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Incentives for Technology Development and Project Based Mechanisms: Case of Renewable Energy Project

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Abstract

Currently, project based mechanisms under Kyoto protocol are prospering while its critical appraisal and examination of alternative options are undergone in the negotiation for post Kyoto schemes. Here, we investigate the mechanism from the viewpoint of new technological development, which is much awaited as the ultimate resolution for the climate change problem. We first lay out a theoretical model based upon economic theory and hint at possible problems. Then taking up the case of renewable energy projects, we illustrate the presence of the possibly negative effect, and compare this mechanism with other policy options raised in the course of negotiation, utilizing theoretical model based on game theory and theory of industrial organization.

Keywords: Clean Development Mechanism (CDM), Renewable Energy Projects, Technology Development, Entry Barrier.

1. Introduction

Project based mechanisms (CDM (Clean Development Mechanism) and JI (Joint Implementation)) are schemes introduced in Kyoto protocol (1997) as the first attempt to introduce a baseline-credit scheme for emission reduction project in developing country (and hence without an assigned limit) as well as in some developed countries (mostly former socialist counties) so that one could utilize those credits into the amount of emission reduction toward the fulfillment of assignment of Green House Gas (GHG) emissions on the part of developed countries (more exactly, signatory of Kyoto protocol called Annex I (or B) countries). These schemes are more complicated than a mere subsidy scheme for emission reduction, and contains immense conceptual difficulty, which made some people dubious of the functioning of this mechanism (see Bohm and Carlen (2002) for example).

Actually, after years of trial and errors, number of registered projects surpassed 1000 (as of 2008) and now, inclusive of proposed projects (i.e. those in pipeline), expected credits may reach 1.2 billion tones, (as of 2008) which may be sufficient to fill the gap between demand and supply in the upcoming emission trade scheme under Kyoto protocol (2008-2012) according to some speculation. (For a general overview of the current state of CDM, see Capoor and Ambrosi (2008) , Lecocq and Ambrosi (2007) for instance.) Many developing countries were rather skeptical of the mechanism when it was proposed, but now they seem to find more interests in this mechanism and the category of eligible projects as CDM projects tend to be expanded (to include programmable CDM and further policy CDM or sector CDM is proposed). By contrast, some parties start criticizing complicated procedure of CDM as a burden, and propose to replace the mechanism by simpler schemes. In short, even though CDM seems to have launched successfully, but there remains a room for farther controversy. JI is similar but since its formal start line is later (i.e. from 2001 for CDM while 2008 for JI), here we shall mostly deal with CDM, and so below CDM is used synonymously with a project based mechanism.

One issue we have raised concerning CDM earlier is the baseline methodologies (Imai and Akita (2003)). Then we analyze the same issue for a private firm operating in an imperfectly competitive industry (Imai, Akita, and Niizawa (2008)). In this paper, we again consider a private firm in an imperfectly competitive industry, but now our focus is on the incentive to undertake CDM projects for firms whose decisions are related through market demands, and its effect on technology development. Many researchers agree that the technological breakthrough is the key to any successful scheme to cope with climate change problem, and the desire for technology transfer is one driving force for project based mechanisms (Youngman et al (2007), and de Coninck et. al. (2007) estimate the extent to which CDM contributes to

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technology transfer). Hagem (2009) deals with this problem based on the same imperfect competition model of Cournot competition. There, the focus is on whether investment is undertaken or not and a comparison is made between CDM and cap-and-trade scheme. Here, our interests are focused on an incentive for technological development from a dynamic viewpoint if an early adoption of a CDM project by some firm affects the incentives of other firms to do so with a possibly improved technology (in terms of emission reduction), and if so, positively or negatively. Earlier, we have investigated a related question if an adoption of a CDM project by one firm could induce other firms to follow the suit (in Imai, Akita, and Niizawa (2007) to find that the possibility is relatively slim). Therefore under the most modes of oligopolistic competition, such effect is negative, and hence incentive for technological development also tends to be hampered, which is what we show below.

