# Environmental Accounting:

## Project Financing and Strategic Interactions

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### Abstract

This paper discusses the Kyoto Protocol propositions for reducing global warming by financing appropriate projects in developing countries through the Clean Development Mechanism. The paper shows that care must be taken to avoid the global loss of social well-being.


### Introduction

The Kyoto Protocol, agreed upon in December 1997, sets legally binding limits on greenhouse-gas emissions for developed countries.[4] Each country must achieve at least a 5 percent reduction from 1990 levels between 2008 and 2012, a significant departure from current trends. The protocol indicates specific areas for action and sets up a number of mechanisms for international cooperation. One such mechanism is called the Clean Development Mechanism (CDM). The CDM is intended to attenuate the foreseen economic impact of an abrupt reduction in the levels of emissions and to encourage cost-efficiency by establishing an international market for the negotiation of Greenhouse-Gas Emissions (GGEs) between developed and developing countries.

The CDM, as proposed in the protocol, allows for transactions of Credits of Emissions Reductions (CERs). These credits result from exchanges between countries and may be used by developed countries to achieve their GGEs reduction quotas. A list of the developed countries that were original signatories and were part of the Kyoto Protocol's Annex-I can be found in the Appendix, together with their relative levels of GGEs in 1990.

The Kyoto Protocol foresees that developing countries will participate solely through the CDM. Because the greenhouse effect results largely from the emissions of the developed countries, there is an effort to guarantee that the economic growth of these nations will not be curtailed by restrictive environmental policies. Also, imposing environmental controls

that result in economic costs to the developing countries would be impractical without some type of compensation.

CERs may be bought by a developed country or by a firm with headquarters in a developed country. Given the large volume of greenhouse gases emitted by these countries (about 80 percent of the total), it is apparent that, economically, the greater beneficiaries of the CDM will be developing countries with industrial parks that are not subject to strong environmental legislation. These developing countries could generate great volumes of CERs competing directly in the International Trading Quotas market (ITQ), the future emissions quota international market. The great appeal of these CERs is that the costs of emissions reduction in developing countries, it is assumed, are substantially lower than in developed countries.

Intuitively, the primary way in which these exchanges take place may seem to be via direct CER trading. However, direct CER trading with developing countries is not the only way that CERs could be passed onto developed countries. Firms located in developed countries may also finance their emissions-reduction projects directly, instead of trading quotas in an international market. The economies of the developing countries involved would have subsequent advantages from directly participating in a partnership project with a foreign firm from a developed country. Firstly, capital and technology would be attracted and would finance part of the development cost. Moreover, the projects would lead to an improvement in the environment of the affected areas. By taking into consideration the nature of developing economies and the large volume of CERs possibly demanded by developed countries, the question of who finances the projects for emissions reduction becomes fundamental. Another aspect to consider is that when firms from developing countries come to finance their own projects of emissions reduction to get CERs and offer them for sale, the developing economies are the ones financing the environmental policies in developed countries. This financing is amortized by the payment of the CERs.

There may be additional costs imposed on firms in developed countries for implementing this alternative solution. Contrary to initial expectations, as Tietenberg points out, it is possible that the firms headquartered in developing countries have no interest in allowing their emissions to be reduced (even without cost), because these firms expect their market share and their profits to increase due to the change in cost structure of the other firms that reduce their emissions.[7]

This paper develops a model in which such a result *always* emerges, and it does so as a consequence of definitive strategies of two firms: Firm 1 and Firm 2. Firm 1 is located in a developed country, and may or may not be interested in developing a project through the CDM. Firm 2 is located in a developing country which may or may not accept this partnership. The paper also develops a means of incentive in which the firm that proposes a project may induce a better situation for itself, affecting the decision of the other firm. With such a mechanism, the proper agency of environmental control in a developed country can determine a priori whether or not the project can implemented.

In Section 2, a few possible hypotheses are presented and refuted; one hypothesis is accepted and carried out. In section 3, the accepted model is established and its assumptions explained. In Section 4, the effects of the model are analysed and presented and possible consequences evaluated. In Section 5, an alternative conjecture for future work is proposed; it takes into consideration the possibility of external resource financing.

