“Issues and Options in Implementing the Montreal Protocol in Less Developed Countries: A Research-Oriented Perspective”

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Issues and Options in Implementing the Montreal Protocol in Less Developed Countries: A Research-oriented Perspective

Intermediate Report

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1 This report is a draft to stimulate comments. Please do not quote without permission.
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implementation issues in developing countries associated with the Montreal Protocol.
1. Introduction

The increasing threat to stratospheric ozone levels as a result of emissions of ozone depleting substances (ODSs) such as chlorofluorocarbons (CFCs) led to the Montreal Protocol in 1987.\(^2\) As amended in the second meeting of the parties to the Protocol in London, in June 1990 (see UNEP (1990)), Protocol signatories have committed themselves to a complete phase-out of ODSs in developed countries (DCs) by the year 2000 and in less developed countries (LDCs) by the year 2010. This involves finding and deploying alternative technologies and products for accomplishing the myriad of uses for CFCs in the world economy. These uses in refrigeration, in packaging and insulation, and in solvents and cleaning agents for electronic and other high-tech industries are widely dispersed and quite central to the economic well-being of many countries. The phase-out of ODSs will therefore not be a simple matter. While regulation can be the primary means of forcing companies in developed countries to find and deploy non-ODS using technologies and products, the developing world simply does not have the means of responding to such regulations without assistance. The Montreal Protocol therefore foresees providing the necessary financial assistance to developing countries to assist them in meeting the Protocol objectives. The central issue posed by the Protocol is the design of international institutions for assuring the effective time-phased substitution of more environmentally friendly products and technologies for current ODS-using products and technologies. The aim of this paper is to pose this design issue precisely and to investigate alternative institutional designs for financing, monitoring, screening and ranking projects to accomplish a timely phase-out of ODSs in accordance with the Montreal Protocol. We will be particularly concerned with the problems of implementing agencies such as the World Bank, which will have to weigh economic and environmental priorities in screening and financing Protocol-related projects.

A central aspect of the Protocol\(^3\) is providing financial assistance for specific projects in developing countries to achieve the implementation of the phase-out of ODSs within the bounds stipulated by the Protocol. The Protocol stipulates that the Developed Countries will pay for the "incremental costs" required for the LDCs to achieve the phase-out. To provide financing to the LDCs for phase-out projects, the parties to the Protocol have created the Interim Multilateral Fund (IMLF). Disbursements from the IMLF will be managed by the World Bank in collaboration with the UNDP and UNEP. Pilot funding for the IMLF in 1991-93 is to be $160 million, with another $80 million to be added if China and India sign the Protocol.

Disbursements from the IMLF will be guided by the recognition that most of the benefits of these phase-out projects accrue to the larger global community whereas the

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\(^2\) See Morrisette (1989) for a historical background to the Montreal Protocol.

\(^3\) See especially the proceedings of the second meeting of the Parties to the Montreal Protocol -- UNEP (1990).
country undertaking the measures bears the cost. These projects, therefore, are significantly different from the conventional lending activities of the Bank and involve a range of new issues which require the creation of appropriate incentives for cooperation by private and public sector participants in both developed and developing countries. The primary actors in this problem nexus, and some of their concerns, are listed below:

Developing Countries

The participation and cooperation of the developing countries is, of course, fundamental to the success of this program. The primary concerns relative to the LDCs are that they utilize the IMLF funds efficiently and effectively to meet the objectives of the Protocol for complete phase-out of ODSs without compromising other vital developmental needs. As noted earlier, the implementation of the Protocol may have strong effects on the incentives which LDCs perceive for various types of projects.

Developed Countries

The participation and funding of the program by developed countries is likely to be driven by the perceived national benefits of global ODS reduction. It should be noted in this regard that a molecule of an ODS released to the stratosphere will have roughly the same effect on human health no matter where it comes from in the planet. So it is in the developed countries' interest to see LDCs phase-out CFC's and other ODS's such as halons.

Multinational Corporations

Given their ownership of the relevant technologies (both ODS substitute production technologies and end-use technologies) and investment capability in CFC substitution projects, multinational corporations (MNCs) will play a critical role in this program. In many LDCs, the MNCs presently supply the ODSs and influence the nature of the ODS-using equipment, either through direct supply or local manufacture. They will have an even stronger impact in the ODS substitute market and end-use equipment since these will involve major product and process innovations requiring substantial amounts of capital and expertise.

Non-Governmental Organizations

Given the significance of the Montreal Protocol in its own right and in setting precedents for future environmental initiatives, it is not surprising that a number of national and

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4 Thus, financing decisions for global environmental activities will be guided by criteria beyond the usual cost-benefit and efficiency criteria of environmental economics, including criteria such as affordability and international equity. See Munasinghe (1990) for a discussion.
international NGOs consider this an area of importance for their own agendas. They are interested in an open and participative discussion which allows them access to the policy debates surrounding the implementation of the Protocol.

Intermediaries

Intermediaries (including The World Bank, UNEP and UNDP) will act as agents of the coalition of member countries at one level (setting standards, priorities etc.) and the donor countries at another level (funding). The role of the intermediaries would be critical to the successful implementation of Protocol.

Global Coalition

The global coalition consists of the parties to the Montreal Protocol. This coalition is driven by a collective set of objectives which may not be fully consistent with the objectives of individual countries, given the vast differences in per capita GNP, resources and technology among these countries.

A fundamental question that arises with regard to the implementation of the Montreal Protocol relates to the time path over which ODSs are to be eliminated. This is especially pertinent in the case of developing countries, which have been permitted a grace period of ten years before the provisions of the Protocol take effect. A literal interpretation of the language of the Protocol indicates that the elimination of ODSs according to the schedule outlined in the Protocol for the respective country groups would be considered as a successful implementation of the Protocol. On the other hand, this may not be the optimal implementation scenario from the viewpoint of the global coalition. The Montreal Protocol was driven by the urgency of eliminating the use of ODSs and recent scientific evidence (such as the NASA findings earlier this year) emphasize the critical nature of the problem. Indeed, many developed countries have either implemented reduction measures or already achieved levels of ODS reductions far in excess of the Protocol stipulations. On the other hand, Munasinghe and King (1991) have observed that: "There is some evidence that (the ten-year grace period) has introduced a note of complacency in developing countries who do not feel the urgency underlying the Protocol".

Despite a lack of universal agreement on a monetized value for the benefits associated with a kilo of ODS eliminated, there appears to be considerable agreement on the fact that benefits of ODS elimination significantly exceed the costs associated with this elimination. This is supported by the actions of many developed countries in accelerating their ODS substitution and elimination programs. Such a cost-benefit trade-off would suggest a principle of maximizing the net benefits of ODS reduction and imply a Protocol implementation scenario that would achieve the Protocol's quantitative targets well in advance of its stipulated time-bounds. On the other hand, in the absence of such a favorable trade-off, an approach of cost-minimization, under which the Protocol's quantitative targets
are met barely within the Protocol's time bounds, would be sufficient.

On the face of it, it would appear that as far as the contribution of the developing countries to the global ODS reduction effort is concerned, there is no tangible difference between the two polar scenarios outlined above. However, as the data in Table 1 reveals, ODS consumption continues to rise rapidly in many of the larger developing countries, especially China and India. Munasinghe and King argue that the costs of delayed action would be high in such countries. Furthermore, the impact of delays (albeit within the Montreal Protocol time bounds) on the total ODS levels emitted could also be quite considerable.

<table>
<thead>
<tr>
<th>Country</th>
<th>Current Usage b/ ('000 t)</th>
<th>Average Annual Growth Rate Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>China g/</td>
<td>46.0</td>
<td>12%</td>
</tr>
<tr>
<td>India g/</td>
<td>11.0</td>
<td>15%</td>
</tr>
<tr>
<td>Brazil g/</td>
<td>11.0</td>
<td>8%</td>
</tr>
<tr>
<td>Mexico g/</td>
<td>7.9</td>
<td>2%</td>
</tr>
<tr>
<td>Yugoslavia d/</td>
<td>7.5</td>
<td>-10%</td>
</tr>
<tr>
<td>Turkey d/</td>
<td>4.6</td>
<td>-4%</td>
</tr>
<tr>
<td>Egypt d/</td>
<td>2.7</td>
<td>-6%</td>
</tr>
<tr>
<td>Tunisia d/</td>
<td>0.73</td>
<td>6%</td>
</tr>
</tbody>
</table>


b/ Consumption in 1990 in terms of CFC-11 equivalent i.e., Ozone Depleting Potential (ODP).

c/ Based on projected change in ODP to 1996.

d/ Based on projected change in ODP to 1993.
While the issue of implementation scenario is still open (and all of the evidence on implementation in developing countries points to a cost-minimizing approach), this paper outlines an economic framework which underlies the principle of benefit-maximization, while at the same time examining the implications of deviations from this principle. Our approach is consistent with the stance taken by Munasinghe and King, who assert the principle applicable at the country level as being "to maximize benefits associated with ODS reduction". We examine the implications of a Protocol implementation scenario based on this principle at all levels of the global hierarchy identified above.

While the benefit-maximizing and the cost-minimizing implementation scenarios have been treated as polar cases in the context of the above discussion, we must emphasize that benefit-maximization embodies all the principles of cost-minimization. Thus, while the total resources made available for the Protocol implementation and the prioritizing of projects would be driven by consideration of the associated benefits rather than the sums of money required to meet the time-bounds of the Protocol, their actual deployment would be based on the principles of cost-minimization.

Under an optimal implementation scenario, all of the above stakeholders would agree on objectives, resources available and institutions for coordinating their actions and sharing information. Projects would be proposed by LDCs, MNCs and NGOs, these projects would be ranked according to the agreed objectives and implemented with a speed corresponding to available resources. Something like this optimal scenario is indeed embodied in the Protocol and supporting documents. There are several open issues, however, concerning the design of the institutions which will oversee the screening and prioritizing of projects directed at phasing out and destroying CFCs with minimum economic and environmental distress. There are also several questions arising as to the total resources which should be made available to achieve the phase-out of ODSs effectively and efficiently. This gives rise to two basic questions surrounding the implementation of the Protocol, which we address in this paper in the context of a rational economic framework, deploying incentives and game-theoretical principles:

1. How can the Executive Committee for the Protocol and its supporting agencies (UNEP, UNDP and The World Bank) best provide incentives and assistance to the LDCs so that projects proposed by each LDCs are economically and environmentally effective for both the individual LDCs as well as for the Global Coalition in meeting the objectives of the Montreal Protocol?