2. MODEL

2.1 Setup

Our base model considers the incentive consequences of the CDM in an industry where multiple firms potentially compete. Especially we are interested in the effect of the so-called rate-based (Fischer (2005)), or relative (Laurikka (2002)) (or ex post (Imai and Akita (2003)) baseline upon the firms' decisions and ultimately its impact upon emission saving R&D. (As a matter of fact, this coupled with a cap is the most commonly used baseline setting methods, when applicable.)

We start out with a simplistic setup where there is an incumbent monopolist in the industry, and has a chance to engage in a CDM project. After this period, a potential entrant comes up with a new invention which would lower emission further, and faces a decision whether to engage in a new CDM project based on this invention.

(We could consider a similar problem where two firms face similar decision using the same technology under the same time structure. This gives a certain advantage over the incumbent monopolist under some occasions, which parallels the preemption by an earlier investment opportunity, illustrating some advantage incumbent firms may have, as pointed out in the industrial organization literature. Here, implicitly assuming that different technology is monopolized by each firm. Obviously there are various patterns of the ownership of inventions, and what we assume here is one specific case, with some other arrangement discussed in a separate section below.)

In evaluating the effects of CDM project on the production technology, several factors appear as candidates to be affected other than emission levels and investment costs, i.e. fixed and variable costs of production in general. Here to simplify the analysis, we assume that production is carried out through a technology involving no fixed costs and constant unit costs, which are not affected by the projects. Also we assume that emission level is given by a constant emission factor representing emission level per output. Specifically, we assume that by the incumbent monopolist's project, emission factor is lowered from e(0) to e(1) (<e(0)), while the potential entrant's project brings it down to 0 < e(2) < e(1). Investment costs for each project is I >0, and J > 0 (with implicit assumption that J > I).

The most important supposition we have is the way baseline is set under CDM project. When it is appropriate to consider that without CDM credits, nobody adopts the emission reducing projects, then the use of e(0) as the baseline setting emission factor would be approved by the CDM Executive Board. In fact this is along the spirit of the Marrakech Accord and many registered projects employ this type of baseline setting methodology where the emission level from the project can be safely regarded as emission factor times the scale of operation. Thus, for the incumbent monopolist, if the project is admitted, its credit revenue would be (e(0)-e(1))rq, where q is the output level of the monopoly firm and r is the price of emission right determined by the emission trading market. (Throughout, we assume that the project is small so that the emission price is not affected by the project.)

What would be an appropriate baseline setting would be a more arguable issue for the potential entrant. If the incumbent monopolist did not adopt the project, then e(0) may be safely assumed to be the baseline. What if the monopolist adopted the project? We view that e(1) would become the baseline, as when the entrant's project is introduced, prevailing technology is that of the monopolist and hence e(1) gives the natural standard for that period. This creates a twist in the incentives as the monopolist can affect the marginal revenue (or negative costs) of the entrant by adopting the CDM project. An alternative may be to set baseline at e(0), but unless the entrant had some record of operation with the old technology, we believe it is some what not in line with the possible baseline setting methods listed in Marrakech Accord.

The sequence of decisions is very simple. First, the incumbent monopolist decides whether to adopt the CDM project or not in the period 1. Observing the consequence of the period 1, in period 2, the potential entrant decides whether to enter with its CDM project or not. We analyze the subgame-perfect equilibrium outcome of this game.

2.2 Equilibrium Conditions

First, it would help state the gist of the analysis in terms of abstract framework. Let us $\Pi(c,c')$ stand for profits of a firm (net of CDM investment costs) with the own parameter c while the opponent's parameter c'. Writing by $\Pi(c)$, we indicate that profit when the firm is the monopolist. (Like earlier studies, here we utilize the assumption that the firm maximizes the total profits without specifying the sharing scheme among project participants, meaning investors and hosts. This can be justified by assuming that parties are risk neutral or more conveniently the project is a unilateral CDM project, although which makes the assumption that the technology utilized is a new innovation in doubt.)