## Hypothesis

Consider an economy with two countries and two firms. Say Firm 1 is located in Country A, Firm 2 is located in Country B, and both firms are able to do business in the two markets. Country A is developed, whereas Country B is in development. The impact of the CDM on the strategies of the firms is considered here, where the chosen strategy defines the production level. Before the adoption of the CDM, both firms are supposed to be maximizing profits given the competitor's strategies. To simplify, assume

an economy in which information is full, perfect, and symmetrical—a reasonable and convenient assumption in the Internet age.

In order to study the impact of a joint project of emissions reduction on the strategies of the firms, consider the following situation. Given the necessity to control specific GGEs associated with the production of some good in Country A, the agency of environmental control in this country decides to transfer the reduction costs to Firm 1, which is responsible for the GGEs. Firm 1 is assumed to be using the best possible technology for reducing emissions. Two possibilities exist: The agency charges a tax on Firm 1 to finance the purchase of quotas in the ITQ market; or Firm 1 develops a project in partnership with Firm 2, in Country B, that is not using the best technology available for emissions reduction. For simplicity, it is assumed that any project being considered for implementation will generate the exact amount of credits necessary to meet the expected reductions in Country A.

One hypothesis is that the market structure forces the production decisions to be taken in independent and simultaneous form, in a classic model of Cournot competition.[6] The existence of technological differences and input barriers cannot explain a market structure of this type when both firms directly compete in the markets of both countries. The only difference it allows between the firms is the cost due to pollution control. This counterexample can be found, for instance, in the paper and cellulose industry.[1]

Another hypothesis is that technology and plant scale are distinct in such a way that Firm 1 has a bigger plant and is more technologically intensive, with inferior marginal costs. In this way, Firm 1 could exert market pressure to determine, directly or indirectly, the prices of the good in the market. This situation is interpreted through the typical Stackelberg competition model[6] instead of a Cournot model.

This second hypothesis occurs even when the technologies are similar, as long as the production capacities of the firms are distinct. For instance, even though production costs are basically identical, one of the firms is able to raise offers in both markets in order to keep equilibrium marginal prices below production costs in a strategy of dumping. An example of these practices can frequently be found in the Chinese footwear industry, which counts on the state to finance its actions.[2]

This kind of situation is not an anomaly. Moreover, this is a limit-situation: One firm imposes leadership in the market due solely to its ability to use predatory behavior. However, strategies of dumping can become too costly, and their success depends on costs and profits determined in a monopolist market. Therefore, it is probable that firms that operate such strategies do not do so, although they do exert some sort of leadership in the market, either in price or quantity, as treated in this paper.

In general, leadership in the market is justified by scale economies or technological innovations. If such factors were incorporated into the hypotheses, then they would reduce the relative profits that Firm 2 would get once Firm 1, the leader, reduced its participation in the market due to the imposition of environmental policies in Country A. The model presented in Section 3 uses limit-situations where market leadership can be exerted. In these situations, an equilibrium that benefits both countries can emerge by considering the strategic interaction between the firms.

## Model

Consider Firm 1 to be a leader company in a developed country, and Firm 2 a follower in a developing country. Their strategic interactions in the market are treated through a Stackelberg duopoly model.[6] The leader firm directly decides its profit maximization strategy by predicting the reaction function of the other firm. The latter, in turn, maximizes its profits, given the leader's chosen strategy.

Some assumptions are necessary so that the payoffs for both firms are determined:

1. The fixed costs for both firms are irreversible.[8]
2. The cost for Firm 1 to carry on the project in partnership with Firm 2 is also irreversible and equal to $k$.

3. The tax charged by the environmental agency is applied to the level of production of Firm 1 and is equal to $\delta$, where $0 \leq \delta \leq 1$.
4. There is some type of restriction hindering the firms from establishing plants of production in the other country.
5. Both firms are profit maximizers.

Given the imposition of the emissions control agency, Firm 1 in Country A contemplates the following strategies: Either pay the agency tax or implement the project in partnership with Firm 2 in Country B. Firm 2, in turn, also contemplates two strategies: Accept or reject a partnership with Firm 1. Given Assumption 4 above, the possible strategies for Firm 1 are significantly reduced. In fact, as Motta and Thisse[5] indicate, the imposition of environmental standards in a country can lead to the relocation of the plants to countries where environmental policy practices are less restrictive. However, this situation only occurs in special circumstances, such as when the costs of implementing a new plant are relatively low in relation to the costs of the environmental policies. The capital-intensive nature of most firms makes this situation improbable.