2. What is the size and timing of financial resources which the Global Coalition should make available in order to implement projects proposed under the institution selected to implement the Protocol.

As we will demonstrate, these questions are tightly interlinked with the question of the optimal implementation scenario which is agreed upon by the above group of stakeholders.
On the one hand, the institutional mechanisms adopted for implementing the Protocol and the level of financial resources that are made available will drive the implementation scenario. On the other hand, the implementation scenario will determine the appropriate institutional mechanisms and resource levels.

The Protocol itself specifies the basic fabric for answering the above questions. Concerning the first question, for example, the Protocol and supporting documents call for objectives of efficiency and effectiveness and various organizational matters which explain how the Protocol shall be implemented. On the second question, LDCs are essentially to receive the incremental costs they incur in responding to the Protocol. Thus, adding together the total incremental costs required by each LDC to achieve its Protocol objectives, while accounting for the timing of use of these funds for individual projects, yields the required budget which the Global Coalition must finance. Thus, Protocol implementation will be achieved by having each LDC develop a country plan, with specific projects and sectors targeted for ODS phase-out at various points in time. These country plans will be coordinated and funded through the Protocol Executive Committee and its agents, with funding provided by the developed countries on an as-needed basis to assure timely implementation of agreed projects.

This intuitive scenario for implementing the Protocol is shared broadly among both implementing agencies for the Protocol as well as other involved stakeholders. Nonetheless, there are a number of detailed questions concerning how this process should be implemented. Some of these questions result from alternative interpretations of the Protocol language. Others are concerned with the continuing exploration of implementation issues associated with evaluating projects and programs which have both economic and environmental consequences. As we argue below, these questions have very serious consequences for how the Protocol should be implemented and ultimately for the speed and cost of phasing out ODSs. We first discuss, in the next section, the issue of interpreting the intent and language of the Protocol. We then turn in the following section to the question of alternative institutional designs for implementing the Protocol to achieve both its economic as well as its environmental objectives. Our concluding section will address research issues we identify along the way.
2. Interpreting the Montreal Protocol

We now analyze several areas of interpretation in the Protocol language. Our purpose is to highlight important issues for understanding the institutional design problem of interest here. We also wish to point to possible resolutions of conflicting interpretations where these exist.

2.1 Are the Incremental Costs Principles and Guidelines (ICPG) internally consistent and also consistent with the objectives of the Montreal Protocol?

The broad goals of the Montreal Protocol and the major factors to be taken into consideration in pursuing these goals are set forth in the 6th paragraph of the preamble to the amended Protocol:

"Determined to protect the ozone layer by taking precautionary measures to control equitably total global emissions of substances that deplete it, with the ultimate objective of their elimination on the basis of developments in scientific knowledge, taking into account technical and economic considerations and bearing in mind the developmental needs of developing countries."

The specific required actions to control, and finally to eliminate, the emission of Ozone Depleting Substances (ODS) are detailed in Article 2 of the Amended Protocol. In essence, Article 2 requires that the developed countries (DCs) phase out consumption (production + imports -exports) of ODS in a staged, time specific manner with cessation of all production in the year 2000.

Similar provisions obtain for the less developed countries (LDCs) except that the control measures in regard to phase-out and cessation of production are displaced by 10 years (i.e., all production by LDCs to cease in the year 2010).

The equity, technical, and economic considerations, as well as the needs of the LDCs are taken into account by the creation of a "Financial Mechanism". The Financial Mechanism has the purpose of "providing financial and technical cooperation, including the transfer of technologies" to LDCs "to enable their compliance with the control measures set out in Articles 2A and 2F of the Protocol." (We refer to such compliance as meeting the Time Bound Obligations (TBO) of the Protocol). Further, "The Mechanism"--(financed by the DCs)--"shall meet all agreed incremental costs of such Parties (LDCs) in order to enable their compliance with the control measures of the Protocol."

\[^5\] see UNEP (1990).
If the Protocol limited itself to the provisions cited above, there could be good consistency between the objectives of the MP and the purpose put forward for the Financial Mechanism. While paragraph 6 of the preamble is silent on how fast elimination of ODS should proceed, the control measures in article 2 of the MP specify this well, and the payment of incremental costs is keyed in article 10 "to enable their (LDCs) compliance with the control measures of the Protocol." All that would remain is for the Parties to establish consistent "agreed incremental costs" using the decision process set forth in the Protocol.

However, this apparent harmony is potentially disturbed by the particular guidelines and principles adopted in regard to the Financial Mechanism. These are put forth in Annex IV, Appendix I of the Protocol:

"1. The evaluation of requests for financing incremental costs of a given project shall take into account the following general principles:

(a) The most cost-effective and efficient option should be chosen, (emphasis added) taking into account the national industrial strategy of the recipient party. It should be considered carefully to what extent the infrastructure at present used for production of the controlled substances could be put to alternative uses, thus resulting in decreased capital abandonment, and how to avoid de-industrialization and loss of export revenues;

(b) Considerations of project proposals for funding should involve the careful scrutiny of cost items listed in an effort to ensure that there is no double-counting;

(c) Savings or benefits that will be gained at both the strategic and project levels during the transition process should be taken into account on a case-by-case basis, according to criteria decided by the Parties and as elaborated in the guidelines of the Executive Committee;

(d) The funding of incremental costs is intended as an incentive for early adoption of ozone protecting technologies. (emphasis added) In this respect the Executive Committee shall agree which time scales for payment of incremental costs are appropriate in each sector.

2. Incremental costs that once agreed are to be met by the financial mechanism include those listed below. If incremental costs other than those mentioned below are identified and quantified, a decision as to whether they are to be met by the financial mechanism shall be taken by the Executive Committee consistent with any criteria decided by the Parties and elaborated in the guidelines of the Executive Committee. The incremental recurring costs apply only for a transition period to be
defined. (emphasis added) The following list is indicative:⁶ (A list follows indicating that the concept of incremental cost is intended to apply quite broadly to any costs incurred in implementing a Protocol-ratified project.)

These principles introduce some new terms and concepts which are not defined in the Protocol. In our view, the most important and potentially troublesome of these undefined terms and concepts are the following:

a) "the most cost-effective and efficient option should be chosen"

b) "funding of incremental cost is intended as an incentive for early adoption of ozone protecting technologies"

c) "incremental recurring costs apply only for a period to be defined."

The point here is that how one interprets these guidelines of the MP may introduce the potential for inconsistencies. For example, depending on how it is detailed, the limitation on recurring incremental costs can be at variance with the MP's promise of "equity" and attention to the "developmental needs of LDCs" as well as the principle of incentives for early adoption and cost effectiveness. For example, a limitation to funding only the first, say, five years of recurring incremental costs (versus initial capital costs) may make the substitution of a more labor-intensive, non-ODS using technology for servicing air conditioners unaffordable for a service firm in an LDC. At the very least, such a firm would find it desirable to delay adoption of the substitute technology as long as possible, perhaps conflicting with the early adoption principle noted.

One might also question where in the MP is the textual basis for the incentive for early adoption? While a resolution⁷ was offered by a number of DCs advocating an accelerated phase-out of CFCs ("as soon as possible but not later than 1997") and the EEC joined in and endorsed this resolution, it should be noted that the resolution was not endorsed by the USSR, USA, Japan or a significant number of the LDCs. It remained as a viewpoint and did not become incorporated into Article 2 of the Protocol. Both the principles of incentives for early adoption and the limitations on recurring payments are also potentially in conflict with the "cost-effectiveness" principle. The question is: effectiveness of what? Meeting the "time bound obligations" in regard to ODS? The amount of ODS phased out? The time at which the phase-out is accomplished? Economic development in the concerned LDC? Or is it some combination of the above? Depending on the metric

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⁶ Appendix I of Annex 4 in UNEP (1990) contains the list.

⁷ see UNEP (1990), p.20
chosen for effectiveness, either the recurring cost and/or the incentives principle could be at cross purposes with each other or the cost effective principle.

These are not purely academic concerns. They lead to real problems for the agencies responsible for the administration of the Interim Multilateral Fund (IMLF), as we show below through the analysis of an individual ODS reduction project.

2.2 To what extent do the Protocol's stated objectives and incremental cost principles and guidelines (ICPG) meet the current expectations of the different classes of major Stakeholders?

There is a considerable gap between the goals of significant groups of stakeholders and the actions that will potentially result from implementation of one or more of the ICPG. Most of the developed countries have adopted programs that call for elimination of the consumption and release of ODS much in advance of the "time bound obligations" (TBO) of the Montreal Protocol. Some of the LDCs, Mexico for example, have also put forth programs on their own initiative to curtail consumption of ODS, e.g. in aerosols, perhaps for good economic reasons in part, but not entirely on this basis. Certainly, many NGO's in the environmental movement have not accepted the "time bound obligation" of the Protocol as their goal. They argue for much speedier implementation, the bypassing of the interim use of HCFCs, (e.g., the National Resources Defense Fund (NRDC)), and even in some cases for the elimination of HFCs (German Bund).

These problems will need to be cleared up if operational guidelines for project financing are to be clear. For example, the World Bank has recommended that CFC recycling projects "be supported by grant financing" presumably because pilot recycling projects would fit the criterion of "maximizing the savings of physical emissions of ODS per dollar invested from the fund". If cost/effectiveness is measured in terms of meeting "time bound obligations," then recycling projects in LDCs could easily be delayed for 10 years, or until the time that the price of "virgin" CFCs equaled the cost of recovered CFCs, thus avoiding or minimizing total incremental costs to the country. As noted above, and explored more fully below, the principle of limitation on recurring costs narrowly interpreted is also at variance with the encouragement of an early start for many recycling projects. For

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8 See Secretaria de Desarrollo Urbano y Ecologia et al. (1990).

9 Based on an interview by one of the authors with the German Bund, Bonn, January 11, 1991.


example, starting any of the recycling projects detailed in the Mexico Study\textsuperscript{12} before the latest date congruent with Mexico's TBO would lead to increased costs to the country, all other things being equal.

Clearly then, many of the DCs and other stakeholders\textsuperscript{13} in the Montreal Protocol have an objective that is different than that of solely meeting "time bound obligations." What emerges from the formal documentation developed in support of the Protocol implementation, the actions of the DCs (see discussion below) and from extensive interviews conducted by the authors of this report is that many stakeholders see a natural tradeoff between the speed with which phase-out occurs and the resources devoted to achieving this phase-out. We argue below that this tradeoff perspective is appropriate and compatible with the Protocol. However the TBO perspective has its adherents as well. They point to the fact that the TBO interpretation provides a clear benchmark for implementation and for the assessment of required resources to achieve this benchmark, namely resources equal to the minimum incremental costs required to meet the TBO.