Relevant comparisons are the cases where c's stand for constant marginal costs inclusive of CDM (marginal) revenue. That is, c_0 stands for the marginal costs when the incumbent monopoly firm without CDM, c_1 for the monopoly firm with a CDM project, and c_2 for the entrant firm entered with a new CDM project when the incumbent monopolist firm has adopted the CDM project, while c_3 for the entrant firm entered with a new CDM project when the incumbent monopolist firm has not adopted the CDM project. (we assume that $c_0 > c_1 > c_3$ and $c_2 > c_3$) Thus, $\Pi(c_3, c_0)$ stands for profits of the entrant firm (at period 2) when the monopoly firm did not adopt the CDM project in period 1, and $\Pi(c_0, c_3)$ represents that of the monopoly firm. With a discount factor $\delta > 0$, the total profits of the monopoly firm in this case is given by $\Pi(c_0) + \delta\Pi(c_0, c_2)$. Similarly, $\Pi(c_2, c_1)$ and $\Pi(c_1, c_2)$ represent profits of the entrant firm and the incumbent monopoly firm in period 2 when the incumbent firm engaged in the CDM project, and its total profits are given by $\Pi(c_1) + \delta\Pi(c_1, c_2)$. Finally, if the entrant stayed out, then depending on whether the monopolist employed the CDM project or not, its gross profits are given by $\Pi(c_1) + \delta\Pi(c_1)$ or by $\Pi(c_0) + \delta\Pi(c_0)$. Note that in some occasion, some firm may be forced to exit (or entry is de facto deterred), because of the equilibrium output level becomes 0, but we keep notation for duopoly in the notation we employ here. (As a matter of facts, we shall not focus upon such cases below.)

Now, the equilibria can be classified in terms of these notations:

Case 0: $\Pi(c_3, c_0)$ <J: even without CDM, entry is not worthwhile, and this case is subdivided into two sub-cases—

Case00: $\Pi(c_0) + \delta\Pi(c_0) \geq \Pi(c_1) + \delta\Pi(c_1) - I$: The incumbent firm does not employ the CDM project.

Case01: $\Pi(c_0) + \delta\Pi(c_0) < \Pi(c_1) + \delta\Pi(c_1) - I$: The incumbent firm chooses to adopt the CDM project;

Case 1: $\Pi(c_2, c_1) - J < 0 \leq \Pi(c_3, c_0) - J$: without CDM, the entrant enters;

Case10: $\Pi(c_0) + \delta\Pi(c_0, c_3) \geq \Pi(c_1) + \delta\Pi(c_1) - I$:the monopolist prefers entry without the own CDM than blocking the potential entry;

Case11: $\Pi(c_0) + \delta\Pi(c_0, c_3) < \Pi(c_1) + \delta\Pi(c_1) - I$:the monopolist chooses the CDM project for the sake of entry prevention;

Case 2: $0 \leq \Pi(c_2, c_1) - J \leq \Pi(c_3, c_0) - J$: the entry occurs whatever the monopolist chooses;

Case20: $\Pi(c_0) + \delta\Pi(c_0, c_3) \geq \Pi(c_1) + \delta\Pi(c_1, c_2) - I$: the monopolist still does not wish to engage in the CDM project;

Case21: $\Pi(c_0) + \delta\Pi(c_0, c_3) < \Pi(c_1) + \delta\Pi(c_1, c_2) - I$: the monopolist adopt the CDM project.

3. Renewable Energy Project

Now, we apply the above model to a renewable energy project. One of the characteristics of energy industry is that there is a tendency for it to be regulated. Regulation often implies that price is not a choice variable for the firm in consideration. Further, the characteristic of some power plants is that it is only economical to operate at its maximal capacity level, so that at least at the plant level, supply of output is more or less fixed.

