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Technology development and project based mechanisms in international climate change policy

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Abstract: In the earlier paper, we analyzed a possibility of CDM domino, where CDM (Clean Development Mechanism) is a flexibility mechanism adopted in the Kyoto protocol (KP) for the international scheme to prevent climate change due to emission of green house gases (GHG), and domino means adoption of one CDM project induces other CDM projects. In this paper, we attempt to analyze the opposite effect of project based mechanisms including CDM, i.e. the negative impact of adoption of one project upon other potential projects. This possibility has an important implication on the technological development for the prevention of climate change, as the early adoption of a technology receives an unduly special position so that newly developed technology has relatively fewer chances of a success. Even though people disagree over many issues, there seem to be widespread agreement that technological breakthrough is a key element for the long run success of international climate policy. Thus the evaluation of the effect of mechanisms on the technology development to overcome current reliance on carbon intensive technology is important, especially in the ongoing negotiation toward new schemes to be instituted for the period following the period covered by (KP).

There are several factors contributing this possible preemption property of project-based mechanisms, in the design of these mechanisms. Especially important is the baseline setting methods, so that credits from projects are computed as the excess reduction of GHG over baseline emission level. When there is an existing firm operating in an industry, adopting a mechanism employing one emission reduction technology which is registered as a CDM, then this technology itself would naturally be a candidate for the baseline for next generation of projects. However, this would set the hurdle higher for a potential project, which further reduces emissions from this technology. In return, there would be an incentive to adopt such a technology as an entry barrier for an incumbent firm. This baseline setting problem is further complicated by the fact that there are several methods proposed and also listed in the Marrakech Accord, which stipulates the concrete rules concerning these mechanisms. Given these potentially negative dynamic effects on the incentives for technological developments, of the current practices in the operation of project-based mechanisms, one important question would be the way to alleviate this kind of effects. There are several tools to be utilized from the choice of project years and extension criterion, to the possibility of changing project boundaries.

We carry out this research through a simple dynamic game involving a firm considering whether to engage in a project based mechanism and a firm (inside or outside of the industry) engaging in a R&D activity. Through this, we evaluate the extent of the so-called lock-in effect of CDM so that the further incentive to develop better technology is hampered. Then we expand our analysis to the case of multiple firms operating in the industry, and also multiple firms engaging in potential R&D activities. The result is an alleviation of the adversarial effect due to competition to some degree. Also, we introduce the risk element into the model which again is well developed in the literature of R&D competition in industrial economics. Especially important is the effect of uncertainty involved in appraising the future course of international agreement. We also consider the possible alternatives to the CDM proposed somewhere which involves an upfront subsidy paid out to the project participants, instead of employing baseline-credit scheme. Uncertainty is the most important element and at the presence of multiple developers, the scheme could run into a difficulty. Another proposal compared is a streamlining of current CDM scheme which as is expected has several undesirable effects from environmental viewpoints.

Keywords: *Clean Development Mechanism (CDM), baseline, oligopoly, technology development*

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 convert emission reduction project in developing country (and hence without an assigned limit) as well as some developed countries (mostly former socialist counties) into the amount of emission toward 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 (called ones in the 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 is the baseline methodologies (Imai and Akita (2001)). 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 contribute to 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 an 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

We consider 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 (2001)) baseline upon the firms' decisions and ultimately its impact upon emission saving R&D. (As a matter of fact, this 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 come 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 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.)

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 the 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 base line setting technology where 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 analyse 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 the 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_0 for 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. 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 $\delta(\in(0,1))$, 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.

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 subcases--

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;

Case 10: $\Pi(c_0)+\delta\Pi(c_0,c_3)\geq\Pi(c_1)+\delta\Pi(c_1)-I$: the monopolist prefers entry without the own CDM than blocking the potential entry;

Case 11: $\Pi(c_0)+\delta\Pi(c_0,c_3)<\Pi(c_1)+\delta\Pi(c_1)-I$: 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;

Case 20: $\Pi(c_0)+\delta\Pi(c_0,c_3)\geq\Pi(c_1)+\delta\Pi(c_1,c_2)-I$: the monopolist still does not wish to engage in the CDM project;

Case 21: $\Pi(c_0)+\delta\Pi(c_0,c_3)<\Pi(c_1)+\delta\Pi(c_1,c_2)-I$: the monopolist adopt the CDM project.

3. COURNOT EXAMPLE

One commonly used model (in theory) is the Cournot duopoly model. As an illustration, we shall utilize this model with specific assumptions of linear demand and constant unit costs. Demand function is p=1-Q (ore more correctly, max{1-Q, 0}), where p is the price and Q is the demand. When there is a single firm, it sets its production level in order to maximize its profit (p-c)q=(1-q-c)q where q is the production level and c is the unit cost of production. When there are two firms, writing q' for the second firm's production level, profits are given by (p-c)q=(1-q-q'-c)x for the first firm and (p-c')q'=(1-q-q'-c')q' for the second firm where c' is the second firm's unit production cost.

In our context, we further assume that the unit price of emission at 1, and write X for e(0)-e(1) and Y for e(2)-e(1). More importantly, we repeat the assumption that the unit cost of production is the same for both the incumbent monopolist and the entrant, and also it does not change under any CDM project, for the sake of simplicity. Moreover, we set it to be 0. Besides, we also set $\delta=0$.

Under these notation, and concentrating on the case where non-negativity constraint on the output level does not bind, we show the pattern of subgame-perfect equilibrium outcomes for possible combination of values of (X,Y) given values of I and J.