There also exists concerns among the parties to the MP about other environmental and health and safety impacts associated with the elimination of CFCs. The resolution cited in UNEP (1990), notes the concern with the global warming aspects of CFCs and the London Convention instructed the Technology Panels\textsuperscript{14} to study and report on methods of effectively destroying CFCs as well as on factors such as other environmental, safety, energy use, and toxicity effects associated with programs to replace or eliminate CFC use. National and international leaders of the environmental movement interviewed by the authors said that no alternative technology should be funded by the Interim Multilateral Fund unless provisions were made for minimizing environmental impacts. One very prominent environmentalist felt that any impacts greater than those permitted in the most advanced DC should not be accepted. Thus, in addition to timing issues related to implementation, there are several other concerns on the ancillary risks of Protocol projects in other areas than simply cost and ODS reduction. It is clear that both timing and acceptance standards for other external risk effects must be addressed if operational screening and prioritization of Protocol projects is to proceed with clarity.

\textsuperscript{12} Joint report by USA EPA and Mexico on implementing the MP

\textsuperscript{13} Morrisette (1989) describes the important, perhaps critical, role that non governmental organizations (NGOs) played in the shaping and concluding of the MP. NGOs of particular importance were the Public Interest environmental groups, chemical trade associations and the "scientific establishment".

\textsuperscript{14} UNEP (1990), decision II/13 c.p.17.
2.3 How do the Protocols' Objectives and Incremental Cost Guidelines Address the Issue of Maximizing the Benefits Achievable with the Resources Expended in Response to the Requirements of Protocol?

The rationale for the Protocol itself has been avoiding the anticipated negative effects for humans and plant and animal populations associated with increased ultraviolet rays resulting when the protective ozone layer is thinned. While there continues to be considerable uncertainty about the precise consequences of ozone depletion, it is broadly agreed that the benefits of avoiding these effects and the attendant uncertainties are very significant indeed. Because of the long-lived nature of ODSs in the stratosphere and their continuing destructive capability for ozone once in the stratosphere, the benefits achievable from the Protocol are essentially related to the total stock of CFCs released. A surrogate for benefit assessment is therefore total avoided releases from now on. It is this "Benefits Perspective" which gives rise to minimizing the total ODSs released over time for a given Protocol budget. This will be the perspective we pursue below in our discussion of institutional design. And, as noted, while this Perspective was clearly the driving force behind the adoption of the Protocol itself, it is nonetheless interesting to inquire how this perspective is reflected in the language of the Protocol.

Paragraph 6 of the preamble to the Protocol states that actions taken towards phase-out and elimination of ODS will "take into account technical considerations" and "the developmental needs of developing countries." Thereafter, the Protocol is silent on the subject of economic considerations except for language such as that in Annex IV, Appendix 1 of the MP which notes that requests for the financing of incremental costs will take into account the "national industrial strategy of recipient party(s)" (LDCs).

The benefits of controlling ODS are not mentioned explicitly anywhere in the Protocol except in Appendix 1 under the "Indicative List of Categories of Incremental Costs" where it is stated that "savings or benefits that will be gained at both the strategic and project level should be taken into account, on a case-by-case basis, according to the criteria decided by the parties and as elaborated in the guidelines of the Executive Committee." The criteria decided by the parties is scoped out by an "indicative" list of agreed costs and presumably the Executive Committee is to be limited to elaborating on this list, rather than adding entirely new areas. In fact, the indicative list contains essentially items of a financial nature. The social costs at the country level are touched on in regard to items such as energy savings, but not in regard to items such as environmental safety and health impacts at the country level. Similarly, environmental impacts on the Global level are not mentioned, with the exception of support for effective ODS waste destruction systems.

Thus, while the background of the discussions leading to the Protocol was benefits driven (as measured by avoiding the consequences of continuing ozone depletion)\(^{15}\), the

\(^{15}\) See, e.g., Morissette (1989) for a discussion of the shaping of the Protocol.
Protocol document itself only deals peripherally with this important issue. The Protocol is much more focused on cost recovery guidelines for ensuring that LDCs can contribute to the global effort without financial strains. This notwithstanding, it is important to deal explicitly with the nature of costs and benefits, including total environmental effects, of Protocol projects. This will promote both clarity in the operational screening and ranking of such projects as well as promoting an awareness of the broader implications of Protocol projects, both locally and globally.

2.4 If present, what problems do the possible dichotomies and lack of operational definitions present to the implementing agencies and the parties to the MP?

As noted above, three of the principles that the implementing agencies are to take into account in evaluating projects are:

1. Cost-effectiveness and efficiency.\textsuperscript{16}

2. Incentives for early adoption of ozone protecting technologies.

3. Time Period Limitation of payments for recurring costs.

The problems that could arise from the inconsistencies in these guidelines become apparent if one examines how an LDC and the World Bank (as the financial agent of the Interim Multilateral Fund) would approach projects to displace ODS in specific applications. For illustrative purposes, we analyze in Appendix 1 several scenarios pertaining to a relatively simple case: one on one (Kilo for Kilo) "drop-in" replacements of a CFC in an existing application with a substitute. A number of such "drop-in" substitutes have been developed by chemical producers and endorsed in country studies such as that for Mexico\textsuperscript{17} which contains proposals for the use of "drop-in" substitutes in end use applications ranging from supermarket refrigeration to sterilization. We assume in this example that all initial capital costs are paid for only in the first five years of the project.

Most of the findings from analyzing this example are obvious:

\textsuperscript{16} It is not clear what differences, if any, the framers of the Protocol saw in the terms cost-effectiveness and efficiency. One might speculate that efficiency was meant to cover broader economic effects of Protocol projects, including the social and transaction costs (particularly external ones) involved in carrying out programs based on different technologies, and that the parties wished to include such transaction costs considerations into the choice of different technologies.

\textsuperscript{17} Secretaria de Desarrollo Urbano y Ecologia et al. (1990), page 141.
1. The later a country starts the program, the lower the net costs to the country (net of payments from the IMLF) and the greater the number of kilos of CFC released to the atmosphere\textsuperscript{18}. The reason for this result is that the country is receiving its incremental recurring costs for only five years. It must then pay recurring costs in all future years. Delaying is clearly optimal, especially when technological progress in substitutes may further decrease the recurring costs of substitutes.

2. On a per kilo basis of ODS release avoided, the later a country starts the program, the lower the total 5 year incremental costs that must be paid by the IMLF to the country. The total costs to the fund are about 5 times greater for the latest onset time (case D) than for the earliest case (A).\textsuperscript{19}

The reason for this difference is that the price of the CFC substitute is expected to drop 5-fold over the 1990-2008 period from $7165/tonne to $1929/tonne\textsuperscript{20}, while the price of the CFC (CFC-12 in this example) is expected to stay constant at $1433 per tonne. Thus

\textsuperscript{18} Caveat - It is assumed that each kilo of CFC that is not displaced eventually is released to the environment. However, this would not occur if the country could collect all CFCs used in the application and then subsequently destroy their ODP before release to the atmosphere through incineration in the country or by sending the material to an incinerator outside the country. There appears to be no financial incentive for a country to undertake such a costly program unless it receives full compensation from the IMLF. Present costs for the incineration of a kilo of CFC in the United States are 2 to 3 dollars per pound, which does not, of course, include the cost of collecting the CFC.

\textsuperscript{19} If a country were to avoid any restraint in the growth of an application and postpone any substitution for CFC's in this application until required to by its time bound obligations under the Protocol (approximated by case A), then assuming growth rates similar to those assumed by UNEP, the volume of the application would roughly triple over 18 years. Thus taking growth into account narrows the apparent difference in cost to the IMLF. Under some circumstances (very fast price decay and very fast market growth projections) the order of cost increase might even reverse i.e., the earlier five year interval would cost less than the later one. However, since the cost differential between the CFC substitute and the CFC is expected to drop 10-fold over the 18 year period from 1990 to 2008, volume growth would have to increase by a similar amount to balance this out. This, of course, does not consider discounting over time.

However, neither consideration changes the preferred choice for the country. Later is always less costly when dealing with a pure substitution program unless one assumes the unlikely situation in which the substitute costs less than the CFC it replaces and/or the size of the application is projected to decrease.

\textsuperscript{20} See Markandya (1990).
the incremental cost to replace a kilo of CFC in 1990 is $5.7 ($7.16-$1.43) while in the year 2008 it is $0.5 ($1.92-$1.4). The cost differential between later over sooner would be increased if one discounted the cash flow streams.

3. The average cost to the country (net of payments by the IMLF) of preventing the release of one kilo of CFC to the atmosphere decreases with the onset of time of the substitution program. This is because the price differential between the CFC substitute and the CFC decreases over time.

In general the LDC will not fully recover its incremental costs of Protocol participation. The only circumstances under which the country's incremental costs are fully covered by the IMLF is when the country starts its substitution program 5 years before the time at which there is no price difference between the substitute and the CFC to be replaced.

4. The earlier a country starts its program, the lower the amount of total CFC potentially releasable. This follows because one can logically expect that if the LDC starts its CFC replacement program in 1992, for example, it will continue on with the use of the replacement thereafter even if the IMLF only funds its recurring incremental costs for the first 5 or 10 years of the LDC's "one for one" substitution program. Thus, starting in 1992 (assuming TBO to go to zero usage in year 2010) leads to 18 kilos of CFC potential release eventually prevented, whereas starting in year 2005 results in only prevention of 5 kilos of CFC potential release. (Of course, if all the CFC used is subsequently incinerated the potential release is prevented).

We assume in this example that the self-interest of the LDC is best served by pursuing the lowest cost route to meeting its TBO and that such actions are completely compatible in a moral and legal sense with its other obligations under the MP.

Note that if there is no limit on recurring incremental operations costs, the country will be indifferent, on a strictly cost basis, to the starting date for switch over. Of course, the Executive Committee of the Protocol and the administrators of the IMLF will not and should not be indifferent. Given conditions of technological progress and learning associated with substitutes, and given the ultimate health effects of continuing releases of ODSs to the atmosphere, the Executive Committee must determine an appropriate tradeoff between the cost and speed of implementation and the resulting total stock of ODSs released to the atmosphere.

