4. Investing in the Common Good: Financing Global Environmental Initiatives

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1. AN ECONOMIC FRAMEWORK FOR MODELLING GLOBAL ENVIRONMENTAL INVESTMENTS

The problem of reducing greenhouse gas (GHG) emissions is greatly complicated by several of its attributes:

- uncertainty in impacts;
- asymmetry in the projected impacts;
- unequal allocation of initial conditions in the use of the global atmosphere as a commons resource;
- unequal ability to shoulder the burden of emissions reductions;
- changes from the status quo (free access) are viewed as losses.

While all nations have a stake in the use of the commons resource, the rights of national sovereignty imply that no international body can impose monitoring or enforcement powers. Therefore participation in any agreement is voluntary and subject to renegotiation. The problem is to design incentives which will be effective in reaching efficient levels of global GHG concentrations resulting from country-specific emissions and sinks.

This framework is built around a group of countries or country groups with heterogeneous preferences and incomes. We first investigate outcomes when countries carry on with 'business-as-usual', (non-cooperatively) maximizing their individual welfare, allocating resources for consumption and GHG-reducing investment accordingly. We compare this non-cooperative outcome with the outcome achieved when countries cooperate in global efforts to mitigate global climate change. Our focus is on analysing the opportunities for efficiency
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gains through international resource transfers used to leverage the funding of
GHG mitigation projects, especially in developing countries where projects
could not be undertaken without such support.

The buildup of GHGs in the atmosphere is a dynamic process and should be
so modelled. We take the simplest dynamic model, a two-stage model, preceded
by a pre-planning bargaining stage. At stage 0 we assume the global community
decides on the framework (if any) it will use for coordinating its efforts to reduce
GHGs. At stage 1, each country makes investments to either reduce GHG
emissions or to set up the possibility of mitigating the effects of these in stage
2. Further investments and mitigation measures are undertaken in stage 2 after
uncertainty about the extent and consequences of GHGs on global climate
change is resolved. Forward and options contracts may be signed between
various countries at stage 0 and the results of these contracts are realized in stage
2.

We use the following notation:

\( \theta \) = country index, where the set of all countries is denoted \( \Theta \)
\( x(\theta) \) = investment by country \( \theta \) to reduce GHGs at stage 1
\( X = \{x(\theta) \mid \theta \in \Theta\} \), the vector of all country investments
\( y(\theta) \) = consumption by country \( \theta \) at stage 1
\( Y = \{y(\theta) \mid \theta \in \Theta\} \), the vector of all country consumptions
\( f(\theta) \) = income for country \( \theta \) in stage 1
\( \omega \) = uncertain state of the world, realized at stage 2, where we assume
that \( \omega \in \mathbb{R}^+ \)
\( F(\omega) \) = probability distribution on the states of the world
\( s(\theta) \) = monetary transfer payment to country \( \theta \) at stage 1
\( S = \{s(\theta) \mid \theta \in \Theta\} \), the vector of all ex ante transfers

Let \( g(x(\theta), y(\theta); \theta) \) (which may be thought of as the 'GHG impact function'
for country \( \theta \)) denote the total GHGs (measured in units of global climate change
potential) generated by country \( \theta \) in stage 1, and let the total GHGs generated
in all countries be denoted by \( G(X,Y) \) so that

\[
G(X,Y) = \sum_{\theta \in \Theta} g(x(\theta), y(\theta); \theta).
\]  \( \text{(4.1)} \)

We assume throughout that, for each \( \theta \), \( g(x, y, \theta) \) is increasing in consumption
and decreasing in mitigation investments, i.e., \( g_x < 0, g_y > 0 \). We also assume
that \( g(\cdot, \theta) \) is jointly convex in \( (x, y) \), so that investments in \( x \) have a declining
marginal impact on (reducing) \( G \) and consumption has an increasing marginal
impact on \( G \). We assume the following aggregate welfare function, denoted
\( U(\theta) \), for country \( \theta \):
$U(X, Y, \omega; \theta) = V(G(X, Y), \gamma(\theta), \omega; \theta)$ \hfill (4.2)

so that $U$ depends on $X$ only through aggregate GHG emissions $G$. We assume that $V$ is decreasing in $G$, increasing in $\gamma$ and jointly concave in $G$ and $\gamma$. Given these properties of $G$ and $V$, it is straightforward to show that, for each $\omega$ and $\theta$, $V$ is concave in $(X, Y)$, from which it follows that for each $\theta \in \Theta$, the expected value of $V$ over $\omega$ is concave in $(X, Y)$.

