optimal CDM contract involves the transfer of abatement technology for agents with $\beta \in [\beta_1, \beta_2]$ to an amount K=E*(β$_k$) where $\beta_k \in [\beta_1, \beta_2]$. There will be no rents for such agents, although rents are positive for agents with $\beta \in [\underline{\beta}, \beta_1]$ and $\beta \in [\beta_2, \overline{\beta}]$. Like before, demanded emission reductions are distorted downwards in the low cost region and upwards in the high cost region. At the extreme points, there will be efficient levels of emission reductions.

Proof: See Lewis and Sappington (1989a).

The important result is that the use of technology transfers reproduces the effect of intrinsic countervailing incentives. In the intermediate region, $\beta \in [\beta_1, \beta_2]$, the principal should transfer technology and demand a fixed emission reduction. For this mid interval of agents, the two

[8] In comparison with the basic model, any commercial rent is omitted for simplicity.

countervailing incentives then offset each other and so, agents receive zero rent from the project. The emission reduction levels are distorted downwards in the low cost region, and upwards in the high cost region. Emission reductions are efficient at the extreme points. Compared to the basic model result in Proposition 1, the information rent gained by agents due to their private information is thus reduced.

The source of the countervailing incentives are the technology transfers in the form of productive capacity K. Without the technology transfer, the agent would have incentives to exaggerate the emission reduction cost parameter β in order to receive a higher compensatory transfer payment. With the technology transfer included, overstating β means exaggerating the value of the technology to the agent, a value which the agent rather would like to understate, and so, the agent's original incentives not to reveal costs truthfully are partially counterbalanced.

5. Policy implications and practical problems

An application of the theory of countervailing incentives to the problem of writing emission reduction contracts under the CDM showed that technology transfers can help to provide correct incentives for truthful emission reductions when there is asymmetric information between the investor and the host country. The amount of costly information rents that normally would be paid to agents is thus reduced. Below, I will discuss the policy implications with reference to previous research on the implementation of the flexible mechanisms in the Kyoto Protocol, thus emphasising the new results of this analysis.

This paper modelled the host country as an agent and the investor country as the principal. A more detailed analysis of the CDM would comprise at least four parties: the investing party, the government of the country of the investing party, the investment partner in the host country, and the host government (regulator in charge of overseeing the implementation of the CDM), in addition to the true principal: the Conference of the Parties to the United Nations Framework Convention on Climate Change. Janssen (1999) showed that credible enforcement on behalf of the host government on any cheating host party could guarantee implementation of a CDM contract yielding real emission reductions. The possibility of either relying upon the enforcement power of the host country or the delegation of the contract obligations to a credible non-interested third party are means of circumventing the inherent incentive problems of the CDM when there are monitoring difficulties of actual emission reductions and costs. When such possibilities are not available, this paper has shown an alternative means of improving the incentives to produce real emission reductions.

The approach taken in this paper of modelling the investing country as the principal is related to some previous research results. Wirl, Huber and Walker (1998) propose that the objective of a regulator maximising global welfare can be delegated to the investing (industrial) country by allowing the industrial country to deduct emission reductions obtained abroad from an exogenously specified emission reduction baseline (Proposition 2 in Wirl, Huber and Walker, 1998). Whereas total emission reduction objectives under the Kyoto Protocol are exogenous since set according to a base year of 1990, it is difficult to imagine the specification of fully exogenous baselines for particular emission reduction projects. This is indeed part of the observability problem of project based mechanisms such as the CDM and JI.

The novelty of this analysis is to explicitly account for the possibility of technology transfers and to show their role in creating counterbalancing incentives to any incentives for cheating on emission reductions. There is no explicit incorporation of technology transfers in the Kyoto Protocol. Indeed, Grubb (1999) argues that the Protocol treats technology transfers as a separate topic, despite its importance being realised by most parties. Here, we have shown that technology transfers are not only a matter of equity but that such transfers can help to contain incentives for misrepresentation of actual emission reduction costs and hence emission reductions obtained under the CDM. The use of financial transfers as side-payments to induce participation in international agreements has a long history, and a precedent for environmental agreements is the Montreal Protocol on Substances that Deplete the Ozone Layer. Here, the transfers are not simply financial, but represent real technology transfers. It is the transfer of the property right to the emission reduction capacity that creates counterbalancing incentives for the agent. This is seen in equations (13a) - (13c), where it is clear that if the unit cost of the capacity were not different between the principal and the agent, the transfers would amount to standard financial transfers.