The clear implication of this example is that defining incremental costs properly is critical if LDCs are to perceive proper incentives for proposing and implementing the right projects in a timely manner. A further implication is, of course, that the benefits of avoided ODS releases must be explicitly accounted for in determining whether and when a project such as that discussed here should be funded for implementation.
Concerning the definition of incremental costs, we develop in Appendix 2 a detailed analysis of incremental costs for a profit-maximizing project manager in an LDC. We argue that incremental costs for such a project should satisfy the "neutrality principle" in the sense that (welfare-neutral) incremental costs are the total additional funds required by a project in an LDC (or a profit-maximizing agent within an LDC) to make that LDC just indifferent between implementing the Protocol project and not doing so. We argue below that at least this level of incremental costs should be provided to LDCs in order to avoid the strategic delay apparent in the above example. This neutrality principle also seems very compatible with the general tenor of the Montreal Protocol which is that LDCs should not bear an unfair burden in meeting Protocol obligations. It should be plain, in any case, from this example and general logic that failing to observe the neutrality principle will open the Bank and other Protocol stakeholders to behavioral uncertainties on the timing and magnitude of ODS phase-outs as LDCs attempt to meet Protocol obligations while observing their own developmental constraints.

If the IMLF administrator decides to forego the lowest cost case, how much of an incentive should it offer? What rationale will it use to defend its stewardship against the inevitable charges that it gave either too little or too great an incentive in any one particular case or in general? Further difficulties emerge when the question arises as to which of the substitution cases analyzed above represents the most cost-effective use of the IMLF’s funds? We assume that cost is defined as the total incremental cost of a project. But what measure of effectiveness is to be used? Timely compliance by the LDC with its TBO? Total avoided releases of ODS actually achieved?

Clearly the IMLF agencies will face problems in executing their stewardship role unless they can arrive at a rationale capable of supporting an internally consistent set of operational instructions for the loan officers of the World Bank. We turn now to possible approaches to the solution of these problems.

2.5 What changes in the interpretation, framing and/or implementation of the ICPG would allow the implementing agencies, in particular the World Bank, to carry out their assigned tasks for the Fund in a manner that maximizes approval of their stewardship from both the Protocols' signatories and its other stakeholders?

Before putting forth our answers to the question posed above, we will summarize our observations on origin and nature of the dichotomy facing the implementing agencies of the IMLF and review the assumptions upon which our recommendations for dealing with this dilemma are based.

\[21\] See Munasinghe and King (1991) for a further discussion on the problem of estimating full incremental costs for a Protocol project.
The 1990 (London) revisions of the 1987 Montreal Protocol\textsuperscript{22} reflected a consensus among DCs that, in order to adequately protect their interests in the light of new information on the increased rate of Ozone depletion, it was necessary to increase both the amount of ODS phaseout mandated in the 1987 protocol and the number signatory countries to the MP, in particular, the adherence of the most populous LDCs i.e., China and India. This consensus was reflected in amendments that increased the mandated phase-out of an increased list of specified ODS from 50% to 100%, the creation of a Financial Mechanism and the funding of the IMLF.

While a consensus existed on the above points, there was substantial disagreement over both the magnitude of ODS restrictions warranted and the monetary incentives needed to attract adherence of additional LDCs to the Protocol. As a result many of the provisions of the Protocol that addressed both of these critical issues represented a compromise rather than consensus.

The resolution of particularly contentious issues appears to have been accomplished by enacting separate, potentially contradictory, IMLF provisions to nominally meet each of the major camp's positions. As indicated in the above discussion, these provisions use ambiguous terminology that could, depending on the meaning given to this terminology, be interpreted by each of the protagonists as meeting their position. For example, protagonists wanting a faster phase out of ODS substances obtained language that said "The funding of incremental costs is intended as an incentive for early adoption of ozone protecting technologies." Protagonists who either were satisfied with present phase out provisions or were concerned about limiting costs to the DCs could take comfort in the second sentence of this principle: "In this respect the Executive Committee shall agree which time scales for payment of incremental costs are appropriate in each sector." In the absence of a definition for "appropriate" this principle lacks content. Similarly, other conflicts are reflected in ambiguities pointed out already concerning terms such as "cost-effective and efficient" and the "transition period" over which "incremental recurring costs apply."

Given the noted ambiguities in Protocol language, ultimate conflict resolution has been passed to the Executive Committee\textsuperscript{23} and the debate is now framed in terms of operationally defining terminology so as to resolve as much of the conflict as possible and devising ways to best operate the IMLF with the remaining residual conflicts.

\textsuperscript{22} See Morrisette (1989) for a summary of the positions of the various parties and stakeholders just before they became involved in the negotiation of the 1990 London amendments to the MP.

\textsuperscript{23} The Executive Committee which consists of representatives from 7 DCs and 7 LDCs.
On a smaller scale, similar considerations and conflicts occurred within the 1990 London convention in regard to global and local environmental side effects of an ODS elimination program as occurred in regard to the CFC elimination program. In most cases these issues were set aside and remanded for further study or set aside completely. Nevertheless, it can be expected that over the near future events such as the 1992 Conference on Global Warming will give such issues greater prominence and force the Executive Committee of the IMLF to decide how it will factor these side effects into its funding and benefit considerations.

Depending on what meaning and definition is attached to these critical terms, it will more or less difficult or in some cases impossible for the Fund to simultaneously act in conformance with all of the "provisions" and guidelines. An example of such a situation was illustrated above using the hypothetical cases dealing with substitution of an ODS with a non ODS "drop in" replacement product. In this situation, a 5-year limitation on recurring incremental costs leads to an LDC postponing this type of switch over to as late a date as possible with the resultant release to the atmosphere of substantial amounts of ODS.

ODSs act over a long time period and the injury they cause is related to the total amount of ODS released to the atmosphere, not the rate of release at any particular location or point in time. In other terms, a kilo released in a DC is equivalent to one released in an LDC. A kilo of ODS released now poses a risk that is roughly equivalent in total injury caused to one released 10 years later, though such injury will be shifted to the future. While it takes a number of years before CFCs released to the atmosphere reach the stratosphere and react with the ozone layer, this period of time is well within the time period encompassed by the MP TBO phase-out (2010). In that sense, early action to decrease the total amount of CFCs released will benefit the generation presently alive as well as lower total injury to future generations. Using U.S. EPA and UNEP studies, one can estimate that each metric ton of an ODS with an Ozone depletion value of 1 will lead to the onset of a given number of skin cancers over the life time of the average ODS. Translating this into a monetized benefit is something we will touch on below.

Even as the Executive Committee continues to discuss how to arrive at operational resolution of these papered over issues, the DCs are presently acting to prevent the release of ODS in their own countries at a faster pace than is required of them under the terms of the Protocol and are considering even further acceleration of their programs in the future. Based on such actions, it can be concluded that the DCs perceive that the value of the benefits to be obtained (future avoided costs) by preventing the release of additional

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24 see EPA (1988).

amounts of ODS is at least equal to the marginal costs they are bearing in accelerating ODS phaseout faster than the Protocol requires of them and that this activity represents the best use of such funds.  

It is unlikely that a monetized value for the benefit of preventing the release of ODS can be arrived at by consensus even though a consensus does agree that such benefits greatly exceed the costs of preventing such releases. In fact, there is every reason to believe that the monetized benefits will vary greatly among the different Parties to the MP (as apparent, for example, in the economic panel report of UNEP, which cites various studies on the benefits from ODS elimination programs). In the DCs, the bulk of these benefits arise out of deaths from cancer that are avoided (not years of life extension). In the LDCs, one can expect both different valuation criteria as well as other pressing priorities for funds.

Preferred Outcomes for the Different Parties to the MP

In those LDCs where the benefits associated with ODS reduction are perceived to be lower than the costs associated with this reduction, the preferred outcome is likely to be to meet their time bound obligations under the Protocol at the lowest net cost (gain is even better) to themselves. Because such LDCs are likely to be small players, they will receive almost the same benefits (lower to an LDC than for a DC) from a minimum compliance strategy as from a pro-active program. In any case, they can generally use funds in an alternative manner which will have a higher social return to itself than prevention of ODS releases.

The preferred outcomes for the implementing organizations of the fund is to administer the fund in a manner that maximizes the approval and resultant political and financial support they get now and seek in the future from the signatories and other stakeholder of the Protocol.

The preferred outcomes for the countries designated as DCs in the Protocol and those LDCs that perceive high benefits from ODS reduction probably do not fall into as narrow a range as is the case with the previous group of LDCs. In addition, since DCs pay into the fund and also receive benefits that at least the politically controlling group perceives as significant, they have an interest in both minimizing the costs of administering whatever programs the fund undertakes and of course in maximizing the benefits to them that are

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26 Of course such conclusions represent an assumption of economic rationality, and there are many recognized cases where these assumptions do not obtain. See for example EPA (1990).

related to total ODS removed. Moreover, there is undoubtedly a real difference in opportunity costs among DCs. In addition the benefits will also vary depending on such factors as the location of the country, its health system infrastructure and costs, and the skin coloration of the population.

In spite of these differences, one would expect that a strong case could be made that any single DC should approve of any expenditure by the IMLF which led to an LDC preventing the release of ODS at a cost that was lower than either what the individual DC perceived to be the benefits to their country and/or at a cost lower than what they were expending within their country to eliminate an equivalent amount of ODS at a similar point in time. The lowest such value for any DC would set a lowest common denominator implicit value on the prevention of the release of an additional kilo of ODS. One might hope that a consensus "benefit" value could pegged at some figure that was close to this lowest common denominator.

Implications for Institutional Design for IMLF Administration

The above analysis suggests some areas of ambiguity with respect to the Montreal Protocol. Nonetheless, the spirit of the Protocol should also be understood as one of international cooperation, rather than contentious compromise. In this same spirit, we list here our sense of the principles for institutional design for IMLF administration which seem to us to provide the best fit with the spirit of maximizing the benefits of international cooperation embodied in the Protocol.

Defining Project Incremental Costs Properly: Incremental costs for Protocol projects should be defined so as to assure at least welfare neutrality for economic agents implementing these projects, where welfare neutrality means that the full incremental costs of the project over time are recognized (see Appendix 2 for details). In particular, temporal limits on recurring or capital costs should be avoided since these limits can lead to delayed implementation of worthwhile projects.