We are interested in characterizing the Pareto-efficient outcomes to the collective consumption-investment problem associated with the above country welfare functions $U(\theta)$. For this purpose, we will define a (weighted utilitarian) global welfare function $W$ as

$$W(X, Y) = E_{\omega} \left\{ \sum_{\theta \in \Theta} \eta(\theta) U(X, Y, \omega; \theta) \right\} \hfill (4.3)$$

where $\eta(\theta)$ satisfy:

$$\eta(\theta) \geq 0; \quad \sum_{\theta \in \Theta} \eta(\theta) = 1. \hfill (4.4)$$

Since the expected utility functions $E[V(\cdot; \theta)]$ are concave, the Pareto set of allocations from any convex feasible set are given by the argmax $W_{\eta}$ as the weights $[\eta(\theta) \mid \theta \in \Theta]$ vary over the feasible set defined by (4.4).

$U$ may be thought of as the net economic benefits realized from the country’s activities in stages 1 and 2. We assume that investments $x(\theta)$ in GHG reduction and consumption $\gamma(\theta)$ are related by the following budget constraint:

$$l(\theta) = x(\theta) + \gamma(\theta) - s(\theta) \hfill (4.5)$$

Thus, investments in GHG reduction will necessarily reduce consumption $\gamma(\theta)$ unless offset by transfers $s(\theta) > 0$ to $\theta$ from other countries. For feasibility, we require the following restrictions on transfers among countries:

$$\sum_{\theta \in \Theta} s(\theta) = 0. \hfill (4.6)$$

1.1. The Non-cooperative Solution

We develop here the benchmark non-cooperative (NC) solution based on uncoordinated actions by individual countries. To characterize this non-cooperative solution, we use the Nash equilibrium concept for the associated game in which each country attempts to maximize (4.2) subject to (4.5), with $s(\theta) =$
\[
\frac{\partial L^C}{\partial x(\theta)} = 0 = E \left[ g_x(\theta) - g_x(\theta) \right] \left[ \sum_{\zeta} \eta(\zeta) V_G(\zeta) \right] - \eta(\theta) V_x(\theta) \]  
(4.13)

\[
\frac{\partial L^C}{\partial \delta(\theta)} = 0 = E_\delta \left[ g_y(\delta) \right] \left[ \sum_{\zeta \in \Theta} \eta(\zeta) V_G(\zeta) + \eta(\theta) V_y(\delta) \right] - \mu \]  
(4.14)

where \( \mu \) is the dual variable associated with (4.6). (4.12) implies that the change in global benefits associated with transferring a monetary unit from consumption to investment for GHG reduction in country \( \theta \) must just equal the marginal cost \( E_\delta \eta(\theta) V_y(\delta) \) in lost consumption.

We can compare (4.10) obtained earlier for the non-cooperative (NC) case with (4.13) above. We see that (4.10) implies a similar benefit–cost equality to that discussed above for (4.13). In the NC case, however, country \( \theta \) equates the marginal loss in consumption benefits to the benefits for itself of transferring a monetary unit in that country from consumption to investment. By contrast, for Pareto efficiency, marginal consumption losses are equated to global benefits of increased investment in mitigating GHGs. Proposition 1 below shows that the NC solution is never cost effective in the sense that resources used to mitigate GHGs are never used efficiently in the NC solution, whereas they always are in the cooperative solution. This suggests that the essential focus of institutional design should be on improving efficiency in GHG mitigation efforts by focusing on the best alternatives for GHG mitigation investments globally.