As for the case of renewable energy supply, there are several instances. In some countries, distribution of power is monopolized, while the market for power generation is competitive, with power distribution company is obligated to purchase supply of renewable energy within certain limit. We shall model this situation below as a simpler case, with another simplifying assumption that the price the entrant receives is the same as the consumer price.

Suppose there is a single firm granted the position of monopolistic distribution firm, which is also a monopolist in power generation at its inception. Potential entrant is a power generation firm with renewable energy. Market demand is fixed at Q, and when the entrant enter, its size of supply is also fixed at q < Q. Price is fixed by the regulator, which we normalize at 1 and all the relevant marginal costs are assumed to be below 1.

Now, the profits for the firms are

$$\Pi(c_0) = (1-c)Q$$

$$\Pi(c_1) = (1-c+r)Q$$

$$\Pi(c_0, c_3) = (1-c)(Q-q)$$

$$\Pi(c_1, c_2) = (1-c+r)(Q-q)$$

$$\Pi(c_2, c_1) = (1-c'+r')q$$

$$\Pi(c_3, c_0) = (1-c'+r+r')q$$

The most interesting case is Case 11, where monopolist adopts CDM project just for the purpose of blocking the entry, and entrant's attempt to enter is deterred. The conditions for this case were:

CDM project itself was not attractive for the monopolist

$$\delta\Pi(c_0) > \delta\Pi(c_1) - I$$

but it is attractive to deter entry

$$\delta\Pi(c_0, c_3) < \delta\Pi(c_1) - I$$

And for the entrant, entry with CDM is attractive if the monopolist has not adopted its CDM project yet,

$$\Pi(c_3, c_0) > J$$

But if the monopolist has adopted its CDM project, entry is not attractive

$$\Pi(c_2, c_1) < J$$

Combining these conditions, we have

$$\delta(rQ + (1-c)q) > I > \delta rQ$$

$$(1-c'+r+r')q > J > (1-c'+r')q$$

This yields simple inequalities for this case to take place.

As we assumed that Q > q, one may question that relationship between I and J may depend upon the size of the operation too, and hence one may alter the setup so that the investment costs are IQ or Jq to eliminate the effect of the size. This yields a slight modification to the above formula

$$\delta(r + (1-c)q/Q) > I > \delta r$$

$$(1-c'+r+r') > J > (1-c'+r')$$

One notable difference would be the role of relative size of encroachment enters into the formula, with an obvious interpretation.

One interesting sub-case worthy of further investigation would be the case where the incumbent monopolist itself adopts a renewable energy project as CDM. In this case, we had better assume J < I, because otherwise, there would be no point for the entrant to enter. Along with the analysis carried out as above, entrant would enter even though there is no CDM benefits, because its output is purchased by the monopolist as a requirement, whereas monopolist adopts renewable energy already. Thus to consider the potential problems which might occur under this circumstance, one must rethink the supposition that the monopolist's CDM project covers all of its production capacities, or the presumption that the monopolist must purchase all the supplies, which lies outside of the scope of this exercise.

4. Ownership Structure

One important exercise is an examination of the effect of ownership of invention. Suppose the outside R&D firm has the invention corresponding to the technology which we assumed that the potential entrant owns. Then we ask if this R&D firm would sell this technology to the monopolist or to the potential entrant. In other words, which firm would pay higher price for this invention?

To this end, we retain our assumption that the monopolist with own CDM project must apply for the new CDM project (rather than applying for a deviation from the ongoing project) and in that event, baseline is given by the own CDM project. As to the timing of purchase, we assume that the monopolist firm first decides whether to go for its own CDM or not and then together with the potential entrant, it bids for the invention. To examine this situation, there are several alternatives which would affect conclusions. In particular, the way price of invention is set and the possible commitment by parties for the future actions would affect the result significantly. Here, mostly for the purpose of illustrating the similarity of the situation with the case we have already looked at, we employ the assumptions that the R&D laboratory has the power to set the price and that commitment by contract is not possible. Also we omit the first period payoffs, to yield an extensive game.