Country Plans and Incremental Costs: Several benchmarks can be established at the country level for budgetary requirements for the IMLF. Foremost amongst these is the minimum incremental costs for the country to meet its TBO according to the Protocol. In addition to this TBO plan, and in view of the significant benefits likely to result from accelerated phase-outs, countries should also be encouraged to develop alternative, accelerated plans for ODS phase-out. The Incremental Costs for these alternative country plans will generally be higher. When aggregated across countries, the resulting country incremental costs will provide a spectrum of budgetary alternatives, which can then be evaluated against the benefits of reduced ODS stock in the stratosphere resulting from

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28 For an interesting game-theoretic analysis of these conflicting motives and their likely results for the global coalition, see Hoel (1991).
accelerated phase-out (we develop a tradeoff model in more detail below).

**Country Incentives:** To assure that LDCs have a reason to participate with vigor in the implementation, and given the apparent large excess of benefits over costs, required incremental costs for each country can and probably should be grossed up further to provide administrative incentives for early adoption (as explored further below in the discussion of institutional designs).

**Fundamental Principle of Benefits Maximization:** The basic principle underlying the implementation of the Protocol is to provide incentives to countries, MNCs and project developers to develop and implement Protocol projects which provide the maximum benefits in avoided ODS releases to the stratosphere, subject to the IMLF budget constraint and subject to funding projects at least at the level of project incremental costs. We develop in Appendix 3 a definition of project benefits which is compatible with minimizing the total stock of ODS released to the stratosphere. It is clearly this total stock of ODS which presents the ultimate danger to the ozone layer and, given the arguments above, it seems reasonable to concentrate on minimizing the aggregate stock of ODS potentially released to the stratosphere as the ultimate objective of the Executive Committee of the Protocol.

These principles provide a background for specifying and evaluating the performance of alternative institutional designs in terms of their ability to achieve maximum avoidable ODS releases for any fixed budget level available to the IMLF. We assume, of course, that the IMLF will have at its disposition at least sufficient funds to meet the minimum incremental country costs associated with the TBO. We also assume that all signatories to the Protocol are in fact motivated to meet at least their TBO, provided that all incremental costs are covered by the IMLF. We now consider alternative institutional designs for implementing the Protocol in light of these principles.
3. Institutional Design for Implementing the Protocol

We first illustrate the institutional design problem for implementing the Protocol in a static framework in which we consider a particular period, say a given year within the Protocol implementation period, and determine which among a set of feasible projects should be implemented to maximize total benefits from ODS phase-outs and destruction, subject to a given budget constraint for that year's activity. We consider dynamics thereafter. In our static framework, we will be interested in a procedure for determining the best set of projects to implement to reduce total ODSs.

We use the following notation:

\[ N = \{1, 2, \ldots, n\} = \text{the set of LDCs which are signatories to the Protocol;} \]

\[ L_i = \text{the list of projects available in country } i \text{ for reducing ODS use--a typical such project will be denoted } L_{ij} \]

\[ C_{ij} = \text{the total incremental cost of project } L_{ij};^{29} \]

\[ R_{ij} = \text{the total ODS (measured in standard normalized units of ODP) whose release is prevented by implementation of } L_{ij};^{30} \]

\[ B = \text{the available budget to the Committee.} \]

We note that the projects under consideration could be substitution projects, as described in Appendix 1, or they could be recycling projects to conserve ODSs in existing uses, or they could be destruction projects to destroy ODSs which would otherwise be released. In all cases, \( R_{ij} \) is to be understood as prevented releases relative to a base case, e.g., an extrapolation from current rates of production + imports - destruction, as in Table 1 above. We return below to the issue of establishing the base case and monitoring production and uses of ODSs.

Under conditions of perfect information, the design problem of interest can be stated as follows: select from the set of feasible projects \( \{L_i \mid i \in N\} \) that subset which achieves the maximum ODP reduction while not entailing total incremental costs larger than the available budget. In more formal terms, this problem can be expressed as follows:

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\[ ^{29} \text{See Appendix 2 for a discussion of incremental costs.} \]

\[ ^{30} \text{See Appendix 3 for a definition of project benefits compatible with minimizing the total stock of ODS released to the stratosphere.} \]
\[ \text{Maximize} \sum_{i=1}^{n} \sum_{j \in P_i} R_{ij} x_{ij} \]  

subject to:

\[ \sum_{i=1}^{n} \sum_{j \in P_i} C_{ij} x_{ij} \leq B \]  

\[ x_{ij} \in \{0, 1\}, \text{ for all } i,j. \]  

The variables \( x_{ij} \) in (1)-(3) are indicator variables such that \( x_{ij} = 1 \) or 0 respectively depending on whether \( L_{ij} \) is implemented or not at optimum. The problem (1)-(3) is referred to in the literature as the \textit{knapsack problem}\(^\text{31}\), and solutions for this problem are easily obtained. We will focus on a particular intuitive solution to this problem determined by the so-called "greedy heuristic" of implementing projects in decreasing order of their "bang per buck", i.e. in the order of \( R_{ij}/C_{ij} \), so that those projects which have the highest performance measured in avoided releases of ODS on a lb/$ basis are implemented first. If all projects have similar costs (the \( C_{ij} \) are all equal), then the bang per buck principle yields the optimal solution. In any case, if all projects have costs which are small relative to the total budget \( B \), which is reasonable to assume in the Montreal Protocol context, then implementing projects in the order of their benefit-cost ratio \( R/C \) will yield a near-optimal solution to (1)-(3).\(^\text{32}\) We will call the solution to (1)-(3) a \textit{first-best solution} since this is

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\(^{31}\) The name derives from the similarity of this problem to that of maximizing the benefit of provisions carried in a knapsack, when the volume of the knapsack is fixed and different provisions take up more or less volume in the knapsack.

\(^{32}\) In fact, defining \( \delta = \max \{ C_{ij}/B \mid j \in L_q, i \in N \} \), it is easily demonstrated that ranking projects in order of their benefit-cost ratio will yield a solution not more than 1006 \% lower than the overall optimum. A similar line of argument shows that if all projects are financially completely divisible (so that fractions of projects can be implemented at the same benefit-cost ratio), then the greedy heuristic is optimal for the problem (1)-(3).
clearly the best solution the Committee could implement.  

An alternative manner of illustrating this problem is the graphical solution given in Figure 1. Here we plot the marginal cost for a given country i of reducing ODS by implementation of projects from country i's feasible set L_i. Following normal terminology, we will refer to this as the (ODS-reduction) supply curve for country i. We assume that projects are numbered in order of increasing benefit-cost ratio R/C, or equivalently in order of decreasing cost-benefit ratio C/R. Then, as above, assuming that projects with higher benefit-cost ratios are implemented first, the marginal cost of achieving any feasible level of ODS reduction in the given time period is as shown in Figure 1.

\[ M_{ik} = \sum_{i=1}^{k} R_{ij} \]

Note:

- **P** = Price = Marginal Cost ($/lb) of a unit reduction in ODS stock.
- **Q** = Quantity (lbs) = total reduction in ODS stock.

\[^{33}\] In addition to the constraints (2)-(3), other constraints might also be appended to this formulation, e.g., country-level constraints relating to (not exceeding certain) budgetary allocations to individual countries, project interdependencies within or across countries, and so forth. Representing these formally is well understood in the capital budgeting and project planning literatures, and we will not pursue these issues further here.
In Figure 1, the height of the line segment FG is just the cost-benefit ratio $C_{ii}/R_{ii}$ for project i. The area under the supply curve for a given set of projects thus represents the total cost of implementing this set of projects. For example, the hatched area in Figure 1 represents the cost of implementing projects 1 through j in country i. This would be the total incremental cost to country i of implementing projects 1 through j. Indeed, under our assumption of financial divisibility of projects, we can easily see from Figure 1 which projects should be implemented for any given country budget allocation level $B_i$. Simply implement projects in order of increasing cost-benefit ratio until the budget $B_i$ is exhausted.

To simplify our graphical analysis, but in no way restricting its generality, we will depict the country supply curves by continuous (upward-sloping) contours, rather than the staircase form of Figure 1. In Figure 2, we show the country supply curves $S_i$ for several countries, $i = 1, 2, 3$. We also show the global supply curve $S$, which is just the horizontal sum of all country supply curves. The global supply curve represents the marginal cost of the best implementation strategy for the Executive Committee. Indeed from the global supply curve, we can see immediately which projects should be implemented for a given budget restriction--namely all those projects which have a marginal cost (i.e., a $C/B$ ratio) less than or equal to a fixed amount. Thus, projects from all countries are ranked in order of their cost-benefit ratio and implemented until the budget is exhausted.

Global Ranking: Suppose the Executive Committee receives all information on costs and benefits of all projects from LDCs. If we neglect the transactions costs of obtaining this information, then the Committee can clearly achieve the first-best solution by ranking and implementing projects as described above. Projects will be implemented until the global budget $B$ is exhausted. We show this in Figure 3; precisely those projects from LDCs will be implemented which have a marginal cost (i.e., a $C/R$ ratio) of less than or equal to MC($B$), as shown.

\[34\] This assumes, of course, that the Executive Committee knows all the cost-benefit ratios for all feasible projects, a point to which we return below.
Global Bidding: Suppose the Executive Committee wishes to implement project screening on a more decentralized basis. One way of proceeding is this. The Executive Committee announces a price $P = \$/lb$ that they would be willing to pay (in the given year) for ODS reductions, wherever they may occur. Countries then propose projects from their country feasible project lists $L_p$, which they are willing to implement in return for a price $P$ per lb
of benefit. It is clear that, if the benefits $R_{ij}$ can be accurately measured (see below), and the country knows its costs $C_{ij}$ and if the Executive Committee can monitor implementation success, then the country will propose precisely those projects which satisfy

$$\frac{C_{ij}}{R_{ij}} \leq P$$

(4)

i.e., precisely those projects whose cost-benefit ratios do not exceed the announced price $P$. In particular, in Figure 3, if the price $P = MC(B)$, precisely the same projects would be selected under the decentralized global auction as under the global ranking procedure. Note, however, that now some surplus will be generated for each country. In fact, at $P = MC(B)$, the cost to the Executive Committee will be $MC(B)Q(B)$. That is, a surplus in the amount of the area $O-MC(B)-F$ will be paid to the LDCs over and above the incremental costs $(B)$ of implementing the projects they implement.

Now let us just compare these two institutional designs on several criteria. Both implement projects in the same, efficient order. Moreover, for both designs, the marginal cost of the final project implemented (e.g., under the global ranking, $MC(B)$ in Figure 3) can be compared against the marginal cost of projects being implemented in DCs to provide a benchmark for the incremental opportunities of investing in LDCs by DCs for reducing ODSs.