**Proposition 1:** Let superscripts \( C \), respectively \( NC \), denote the solutions to the cooperative, first-best problem (4.12) (subject to (4.6)) and the non-cooperative problem (4.9).

i. The non-cooperative solution is Pareto inefficient in the sense that there are weighting vectors \( \{ \eta(\theta) \}_{\theta \in \Theta} \) such that the corresponding cooperative solutions \( (X(\eta), Y(\eta)) \) leave every country better off than under the non-cooperative solution. In particular, unless all countries have identical preferences \( V(\theta) \) and identical emission technologies \( g(\theta) \), the non-cooperative solution is not efficient in the sense that lower aggregate GHG emissions can be achieved from the total mitigation investments \( \sum \lambda^{NC}(\theta) \), i.e.

\[ G(X^{NC}, Y^{NC}) > \text{Minimum} \left\{ G(X, Y^{NC}) \mid \sum_{\theta \in \Theta} x(\theta) \leq \sum_{\theta \in \Theta} x^{NC}(\theta) \right\} \]

ii. The level of aggregate GHG emissions \( G(X^C, Y^C) \) achieved under any cooperative solution is efficient in the sense that it is the minimum aggregate
emission level achievable from total mitigation investments \( \sum x^C(\theta) \). That is, for the cooperative solution:

\[
G(X^C, Y^C) = \text{Minimum} \{G(X, Y^C) \mid \sum_{\theta \in \Theta} x(\theta) \leq \sum_{\theta \in \Theta} x^C(\theta) \}
\]

Proof: See Technical Appendix.

2. INSTITUTIONAL MECHANISMS FOR EFFECTIVE GLOBAL RESOURCE TRANSFERS

We briefly consider here the issue of designing institutions for monitoring GHG emissions and for funding GHG mitigation projects and programmes. The nature of the institutions deployed to effect cross-border investments will clearly have a significant impact on the efficacy of the programme and the extent to which the expected benefits are realized. It is an area of formidable complexity given:

- the heterogeneity of sources and sinks;
- information barriers and transactions costs;
- the lack of control or lack of responsiveness to price mechanisms;
- national sovereignty, heterogeneity of interests, and problems of enforcement.

These issues point to difficulties in monitoring results and, given the costs of GHG mitigation, to difficulties in assuring cooperative compliance with commitments made by individual countries who receive resources to undertake mitigation projects. Thus, the key issue for design will be to focus on monitoring, sharing of information and, with this, efficient decentralization of implementation. Decentralization can occur at two levels:

1. between the country/countries financing investments and the recipient country (the global level);
2. within individual countries (the national level).

Our focus here is on institutional mechanisms pertaining to the first of these, the global level. Decentralization at the national level has been extensively analysed and various schemes, most notably tradable permits and taxes, have been developed to achieve target reductions in GHGs in various sectors efficiently. These alternative approaches themselves have yet to be examined fully in an empirical setting, and it seems likely that no single scheme will be optimal for every country (see Wheeler 1992). Thus, decentralization at the national
level should be understood in terms of both differing sectoral targets for GHG mitigation, but also differing effectiveness of alternative policy instruments in achieving these sectoral targets in different countries. Thus, the key issue is that each country commits itself to a well-intentioned effort to achieve fair targets for GHG reduction. How they achieve this will be country specific, although sharing of best practices and new technologies across countries should be facilitated (see below).

At the global level, we focus on two polar extremes in the possible set of institutional mechanisms:

- pure multilateral schemes such as the Global Environmental Fund (GEF);
- pure bilateral schemes such as the joint implementation programmes currently being proposed by the US and some other countries that plan to finance GHG reduction investments in developing countries.