The issue of technology transfers in the implementation of the flexible mechanisms of the Kyoto Protocol was previously raised by Yang (1999) in a somewhat different context of climate change policy. Yang (1999) analyses the impact of transfers from the North to the South in a regional dynamic general equilibrium model (a modified RICE model) including a global externality such as greenhouse gas accumulation. The financial transfers of that model can be interpreted as real technology transfers and motivated by differences in abatement costs of a global externality across countries. Some of the policy relevant results from the analysis are that transfers do not have a strong impact on domestic abatement rates; that transfers are not large in proportion of domestic GDP (below 0.5 per cent); and that transfers can increase the welfare both of the North and the South (Yang, 1999). Yang's analysis brings empirical evidence in support of technology transfers. Here, I have used a theoretical model due to Lewis and Sappington (1989a, 1989b) in order to argue for the positive incentive effects of technology transfers when monitoring problems complicate emission reduction projects.

The practical difficulties of actually implementing technology transfers are multiple. First, the relevant technology may not be in the hands of the investor. The model presented here includes the principal's cost of the technology, which represents any licence fees that must be paid by the investor in order to transfer the technology. The issue is further complicated, however, if the owner or patent holder of the technology has prohibited users to pass the technology on to certain countries. In addition, technology transfers are not limited to the narrow definition of hardware transfer. In order to be successful, the transfer has to include training of local management and it is also dependent on a supporting infrastructure.[9]

Still, it seems likely that the advantages of technology transfers for the abatement of greenhouse gas emissions will outweigh the difficulties cited above. In particular, including technology transfers in JI or CDM contracts might alleviate the concern that the use of flexible mechanisms reduce incentives for host countries of JI projects to undertake investments increasing energy efficiency and thus reducing long-run emissions (Hagem, 1998). The dynamic effects of the policy proposed in this paper are thus important to investigate in future research.

In the debate surrounding the implementation of the flexible mechanisms of the Kyoto Protocol, it has been suggested to bar some technologies completely from entering into the CDM. Proposals from the WWF, for example, include non-eligibility for non-renewable energy, and nuclear energy in particular, in the CDM. The aim of such a limitation on technology would be to further the objective of sustainable development, but its impact on the availability of technology transfers and incentives under the CDM needs to be explored further.

[9] MacDonald (1992) elaborates on the conditions for successful technology transfers, illustrated with empirical case studies.

6. Conclusions

The paper presented an analysis of the incentive problems of implementing the CDM under monitoring difficulties, giving explicit attention to the role of technology transfers. It was argued that the inclusion of technology transfers is not only a matter of equity, but that such transfers in fact can contribute to incentive-compatible CDM contracts.

The investing party was modelled as the principal with the objective of implementing a certain emission reduction abroad. The host country objective is to maximise the transfer payment earned from the emission reduction project net of costs. The model also included any commercial rents created by the project. First, I showed that the basic model leads to a well-known result from contract theory: asymmetric information between the principal and the agent (host country) on a parameter representing the agent's technological efficiency limits the efficiency gains from the emission reduction project. Then I argued that special features of the CDM could reduce such problems.

The first possibility resides in the intrinsic features of the CDM. In particular, the cumulative abatement effect imposed on host countries anticipating a future emission reduction target would yield a type-dependent utility that, under certain conditions, partially could alleviate the incentive problems caused by asymmetric information about the efficiency parameter. Second, and maybe more likely, is that a positive correlation between the commercial rent of the project and the technology parameter could help to counterbalance any incentives to overstate costs. However, even in the absence of such intrinsic features due to the characteristics of the reservation utility or the correlation between the technology parameter and commercial rent, the principal can design contracts to counterbalance the incentives to overstate costs. In order to do so, the principal should transfer abatement technology (capital) to the agent who should be free to exploit the capital for other revenue-producing options, including the generation of additional credits for sale on international emission markets. This is an application of the theory of countervailing incentives (Lewis and Sappington, 1989a, 1989b; Maggi and Rodriguez-Clare, 1995). By transferring control of a productive resource to the agent, countervailing incentives are created in order to contain the incentives for the agent to misrepresent private information.