As expected intuitively, the centralized global ranking procedure requires a smaller budget to effect the implementation of a given set of projects. Note, however, that the transactions cost of obtaining at the Executive Committee level all of the details on projects to be implemented by each LDC and then to subject these to a centralized screening procedure may well entail transactions costs well beyond any savings in LDC surplus which may be effected by the more centralized procedure. In any case, it is important to note that a decentralized procedure like global bidding does not require the Executive Committee to micro-manage projects in LDCs. It need only check that promised project results are obtained (with final payment for projects only on their audited success).

There are, of course, other benefits to having a more decentralized procedure. These would include increased local autonomy and ownership of the problem of Protocol compliance, increased flexibility and speed of implementation, and an increased policy versus operating role for the Executive Committee. Moreover, the presence of a surplus may act to both accelerate the generation of projects within LDCs as well as to ease the administrative burden in LDCs of monitoring and controlling implementation. Of course, these effects themselves need to studied further, as to magnitude and to efficacy in accelerating compliance with the Protocol's objectives. It is quite possible that some mix of centralized and decentralized control by the Executive Committee is desirable. For example, the Committee might see large opportunities with state of the art technology to quickly implement recycling in commercial and industrial refrigeration uses. The Committee might very well undertake a centralized initiative in this area, with targeted funding, while
simultaneously also promoting decentralized initiatives in all LDCs through the global bidding process.

To appreciate further the issue of surpluses and incentives for LDCs to propose projects under a decentralized design such as global bidding, let us consider a dynamic version of the above problem.\textsuperscript{35} Suppose now that the global bidding procedure is implemented on an annual basis. Assume, as above, that each year the Executive Committee announces a price $P_t$ which will obtain for that year's projects. Assuming that all projects are known at the beginning of the planning period and that there is no technological progress, we can use the same country and global supply curves as before. Moreover, as shown in Figure 4, it seems reasonable to assume that the Committee will declare over time a non-decreasing set of prices, i.e.,

$$P_1 \leq P_2 \leq \ldots \leq P_T,$$

(5)

where $T$ is the end of the planning horizon (e.g., 2010). Assuming that LDCs propose in each year $t$ all those projects which have not yet been begun and which have a cost-benefit ratio not exceeding the announced price $P_t$, and assuming that all projects are perfectly executed and yield the predicted costs ($C_{ij}$) and benefits ($R_{ij}$), then the net benefits in response to this dynamic form of global bidding will be as indicated in Figure 4: by the end of year $t$, the aggregate quantities $Q_t$ of avoided releases will have been achieved. The total resources expended to effect this will be the minimum incremental costs (the area O-H-I in Figure 4) plus the surpluses gained by all LDCs in each period. The surplus over and above the minimum incremental cost required to execute projects in year $t$ is shown as the cross-hatched area in Figure 4. Thus, the surplus in year 1 is the area O-P$_1$-E in Figure 4; in year 2 it is the area E-F-G, etc.

Note that the implied annual budget $B_t$ for any given price vector $P = \{P_1, \ldots, P_T\}$ is simply the area implied by the new projects brought on line in year $t$: e.g., for year 1, $B_1 = O-P_1$-E-$Q_1$; for year 2, $B_2 = Q_1$-F-G-$Q_2$; etc. The Executive Committee's overall design problem for the dynamic global bidding scheme may be viewed as determining an appropriate price vector $P$ (which will imply a corresponding set of annual budgetary requirements) so as to maximize total benefits (in avoided ODSs) subject to, say, the net

\textsuperscript{35} See Hoel [1991] for an alternative dynamic model in the context of global warming. Hoel's model is based on unit taxation for use of environmentally damaging products or substances (e.g., carbon taxes). Our model is based at the project level, since this is the basis of the formulation of the Montreal Protocol. Of course, taxation models are possible for the CFC problem as well as for the global warming problem.
present value of the annual budgetary requirements not exceeding some given level B.\textsuperscript{36}

\textbf{Figure 4: Illustrating Dynamic Global Bidding}

An interesting point arising from this dynamic analysis is that the issue of surplus payments (in excess of incremental costs) is not as significant as might be thought from Figure 3. In particular, if projects are proposed and implemented over time, then the magnitude of the total surplus generated to LDCs could be quite small. How large it will be depends of course on the slope of the global supply curve and the magnitude of the price differences between years. If in addition, technological progress flattens the global supply curve out over time, then price increments to achieve a given increment of ODS-phase-out can be correspondingly smaller and surpluses per unit ODS could be rather insignificant, at least in later years. Perhaps most importantly, given the generally agreed very large excess of benefits over costs from ODS reduction, the issue of surpluses probably pales in significance in relation to the accompanying incentives for early adoption which these surpluses may provide, especially in the early years of the Protocol implementation.

\textsuperscript{36} We will not pursue this problem here, but in the simple form stated (no technological progress or uncertainty) it is in fact relatively straightforward to characterize the solution to this problem.
All of this points to the fact that the benefits of a decentralized design such as global bidding may be obtainable at rather low cost in terms of increased budgetary requirements. Thus, in choosing the least cost institutional design, including total budgetary costs (with any surpluses present) as well as transactions costs of information processing, monitoring and screening, a design like global bidding is likely to be superior to any centralized system, e.g. global ranking. The point here is that the issue of cost effectiveness and efficiency in institutional design is not simply a matter of project costs, but also of which projects are developed and proposed for implementation, and of course of the ultimate full implementation costs. In any case, the priority ordering of feasible projects which would result from the global bidding procedure is the efficient order. There would be no reason for an LDC to propose projects in response to this institution in some other order than increasing cost-benefit ratio.37

The above provides a basic framework for analyzing institutional design issues of interest. A number of generalizations of this framework should be mentioned. In particular, we confined our attention only to two basic forms of institutions. Both of these institutions imply budgetary allocation at the global level, using a price signal to determine which projects will be implemented. An alternative design would provide countries with budgetary allocations over time and corresponding commitments, perhaps based on country plans, for ODS reduction in each country. One interpretation of the global bidding scheme is that the Executive Committee would provide an annual budget to each country based on the projects which that country puts forward as meeting the criterion: announced price \( \geq C_{ij}/R_{ij} \). One can imagine, however, using other rules for determining budgetary allocations to individual countries (e.g., a time-phased implementation of the country’s approved "strategic plan").

In addition to analyzing other institutional designs, the present analysis can be extended in several directions to take account of the following factors, which were neglected above:

- Technological progress; in reality, significant technological progress, both in terms costs as well as benefits, is expected over time.

- Uncertainty in terms of costs and benefits of projects; in reality one would expect

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37 Note that we are assuming here the principle of welfare neutrality for the LDC and its agents in the definition of project incremental costs (see Appendix 2). If this principle is not valid, then the incremental costs depicted in the figures above may reflect only the priority ordering for the DCs funding the IMLF, and not necessarily for the LDCs. In fact, under the welfare neutrality principle, LDCs are indifferent as to the ordering of projects selected for implementation. They, of course, strictly prefer the lower cost-benefit, more efficient projects under the global bidding scheme, since these yield a higher surplus. This is perhaps another reason to prefer the decentralized price-based global bidding system, since it provides added incentives for implementing max benefit-cost ratio projects first.
such uncertainty and one would expect LDCs to have better information on the impact of local projects than the Executive Committee or its agents:

Strategic behavior dynamically; LDCs might well delay projects, as discussed above, in anticipation of larger surplus payments in future years. Clearly a more detailed dynamic model to account for these incentives would be desirable.

Externalities to other health, environmental or safety effects; in reality, ODS reduction projects may have significant externalities to other environmental areas, such as global warming.

Accounting for these generalizations, while important, should not undermine the basic rationale advanced above on the simple economics of institutional design for implementing the Protocol. The essential ingredient driving efficient institutional design must consider both the incentives which this design will provide to LDCs for efficient generation and implementation of ODS-reducing projects as well as the transactions and governance costs of this institution.
4. Implications for Future Research

The discussion in the previous sections points to several open areas for future research. In broad terms these relate to:

1. The selection of an optimal implementation scenario and the determination of an appropriate budget for implementing this scenario.

2. Analysis of the above institutional structures in a dynamic setting, having regard to the evolution of incentives for Protocol compliance and contractual performance over time.

3. Policy analysis associated with some of the Protocol provisions discussed above and the institutional structures proposed in section 3.

Our introductory remarks and the interpretation of the Montreal Protocol in section 2 has underscored the importance of reaching agreement on an optimal implementation scenario at the global level, in keeping with the spirit of the Protocol. While a literal interpretation of the Protocol would suggest compliance with the time bound obligations as the appropriate implementation path, available evidence on benefits associated with early elimination of ODS (or the heavy costs associated with delays in elimination) would suggest a careful re-examination of this question. As the developed countries proceed with their accelerated ODS elimination programs, and the marginal costs of elimination increase in tandem with this process, we would foresee an increased focus on the LDC situation, and a call for accelerating the process of ODS elimination or use avoidance in these countries so as to keep pace with the investment already undertaken in the developed world. At the same time, the developed countries would need to realize that LDCs would not be in a position to accede to such calls without the requisite financial, infrastructural and technological resources. Thus, an optimal implementation scenario in developing countries and the provision of resources for ODS elimination by the developed countries must proceed hand in hand.

In order to support decision-making in regard to both the framing of an optimal implementation scenario as well as determining the level of resources required, a fundamental question to be addressed is the marginal benefit (measured either in global or developed country terms) of the elimination of a kilo of ODS in developing countries given the current programs of ODS elimination being undertaken in the developed countries. One way to proxy this would be to actually measure these expenditures through industry studies and other research. Another way is to estimate the human impacts (increased life expectancy, avoided medical costs, avoided loss of productivity etc.) and develop monetized estimates of these impacts.

The analysis of alternative institutional structures in section 3 has been carried out at a rigorous level only in a static setting. Given the long-lived nature of some of these
projects (and, of course, the relatively long time span implied by the Protocol's time bounds) an extension of this analysis to a dynamic setting would be of some considerable importance, in order to investigate the dynamic incentives associated with the institutional structures introduced in section 3.

Finally, we are of the view that further analysis is essential on detailed policy issues associated with the implementation scenarios developed and institutional structures that are adopted to guide the process of ODS elimination in the coming years. In this report we have dealt with the question of institutional design at a broadly conceptual level. Applying these principles to the multi-layered setting described in the introductory section would require a careful examination of the detailed institutional issues to assist policy formulation. This area of research would include case-studies at the global and especially the country-level.