Multilateral schemes are characterized by a central pool of funds contributed by the investing countries which is then disbursed to recipient countries based on specific criteria, such as the incremental costs of the projects funded. Donor countries are not able to identify themselves with individual projects, which places a heavy burden of project monitoring on the central agency. In bilateral schemes, on the other hand, the terms of financing can be agreed by the two sides, and the country putting up the financing can monitor the progress of the projects. In such a bilateral approach, countries making cross-border investments may obtain credit or offsets against their own obligations under the Framework Convention. The benefit accruing to the financing countries, which is the avoided cost differential between the cost of domestic and cross-border investment, is very visible, which makes it politically tenable to put up the financing from public funds. After assessing the advantages and disadvantages of these schemes at some length, we consider the potential for hybrid approaches which combine the better features of multilateral and bilateral schemes. We consider the following criteria in our assessment:

- price per unit of GHG reduced and total cost to investing countries;
- incentives for project nomination and efficient implementation;
- monitoring and informational efficiency;
- transactions costs.

2.1. Cost to Investing Countries

A key issue that arises regarding price per unit of GHG reduced and the cost to investing countries relates to the basis on which transfer payments are made to recipient countries for the ‘purchase’ of GHG mitigation. In the past, most
notably in the case of the Montreal Protocol implementation, the basis for payment has been the incremental cost borne by the country implementing the project. This approach has been criticized for being administratively cumbersome and providing few incentives (if any) for project acceleration by the recipient countries (see Fernando et al. 1993). Recent anecdotal evidence, especially pertaining to the slow pace at which funds have been disbursed for the mitigation of ozone-depleting substances, seems to confirm this view.

Assuming recipient countries agree, incremental cost financing gives the highest ‘bang-for-buck’ for the investment. If recipient countries are firmly committed to a schedule of investments which is not conditional on the availability of external financing, such an approach may be somewhat realistic, especially if undertaken via a single multilateral agency such as the GEF. On the other hand, if the pace and size of GHG mitigation investment in recipient countries is dependent upon the scale of external financing, which seems to be a plausible scenario especially in the case of larger countries such as India and China, we would argue that payments in excess of incremental costs would be required for effective and speedy implementation of GHG mitigation projects.

Such an outcome is likely in a bilateral scheme where investor countries may be thought of as ‘competing’ for low-cost GHG mitigation projects especially in the developing world. The likely result of such competition is that investor countries would be willing to pay recipient countries somewhat more than incremental costs to secure offsets through their investment in low-cost projects. In an extreme case, a single global ‘market-clearing’ price which equals the incremental cost of the last project undertaken will be paid by investor countries for their cross-border GHG mitigation investments. While payments above incremental costs would clearly be more expensive for the investing countries, we argue below that they are likely to be more effective from the standpoint of incentives for implementation of the projects by the recipient countries.

2.2. Incentive Implications

As noted above, the payment mechanism associated with the institutional scheme has a direct impact on the incentives for participation and active cooperation by the recipient countries. Buying GHG reductions at their incremental costs, may be least-cost from the standpoint of the investing countries. However, as pointed out for the analogous case of ozone layer protection in Munasinghe and King (1992), such an arrangement provides no financial surplus to the recipient countries—which is likely to have an adverse effect on their incentives to cooperate by nominating and implementing projects speedily. This may be a less significant factor if the recipient countries are obligated by the Framework Convention to undertake these projects anyway, with or without external financing. However, it is unlikely that the cooperation of many developing countries can be obtained without such financing, and the experience to
date shows that this may need to be in excess of the costs that they incur—to provide an additional incentive.

Surplus payments in excess of costs may be viewed as ‘lubricants for cooperation’. Since these surplus payments are likely to be highest for the lowest-cost (highest ‘bang-for-buck’) projects, they create strong incentives for recipient countries to locate and nominate these projects for financing. They also create incentives for accelerated implementation of high ‘bang-for-buck’ projects, which is very desirable from the standpoint of the objectives of a Framework Convention.

Also as we have noted above, surplus payments are almost inevitable in bilateral schemes if investing countries compete globally for the cheapest projects. However, taking account of the relative strengths and weaknesses of the parties to these bilateral schemes, the considerable barriers to information flow, and the obligations imposed on the parties to the Framework Convention, it is very unlikely that prices will increase all the way to levels associated with full competition for mitigation projects.