For each country $i$, let $Q_i$ be the total production, let $P_i$ be the price established for the good being produced, and let $\alpha_i$ be the stand-alone consumption. According to Pindyck and Rubinfeld, the typical demand function is then:

We can assume that $\alpha_A$ is greater than $\alpha_B$ because consumption in developed Country A is likely to be larger than that of developing Country B. The costs of production are constant and equal to $c$ for both firms.

The nature of a Stackelberg game is dynamic (Firm 2 plays after Firm 1), but the assumptions that the information is full, perfect, and symmetrical allow the payoff of each type of approach, by each firm, to be calculated. The game can then be reduced to its standard form, a reduced 2 x 2 payoff matrix, through a refinement known as retroactive induction. The payoff matrix of a two-firm game has rows labeled by Firm 1's strategies and columns labeled by Firm 2's strategies. The $xy$th entry of the matrix is the payoff that accrues to each firm in the event that the "row player" uses strategy $x$ and the "column player" uses strategy $y$. When analyzing any game, we make the following assumptions about both firms:

1. Each firm makes the best possible move.
2. Each firm knows that its opponent is also making the best possible move.

The strategy for Firm $j$ is an ordered pair of quantities ($q_{jA}$, $q_{jB}$) sold in Countries A and B, respectively. The reduced payoff matrix is given by the profit associated with the chosen strategies. The possible strategy pairs related to the environmental policies in Country A and the choice of Firm 2 regarding the implementation of an emissions reduction project are shown in Table 3-1.

**Table 3-1. Dynamic Strategy Choices**

| | |
|---|---|
| Case 1 | Firm 1 chooses to pay the tax<br>Firm 2 would accept the project implementation |
| Case 2 | Firm 1 chooses to pay the tax<br>Firm 2 would not accept project implementation |
| Case 3 | Firm 1 chooses to propose partnership<br>Firm 2 does not accept project implementation |
| Case 4 | Firm 1 chooses to propose partnership<br>Firm 2 accepts project implementation |

For comparison purposes, the equilibrium solutions are given here prior to the implementation of environmental policies. Since the algebra of the standard Stackelberg model is simple, only the strategies and the profits associated are presented. Additionally, the production cost $c$ is such that the amounts of equilibrium are strictly positive.

Each firm presents the following profit functions $\pi_i$ in their initial configurations:

(3-1)

(3-2)

Profits associated with equilibrium strategies $\pi_i^*$ for each firm are given by

(3-3)

(3-4)

Quantities $Q_i$ sold in each country $i$ are given by

(3-5)

Case 1 in Table 3-1 occurs when Firm 1 prefers to pay the tax, even when Firm 2 would accept the implementation of a joint project of emissions reduction. In this case, the profits $p_i$ are given by Equations 3-1a and 3-2a.

(3-1a)

(3-2a)

Recall that $d$ is the tax charged by the environmental agency. Thus the updated profits for each firm associated with the equilibrium strategies $p_i^*$ are given by expressions 3-3a and 3-4a.

(3-3a)

(3-4a)

Given that in Case 1 Firm 1 pays the tax $d$, the amounts negotiated in each country $i$ are given by

(3-5a)

By comparing Equation 3-5 with Equation 3-5a, when Firm 1 opts to pay an environmental tax, the equilibrium quantities are reduced in both countries, and the prices must be raised relative to the original equilibrium. More importantly, Firm 1's profit may or may not decrease, while Firm 2's profit certainly increases.

Case 2 occurs when Firm 1 pays the tariff and Firm 2 does not accept project implementation. The strategies and payoffs associated with this case are the same as in Case 1. Therefore, when Firm 1 chooses to pay the tax, Firm 2's decisions do not affect the final result of the game.

Case 3 occurs when Firm 1 prefers to implement the project of emissions reduction, and Firm 2 accepts the partnership. Firm 1 then pays for all costs of the project $k$ if there is a reduction of emissions in Country B. In this case, the profit functions are given by Equations 3-1b and 3-2b.