First, corner solutions are avoided if

$$X\geq Y/2, Y\geq X/2, X+Y\leq 1 \quad (1).$$

Condition for the Case 0 becomes

$$3\sqrt{J}>1+2(X+Y) \quad (2)$$

While conditions for Case 1 is

$$1+2Y-X<3\sqrt{J}<1+2(X+Y)\ (3)$$

And that for Case 2 is

$$1+2Y-X>3\sqrt{J}\ .(4)$$

(We shall not try to express the border line case in these classifications.)

Case 00 entails if

$$X<-1+\sqrt{1+2I}\ (5)$$

while Case01 obtains if the opposite inequality holds.

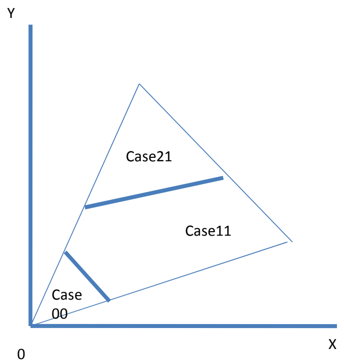

Figure 1.

The condition for Case 11 is

$$1+X-\frac{\sqrt{4(1+X)^2+(5+44X+14X^2-36I}}{2}<Y<1+X+\frac{\sqrt{4(1+X)^2+(5+44X+14X^2-36I}}{2}$$

whereas Case 10 corresponds to the situation where the above inequality is not met.

Similarly, the condition for Case 21 becomes

$$\frac{24X+4-\sqrt{(4+24X)^2+12(50X+9X^2-36I)}}{12}<Y<\frac{24X+4+\sqrt{(4+24X)^2+12(50X+9X^2-36I)}}{12}$$

while Case 21 represents the complementary occasions.

The configuration for a particular case of I = 0.19 and J = 0.24 is illustrated in Fig. 1. The triangular region corresponds to the values of (X,Y) resulting in interior equilibrium for any possible two firms situations. For these particular values, only three cases, Cases 00, 11, 21 appear.

Case 11 is the typical case of preemption. I.e. the incumbent monopolist would not adopt the CDM if (5) does not hold, but in this region, CDM is adopted only for the purpose of preventing the entry of the potential entrant in the period 2. But more conspicuous would be the prevalence of Case 2. To compare, think of the case where baseline for the entrant's CDM project is given by e(0) regardless of whether the incumbent monopolist adopts its CDM project. Corresponding Case 2' is depicted in Fig. 2. One can see that the area for the preemptive move expands under the current baseline setting method.

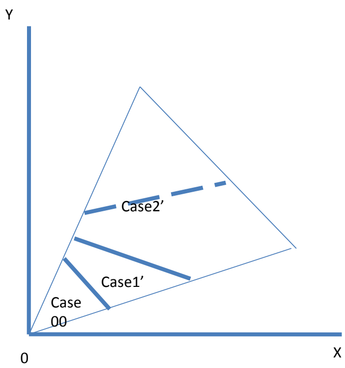

Figure 2.

4. ANALYSIS AND EXTENSION

4.1. Analysis

As to the incentive for the technological development, the above analysis suggests that the way baseline is set according to the prevailing emission level at the time of launching the CDM project, discourages development compared to the case where the same baseline is used for both the incumbent and the entrant. Thus the shrinkage of the region corresponding to Case 1 in Fig. 1 represents the extent of the discouragement. This can be generalized to the extent that the so-called "additionality" requirement of CDM requires that the CDM project must generate additional emission reduction relative to the existing activities, and so any new emission reduction technology can command only the value of the extra reduction.

However, the framework we employed in the above analysis is quite limited. For instance, we assumed that the potential entrant is engaging in a R&D activity on the one hand, and on the other hand, we assume that the project of potential entrant is a sort of unilateral CDM project. This combination of assumption is rather unrealistic. One may wish to include the case of an outside R&D company selling its invention to either firm. To accommodate such a situation, there is another conundrum associated with the CDM. If a firm adopting a registered CDM project switches its technology yielding a further emission reduction. Certainly this corresponds to an amendment of Project proposed and registered. For such amendment, could one keep using the initial baseline? If it is the case, then it gives an enormous edge to the incumbent CDM firm over the prospective entrants. If not, then there is a scant incentive for the incumbent firm to employ a mild improvement in its emission technology. Instead, there may be an incentive for the incumbent firm to purchase and shelve the technology. We do not have such a case to arise in reality to our knowledge, and we do not explore such possibility further, here.

There are many more variations which one can investigate, like modes of competition, design of patent contracts, dependence of inventions, etc.. One thing notable is the possibility of upfront payment for the prospective emission reduction by the world agency, which corresponds to REDD for forest restoration projects under UNFCCC, and some advocate the use of such policy for general emission reduction projects in the developing countries. Similar scheme is known to perform much better in terms of efficiency in the case of inventions compared with the patent system. Along with the problem laid out here, the problem of the extent to which the entrant plans to penetrate into the market share of the incumbent, and certainly it depends on the way it is rewarded. More curious may be the case of the incumbent monopolist here. With an upfront payment instead of CDM credits, its incentive to deter entrant's entry would be contained substantially. In this regard, a scheme based on upfront payments may be worthwhile considering.

4.2. Extensions

Again, numerous extensions are possible and desirable. Among those, we pick up two such possibilities. First, one of the fundamental nature is uncertainty associated with it, and so incorporating uncertainty into our model would be of primary importance. One of the curious aspects of the Cournot example we employed above is the fact that the profit function becomes quadratic (within one Case) forcing the firm to act as if it is risk loving. For instance, given X, there would be an uncertainty concerning the value of Y, whose realized value is only known in the next period. Facing the decision of adopting CDM project or not, this "risk loving" incumbent firm may be led to choose not to preempt the market, in some critical cases. This sort of phenomena would be worthy of further studies.

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. All these are the agenda for future research.

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