Surplus payments may be very desirable in multilateral schemes also, to overcome the incentive problems that were discussed above. One approach to enhance incentives would be to conduct what amounts to a global auction (see Fernando et al. 1993) which is effected by announcing a fixed price (in $/ton) which the multilateral institution would pay for mitigation projects. The effect of such a price offer is to attract all projects that have unit costs of GHG mitigation that are below the offered price, which will be the best projects available globally. Over time, the bid price can be increased progressively to attract higher cost projects, up to the desired aggregate level of GHG mitigation.

2.3. Monitoring and Informational Efficiency

In order for a scheme of cross-border investments to work, the following criteria must be met regardless of the institutional mechanism that is adopted for implementing the scheme of resource transfers:

1. the investing countries should be able to monitor the investments/measure emissions and whether or not the desired results have been achieved;
2. the investing countries should be able to impose (at least moral if not financial) sanctions on non-compliant countries.

A third desirable characteristic of efficient decentralized implementation is that the shadow price of GHG reduction in each country and sector be estimable so that a rough efficiency benchmark (namely, equalized incremental abatement costs) is evident to all participating countries. Using market mechanisms at the national level could enhance significantly the estimation of incremental abatement costs in each country. For example, in the electric power sector if an
efficiently functioning emissions trading market were present, the market price for an emissions permit for GHGs would represent the cost of a unit reduction in GHGs in that sector. The challenge is to link sectors such as electric power, which are more easily monitored and controlled, with other sectors, such as agriculture and manufacturing, where the total GHG emissions and the cost of reducing these will be considerably more difficult to estimate on an ongoing basis. In these sectors, from both a national as well as a global perspective, it seems likely that a variety of country-specific instruments and projects will be required to achieve efficient GHG mitigation.

From the standpoint of monitoring and enforcement pertaining to specific projects, there appears to be no obvious advantage to one or other of the two mechanisms we have been considering here. Where it is possible to leverage off existing trade/investment/aid links between two countries, monitoring in a bilateral scheme could be very effectively handled. A multilateral agency, on the other hand, would have the benefit of some scale economies, especially in the use of specialized expertise.

From the standpoint of gathering and disseminating information across countries, on the other hand, a centralized multilateral agency is at a clear advantage. Thus, even with bilateral investment flows, such a multilateral agency established and funded by the investing countries could perform a very valuable role in promoting cooperative activity by each signatory country, including sharing of best practices, publishing information on potential investments and their costs, highlighting priority areas and providing technical assistance.

2.4. Transactions Costs

The transactions costs of project selection, implementation and monitoring are clearly an important consideration in institutional design for GHG mitigation investment. Because of issues of national sovereignty and physical separation between investing and host countries, it is clear at the outset that the magnitude of transactions costs associated with specific projects will depend on the stance taken by the host country institutions towards these projects. Thus, for example, much of the work associated with the project could occur at the local or project level if the host countries were to take an active interest in the project, which would depend in part on their stake in the project. It is clear also that the transactions costs associated with project identification, financing and monitoring are likely to be very much a function of the size and complexity of the project, and also the role and competence of its local partners. If the incentives for local participation can be correctly structured to be consistent with the overall objectives of the project, this would greatly reduce monitoring needs and associated costs.

The level of transactions costs would also depend upon existing institutions.
Many industrialized countries have existing agencies for the purpose of channeling foreign aid on a bilateral basis, which could also be used for the purpose of channeling these investments. On the other hand, there is a long tradition of channeling development aid through multilateral institutions such as the World Bank. Hence, from the standpoint of transaction costs, the success of a new scheme of financing GHG mitigation projects would depend upon the extent to which existing institutional resources can be utilized.

2.5. Hybrid Approaches

It is clear from the foregoing that multilateral and bilateral schemes have their relative advantages and disadvantages. Multilateral approaches are informationally more efficient, since all available information can be centrally aggregated and then disseminated as available. On the other hand, paying out only incremental costs, as is currently the practice of the GEF, greatly reduces the incentives for host countries to take a proactive role in nominating and implementing projects. In the longer term, the cost of this may be considerably higher than the immediate savings in disbursements to the host countries.