In respect to case studies, and implementation more generally, an analysis by Kottak [1990] has indicated that an additional trajectory needs to be considered—the cultural, national, and socially specific mechanism of implementation. He concluded through a review of the efficacy of a set of World Bank projects that those that included anthropological data had significantly higher success rates—economically and otherwise—than those which did not. Thus, there appears to be a significant "bang for the buck" for the World Bank in attending to the cultural and social side of implementation, and assuring that the economic design issues explored here are as compatible as possible with country-specific details of implementation. Exploratory case studies seem therefore especially important in implementing the global dictates of the Montreal Protocol.
Appendix I
Analysis of a Substitution Project

For the purpose of this discussion, we will assume that the Fund's time period limitation on covered incremental costs is 5 years. The assumption of a five-year period is based on draft proposals put out for discussion among the implementing agencies (World Bank, UNEP and UNDP). Further, we will assume that, over time, the prices for CFCs and their replacements follow the "Global" estimates of A. Markandya. Markandya postulates that over the period, 1990 to 2008, in constant dollars, the price of CFC's will stay at $1433/tonne while the "average" price of substitutes will be $7165 (5x$1433) in 1990 and decline in cost as production increase with elasticity of - 0.2 percent with respect to cumulative production.

Assume that in 1990, a LDC is made aware that it can reduce its use of ODS by "drop-in" replacements of a CFC (cost $1433/metric ton) with a HCFC-based proprietary blend (cost $7165 per metric ton). Assume also that the country believes that future prices will behave as projected by Markandya. Also assume that there are no hidden capital or transaction costs. With these assumptions, replacing one Kilo of CFC in this manner results in an incremental cost of $5.73/Kilo in 1990, $4.22/Kilo in 1991 and so forth as per Markandya.

The questions that will be examined are:

1. When should such a project be initiated to maximize the benefits to the LDC?

2. What are the consequences to the IMLF of the LDCs pursuit of it's own self interest?

It will be assumed that the LDC maximizes its benefits by meeting it's TBO under the MP at the lowest cost to the LDC.\textsuperscript{39}

\textsuperscript{38} see Markandya (1990), Table I, page 10.

\textsuperscript{39} The LDC has no obligations under the Protocol that are in conflict with minimizing its costs to meet it's TBO. The principles put forth to guide disbursement of funds from the Interim Multilateral Fund and the terms of the MP, place no moral or legal obligations on the LDC other than to meet it's TBO nor will it be required to contribute additional money if the Fund is administered inefficiently. There would be some gain to the LDC if it expended it's own funds to prevent additional amounts of ODS from being released into the atmosphere, provided the marginal cost of doing this was less than the marginal benefit to the LDC and this expenditure represented the lowest social opportunity cost available for achieving similar benefits for it's citizens. This is not likely to be the case with most LDCs.
Table A1 presents the data on 9 cases whose scenarios are summarized in Table A2. We have arbitrarily assumed a base case (no substitution) period that extends from Jan 1 1991 and ends Dec 31 2008 (18 years). The 8 other cases represent decisions by the country to start their substitution programs on the first day of four different years, 1991, 1996, 1999 and 2004 at 2 different pricing levels for the CFC substitutes (1x and 2x the prices given in Markandya). For simplicity, the substitution is assumed to take place instantly and completely on the first day of the first year that the country decides to implement its program.

The price of the substitute for the year in question is taken directly from Markandya. It is also assumed that the country will claim payment from the Multilateral fund (for the first 5 year interval of its substitution program, since this is the time period over which the incremental cost of the CFC substitute is greatest.

The calculations in Table A2 are done on a per kilo basis: Total costs for any specific market segment are obtained simply by multiplying the per kilo costs by the total kilos consumed in that application in the different time periods covered. It is also assumed that if a country starts a substitution program in year x of the 18 year period we are examining, it will continue on that program throughout the remaining 18-x years. In other words, a commitment to substitute in year x is actually a commitment to purchase 18-x kilos of substitute. Finally, to simplify discussion, it is assumed that, contrary to Markandya’s projections, there is no costs difference between the substitute and the CFC replaced after the year 2008. Markandya’s actual projections continue to show a small price difference in 2008.

To summarize: capping the recoverable recurring costs for an LDC at 5 years leaves a residual cost for the LDC to cover. The consequences of this residual cost are that the later an LDC implements the project (which will cost it money), the better off the LDC is. The magnitude of decline in residual cost to the LDC depends on a host of factors, of course, including growth in the application in question, the cost of the CFC substitute, the discount rate, and so forth. But the basic effect reflected in this example results from the policy of funding only 5 years of recurring costs, when such recurring costs will continue for much longer than this.
CFC Substitution Project -- TABLE A1

Case Scenarios

Base Case - No substitutions - CFC's are used for the whole of the 18 year period starting in 1991 and running through 2008
Case A - CFC substitution starts Jan 1, 2004 and continues through 2008
Case A (2x) - Same scenario as case A except the price of CFC substitutes is twice that assumed in Case A
Case B - CFC substitution starts January 1, 1999 and continues through 2008
Case B (2x) - Same scenario as Case B except the price of CFC substitutes is twice that assumed in case B
Case C - CFC substitution starts January 1, 1996 and continues through 2008
Case C(2x) - Same scenario as case C except the price of CFC substitutes is twice that assumed in case C
Case D - CFC substitute starts January 1, 1991 and continues through 2008
Case D (2x) - Same scenario as case A except the price of CFC substitutes is twice that assumed in case D
<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>Total CFC cost Over Interval of use in case</th>
<th>Interval of CFC use as per case.</th>
<th>Tot. Kilos CFC Used in case.</th>
<th>Total NonCFC Cost over case Interval</th>
<th>Interval of NonCFC Use as per Case.</th>
<th>Total Non CFC Use as per case</th>
<th>Tot.LDC Gross Cost of Case</th>
<th>Tot.LDC Cost Net Base Case</th>
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<td>Units</td>
<td>$/Kilo</td>
<td>Months</td>
<td>Kilos</td>
<td>$</td>
<td>Years</td>
<td>Kilos</td>
<td>$</td>
<td>$</td>
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<tr>
<td>Base Case</td>
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<td>1991 - 2008</td>
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<td>0</td>
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<td>18.6</td>
<td>1991 - 2003</td>
<td>13</td>
<td>10</td>
<td>2004 - 2008</td>
<td>5</td>
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<td>8</td>
<td>21.2</td>
<td>1999 - 2008</td>
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<tr>
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<td>1991 - 1998</td>
<td>8</td>
<td>42.4</td>
<td>1999 - 2008</td>
<td>10</td>
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<td>5</td>
<td>29.1</td>
<td>1996 - 2008</td>
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<td>5</td>
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<td>1996 - 2008</td>
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<tr>
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<td>0</td>
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<tr>
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<td>-</td>
<td>0</td>
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<td>1991 - 2008</td>
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### CFC Substitution Project — Table A2 (contd.)

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<tr>
<th>SCENARIO</th>
<th>Tot. LDC cost NetBase Case &amp; IMLF Payment</th>
<th>LDC Cct.to Desp. Yr. CFC Net B.Case</th>
<th>LDC Cctto Desp. Yr. CFC net B.Case &amp; IMLF Payment to LDC</th>
<th>Tot. cost of NonCFC over 3 Year covered Incrmt. cost Period</th>
<th>Tot IMFL Pay. to LDC with 5 Yr. Limit on Recur. Incrmt. Costs</th>
<th>Interval for Incrmt. pay by IMFL to LDC</th>
<th>IMFL Cost to Displace TKof CFC in LDC</th>
<th>Total Costs of CFC over Period of Incrmt. Pay by IMFL to LDC</th>
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<tr>
<td>Units</td>
<td>$</td>
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<td>$/Mio</td>
<td>$</td>
<td>Years</td>
<td>$</td>
<td>$</td>
<td>$</td>
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<td>L/H=N</td>
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<td>PH=R</td>
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<td>2004 - 06</td>
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<td>1996 - 2000</td>
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<td>1.66</td>
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<td>18</td>
<td>1996 - 2000</td>
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<td>Case D (1x)</td>
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<td>1.29</td>
<td>0.58</td>
<td>20</td>
<td>12.6</td>
<td>1991 - 95</td>
<td>0.71</td>
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<td>2.2</td>
<td>46</td>
<td>32.6</td>
<td>1991 - 95</td>
<td>1.82</td>
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Appendix 2
Defining Costs and Benefits at the Project Level

1. Introduction

The Montreal Protocol specifies time-bound obligations for eliminating CFCs and other ozone depleting substances (ODSs). A central aspect of the Protocol\textsuperscript{40} is providing financial assistance for specific projects in developing countries to facilitate the meeting of the time-bound obligations and, where possible, to speed up the implementation of the phase-out of ODSs. It has been widely recognized that a central aspect of this process is assuring that the costs and benefits of specific projects and of groups of projects at the country level are properly assessed, so that the developing countries and agents operating within them can undertake these projects without additional financial burden. Defining costs and benefits at the project level is also clearly important for meeting the ancillary objectives of the Protocol to achieve cost effective and efficient implementation and allocation of resources. As the administrator for project evaluation and financing for the Executive Committee of the Protocol, the World Bank has a special interest in this topic and has begun an active inquiry on it.\textsuperscript{41}

The topic of projects costs and benefits is important for several reasons. First, the concept of "incremental costs" is intended to capture the needed funding for individual projects to assure that they are undertaken and is therefore central for both the Bank's purposes, as agent for the Executive Committee, as well as for defining the total funds necessary over time to assure a given time path for eliminating ODSs. Secondly, for developing countries, understanding costs and benefits of particular projects is important in assessing the country-wide impacts of phase-out, both in aggregate and on various economic agents who will have to undertake necessary projects to achieve phase-out. Finally, an accurate estimate of project costs and benefits is necessary for several institutional governance structures for implementing the Protocol globally, e.g., for assuring that the most cost-effective projects for CFC phase-out are selected at any point in time.\textsuperscript{42} In particular, one may expect that inaccuracies in defining or estimating project costs and benefits will lead to poor timing of projects or funding the wrong projects, which could have quite significant economic and health consequences.

\textsuperscript{40} See especially UNEP (1990).

\textsuperscript{41} See World Bank (1991).