(3-1b)

(3-2b)

Because Firm 1 pays all the costs of the project, which are fixed and equal to $k$, the strategies and equilibrium payoffs do not differ from the initial situation, except in relation to the profit of Firm 1. Profits for each firm associated with the equilibrium strategies $p_i^*$, taking into account this cost, are given by Equations 3-3b and 3-4b.

(3-3b)

(3-4b)

It follows that Firm 1's choice modifies neither the prices nor the equilibrium quantities in either country.

Case 4 occurs when Firm 1 prefers to implement the project, but Firm 2 does not accept the partnership. In this case, Firm 2's

**Table 3-2. Payoff Matrix**

| |
|---|
| Case 1 |
| Firm 1: Pays tax |
| Firm 2: Accepts project |
| Case 2 |
| Firm 1: Pays tax |
| Firm 2: Refuses project |
| Case 3 |
| Firm 1: Proposes project |
| Firm 2: Refuses project |
| Case 4 |
| Firm 1: Proposes project |
| Firm 2: Accepts project |

decision affects game payoffs because when it refuses the project, the best (and only) option for Firm 1 is to pay the tax. The strategies and equilibrium payoff in this case are identical to those indicated in Case 1.

Once payoffs for each case have been established, the payoff matrix can be expressed as shown in Table 3-2. Note that this matrix is formed using the assumption that the information is perfect, symmetrical, and full, and in this case, that each firm can anticipate the results that will take place, given its choices.

If there is a set of strategies with the property that no player can benefit from changing strategies mid-game, then that set of strategies and the corresponding payoffs constitute a Nash equilibrium.[9] Thus, the resultant Nash equilibria from this analysis are perfect in subgames. Each cell presents the profits of Firms 1 and 2, respectively, associated with each of their strategy choices.

The payoff matrix in Table 3-2 reveals that the dominant strategy for Firm 2 is to refuse the partnership exactly when Firm 1 considers the project without any type of cost for itself. The strategy for Firm 1 depends on the cost of the project in relation to the total cost of the tax: The bigger the differences between the emissions reduction technologies for the firms, the smaller the tax. A reduction in $d$, in turn, reduces $k$. Conversely, the bigger the differences between $k$, $a_A$, and $a_B$, the bigger the charged tax $d$. Still, no matter how much Firm 1 earns with the implementation of the project, the Nash equilibrium is achieved exactly when Firm 1 pays the environmental tax and Firm 2 benefits from the smaller market share taken by Firm 1, raising its profits in relation to the original equilibrium.

Therefore, a clear loss of well-being occurs in Country A as a result of the reduction in the profits of Firm 1. In Country B, there is a loss due to the price increase. As Firm 2's profits increase, it is necessary to verify which of the effects predominates. Since $d$ is less than 1, its dimension relative to consumption $a_i$ has to be significantly reduced, indicating that the ensuing social costs of demand reduction and price increase also have to be reduced. Only Firm 2's shareholders benefit from this result. Moreover, the increase in profit by Firm 2 is inferior to the profit loss of Firm 1; hence, the imposition of environmental policies in one of the countries causes a global loss of social welfare. These results indicate that a restrictive environmental policy in the developed country, in addition to a mechanism such as the CDM, instead of inducing a cost-efficient solution, would lead to a solution where there is loss of well-being.

The possibility that Firm 1 generates emissions reduction savings in a less technologically advanced country adds value to the excess emissions of Firm 2; Firm 2 is the one that is on the receiving end of the projects. In the model used here, this value is given by the extra profit that Firm 2 gets by inducing Firm 1 to pay an environmental tax. Firm 2 only accepts the project if Firm 1 offers a greater value than this extra profit for the right to implement a project of emissions reduction. In this case, it can be said that Firm 2 sells its excess of emissions to Firm 1.

## Incentive Strategies' Effects

We now consider strategies that induce Firm 2 to cooperate when requested. As seen in Section 3, Firm 2 does not have any incentive to cooperate and allow the implementation of a project of emissions reduction. The imposition of an environmental tax on Firm 1 reduces its participation in the market, and part of this loss is reverted as profit to Firm 2. Allowing the project to be carried through, however, does not increase its profit.