A potential hybrid arrangement is where a centralized multilateral institution (e.g. a Global Environmental Coordinator) would undertake information transfers, assisting in project identification and technical assistance, and possibly keeping a scorecard of environmental investments and setoffs by individual countries. Investments themselves can be undertaken bilaterally, or directed through multilateral funds such as the GEF, depending upon the preferences of the countries concerned.

3. CONCLUSIONS

This chapter has focused on two key issues associated with the current debate on a global initiative for reducing greenhouse gases—understanding the benefits of global cooperation through international resource transfers and developing effective institutional arrangements to put such cooperation into practice. The theoretical framework summarized here and elaborated in our other work (e.g. Fernando et al. 1995) clearly shows that cooperative outcomes can dominate business-as-usual non-cooperative outcomes in terms of GHG reduction and welfare improvement for all countries. Unlike in the case of the Montreal Protocol, where resource transfers to developing nations were motivated primarily by equity considerations, the cost effectiveness of a programme to reduce the emission of greenhouse gases hinges critically on the cooperation of developing nations.

Capturing the fruits of cooperation is contingent upon the development of
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effective institutional arrangements to transfer resources between countries. Given the nature of the investments (not so much the technology itself but the overlay of issues related to the externalities associated with the investments, national sovereignty and spatial dispersion), it is very important to have as many actions as possible undertaken by the host countries themselves in a way that is consistent with the objectives of the investing countries. As we have noted, this can be accomplished by a more equitable sharing of benefits between host and investing countries. Both bilateral and multilateral institutional arrangements can play a valuable role in achieving this end.

TECHNICAL APPENDIX

Proof of Proposition 1

(ad i): The fact that the Nash non-cooperative solution characterized by (4.10) is Pareto inefficient follows from the original Kuhn–Tucker approach to vector optimization problems. Let \( \nu \in \Theta \) be any country and consider the following problem:

\[
\text{Maximize } E_{\omega} \left\{ V(G(X, I - X + S, I(\nu) - x(\nu) + s(\nu), \omega, \nu) \right\}
\]

subject to (4.6) and:

\[
E_{\omega} \left\{ V(\theta) \right\} \geq E_{\omega} \left\{ V^{NC}(\theta) \right\}, \quad \text{for all } \theta \in \Theta \setminus \\{\nu\}
\]

where \( V^{NC}(\theta) \) represents the payoff for country \( \theta \) from any non-cooperative solution. A feasible solution to (4A.1–4A.2) is clearly the given Nash non-cooperative solution which satisfies both (4A.2) as well as (4.6) (note that (4.12) implies \( x(\theta) = 0 \) for all \( \theta \)). So much verifies that the solution to (4A.1–4A.2) weakly dominates the non-cooperative solution. Actually, by assigning Lagrange multipliers to the constraints (4A.2), it is easily verified that any solution to the necessary and sufficient conditions obtained for (4A.1–4A.2) cannot be a solution to the first-order conditions (4.10) for any weighting vector satisfying (4.4). Thus, the solution to (4A.1–4A.2) strictly dominates the non-cooperative solution, as claimed.

(ad ii) The fact that resources are used efficiently in mitigating GHGs under the cooperative solution is evident from the structure of the problem. Assuming the country leads directly to a contradiction, since aggregate welfare is always decreasing in total emissions \( G \) and increasing in consumption. Thus, if aggre-
gate emissions can be lowered without affecting consumption (i.e. without using additional mitigation investments) they will be at the cooperative solution. An alternative method of seeing the same result is to note from (4.13) and (4.14) that the marginal emissions $g_e(\theta)$ are equal across countries $\theta$ for which $x^e(\theta) > 0$, which is the necessary and sufficient condition for minimizing total emissions using a fixed investment pool.

To see that the non-cooperative solution is inefficient (when not all countries are identical) requires only an examination of the first-order conditions (4.10). If not all countries have identical preferences and emissions technologies, then (4.10) implies that the just-mentioned condition of equalized marginal emissions will not obtain. Clearly, lower total emissions could be achieved by transferring some mitigation resources from one country to another to equalize marginal emissions.

REFERENCES


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