Several practical problems may arise when actually trying to implement such technology transfers. First, the property right of the abatement technology may not be in the hands of the party investing in the CDM project. The model includes a variable representing the rental cost of the investing party to obtain the technology protected under a patent, so any licence fees should be counterbalanced by the gains to the investing party from the increased efficiency of the CDM project. In certain cases, outright export bans could of course obstruct the technology transfer. Second, in order for technology transfers to be successful, several conditions have to be fulfilled, in addition to the hardware transfer. Primary requirements include free information flow, the existence of a supporting infrastructure, and training of local management for long-term efficient operation.

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APPENDIX

Proof of Proposition 1:

With no commercial rent, the problem reduces to:

$$\underset{T(\beta),E(\beta)}{Max} \quad \int_{\underline{\beta}}^{\overline{\beta}} [V(E(\beta)) - T(\beta)]\, f(\beta) d\beta \qquad \text{(A1)}$$

(IR) $\quad T(\beta) - \beta c E(\beta) \geq 0 \qquad$ (A2)

(IC) $\quad T(\beta) - \beta c E(c) \geq T(\hat{\beta}) - \beta c E(\hat{\beta}) \qquad \forall \beta, \forall \hat{\beta} \qquad$ (A3)

The first and second order conditions for the agent's optimisation problem are:

$$T'(\hat{\beta}) - \beta c E'(\hat{\beta}) = 0 \qquad \text{(A4)}$$

$$T''(\hat{\beta}) - \beta c E''(\hat{\beta}) \leq 0 \qquad \text{(A5)}$$

Since (A4) has to hold as an identity, it can be differentiated:

$$T''(\beta) - cE'(\beta) - \beta c E''(\beta) = 0 \qquad \forall \beta \qquad \text{(A6)}$$

Taken together, (A5) and (A6) imply $\mathrm{E}'(\beta) \leq 0$, and since an incentive-compatible mechanism has to entail truthful revelation of c, we also have that

$$\mathrm{U}'(\beta) = -c\mathrm{E}(\beta) < 0 \qquad \text{(A7)}$$

Since information rents decrease in β, the (IR) constraint will bind only at $\beta = \overline{\beta}$. Using (A7), information rents can be written as $\int_{\beta}^{\overline{\beta}} - cE(z)dz$. Substituting for the transfer to the agent in the principal's objective function gives the modified problem:

$$\underset{E(\beta)}{Max} \int_{\underline{\beta}}^{\overline{\beta}} \left[V(E(\beta)) - \beta c E(\beta) - \frac{F(\beta)}{f(\beta)} cE(\beta) \right] f(\beta) d\beta \qquad \text{(A8)}$$

Emission reductions are given by the first order condition:

$$V'(E(\beta)) - c(\beta + \frac{F(\beta)}{f(\beta)}) = 0 \qquad \forall \beta \qquad \text{(A9)}$$

The second-order condition for a maximum is satisfied since the function V is assumed concave in E.

From (A9) and the concavity of V, it follows directly that for an agent with $\beta = \underline{\beta}$ there is no distortion in the emission reduction compared to the social optimum, whereas for all other agents, the emission reduction is distorted downwards.

Differentiating (A9) gives:

$$E'(\beta) = \frac{c + \frac{d}{d\beta}\left(\frac{F(\beta)}{f(\beta)}\right)}{V''(E(\beta))} \qquad \text{(A10)}$$

The monotonicity constraint, $E'(\beta) \leq 0$, is thus satisfied at the solution characterised by (A9) as long as $F(\beta)/f(\beta)$ is not decreasing in β.