For Firm 1, however, the choice between the project and the tax depends on the costs of each one. Inequality 4-1 indicates that Firm 1 will always prefer the project that has the lesser impact on its profit:

(4-1)

Inequality 4-1 does not have any effect on the result of the game; therefore, it is Firm 2's choice that determines the resultant equilibrium. Note that the application of Inequality 4-1 determines the resultant pair

of strategies, regardless of the fact that the payoffs associated with both of the two strategies are the same. In order to incorporate an incentive restriction to the problem, assume that Firm 2 agrees to allow the implementation of a project, as long as the tax loss of its extra profits is compensated. Thus, Firm 1 could add the extra profit of Firm 2 to the costs of the project $k$ when it pays the environmental tax. Firm 1 would consider the viability of the project depending on the tax payment according to Inequality 4-2 or, alternatively, Inequality 4-2a.

(4-2)

(4-2a)

The idea is that Firm 2 accepts the project when Inequality 4-2a is true. The mechanism of incentive shown above completely modifies the resultant equilibria. The dominant strategy for Firm 2 is now to allow the implementation, and Inequality 4-2a determines game payoff. Assume that, for Firm 2, the implementation of the project without the loss of extra profits is preferable to the extra profits alone, either because of local emissions reduction or for a better image of the firm in the market. In the case that Firm 1 does not request the project, payoff for Firm 2 is indifferent.

When the inequality given by 4-2 or 4-2a is true, Firm 1 proposes the project to Firm 2. For such a proposal to carry through, the differences between project cost and the components dimension of stand-alone consumption for both markets $a_i$, in addition to the value of the environmental tax to be charged $d$, are determining.

For simplicity, denote the left side of Inequality 4-2a as $f(d, k, a_A, a_B, c)$, or $\hat{f}$ in short. Whenever $\hat{f}$ is less than 0, Firm 1 considers the project. An important point becomes visible from the graph of $\hat{f}$ when only the environmental tax is fixed, that is $(d_1 < d_2 < d_3 < d_n)$, as seen in Figure 4-1. The smaller the tax charged for particular values of $k$, the larger the probability that Firm 1 prefers this mechanism.

In Figure 4-1 the parameters that determine the shift to the right are the smaller size of the components of stand-alone consumption, $a_A$ and $a_B$ ,and the higher costs for the implementation of the project. Thus, once the environmental tax is fixed, Firm 1 observes the associated $f(d)$. It then decides whether to propose an environmental project to Firm 2 or whether it should pay the tax to Country A. The resultant equilibrium is then known. For example, if the cost of the project is very small relative to the components of stand-alone consumption, then the curve is similar to that of $d_1$, where even with lower taxes, the environmental project is the more viable alternative for Firm 1.

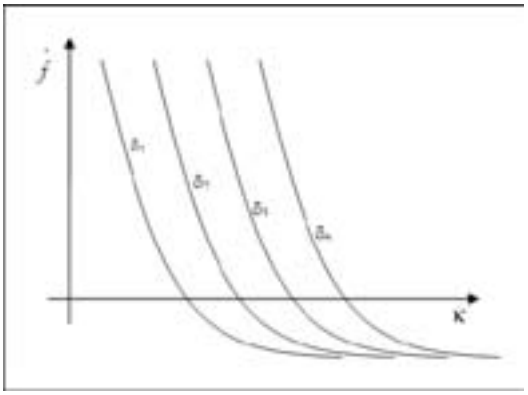


**Figure 4-1. Effects of deferment taxes on project implementation likelihood.**

An alternative use of Inequality 4-2 is to trigger the accomplishment of a project of environmental control in Country B or to trigger the reduction of local GGEs in Country A. Note that with payment of the tax, the amounts produced by Firm 1 are reduced and, consequently, its emissions decrease as well. Because all information is common knowledge, the agency has knowledge of Inequality 4-2 and would establish a tax in compliance with its objectives. Therefore, let $d$ be such that $\hat{f} = 0$, as variations of this tax immediately affect the result of the game. In the specific case treated here, this tax is given by

(4-3)

Another result of using an incentive mechanism, such as that indicated by Inequality 4-2, is that the resultant final equilibrium can by and large be determined in the beginning of the game. Equation 4-4 is comparable to Equations 3-3, 3-3a, and 3-3b. The predicted profits for each firm associated with the equilibrium strategies

can then be expressed by Equations 4-4 and 4-5.