\textsuperscript{42} Cost-effectiveness might be defined on a dollar per kilo avoided release of Ozone Depletion Potential. Of course, cost-effectiveness is not the only performance dimension of interest.
Clearly, project costs and benefits should include an assessment of the following:

(1) The direct financial costs and benefits to the agent or agents undertaking the project;

(2) Any economic or environmental externalities the inclusion of which may make the project more or less attractive to undertake.

In addition, the agent or agents responsible for undertaking the project should have no strategic reasons to either avoid worthwhile projects or undertake projects whose net costs and benefits do not justify their being undertaken. For intuitive reasons, we refer to this as the "Agent-Neutrality Principle". For profit-maximizing agents assuring agent neutrality means funding the incremental costs of the project. At the country level, and across a portfolio of projects, assuring agent neutrality means properly assessing economic externalities across projects so that funding to the country accounts for the net economic impact of the portfolio of projects. The success of any global intervention scheme, such as incremental cost compensation, is likely to depend critically on the extent to which this principle is maintained. The rest of this note is directed at examining this principle in more detail.

2. The Welfare Neutrality Principle

Neutrality at the level of the individual profit-maximizing agent

The agent who directly undertakes the project (e.g. a MNC subsidiary or other public or private corporation) faces the decision at time $t$ of staying with his existing project (i.e. unconstrained by the Protocol requirements) which we shall call project A or switching to an alternative project (the constrained project) which we shall call project B. If the two projects are different, then project B will have a higher Ozone Depletion Potential (ODP). On the other hand, the optimal configuration of project A may call for the transition to a CFC-substitute based configuration at some point in the future, if this becomes relatively cheaper even from the agent's private perspective.  The figure

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43 We follow the Bank's current proposals in assuming that incremental revenue effects, if any, are included in the concept of incremental cost.

44 Due to technical progress, scale economies or other factors.
illustrates the choice confronted by the agent at time \( t \).

**Figure A1: Project Choices at time \( t \)**

Disregarding tax effects, the net cash flow or net revenue \((NR)\) of project \( i \) in any year \( \tau \) would be given by:

\[
NR^i_{\tau} = (P^i_{\tau} - C^i_{\tau})X^i_{\tau} - F^i_{\tau} - I^i_{\tau}; \quad i \in \{A, B\}
\]

where:

- \( X^i_{\tau} \) = output quantity (using CFC or substitute) produced in year \( \tau \)
- \( F^i_{\tau} \) = aggregate fixed cost of output in year \( \tau \)
- \( C^i_{\tau} \) = unit variable cost of output in year \( \tau \)
- \( P^i_{\tau} \) = unit selling price of output in year \( \tau \)
- \( I^i_{\tau} \) = capital investment in project at time \( \tau \)
I, includes the initial investment or periodic reinvestment in the project (to assure the continuation of the project) if that occurred in year \( \tau \).

Present value of each project at year \( t \) will be given by:

\[
P_{V_{NR}}^A(A; t) = \int_t^\infty \exp[-\rho(\tau-t)] \, NR^A_\tau \, d\tau 
\]

\[
P_{V_{NR}}^B(B; t) = \int_t^\infty \exp[-\rho(\tau-t)] \, NR^B_\tau \, d\tau 
\]

This excludes switching costs and the salvage value of project A, if the switch occurs at time \( t \) due to the Protocol provisions.

Incremental Cost would become:

\[
\Delta PV(t) = P_{V_{NR}}^A(A; t) - P_{V_{NR}}^B(B; t) - S^A_t 
\]

\( S^A_t \) = salvage value of project A at time \( t \) (net of switching costs).

This provides an assessment of the incremental cost incurred at the level of the individual (profit-maximizing) agent undertaking the project. Agent neutrality would be preserved by compensating the agent by \( \Delta PV(t) \), since the agent would then be indifferent between the two projects. If \( \Delta PV(t) \) is negative, on the other hand, the switch is likely to occur without any further incentive or other intervention. \( PV_{NR}(A; t) \) is the market value of the agent's investment at time \( t \), or the opportunity cost of giving up the income stream accruing from project A. Under the neutrality principle, this loss is compensated in part by the income stream of project B and in part from the incremental cost transfer.

The above calculation assumed that both cost and revenue might be impacted as a consequence of moving from project A to project B. If only costs were impacted, then the above rule defining \( \Delta PV(t) \) would represent the difference in discounted costs between project A and project B, net of any salvage value or switching costs received or incurred at time \( t \) in moving to project B.
Neutrality at the level of the country

At the level of a country it becomes necessary to extend the analysis of costs and benefits to include the total production and consumption surplus associated with switching to the new project. A country would typically undertake a group of projects, which are likely to induce externalities across each other (e.g. in converting to a new product and process technology for household refrigerators, which may be more expensive for producers but which may entail significant energy savings for consumers). It is also necessary to account for any environmental externalities associated with these projects.

In this assessment it must, however, be noted that whereas the incidence of additional costs are likely to be concentrated (e.g. on individual firms or government agencies), the associated benefits are likely to be widely diffused (as in the case of any environmental effect or even energy saving). Consequently, some adjustments may be called for (perhaps by way of fiscal measures or adjustments in the incremental costs calculation) to ensure that those bearing the costs are appropriately compensated.

In making comparisons across a basket of projects at the country level, it is also necessary to develop a measure of the relative effectiveness of utilization of the country's allocation from the Ozone Defense Fund. One such measure is effectiveness measured in terms of Ozone Depletion Avoided (ODA) per $, relative to some fixed base case. As a first step in developing such a measure, the Ozone Depletion Avoided (ODA) of the project needs to be capitalized to take account of the fact that savings from a project occur cumulatively across time. The "present value" of the ODA of a project may be represented as follows:

\[ PV_{ODA} = \int_{t}^{T} \exp(-\gamma t) \beta_{t} y_{t} dt \]

where:

\[ y_{t} = \text{ODP releases avoided in year } t \]

Rather than maximizing ODA, one could also minimize the total ODP released for a fixed budget. This would lead to minimizing ODP rather than maximizing ODA. For a fixed base case, the two are clearly equivalent.
\( \beta_r \) = value of a unit of ODP release avoided (e.g. S/kilo)\(^{46}\)

\( \gamma \) = discount rate

This measure permits us to develop an "average cost" type measure of the effectiveness of a project in terms of achieving ODA. (i.e. meeting the objectives of the Montreal Protocol):

\[
AC = \frac{\Delta PV}{PV_{ODA}}
\]

It must be noted, however, that individual countries are likely to employ other measures to evaluate projects at the country level, depending upon what objectives are associated with the deployment of funds from the ODF. One such measure, which may not have any bearing at all on Ozone depletion potential, would try to measure the overall net increment in production and consumption surplus associated with the project and compare this to the incremental cost transfers received.

3. Some Open Issues

There are many interesting open issues on defining project costs and benefits. We record a few of these here to stimulate thinking for research:

1. The above discussion treats cashflows at a theoretical level. Operationalizing these to deal with varying accounting standards, depreciation policies and estimation procedures would be useful. For example, if depreciation policies in a country approximate economic depreciation policies (e.g., because competition drives the agents in question to economic depreciation), then the current book value of assets related to incumbent projects will provide a good estimate of the market value of these assets, prior to Protocol interventions. On the other hand, if projects come from state or monopoly sectors in which arguably depreciation policies may not be in line with economic depreciation (e.g. very long lives of equipment assumed in spite of significant technological progress in the sector), then the market value of assets prior to Protocol

\(^{46}\) This value need not be numerically known for developing a project ranking. However, it would need to be the basis on which the total amount of resources to be allocated for ozone depletion would be determined.
interventions would require other assessment methods.

2. There is incomplete and asymmetric information between implementing agents and financial intermediaries. This needs to be accounted for in designing appropriate institutional governance structures to motivate agents to reveal accurately project benefits and costs and resulting project incremental costs. These structures would have to consider available monitoring of results, timing of payments for project implementation and other established financial methods to assure efficient implementation. Moreover, the relationship between project agents and financial intermediaries may not be a direct one, in that country administrations and regulatory authorities may be an intervening level between projects and funding agencies.
Appendix 3
On Defining Project Benefits

As argued above, a central issue in making operational the objectives of the Montreal Protocol is the appropriate definition of benefits from projects directed toward reducing ODS released to the stratosphere. Our purpose here is to provide a measure of project benefits which is compatible with this objective of reducing the overall stock of ODS released to the stratosphere.

Consider Figure A2 below. There we plot, for a particular country or group of countries, the base case (what would happen under a business as usual scenario), the time-bound obligations under the Protocol, and another scenario showing accelerated phase-out relative to the TBO scenario. We will call any contour of potential ODS releases a "release curve". It is the sum of production + imports - destroyed ODS at any point in time. The horizontal axis is just time, while the vertical axis represents total potential ODS releases to the stratosphere, denoted $K_t$ for year $t$. The total stock of ODS ultimately released to the stratosphere is then just the area under any release curve. For the accelerated scenario in Figure A2, this is the cross-hatched area $S$. As argued above, the objective of the Protocol is arguably to minimize the total ODS ultimately released to the stratosphere, subject to the budgetary resources available to the Executive Committee. Thus, the appropriate objective is to minimize the total area under the release curve for the global community resulting from a particular institutional design.

How will release curves, and therefore total ODS stock released to the stratosphere, be changed? They are the result, in fact, of the particular projects implemented by each LDC in response to Protocol incentives. Thus, in Figure A3 below, we show a particular project which is being considered for implementation. The time is $t_j$ and the LDC in question has been pursuing a plan which has led its ODS releases to follow the path $OE$ until $t_j$. A project $L_{ij}$ is being considered for implementation at $t_j$. We propose to measure its benefits as the cross-hatched area from $t_j$ to the TBO scenario, and with height equal to the overall substitution of destruction increment involved in the project in question.
**Figure A2: Illustrating the Protocol Objectives**

![Graph illustrating protocol objectives](image)

*Note: $K_t = \text{Total (Potential) ODS releases in year } t*

**Figure A3: Illustrating Project Benefits**

![Graph illustrating project benefits](image)
What are the properties of this proposed benefit measure? The most property is that maximizing benefits by choosing projects according to this benefit measure will in fact maximize the area OFGHIE. This is, however, the geometric complement of the area (ODEJ) we wish to minimize to accomplish the Protocol objective. The only other property we wish to mention here is that the benchmark point of zero benefits is accomplished by that set of projects which precisely meet the TBO. This would presumably also set the lower bound on required budget for implementation at the minimum incremental country costs, as discussed by Munasinghe and King [1991].
References