First, the R&D firm decides whether it invests J to generate this invention or not. Then the monopolist decides whether to its own CDM project (at the cost I) or not. In case where the monopolist has not adopted its own CDM, if the potential entrant obtained the technology, then monopolist's payoff is $\Pi(c_0, c_3)$ while that of the entrant is $\Pi(c_3, c_0) - B$ where B is the price of invention paid. If the monopolist obtained the invention, then its payoff would be $\Pi(c_3) - B$ (assuming that B is all what is necessary to carry out the investment) while entrant's payoff is 0. Thus the maximal amount the monopolist would pay for the invention is $\Pi(c_3) - \Pi(c_0, c_3)$, while that of the entrant is $\Pi(c_3, c_0)$. Therefore, if

$$\Pi(c_3) - \Pi(c_0, c_3) > \Pi(c_3, c_0)$$

then the monopolist obtains the technology and adopts CDM project with this new technology with $B = \Pi(c_3) - \Pi(c_0, c_3) > 0$, while if the opposite inequality holds, then the entrant enters with $B = \Pi(c_3, c_0)$ provided that B covers all the investment costs. (We may add the option for the R&D company not to sell the technology if the price turns out to be negative, but here, non-negativity of the price is assured.)

Next, suppose that the monopolist has adopted CDM project with its own technology. Then the maximal amount the entrant pays for the invention would be $\Pi(c_2, c_1) - B$, with the payoff for the monopolist being $\Pi(c_1, c_2)$. When the monopolist obtains the invention, its payoff would be $\max\{\Pi(c_2), \Pi(c_1)\} - B$, as it can choose to shelve the invention, while entrant's payoff is 0. Thus the price would be $\Pi(c_2, c_1)$ if

$$\Pi(c_2, c_1) > \max\{\Pi(c_2), \Pi(c_1)\} - \Pi(c_1, c_2)$$

And the entrant obtains the technology while when the reverse inequality holds, the monopolist obtains the invention and either applies for the new CDM or shelves the patent. (We assume that the monopolist does not choose to use the technology but not apply for the new CDM, in which case according to the methodology of the old CDM its deviation is too much and so credits would not be awarded. Still there would be a possibility that such technology may bring benefits to the firm by itself, if the new marginal cost other than marginal credit revenue is substantially lowered by the invention.)

The solution of the game we use is again the subgame perfect equilibrium (which is given by a procedure called backward induction, part of which we have already described). In fact the optimal solution is easily understood once one realizes that in the event that the monopolist has not adopted its own CDM project, then irrespective of the identity of the firm which obtained the technology, the monopolist's payoff is given by $\Pi(c_0, c_3)$ whereas in the event that the monopolist firm adopted its own CDM project, then its payoff would be $\Pi(c_1, c_2)$. This yields exactly the same result as we had before which is due to the assumption that the R&D firm has the right to set the price.

Another possibility would be the case where the potential entrant possessing the new technology may sell (or the monopolist can buy out) the technology. This essentially is tantamount to the case of merger and so by this the problem of mal-alignment in incentives would be eliminated.

5. Sectoral Credits and Other Policy Measures

One proposal as a replacement of CDM is sectoral credit system. Under this scheme, the government of a developing country delineates a certain sector with a target emission level, and any reduction in emission achieved relative to this target level is awarded as credits, which are supposed to be traded in the emission trading markets. No penalty is imposed even if emission turned out to be above the target level (called the "no lose" feature. Other than that the system works more like ex ante baseline, the difference is more on the type of actors, i.e. in CDM, private entities are the main actors, while under this system, government is the primary actor. Of course, in order to provide incentives for the sector to cut down emission beyond the target level, the government could employ several measures, like a domestic cap-and-trade system or other reward system where the government provides reward in proportion to the emission reduction, for instance, but it is up to each government. Note that some reduction by one firm may be cancelled out by the extra emission by another firm and so there may be no smooth connection of the domestic market with the international emission trading market.