(4-4)

(4-5)

## An Alternative Conjecture for Future Work

The final report of the Third Conference of Parts (COP3), carried through in Kyoto in 1997, considers four basic mechanisms for the global control of GGEs.[4] The approach intended in these mechanisms is guided toward the use of environmental markets, where the main contributory element of cost efficiency of this global policy is the ITQ market.

In order to finance the implementation of environmental control programs in developing countries, the CDM was included, by which the decurrent credits of reductions effected from designs implemented in these countries can be used by developed countries to their own advantage. Initially, this mechanism may be the one used because of the great cost savings it can generate, because environmental policies in developing countries are, in general, less rigid. It is also probable that these designs will be directly financed by developed countries or by firms located in these countries.

However, as Hahn and Stavins point out, the role of domestic politics is decisive for the success of the program, as a good part of the GGEs come from industrial processes. As discussed in the previous section, the imposition of one specific environmental policy in a developed country can generate, through the CDM, value for the excess of emissions in developing countries. The responsibility for the fulfillment of quotas agreed upon in Kyoto is transferred to the firms headquartered in developed countries; these can negotiate the right to carry through GGE reductions in developing countries.

Under particular hypotheses, the market is able to provide the necessary instruments to avoid compromising the efficiency derived from the propositions put forth in the Kyoto Protocol. This model, as presented in this paper, is only possible given the assumption regarding the nature of the information between the countries involved. Such assumptions indicate the fundamental role of local environmental authorities in propitiating conditions so that market crashes do not compromise the effectiveness of the program.

Hence, despite the fact that CDM presents a series of advantages for developing countries, some aspects of the partakers' behavior must be considered in relation to the practiced environmental policies in their countries. Individual actions by firms cannot harm the well-being of the population. Alternatives are the immediate mapping of the sources of GGEs in these countries and the imposition of referring external costs provoked by this type of pollution, in order to induce local firms to accept the implementation of designs of emissions control, financed by external resources.

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# Appendix

**Table A-1. A list of Annex-I countries, together with their relative greenhouse-gas emissions levels in 1990, taken from endnote 4.**

| Country | Emissions (Gg) | Percentage of Total Emissions |
|---|---|---|
| Australia | 288,965 | 2.1 |
| Austria | 59,200 | 0.4 |
| Belgium | 113,405 | 0.8 |
| Bulgaria | 82,990 | 0.6 |
| Canada | 457,441 | 3.3 |
| CzechRepublic | 169,514 | 1.2 |
| Denmark | 52,100 | 0.4 |
| Estonia | 37,797 | 0.3 |
| Finland | 53,900 | 0.4 |
| France | 366,536 | 2.7 |
| Germany | 1,012,443 | 7.4 |
| Greece | 82,100 | 0.6 |
| Hungary | 71,673 | 0.5 |
| Iceland | 2,172 | 0.0 |
| Ireland | 30,719 | 0.2 |
| Italy | 428,941 | 3.1 |
| Japan | 1,173,360 | 8.5 |
| Latvia | 22,976 | 0.2 |
| Liechtenstein | 208 | 0.0 |
| Luxemburg | 11,343 | 0.1 |
| Monaco | 71 | 0.0 |
| Netherlands | 167,600 | 1.2 |
| Norway | 35,533 | 0.3 |
| New Zealand | 25,530 | 0.2 |
| Poland | 414,930 | 3.0 |
| Portugal | 42,148 | 0.3 |
| Romania | 171,103 | 1.2 |
| Russia | 2,388,720 | 17.4 |
| Slovakia | 58,278 | 0.4 |
| Spain | 260,654 | 1.9 |
| Sweden | 61,256 | 0.4 |
| Switzerland | 43,600 | 0.3 |
| United Kingdom | 584,078 | 4.3 |
| United States of America | 4,957,022 | 36.1 |
| Total | 13,728,306 | 100.0 |