Since one cannot pin down a particular policy measure the government would employ domestically, direct comparison is not that easy. One possibility is that the government can internalize all the difficulties raised above by ideally rewarding the new and improved technology, so that within the confine of market-based incentive, sectoral credit system works better. However, as is the case with the grand-fathering according to the past performance in the allocation of quota, there could be a beneficial treatment biased toward existing firms which may hamper the development incentives of potential entrants in the case of domestic market. In fact, in the case discussed above, if the monopolist is allocated the amount the same as the emission level in the previous period, while the new entrant has no allocated amount (but with renewable energy, no emission results), the incentive for the entrant to enter with better technology is worse. Some strange effect is that now the monopolist may welcome new entrant because by the amount of demands it loses, extra emission right could be sold, (if it can be sold to entities in the other sector). Let us formulate this problem.

Despite of the caveat above, suppose that the emission price is the same as the world market price. The monopolist's profit would be

$$\Pi(c_0) = (1-c)Q$$

$$\Pi(c_1) = (1-c+r)Q$$

$$\Pi(c_0, c_3) = (1-c)(Q-q) + \pi q$$

$$\Pi(c_1, c_2) = (1-c+r)(Q-q) + \pi q$$

$$\Pi(c_2, c_1) = (1-c')q$$

$$\Pi(c_3, c_0) = (1-c')q$$

Now, in this setup, one easily sees that there is no entry deterrence, as the profits for the entrant remains the same regardless of monopolist's adoption of the emission reduction technology on its own. At the same time, there is no extra incentive for the entrant to introduce better technology. By contrast, the monopolist wishes the entrant to enter, as its own emission is reduced by the amount the entrant steals from the monopolist. The decision to adopt its own emission reduction technology is now made purely by its own profit criterion. This is a quite extreme story. However, it seems that the defect of cap-and-trade system in this regard deserves further attention.

For developing countries joining the CAP-and-trade system either sector-wise or nationally is another alternative. This shares the same properties as above without the possible gap between domestic and international emission credits. R&D incentive of this scheme with patent system in comparison with public reward scheme is a well known topic in the theory of R&D economics.

Yet another policy option is the GIS (Green Investment Scheme) where world organization or developed nation provides money in an upfront manner, with a promise of developing nation engaging in an emission reduction project. This scheme overcomes the difficulty of transaction costs associated with baseline-credit scheme, while the well known problems are the ability to evaluate the appropriate amount to be given for the project before actual project is carried out and the lack of incentives to monitor after the fact as to whether the execution of the announced project is exactly carried out or not. Although immune from the problems raised in this paper, the extent to which this scheme contributes to the incentive to develop technology depends upon the way the reward is given, detail of which is not that clear at this moment.

6. Further Extensions

Numerous extensions are possible and desirable. Among those, we pick up three such possibilities.

First, one of the fundamental nature in the environmental problem is the presence of uncertainty associated with it, and so incorporating uncertainty into our model would be of primary importance. In the current context, one uncertainty may be that of emission price. This issue is related to the problem that if in developing countries, entrepreneurs are more risk averse, which is in part disproved by the prevalence of unilateral CDM, while some claims that the fact that not many ambitious projects are undertakes in CDM may substantiate the above claim to some extent.

Another natural extension would be considering multiple firms. For instance, one can think of the case with multiple incumbent firms. Here, as is well known (and as we show in Imai, Akita, and Niizawa (2008)), the impact of a single firm's entry becomes alleviated, and thus the incentive to preempt again is mitigated. One could similarly extend toward multiple entry firms, and a sequence of entrants in the multi-periods setting.

Finally, and related to the above issues are the dynamic nature of the issues. Especially, development of one technology affects the future incentive for further development. There are several simple dynamic models in the industrial organization literature, and examination of this problem along with those models would be fruitful.

All these are the agenda for future research.

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